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The Lockheed Martin Commercial Space Systems Newtown A2100 General Interface Spec For Commerical Programs, document number is 20032700 Revision H Dated 01/24/07 and associated ECO SSE0365 Revision H dated 01/24/07 have been reviewed and are ITAR controlled documents (technical data controlled under ITAR, 22 CFR 120-130). These documents can only be sent to foreign suppliers with whom lmcss has a technical assistance agreeement currently in place.

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Date 10/5/07

Chuck Depalma

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A2100 Program

General Interface Specification

For

A2100 Bus – Redacted for Export

Lockheed Martin Corporation
Lockheed Martin Commercial Space Systems
100 Campus Drive, Newtown, PA 18940-1784

INITIAL ISSUE DOCUMENT APPROVAL

Author:	R. Filipek	Date	11/15/94
Approved by	Kenneth J. Young	Date	11/21/94
Approved by	A. S. Will	Date	11/21/94
Approved by	A. J. Giacobbe	Date	11/21/94
Approved by	J. Simmerman	Date	11/21/94

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G	Revised per ECO SSE0250.		10/18/05	
H	Revised per ECO SSE0365			

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1 INTRODUCTION

1.1 Scope

This document specifies the general electrical, mechanical, thermal, orbital, and test interface requirements for units (components) and subsystems used on the A2100 satellite.

This document has been screened and reviewed for export control purposes. Approval from Lockheed Martin Export Control is required before distribution to foreign nationals. A complete not for export version of this document is available in GIS20032700.

The goal is that all spacecraft equipment will be compliant with the latest revision of this document, however, it is recognized that Revision B was in force for equipment designed prior to November 2000.

1.1.1 Scope-1 21559

Equipment designed prior to November 2000 **shall** demonstrate compliance with either Revision B or the most current version of this document.

1.2 Exceptions 21560

The Performance Specification for each unit and subsystem **shall** include or specifically refer to the pertinent portions of this Interface Specification (the IS), or **will** clearly and completely define those exceptions approved for that unit or subsystem. It is the responsibility of the Certified Product Engineer (CPE) for a given A2100 unit or subsystem to document each deviation from requirements of the IS as an exception in the unit or subsystem Performance Specification. It is the responsibility of the Electrical and Mechanical Systems Engineer (ESE and MSE) on a program to compile and manage the total list of programs IS exceptions.

1.2.1 Exceptions-1 21561

A justification for acceptance and a corresponding mitigation plan **shall** be provided for each exception.

1.2.2 Exceptions-2 21562

Reporting of these exceptions **shall** be performed at system level PDR and CDR.

1.3 Definitions / Acronyms

This section provides definition for some of the terms used throughout this document.

AC:	Alternating Current
BIT:	Built In Test
BOL:	Beginning of Life
Box:	See Unit
CAD:	Computer Aided Design
CE:	Conducted Emissions
Component:	See Unit
CMD:	Command
CMR:	Command Receiver
CP:	Platinum Range Temperature Sensor
CPC:	Communications and Power Center
CS:	Conducted Susceptibility (when used in reference to EMI/EMC)
CS:	Standard Range Thermistor
CTU:	Command/Telemetry Unit
CW:	Wide Range Thermistor
DC:	Direct Current
EMC:	Electromagnetic Compatibility
EMI:	Electromagnetic Interference
EOL:	End of Life
EPS:	Electrical Power Subsystem
FET:	Field Effect Transistor
GSE:	Ground Segment Equipment
Ground:	Refers to spacecraft single point ground. This is the reference point for all spacecraft buses. It is the location where all external voltages or charges are returned.
ICD:	Interface Control Document.
I/O:	Input/Output
MLI:	Multilayer Insulation
MSB:	Most Significant Bit
Payload:	This refers to the communication subsystem.
OBC:	Onboard Computer
OSR:	Optical Solar Reflector
PRA:	Pyro Relay Assembly
PRU:	Power Regulation Unit
RF:	Radio Frequency
RIU:	Remote Interface Unit
REA:	Rocket Engine Assembly
Return:	Refers to the wire / harness used to return a logic or power signal back to its source. Typically the low side of the load.
RMS:	Root Mean Square

RT:	Remote Terminal
SCD:	Source Control Drawing
SDRC:	Structural Dynamics Research Corporation
SPG:	Single Point Ground
SSPA:	Solid State Power Amplifier
TLM:	Telemetry
TWT:	Travelling Wave Tube
TWTA:	Travelling Wave Tube Amplifier
TT&C:	Telemetry, Tracking, and Command
Unit:	A unit (also referred to as COMPONENT or BOX) is defined as an electronic board or a group of electronic boards which performs a function or group of functions.

2 APPLICABLE DOCUMENTS 21564

Applicable documents **shall** apply to the extent specified herein.

2.1 Applicable Documents-1 21565

Should any conflict exist between the reference document and this specification, this specification **shall** apply. Exceptions to the requirements specified herein require approval from A2100 Systems Engineering.

2.2 Government Documents

2.2.1 Military Documents

MIL-STD-1553B Notice 2	Military Standard, Digital Time Division Command/Response Multiplex Data Bus, 8 September 1986
MIL-DTL-24308	Connectors, Electrical, Rectangular, Miniature, Polarized Shell, Rack and Panel, General Specification for
MIL-PRF-83513	Connectors, Electrical, Rectangular, Microminiature, Polarized Shell, Class M, Crimp Type
MIL-DTL-38999	General Specification for Connectors, Electrical, Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded, and Breech Coupling), Environment Resistant, Removable Crimp and Hermetic Solder Contacts

2.2.2 NASA Documents

GSFC-S-311-P-4	Connectors (and Contacts), Electrical, Rectangular, for Spacecraft Use, General Specification for
GSFC-S-311-P-18	Thermistor, Insulated and Uninsulated, Negative Temperature Coefficient, Specification for
MSFC40M39569	Connectors, Electrical, Miniature Circular, Environment Resisting, 200°C, Specification for

MSFC40M38298	Connector, Electrical, Special, Miniature Circular, Environment Resisting, 200°C, Specification for
MSFC40M38277	Connector, Electrical, Circular, Miniature, High Density, Environment Resisting, Specification for

2.3 Non-Government Documents

2.3.1 Lockheed Martin Documents

GIS20032700	General Interface Specification A2100 Bus – Not for Export
20032596	A2100 Electromagnetic Compatibility (EMC) Requirements Specification
APL20098029	Lockheed Martin Commercial Space Systems Approved Parts List
20032724	A2100 Component Environmental Test Specification
20034877	Fuse, Current Limiting
20048386	Fuse, Current Limiting, Slow Blow
20009426	Thermistor, Negative Temperature Coefficient
2280061	Resistance Temperature Sensor
2629443	Connector, Rectangular, Subminiature, Printed Circuit Applications, (D*M Series), Pin Contacts
20025720	Connector, Rectangular Subminiature, High Density (HD22 Series)
20032754	Connectors, Electrical, Rectangular, Microminiature, Polarized Shell, General Specification for
20032521	Connector, Microminiature D, Flex Cable Assembly
20034844	Connectors, Circular, MIL-C-38999, Series II (Pin Contacts)
20034845	Connectors, Circular, MIL-C-38999, Series I (Pin Contacts)
20038047	Connectors, Circular, MIL-C-38999, Series II (Socket Contacts)
20038048	Connectors, Circular, MIL-C-38999, Series I (Socket Contacts)

20040889	Connector Kit, Triaxial, Jack, Threaded, MIL-STD-1553 Data Bus
20040890	Connector Kit, Triaxial, Plug, Threaded, MIL-STD-1553 Data Bus
PN20095414	LMCSS Materials and Processes Control Plan
20099181	A2100 Survivability and Spacecraft Charging Requirements
20065601	LMCSS Parts Control Plan
PN20032524	A2100 Program Contamination Control Requirements

2.3.2 Other Non-Government Documents

RS-422-A	EIA Standard, Electrical Characteristics of Balanced Voltage Digital Interface Circuits, December 1978

3 REQUIREMENTS

Verification methods for all requirements in this section are identified in Table XI.

Table XI. Verification Matrix

Legend:

Method:	**A = Analysis**
	T = Test
	I = Inspection
	D = Demonstration
Level:	**C = Component**
	S/S = Subsystem
	S/C = Spacecraft
Categories:	**D = Development**
	Q = Qualification
	P = Protoflight
	A = Acceptance

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
3 REQUIREMENTS									
3.1.1 General	Failure propagation	A				X			
3.1.2 Power	+70 V safety	I	I	I	X	X	X	X	
3.1.2.1 General	Power buses		A	T		X	X	X	
3.1.2.2 Main Power Bus									
Para 1	Fusing, distribution		I	I			X		Design verification
Para 2	Voltage drop		A	A		X			
Para 3	Source impedance		A	A		X			
3.1.2.2.1 Main Power Bus DC Voltage and Regulation (Normal Operation)									
Sentence 1	Regulation at load			T			X	X	
Sentence 2	Regulation at distribution point		T	T			X	X	
3.1.2.2.2 Main Power Bus Voltage Transients and Ripple (Normal Operation)									
Sentence 2	EPS ripple, transients	A, T	A	A, T		X	X	X	
Sentence 3	Load ripple, transients	A, T				X			
3.1.2.2.5 Main Power Bus Source Impedance									
Para 1	Source impedance		A			X			
Para 2	Bus at user I/F	A				X			
3.1.2.2.6 Main Power Bus at Turn-on (Pre-launch and Test)	Turn-on characteristics	A				X			Users must survive
3.1.2.2.7 Main Power Bus Under Fault Condition									
Sentences 2, 3	Fault response	A	A	A		X	X		EPS limits levels, users must
Sentence 4	Unit recovery	A				X			
Sentence 6	Fuse non-blow voltage		A			X			
Sentence 7	Unit operation	A		T		X	X	X	

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
3.1.2.2.8 Main Power Bus Undervoltage									
Sentence 1	I/F characteristic	I	I			X			Document in spec
Para a (Sentence 4)	TWTA transponders	A, T				X	X	X	
Para b (Sentences 8-10)	SSPA transponders	A, T				X	X	X	
Para d (Sentences 13-19)	Bus loads	T		T		X	X	X	
Para d (Sentence 20)	Damage to command S/S		A	A		X			
Para d (Sentence 21)	Return to operating	T				X	X	X	
3.1.2.2.9 Main Power Bus Fusing									
Sentence 2	No internal fusing	I				X			Design verification
Sentence 3	Fuse rupture	A				X			
Sentence 4	Derated limits	A				X			
3.1.2.2.10 Main Power Bus Component Off-State Current	Off-state characteristics	T				X	X	X	
3.1.2.2.11 Main Power Bus Overvoltage During Ground Test									
Sentence 1	Overvoltage immunity	A				X			
Sentence 2	Test equipment prevention		A, T		X			X	
3.1.2.4 Fuses	Fusing of loads		I	I			X		Design verification
3.1.2.4.1 Fuse Sizing									
Para 1	Fuse weakest link		A			X			
Para 2, 3	Fuse sizing	A				X			
Para 4	Characteristics per SCD	I				X			Characteristics for analysis
3.1.2.5 Double Insulation		A, I	I, T			X	X	X	
3.1.2.6 Survivability									
Sentence 1	Unit survivability	A				X			
Sentence 2	Stress beyond derating	A				X			
3.1.2.7 Power Application									
Sentence 1	Voltage change		A			X			
Sentence 4	Start-up state	D	D	D		X	X	X	
3.1.2.8.1 Immunity to Power Supply Transients									

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
Sentences 1, 2	Withstand transients	A				X			
Para a) (Sentences 5-6)	Turn-on via relay	A				X			
Para b) (Sentence 7)	Gradual turn-on	D				X	X	X	
Para c) (Sentence 8)	Repetitive transients	T		D		X	X	X	Test at qual only
3.1.2.8.2 Allowable Transients									
Para a) (Sentence 3)	RF filter caps	I				X			Assumption for analysis
Para b) (Sentence 4)	Turn-on transients	A				X			
Para c) (Sentence 5)	RF feedthrough transients	A,T				X	X		
Para d) (Sentence 6)	Pyro bus transients	A				X			
3.1.2.8.3 Turn-off Transient Suppression									
Sentence 1	Inductive spikes	A				X			
Sentence 2, 3	Suppression diodes	I				X			Design verification
3.1.2.9 Turn-on Current Surge	In-rush current	T				X			
3.1.2.10 IR Loss in Harness	IR loss characteristics	A	A			X			Assumptions for analysis
3.1.2.12 Noise Fed Back to Power Source	Ripple levels	A, T				X			
3.1.2.15 Solar Array Voltage	Solar array voltage		A	T		X	X	X	
3.1.3.1 General									
Sentences 1-7	Ground types	D				X	X	X	
Sentences 8-10	Isolation	T				X	X	X	DC isolation measured with low power VOM
Sentences 11-12	Conductive surface grounding			T		X	X	X	
Sentence 13	Chassis grounding			T		X	X	X	
Sentence 14	Metal-to-metal contact	I				X			Design Verification
Sentence 15	Connector bonding	T				X	X	X	
Sentence 16	Harness connectors	A				X			
Sentence 17	Circuit grounding			A		X			Harness configuration
Sentence 18	SPG location	I				X			Design verification
3.1.3.2 Power Ground									
Para 1	Return for main power bus	T	T	T		X	X	X	

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
Para 2	Grounded to SPG	I		I		X	X		Protoflight for S/C-level; Design verification
Para 3	Isolate from chassis	T	T			X	X	X	
3.1.3.3 Signal Ground									
Sentence 1	Zero ref. for dc/dc secondary	I				X			Design verification
Sentence 2	Reference for TLM	I				X			Design verification
Sentence 3	Inner shield reference	I				X			Design verification
Sentence 4	Non-RF grounding		I	I			X		Design verification
Sentence 5	RF signal grounding		I	I			X		Design verification
Sentence 6	Return conductors		I	I			X		Design verification
Sentence 7	Signal returns	I				X			Design verification
Sentence 8	Shield as return	I				X		,	Design verification
Sentence 9	RF shields as return		T				X	X	
3.1.3.4 Shield Ground									
Sentence 1	Use in harness		I	I			X		Design verification
Sentences 2, 3	Terminate to backshell, not inside unit via connector pin	I					X		Harness requirement; Design verification
Sentence 4	Connect inner shield to signal ground	T				X	X	X	
Sentence 5	Grounded at one end		I	I			X		Design verification
Sentence 6	Not electromagnetic shield	A,I	A,I	A,I		X	X		Inspection for design verification
Sentence 7	Data Bus shielding	I,T	I,T	I,T		X	X		Inspection for design verification
3.1.3.5 RF Signal and Chassis Ground									
Sentence 1	Provide in power connector	I				X			Design verification
Sentence 2	DC-connected to case	T				X	X	X	
Sentence 3	Through ground strap		I,T	I,T			X	X	
Sentence 4	Shells grounded to chassis	T				X	X	X	
Sentence 5	Outer shield reference	I				X			Design verification
Sentence 6	Use chassis as return	I				X			Design verification
Sentence 7	No wire for chassis ground	I	I	I		X	X		Design verification, component and harness

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
3.1.3.6 Command Ground									
Sentence 1	Use separate wires	I				X			Design verification
Sentence 2	Ground-to-chassis via RIU		I	I			X		Design verification
Sentence 3	At least two conductors	I	I	I		X			Design verification
Sentence 4	Internally tied together	I	I	I		X			Design verification
3.1.4 Electromagnetic Interference	Electromagnetic Interference	T, A				X	X	X	Test on qual Analysis for P, A in case of design mods
3.1.5 Connector Use and Pin Allocation									
Para 1	Pin list in spec	I				X			Design verification
Para 3	Diode protection	I				X			Design verification
Para 4	Redundant pins	I				X			Design verification
3.1.5.1 Power and Grounds	Power and grounds	I, T				X			Test for EMC compliance at qual
3.1.5.2 Data Outputs	Female connector	I				X			Design verification
3.1.5.3 Relay Drive Commands	Cmd, rtn on same connector	I				X			Design verification
3.1.5.4 Chassis Ground Pin									
Sentence 1	Pin 1	T				X	X	X	
Sentence 2	No connection in harness		I	I			X		Design verification of harness
3.1.5.5 Shield Ground Pin									
Sentence 1	Same connector as shield pins	T				X	X	X	Continuity test
Sentence 2	Use pin only if triax	I				X			Design verification
Sentence 3	Adjacent to shielded wire	I				X			Design verification
3.1.5.6 Signal Output Pins	Signal pins far from power	I				X			Design verification
3.1.5.7 Signal Ground Pins	At least two	I				X			Design verification
3.1.5.8 Spare Pins	Minimum 10% per connector	I				X			Design verification

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
3.1.5.9 Connector Location and Identification	Clearly identified; Characteristics per ICD	I				X	X	X	
3.1.5.10 Connector Keying									
Sentence 1	Preclude mismate	A, I				X			Design verification
Sentence 2	Per ICD	I				X	X	X	
3.1.5.11 Test Connectors									
Sentence 1	Routed through dedicated conn.	I				X			Design verification
Sentence 2	Protective covers	I	I	I		X	X	X	
Sentence 3	Covers withstand environment	A				X			
3.1.6.1 1553 Bus Interfaces									
Sentence 1	Conform to MIL-STD	T				X	X	X	
Sentence 2	Transformer coupled stub	I				X			Design verification
3.1.6.1.1 Protocol Limitations									
Sentence 1	Implement all protocols	T				X	X	X	
Sentence 2	OBC only BC, monitor	T				X	X	X	
Sentence 3	All others function as RT	T				X	X	X	
Sentence 4	Format in component, S/S spec	I	I			X			Design verification
Sentence 5	Odd parity on RT address	I				X			Design verification
Sentence 6	User-defined subaddresses	I				X			Design verification
Sentence 7	Reserved subaddresses	I	I			X			Design verification
3.1.6.1.1. 1 Broadcast Messages	Describe in component spec.	T				X	X	X	
3.1.6.1.1. 2 Status Word Implementation	Respond per STD, Table IV	T				X	X	X	
3.1.6.1.1. 3 Mode Code Implementation	Implement per Table V	T				X	X	X	

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
3.1.6.1.2 Non Cross-Strapped Interface	Separate taps from A&B bus	T				X	X	X	
3.1.6.1.3 Cross-Strapped Interface	One set of taps for both sides	T				X	X	X	
3.1.6.2 Command and Logic Interfaces									
Sentence 1	Immune to noise pulses	T				X			
Sentence 2	Grounding per EMC spec	T, A	A	A, T		X	X	X	Component analysis applies to harness
Sentence 3	Command delivery	T				X			
Sentence 4	Serial bit stream	T				X			
Sentence 5	Modes not dependent on previous mode	A, T				X	X	X	
3.1.6.2.1 Relay Drive Commands									
Sentence 3	On level	T				X	X	X	Requirement on source
Sentence 4	Off state	A				X			Requirement on source
Sentence 5	Pulse duration	T				X	X	X	Users test with duration identified in PS
Sentence 6	Turn-on (Fall) time	A				X			Requirement on source
Sentence 7	Turn-off (Rise) time	A				X			Requirement on source
Sentence 8	Sink current	A				X			Requirement on source
Sentence 9	Fault current limit	T				X	X	X	Requirement on source
3.1.6.2.2 Relay Drive Command Receiver Circuit									
Sentence 2	Meet requirements of 3.1.6.2.1	A,T				X	X	X	
Sentence 3	Transient rejection	A				X			
Sentence 4	DC Offset rejection	A				X			
Sentence 5	Transient suppression	I				X			Design verification
3.1.6.2.4 Logic Level Interface									
Sentence 1	Use circuit in Figure 7	I, T		T		X	X	X	Inspection for design verification
Sentence 2	Configure for cross-strapped, non cross-strapped	I, T		T		X	X	X	Inspection for design verification
Sentence 3	Logic polarity	T				X	X	X	

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
Sentence 4	Positive true logic	I,D				X	X	X	
Sentence 5	Either or neither driver power								
Sentence 6	Guarantee inactive state	T				X	X	X	
Sentence 7	1 to 4 receivers	A				X			RIU analysis
Sentence 8	Fault tolerance	A				X			RIU analysis
3.1.6.2.5 High-Line FET Switch Interface									
Sentence 1-3	Use for heaters, thrusters w/low-line	I		I		X	X		Design verification
Sentence 4	Capable of 70V at 1A	T				X	X	X	
3.1.6.2.6 Low-Line FET Switch Interface									
Sentence 1-3	Use for heaters, thrusters w/high-line	I		I		X	X		Design verification
3.1.6.3 Telemetry									
Sentence 1	I/F per Figure 10	I				X			Design verification
Sentence 2-3	Isolation between sides	T				X	X	X	
Sentence 6	Bit 0 first transmitted, MSB	T,I				X	X	X	Inspection for design verification
Sentence 7	256 words per Tlm frame		D	D				X	
Sentence 8	First word is word 0		I	I			X		Design verification
3.1.6.3.1 Active Analog Telemetry									
Sentence 2	Voltage	T	T	T		X	X	X	
Sentence 3	Source Impedance to voltage	I				X			Design verification
Sentence 4	Source Impedance to ground	I				X			
Sentence 5	Signal bandwidth	A				X			
Sentence 6	Source failure overvoltage	A				X			
Sentence 7	Telemetry signal bandwidth	A				X			
Sentence 9	RIU input impedance	A				X			

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
Sentence 10	RIU mux failure output I	A				X			
Sentence 11	RIU low pass filter	T				X	X	X	
Sentence 12	System accuracy, BOL			A		X			
Sentence 13	System accuracy, EOL		A			X			
Sentence 14	Subsystem accuracy	A				X			
Sentence 15	Source accuracy	A				X			
3.1.6.3.2 Passive-Analog Telemetry									
Sentence 2	Output constant current	T				X	X	X	
Sentence 3	Line capacitance			A		X			Harness requirement
Sentence 4	Parallel resistor	I				X			Design verification
Sentences 5-6	CS type sensor	A,T,I		T		X	X	X	
Sentences 7-8	CW type sensor	A,T,I		T		X	X	X	
Sentence 9	CP type sensor	A,T,I		T		X	X	X	
3.1.6.3.3 Digital Discrete Telemetry									
Para 2	Ground/Open type	T	T	T		X	X	X	
Para 3	Logic level type	T	T	T		X	X	X	
Para 4	Both types	A				X			
3.1.6.3.4 Bidirectional Serial Bus									
Sentence 1	Xfer 32 bits, collect 16 bits	T		T		X	X	X	
Sentence 2	Interface signals	T		T		X	X	X	
Sentence 3	Transmit/Receive definition	I				X			Design verification
Sentence 4	Use interface in Figure 8	I,T		I,T		X	X		Inspection for design verification
Sentence 5	Use interface in Figure 11	I,T		I,T		X	X		Inspection for design verification
Sentence 6	Timing per Figure 12	T		T		X	X	X	
Sentences 7-11	Signal characteristics	T		T		X	X	X	
Sentence 12	Users connected per Fig. 13			I			X		Design verification

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
Sentence 13	16 users per bus	A,T		T		X	X	X	
Sentence 14	One side of RIU off	D				X	X	X	
Sentences 15-16	Parity	T		T		X	X	X	
Sentence 17	Discard commands < 32 bits	T				X			
3.1.6.3.5 Failure Protection	Fail-safe	A				X			
3.1.6.3.6 Telemetry Calibration	Calibrate active analog tlm	T				X	X	X	
3.1.6.3.6. 1 Temperature Testing of Active Analog Telemetry Circuits									
Sentence 1	Test one unit at all plateaus	T				X	X		
Sentence 4	Temperature tlm testing	T				X	X	X	
Sentence 6	Standard calibration curve			T			X	X	
3.1.6.3.6. 2 Test Data Required	Characterization rqmts	T				X	X	X	
3.1.6.3.6. 3 Test Data Accuracy									
Paragraph 2	Temperature	D				X	X	X	
Paragraph 3	Voltage	D				X	X	X	
Paragraph 4	Current	D				X	X	X	
3.1.6.4 Test Points	One of standard types	I				X			Design verification
3.1.6.4.1 Analog Test Points, Spacecraft Output									
Sentence 1	Signal level	T				X	X	X	
Sentences 2-3	Output configuration, impedance	I				X			Design verification
Sentences 4-6	Load impedance, accuracy, overvoltage	A				X			
3.1.6.4.2 Digital Test Points	Per logic level I/F	I,T				X	X	X	Inspection for design verification
3.1.6.4.3 Analog Test Points, Spacecraft Input									
Sentence 1	Signal level	T				X	X	X	
Sentence 2	Input configuration	I				X			Design verification

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
Sentence 3	Overvoltage	A				X			
3.1.6.4.4 Failure Protection	Fail safe	A				X			
3.2.1.1 Interface Control Drawing	Information in ICD	I				X			Design verification
3.2.1.2 Unit Weight	Measured accuracy	D				X	X	X	
3.2.1.3 Unit Center of Mass	CM location accuracy	A				X			
3.2.1.4 General									
Sentence 1	Parts	I				X			Design verification
Sentence 2	Materials and processes	I				X			Design verification
3.2.2.1 Mounting Technique									
Sentence 1	Mounted by bolts	I	I	I		X	X		Design verification
Sentence 2	Positive locking	I				X			Design verification
Sentence 3	Mounting bolt size, hole pattern	A,I		A		X	X		Analysis to determine hole pattern (Qual only)
Sentence 4	Number of bolts	A,I				X			
Sentence 5	Minimum spacing	I				X			Design verification
Sentence 6-7	Foot thickness	I				X			Design verification
Sentence 8	Insert strength	A				X			Analysis performed by unit designer to determine that insert pullout load is not exceeded for unit mounting bolt configuration
Sentence 9	Screw size	I				X			Design verification
Sentence 10	Fastener size	I				X			Design verification
3.2.2.2 Mounting Surfaces									
Sentences 1-3	Flatness	I				X	X	X	
Sentence 4	Roughness	I				X	X	X	
Sentence 5	Electrical contact resistance	A				X			
3.2.2.3 Mounting Hole Positional Tolerance									
Sentence 1	Location/tolerance	I				X	X	X	
Sentence 2	Diameter	I				X	X	X	

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
3.2.2.4 Fastener Clamp Load	No deformation	A				X			
3.2.3.2 Alignment Measurement									
Sentence 1	Provide cube, mirror	I				X	X	X	
3.2.3.3 Optical Tooling	Provide tooling	I				X			Design verification
3.2.4.1 Operations									
Sentence 1	Minimize disturbances			A			X		
Sentence 2	Characteristics in spec	I				X			Design verification
3.2.4.2 Caging									
Sentence 1	Cage remotely	D				X			
Sentence 2	No power to remain caged	D				X			
Sentence 3	Restrain all motions	A,T				X	X	X	
3.2.4.3 External Properties	Not affect thermal properties			A		X			
3.2.6 Dynamic Characteristics	Natural frequency	A				X			
3.2.7.2 Corrosion Protection	See PN20095414	I				X	X	X	
3.2.8 Venting									
Sentences 1-4	Aperture area	A				X			
Sentence 5	Consistent w/EMC	A				X			
3.2.9 Outgassing Materials									
Sentence 1	See PN20095414	I				X			Design verification
3.2.10 Interchangeability	Fully interchangeable	D				X	X	X	
3.2.11 Storage	Period, conditions	A				X			
3.2.12 Protective Covers									
Sentence 1	Protect sensitive areas	I				X	X	X	
Sentence 2	Removeable	I				X			Design verification
Sentence 3	Color coded red	I				X	X	X	
3.2.13 Maintainability									
Sentence 1-3	Factory repairable		D	D		X	X	X	
Sentence 4	No disassembly		D	D		X	X	X	
Sentences 5-6	Accessibility			I			X		Design verification

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
3.2.14 Spacecraft Reference Coordinate System	Per Figure 14			I			X		Design verification
3.3.1 General									
Sentence 1	Conductive coupling or radiation	A		A		X	X		
3.3.2 Unit Temperatures									
Sentence 1	Perform to spec at qual	T				X			
Sentence 2	Start-up, survival	A,T				X	X	X	
3.3.3 Internal Spacecraft Radiative Environment									
Sentence 1	Transfer orbit environment			A			X		
Sentence 2	On-orbit environment			A			X		
3.3.4 Unit Mounting									
Sentence 1	Method in ICD, Spec	I				X			Design verification
Sentence 2	Interface conductance		A	T			X	X	
3.3.5 Unit Surface Finishes									
Sentence 1	Unit conductivity and grounding	I				X			Design verification
Sentence 2	Emissivity	I				X			Design verification
Sentence 6	Delineate in ICD, Spec	I				X			Design verification
3.3.6 Heaters/Temperature Sensors									
Sentence 1	When required		A	A,T		X	X	X	Verify by Thermal Balance Test
Sentence 2	Definition on ICD, in PS	I				X			Design verification
Sentence 3	Location for monitoring	A				X			
Sentence 4	Location in ICD	I				X			Design verification
Sentence 5	Minimum of 1 inside unit	I				X			Design verification
3.3.9 Thermal Dissipations									

Table XI. Verification Matrix (Continued)

Paragraph No.	Requirement Description	Verification Level/ Method			Verification Category				Comments/Approach
		C	S/S	S/C	D	Q	P	A	
Paragraph 1	Thermal dissipation definition	I				X			Design verification
Paragraph 2	Dissipation at interface	A,T		A		X	X	X	Units with local dissipations exceeding guidelines require coupled thermal loads analysis
3.3.10 External Radiation Sources	Earth, Sun radiation			A			X		Assumptions for analysis
3.4.1 Residual Magnetic Dipoles									
Paragraph 1	Unit residual dipole	A				X			
3.4.2 Deleted									
3.5 Environmental Interface	Environmental Test Specs	A,T	A,T	A,T		X	X	X	
3.5.1 Space Radiation Environ									
Sentence 1	Unit comply	A				X			
Sentence 2	System and subsystem comply		A	A		X			
4.1 General Testing Requirements	Per Test Plans	I				X	X	X	
4.1.1 Functional Testing	Design to allow complete testing	A				X			
4.1.3 Unit Substitution	No scheduled unit replacement, connector demating at launch site	A		A		X			
4.1.4 Special Fault Conditions									
Sentence 2	Survive sudden input power termination	A				X			
Sentence 3	Fast turn on/Turn off	A				X			
Sentence 4	No failure mode due to any command sequence	A				X			

3.1 Electrical Interface

3.1.1 General 21574

All spacecraft subsystem units, payload units, and interconnecting harnesses **shall** be designed so that the failure of any interface from that unit **does** not cause the failure of any other unit.

3.1.2 Power

WARNING: The 70 volt dc operating voltage of the power distribution system represents a hazard to human health, and all applicable measures and rules should be followed during component test, harness check-out, initial turn-on, and spacecraft integration and test.

3.1.2.1 General

The spacecraft Electrical Power Subsystem supplies power to all spacecraft subsystem and payload units from two types of power buses:

- One 70 Vdc Main Power Bus, fully regulated at 68 to 71 volts at load interface
- Two Pyrotechnic Buses from the spacecraft batteries, nominally 28 to 32 volts at load interface

The 70 Vdc Main Power Bus distributes power to all spacecraft subsystem and payload units other than applications using high current, short duration pulses such as pyrotechnics or low shock deployment devices.. The Pyrotechnic Bus distributes power for igniting pyrotechnic or low shock deployment devices, and it supplies power to the ESA and SSA assemblies.

3.1.2.2 Main Power Bus 21577

The Main Power Bus is the spacecraft primary bus and supplies 70-volt dc power directly to spacecraft subsystem and payload units. The 70 Vdc Main Power Bus shall distribute power to each unit via fuses located near the Power Regulation Unit (PRU).

3.1.2.2.1 Main Power Bus-1 21578

Where remote fusing is employed, the wires from the PRU to the fuse boards shall be double insulated.

3.1.2.2.2 Main Power Bus-2 21579

Power distributed to primary and redundant functions shall be provided through separate and independent power conductors and fuses.

The voltage at the input to a unit is the 70 Vdc Main Power Bus voltage minus the IR drop in the fuse, connectors, relay contacts, and harnessing in both the feed and return paths to that unit.

3.1.2.2.3 Main Power Bus-3 21580

The maximum power distribution voltage drop for normal bus operating voltage ranges shall be less than 1.0V, including the effect of all losses in both the feed and return circuits including wirings, connectors, any power switching circuits, and fuses, as applicable at the worst case harness operating temperature and maximum specified load current.

The source impedance of the 70 Vdc Main Power Bus is defined in paragraph 3.1.2.2.8 and in general is negligible compared with the impedance of a single load.

The envelope of the Main Power Bus characteristics includes all modes of operation of the Electrical Power Subsystem.

3.1.2.2.4 Main Power Bus DC Voltage and Regulation (Normal Operation) 21581

The Main Power Bus dc regulation shall be 68 to 71 volts at the input connector of each spacecraft subsystem and payload unit

3.1.2.2.4.1 Main Power Bus DC Voltage and Regulation (Normal Operation)-1 21582

The Main Power Bus dc regulation shall be 69 to 71 volts at the central power distribution point. The 70 Vdc Main Power Bus is defined as being in normal operation at these voltages.

Additional design information are redacted for export.

3.1.2.2.5 Main Power Bus Voltage Transients and Ripple (Normal Operation) 21583

The 70 Vdc Main Power Bus has a superimposed ripple voltage which is the result of EPS-generated and load current ripples. The magnitude of this ripple and other voltage transients **shall** not exceed the levels defined in the A2100 EMC Specification, 20032596, under Conducted Emissions, System Power Ripple Limits and System Power Transient Limits.

3.1.2.2.5.1 Main Power Bus Voltage Transients and Ripple (Normal Operation)-1 21584

Units connected to the Main Power Bus **shall** comply with the levels defined in 20032596 under Equipment and Subsystems CE, Equipment Conducted Emissions Limit.

3.1.2.2.6 Deleted.

3.1.2.2.7 Deleted.

3.1.2.2.8 Main Power Bus Source Impedance 21587

The effective source impedance of the 70 Vdc Main Power Bus **shall** be the sum of the power supply fuse resistance (see paragraph 3.1.2.4), the contribution of the spacecraft harness (see paragraph 3.1.2.10), the electrical power subsystem, and the parallel combination of all loads connected to the bus. The source impedance of the power bus at the PRU regulation point including the influence of the loads connected to the bus is less than the value shown in Figure 1.

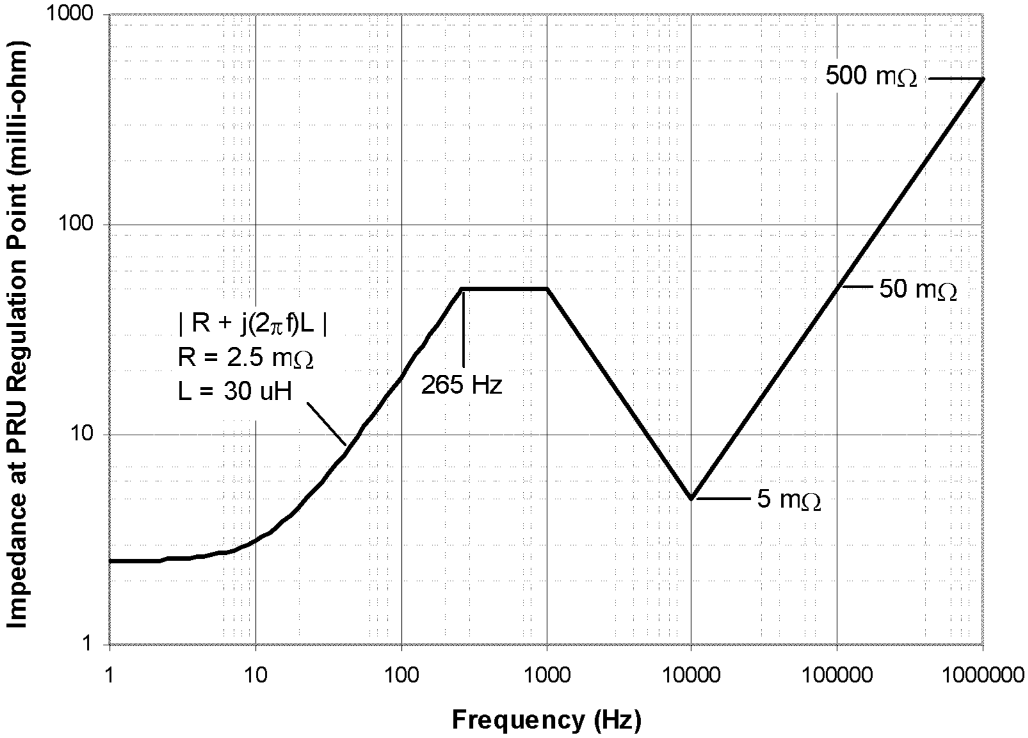


Figure 1 Main Power Bus Impedance at the PRU Regulation Point

The envelope includes the variation arising from the changes caused by the bus being supplied from the solar array only, batteries only, or combinations thereof, but does not include the fuses, connectors, and harness.

3.1.2.2.8.1 Main Power Bus Source Impedance-1 21588

The user of the bus **shall** assume that at the user input power connector the bus can be represented by a voltage generator having the dc and ac characteristics given in Section 3.1.2.2.4 and Figure 1 of this specification, which is supplied via the harness having the following properties:

- An equivalent series resistance less than 1.0V divided by the load current in amperes, or 0.4 ohm, whichever is the lesser value, and
- An equivalent series inductance of less than 5 microhenry for all bus subsystem loads assigned to the 15A PRU load current sensor and all communication subsystem loads, where the positive supply and its return contribute to the harness impedance.
- An equivalent series inductance of less than 15 microhenry for all bus subsystem loads assigned to the 6A PRU load current sensor, where the positive supply and return contribute to the harness impedance.

3.1.2.2.8.2 Main Power Bus Source Impedance-2 21589

The user **shall** report any significant susceptibility in his design to variations in source resistance and inductance.

3.1.2.2.9 Main Power Bus at Turn-on (Pre-launch and Test) 21590

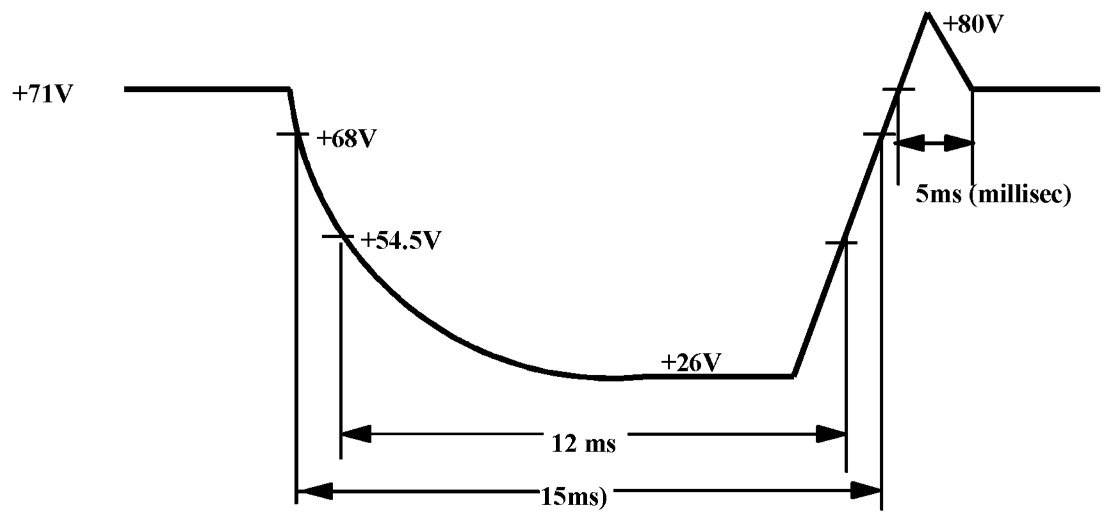
All users shall be capable of withstanding the following which may occur during assembly and test and power subsystem start-up prior to launch.

- Bus voltage changes at any rate up to 50 volts per millisecond
- Bus voltage is constant indefinitely at any voltage between zero and +71 volts.

3.1.2.2.10 Main Power Bus Under Fault Condition

A Main Power Bus fault condition can occur during integration and test, launch operations and on orbit. Under fault conditions, the response shown in Figure 2 may occur.

Worst Case Undervoltage



Worst Case Overvoltage, Rate of Change

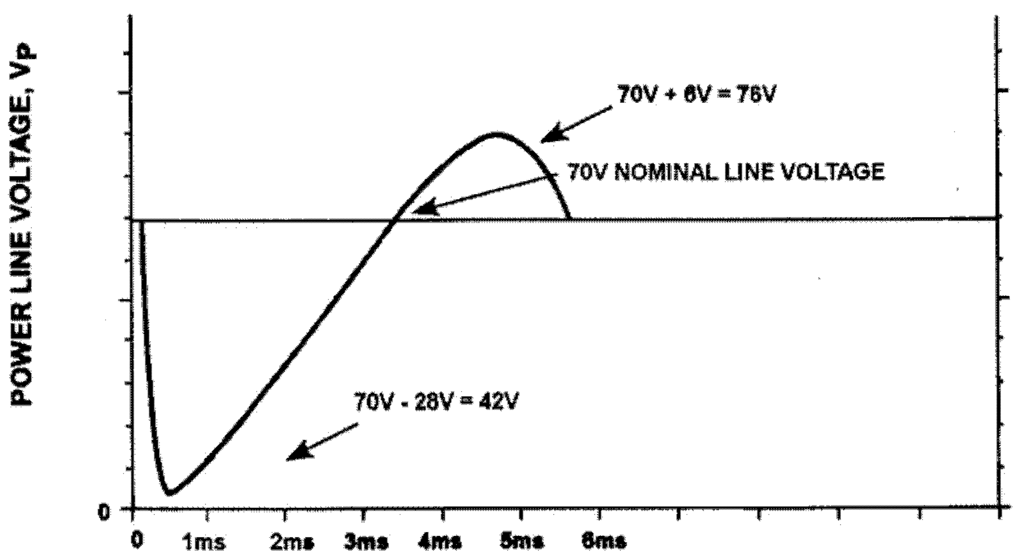


Figure 2 Main Power Bus Fault Response

The Main Power Bus voltage may also fall off at a rate of up to 50 volts per millisecond due to faults which cause the external power supply(ies) to shut down.

3.1.2.2.10.1 Main Power Bus Under Fault Condition-1 21592

Units needed for uplink command reception **shall** automatically resume normal operation following an undervoltage transient caused by a fuse blow. Other equipment may shut down as a result of a fuse blow undervoltage transient.

3.1.2.2.10.2 Main Power Bus Under Fault Condition-2 21593

The power buses **shall** be designed such that negative going transient conditions on the bus due to events other than fuse blow **will** be limited to that defined by paragraph 3.1.2.2.6.

3.1.2.2.10.3 Main Power Bus Under Fault Condition-3 21594

All spacecraft units **shall** continue to operate during voltage transients which are not caused by a fuse blow.

Additional unit-specific requirements are redacted for export.

3.1.2.2.11 Main Power Bus Undervoltage 21595

The detailed performance of any undervoltage turn-off design adopted **shall** be stated as an interface characteristic. Bus voltages defined in this paragraph refer to the voltage at the input connector to the unit.

The following particular requirements apply to:

3.1.2.2.11.1 Main Power Bus Undervoltage-1 21596

a. TWTA Transponders

TWTAs **shall** automatically switch off and latch to, or be in an off state if the bus voltage drops below 66.1 +0.7/-1.0 volt for greater than 1 ms

3.1.2.2.11.2 Main Power Bus Undervoltage-2 21597

Transponders **shall** not be capable of being switched on under the conditions of bus undervoltage.

3.1.2.2.11.3 Main Power Bus Undervoltage-3 21598

Transponders **shall** only turn-on when commanded

3.1.2.2.11.4 Main Power Bus Undervoltage-4 21599

Receivers **shall** latch off at an input bus voltage less than all amplifiers, but no less than 53.0 volts

3.1.2.2.11.5 Main Power Bus Undervoltage-5 21600

b. SSPA Transponders

SSPAs **shall** automatically switch off and latch to, or be in an off state if the bus voltage drops below a shutdown voltage of 64.0 + 1.5 volt

3.1.2.2.11.6 Main Power Bus Undervoltage-6 21601

Transponders **shall** not be capable of being switched on under the conditions of bus undervoltage.

3.1.2.2.11.7 Main Power Bus Undervoltage-7 21602

Transponders **shall** only turn-on when commanded

3.1.2.2.11.8 Main Power Bus Undervoltage-8 21603

c. Receivers **shall** latch off at an input bus voltage less than all amplifiers, but no less than 53.0 volts

Payload Panel Heaters

Redacted for export.

3.1.2.2.11.9 Main Power Bus Undervoltage-9 21604

d. Bus Subsystem Loads

a) The following spacecraft loads which are required to restore normal spacecraft operation **shall** operate functionally down to 54.5 volts:

Command Receivers

Beacon Transmitter

b) List of additional loads is redacted for export.

3.1.2.2.11.10 Main Power Bus Undervoltage-10 21605

c) The command subsystem **shall** not be damaged if the power bus voltage drops below 54.5 volts.

3.1.2.2.11.11 Main Power Bus Undervoltage-11 21606

d) The command subsystem **shall** automatically return to its normal operating mode when the voltage returns to within the required operating range.

e. Electrical Power Subsystem Equipment

Redacted for export.

3.1.2.2.12 Main Power Bus Fusing 21607

All users **shall** meet the following requirements:

- Have no internal fusing
- Ensure that the external fuse is protected from rupture during the bus fault condition (as defined in paragraphs 3.1.2.2.10 and 3.1.2.2.11)
- Ensure that the fuse operates within derated limits under all normal conditions of applied voltage

Specific fuse requirements are contained in paragraph 3.1.2.4.

3.1.2.2.13 Main Power Bus Component Off-State Current 21608

Users of the Main Power Bus **shall** draw less than 500 µA (35 mW) when in the off state except for bus subsystem components.

3.1.2.2.13.1 Main Power Bus Component Off-State Current-1 21609

Bus subsystem components shall draw less than 2 mA when in the off state.

3.1.2.2.13.2 Main Power Bus Component Off-State Current-2 21610

All loads except for those involved in command reception **shall** be off-commandable.

3.1.2.2.14 Main Power Bus Overvoltage During Ground Test 21611

All users **shall** be capable of withstanding an overvoltage on the Main Bus of up to 74 volts for a duration of up to 5 minutes without permanent degradation in performance.

3.1.2.2.14.1 Main Power Bus Overvoltage During Ground Test-1 21612

Ground test equipment **shall** limit bus voltage to less than 74V at the PRU.

3.1.2.3 Pyrotechnic Bus

Redacted for export.

Figure 3 Deleted

3.1.2.4 Fuses 21614

The Electrical Power Subsystem provides fuses required by units operating on the Main Power Bus. All spacecraft loads other than pyros **shall** be fused.

3.1.2.4.1 Fuse Sizing 21615

The system design and fuse selection **shall** ensure that the fuse is the weakest link in the current path; a criteria that puts a rating limit on the high as well as the low end of the fuse rating selection. Final fuse selection for individual units will be made by A2100 Systems Engineering.

3.1.2.4.1.1 Fuse Sizing-1 21616

Fuses **shall** be sized according to the derating requirements specified in APL20098029, including both steady state (dc) and normal operating pulsed load (rms) currents.

3.1.2.4.1.2 Fuse Sizing-2 21617

Each fuse **shall** be selected such that the smallest fuse is used which meets as a minimum, the following concerns:

3.1.2.4.1.2.1 Fuse Sizing-3 21618

Maximum applied current during normal operation, as defined in paragraph 3.1.2.2.4, shall not exceed the calculated derated maximum current through the fuse as specified in APL20098029.

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3.1.2.4.1.2.2 Fuse Sizing-4 21619

Worst case voltage drop limits shall not exceed the value in the allocation specified in paragraph 3.1.2.2.

3.1.2.4.1.2.2.1 Fuse Sizing-5 21620

This voltage drop limit **shall** be calculated by multiplying the worst case steady state current during normal operation by the average "hot" resistance of the fuse.

3.1.2.4.1.2.3 Fuse Sizing-6 21621

Very high amplitude short duration transients shall not exceed the calculated derated maximum current for the duration of the transient (as determined from the fuse characteristic curves – current vs. time and let-thru energy).

In order to ensure that the fuse is the weakest link in the current path, the load must be capable of sinking sufficient current to blow the fuse given worst case conditions for blowing the fuse (which is twice the rated current for 30 seconds for a fast blow fuse).

The fuse must be capable of withstanding, without degradation, the stresses placed upon it during testing, where the bus voltage may be applied or removed from the loads at the rate specified in paragraph 3.1.2.2.

Table I DELETED

3.1.2.5 Double Insulation 21622

All unfused, non-isolated, or otherwise unprotected components **shall** employ double insulation techniques to ensure that no single insulation failure will cause loss of the spacecraft or degrade system performance capability other than loss of redundancy.

3.1.2.6 Survivability 21623

All units **shall** survive any fault or abnormal operating condition of the 70 Vdc Main Power Bus and Pyrotechnic buses specified in this document, and subsequently be able to operate within specification after return to the normal operating condition.

For all conditions other than normal operation, components may be stressed beyond the derating values stated in APL20098029, but not beyond any specified maximum ratings.

3.1.2.7 Power Application 21624

At spacecraft turn-on, the voltages on the 70 Vdc Main Power Bus will be increased from 0 V to 70 V on the external power supplies at an average rate not to exceed 35 V per second.

For the purpose of design and analysis, power bus users **shall** assume that the instantaneous rate **does** not exceed the rate specified in paragraph 3.1.2.2.9.

3.1.2.7.1 Power Application-1 21625

Upon spacecraft start-up, all payload units on the 70 Vdc Main Power Bus **shall** be in the off state (e.g., TWTAs, SSPAs, panel heaters). The following units will be on at power application:

- Command Receivers
- Command & Telemetry Unit (CTU)

Additional requirements are redacted for export.

3.1.2.8 Transients

3.1.2.8.1 Immunity to Power Supply Transients 21627

All units **shall** withstand, without damage or impairment of component life, the following transient conditions.

3.1.2.8.1.1 Immunity to Power Supply Transients-1 21628

The unit **shall** operate within specification and exhibit no degradation of life or performance after return to normal operating voltage.

3.1.2.8.1.1.1 Immunity to Power Supply Transients-2 21629

Power supply contact bounce: Upon application of power to the unit via relay, no more than 10 milliseconds of contact bounce will exist, during which time the line may vary from the supply voltage to an open condition. All units **shall** withstand this transient condition with no unit producing inductive power supply voltage spikes or other spurious outputs detrimental to system performance during that interval.

3.1.2.8.1.2 Immunity to Power Supply Transients-3 21630

Gradual Turn-on: All units **shall** withstand gradual application of power, such as encountered during bench testing using manually operated power supplies.

3.1.2.8.1.3 Immunity to Power Supply Transients-4 21631

Power Line Transients: All units **shall** operate within specification in the presence of repetitive voltage pulses superimposed on the power line in accordance with 20032596 under Spacecraft and Equipment CS.

3.1.2.8.2 Allowable Transients 21632

The transient load current drawn by any unit from the Main Power Bus **shall** meet the following requirements:

3.1.2.8.2.1 Allowable Transients-1 21633

Charging current of RF filter capacitors equal to or less than 0.01 μF **shall** be excluded from the turn-on surge current requirements.

3.1.2.8.2.2 Allowable Transients-2 21634

Transients generated by the unit, including those at power turn-on, **shall** be contained within the appropriate allowable fuse overload interrupt time defined by the fuse SCD.

3.1.2.8.2.3 Allowable Transients-3 21635

Transients, excluding those generated by RF feedthroughs, generated by the unit **shall** not exceed the levels defined in 20032596 under Equipment and Subsystems CE, Equipment Repetitive Power Transient Limits.

3.1.2.8.2.4 Allowable Transients-4 21636

Pyrotechnic Bus transients **shall** be reviewed for acceptability by A2100 Systems Engineering.

3.1.2.8.3 Turn-off Transient Suppression 21637

No unit **shall** produce inductive voltage spikes on any of its power or signal interfaces upon sudden removal of the applied power or any change in operational mode.

3.1.2.8.3.1 Turn-off Transient Suppression-1 21638

If diode suppression is employed, a minimum of two series diodes **shall** be used.

3.1.2.8.3.2 Turn-off Transient Suppression-2 21639

The diodes **shall** be connected between power line and power return in such a fashion as to confine all circulating transient suppression currents within the unit.

3.1.2.9 Turn-on Current Surge 21640

When a unit connected to the Main Power Bus is commanded on, the inrush current **shall** not exceed the levels defined in 20032596 under Equipment and Subsystems CE, Transient Inrush Current Limits. Allowable transients (paragraph 3.1.2.8.2) are excluded from the surge requirements.

3.1.2.10 IR Loss in Harness. 21641

In the absence of appropriate data supplied in the Source Control Drawings, the following data **shall** be used to calculate the voltage drop in the harnessing from the fuse output to the input of the unit.

Resistance of Connector pair:

MIL-C-83513 (Microdot) or equivalent connector used for Logic Signals:
8 m ohm (max) (Does not include pigtails)

MIL-C-24308 (Cannon) or GSFC-311-P-4/07 (AMP High Density) connector used for Power or Logic Signals: 3 m ohm (max).

3.1.2.10.1 IR Loss in Harness-1 21642

3 m ohm (max). Maximum current per connector contact **shall** be as shown in the connector procurement specification.

MSFC40M39569 connector used for Enable Plugs:

2 m ohm (max) for 20 gauge contacts
1 m ohm (max) for 16 gauge contacts
0.63 m ohm (max) for 12 gauge contacts

Harness Wire Resistance: See Table II.

Table II Harness Wire Resistance in m ohm / ft. (@25°C)

AWG	Copper Wire	Copper Clad Aluminum	Be/Cu Wire
8	N/A	0.86	N/A
10	1.19	1.94	N/A
12	1.9	3.3	N/A
14	2.87	4.8	N/A
16	4.54	7.4	N/A
18	5.8	9.4	N/A
20	9.09	14.6	N/A
22	14.8	24.4	N/A
24	28.1	38.2	N/A
26	44.4	48.5	142.0
28	76.4	84.5	226.0
26	120.5	N/A	360.0

3.1.2.11 Deleted.

3.1.2.12 Noise Fed Back to Power Source 21644

The peak-to-peak electrical noise developed across a standard power source **shall** not exceed the requirements of 20032596. The characteristics of the standard power source and methods of measurements are described in that document.

3.1.2.13 External (GSE) Power Considerations

Redacted for export.

3.1.2.14 Deleted

3.1.2.15 Solar Array Voltage 21647

The voltage on the main power bus shall not exceed 1.0 volt when the spacecraft is powered off with the solar arrays installed and illuminated under ambient conditions.

3.1.3 Grounds

3.1.3.1 General 21649

The grounding system of the unit **shall** include the following grounds as applicable:

- Power Ground
- Signal Ground
- Shield Ground
- RF Signal and Chassis Ground
- Command Ground
- Pyrotechnic Return

3.1.3.1.1 General-1 21650

DC and AC isolation between all grounds within each unit **shall** be maintained except in the case of RF equipment, and any other equipment where the Signal and chassis ground are common.

For the purposes of this section, DC isolation is defined as not less than 100 kΩ resistance, and AC isolation is defined as not greater than 0.5 uF capacitance between grounds. If loss of a ground connection may result in equipment damage or single-point failure, separate grounds may be connected through diodes, subject to systems engineering approval, in which case the 100 kΩ minimum isolation applies when subjected to low voltages not exceeding ±100 mV. RF components include the Command Receivers, Beacon Transmitters, Payload Receivers, Transponder Amplifiers and their EPCs, and all antenna and associated passive components.

3.1.3.1.2 General-2 21651

Box chassis **shall** be grounded to the primary spacecraft structure.

3.1.3.1.3 General-3 21652

Metal-to-metal contact **shall** be maintained between all walls and elements comprising the chassis.

3.1.3.1.4 General-4 21653

Connectors **shall** be bonded to the chassis to provide a method to maintain unit shielding.

3.1.3.1.5 General-5 21654

Harness connectors **shall** provide a conductive path to chassis and the spacecraft ground.

3.1.3.1.6 General-6 21655

Circuit grounding external to units **shall** be controlled to limit circuit loop area.

3.1.3.1.7 General-7 21656

Spacecraft Single Point Ground **shall** be connected to spacecraft structure.

Additional requirements are redacted for export.

3.1.3.2 Power Ground 21657

Power ground (+70 volt return) **shall** be used as the return for all current drawn from the spacecraft Main Power Bus.

3.1.3.2.1 Power Ground-1 21658

The primary power returns **shall** be grounded to spacecraft Single Point Ground within the PRU.

3.1.3.2.1.1 Power Ground-2 21659

Power return conductors **shall** be provided for all current drawn from spacecraft power buses.

3.1.3.2.2 Power Ground-3 21660

Power users **shall** dc isolate primary power conductors from spacecraft structure or chassis with power return disconnected from the single ground point.

3.1.3.2.2.1 Power Ground-4 21661

Distributed secondary power users **shall** dc isolate power conductors from chassis or spacecraft structure.

3.1.3.3 Signal Ground 21662

Signal ground **shall** be the zero reference voltage for the secondary side of all DC/DC converters.

3.1.3.3.1 Signal Ground-1 21663

Signal ground **shall** be used as the reference and return for all telemetry circuits.

3.1.3.3.1.1 Signal Ground-2 21664

Signal ground **shall** also be used as the reference ground for the inner shield of any triaxial cables.

3.1.3.3.2 Signal Ground-3 21665

Non-RF signals **shall** be grounded to spacecraft structure only at the RIU via its signal ground connection to Single Point Ground (SPG), except in the case of telemetry signals originating from RF boxes, which may be grounded through the source box's signal ground connection to the chassis.

3.1.3.3.2.1 Signal Ground-4 21666

RF signals shall be grounded to spacecraft structure at both ends.

3.1.3.3.2.2 Signal Ground-5 21667

Signal wires **shall** be routed with a return conductor to reduce the circuit loop area to a minimum.

3.1.3.3.2.3 Signal Ground-6 21668

A minimum of 2 returns per unit **shall** be provided where single conductor wires are used for telemetry. Signals that use a shield as the return conductor may connect to the signal circuit reference and not be grounded to spacecraft structure directly.

3.1.3.3.2.4 Signal Ground-7 21669

RF signals **shall** use a shield as the return conductor that is grounded to structure via the connector shell and unit chassis.

3.1.3.4 Shield Ground 21670

The use of shields on wires contained within spacecraft harnesses **shall** be as specified in Paragraph 3.1.7.

3.1.3.4.1 Shield Ground-1 21671

Grounding of all outer shields **shall** be done by terminating them outside the unit to connector backshells on both ends.

3.1.3.4.1.1 Shield Ground-2 21672

Electromagnetic shields **shall** not be terminated inside a unit via a connector pin.

3.1.3.4.1.2 Shield Ground-3 21673

If any triaxial cables are used, the inner shield used for an isolated return conductor **shall** be terminated via a dedicated connector pin to signal ground.

Individual shields used as signal return may be grounded at one end to chassis or structure. The shield used as return should not be considered an electromagnetic shield and may be connected to signal reference at both ends.

3.1.3.4.2 Shield Ground-4 21674

Shielding of the MIL-STD-1553B data bus harnesses **shall** be in accordance with that standard.

3.1.3.5 RF Signal and Chassis Ground 21675

A connection to the chassis case ground **shall** be provided on the same connector used to interface with the spacecraft power input to the unit.

3.1.3.5.1 RF Signal and Chassis Ground-1 21676

Chassis ground **shall** be DC connected to the case (including outside wrapper and mounting surface) of the unit.

3.1.3.5.1.1 RF Signal and Chassis Ground-2 21677

The chassis ground connection to the spacecraft **shall** be made through a ground strap which ties to the spacecraft structure via inserts.

3.1.3.5.1.2 RF Signal and Chassis Ground-3 21678

The shells of all connectors interfacing with the spacecraft harness **shall** be grounded to the chassis of the unit.

3.1.3.5.1.3 RF Signal and Chassis Ground-4 21679

Chassis ground **shall** be used as the reference ground for the outer shield of any triaxial cables which interface with the unit.

3.1.3.5.1.4 RF Signal and Chassis Ground-5 21680

RF signals and circuits **shall** use chassis as the return path via internal connections.

3.1.3.5.1.5 RF Signal and Chassis Ground-6 21681

No wire connection through external connectors for chassis ground shall be allowed, except in the case of RF boxes, where connection to chassis ground may be made for the purpose of providing a reference for telemetry signals.

3.1.3.6 Command Ground 21682

The unit **shall** use separate wires (command ground) for the return current from relay coils or on/off circuits using the relay drive interface when they are commanded.

3.1.3.6.1 Command Ground-1 21683

Relay and discrete command circuits **shall** be grounded to chassis or structure through the RIU connection to SPG only.

3.1.3.6.1.1 Command Ground-2 21684

At least 2 command return conductors back to the source **shall** be provided for each electronic equipment unit using relay drive interfaces.

3.1.3.7 Pyrotechnic Return

Redacted for export.

3.1.4 Electromagnetic Interference 21686

Units connected to the 70V Main Power Bus shall be subject to the requirements of the EMC specification, 20032596.**will** be used as the basis for the EMI test program to be performed at the unit level.

3.1.4.1 Electromagnetic Interference-1 21687

The EMC specification, 20032596, shall be used as the basis for the EMI test program to be performed at the unit level.

3.1.4.2 Electromagnetic Interference-2 21688

Retesting **shall** be performed whenever a design modification is implemented within the unit which could change the EMI behavior of the unit.

3.1.4.2.1 Electromagnetic Interference-3 21689

In the event that such a change is proposed, agreement to the amount of retesting **shall** be established between the designer or subcontractor and A2100 Systems Engineering.

3.1.5 Connector Use and Pin Allocation 21690

Each unit's performance specification **shall** include a complete list of all inputs and outputs, each identified by a signal name.

3.1.5.1 Connector Use and Pin Allocation-1 21691

A2100 Systems Engineering **shall** generate an identification for unit and box connector pin designations including abbreviated signal names, and will reconcile any differences in these inter-unit signal names.

3.1.5.1.1 Connector Use and Pin Allocation-2 21692

In addition to identifying the signal names at the I/O connectors, each unit's Performance Specification **shall** include an Electrical Interface Control Document which will also identify the signal type, wire type, current levels for power interfaces, and the unit destination for each signal.

Preferred connector types are given in Table III.

Table III Preferred Connector Types

Flight Part Number	Type	Unit	Harness
20032754 20032521	Microminiature D (MIL-C-83513) Microminiature D with flex cable Malco MCK Series, ITT Cannon MDM series	X X	X
GSFC-S-311-P-40x Specs	D Subminiature; Standard and High Density (MIL-C-24308)	X	X
20025720	D Subminiature, High Density, Posted Pin (MIL-C-24308)	X	
2629443	D Subminiature, Standard Density (MIL-C-24308)	X	
MSFC40M39569 MSFC40M38298 MSFC40M38277	NB Series, Circular, Standard Density NBS Series, Circular, Standard Density NLS Series, Circular, High Density	X X X	X X X
20034844 20034845 20038047 20038048	Circular, Series II, pins Circular, Series I, pins Circular, Series II, sockets Circular, Series I, sockets (MIL-C-38999 upgrade)	X X X X	X X X X
20040889 20040890	Raychem DK-621-0412-P (Bus A), -S (Bus B) Raychem DK-621-0411(-P,-S) Triax (MIL-STD-1553)	X	 X
Note: For Subcontractors, SCD number is for reference only.			

3.1.5.2 Connector Use and Pin Allocation-3 21693

External electrical power supplied through test connectors and launch site umbilicals **shall** have diode protection on the spacecraft side of the interface.

3.1.5.3 Connector Use and Pin Allocation-4 21694

All units **shall** have redundant input power and return pins. Both sets will be used when additional harness wiring is required for current carrying or voltage drop considerations.

3.1.5.4 Power and Grounds 21695

Excluding pyrotechnic interfaces, all power inputs and power grounds **shall** be on the same connector of the unit.

3.1.5.4.1 Power and Grounds-1 21696

This connector **shall** be a male connector on the unit unless a MIL-C-83513 (Microdot) connector is used, in which case the unit-mounted connector **shall** be a female connector.

3.1.5.4.2 Power and Grounds-2 21697

Main bus power and return pins **shall** be assigned such that they are physically separated on the connector.

3.1.5.4.3 Power and Grounds-3 21698

That is, at least one spare pin location **shall** separate main bus power from its return and from other signal or return pins.

3.1.5.4.4 Power and Grounds-4 21699

The power and ground return characteristics for all spacecraft equipment with power supplies **shall** be in accordance to the requirements stated in 20032596.

3.1.5.5 Data Outputs 21700

All data outputs other than those located on the connector which accepts power and ground from the spacecraft harness **shall** be located on female connectors, unless a MIL-C-83513 (Microdot) connector is used, in which case the unit-mounted connector **shall** be a male connector.

3.1.5.6 Relay Drive Commands 21701

Command inputs for activation of relays or other switching circuits and the associated command ground **shall** be assigned on the same connector.

3.1.5.7 Chassis Ground Pin 21702

Pin l of the power input connector to the unit **shall** be assigned to chassis ground.

3.1.5.7.1 Chassis Ground Pin-1 21703

The flight harness **shall** not make any connection to this pin.

3.1.5.8 Shield Ground Pin 21704

The shield ground (see Section 3.1.3.4) input to the unit **shall** be assigned to a pin on the same connector as the shield pins. Shield ground pins are only required for interfaces using triaxial cable.

3.1.5.8.1 Shield Ground Pin-1 21705

The pin assigned to the shield of a shielded wire **shall** be adjacent to the pin assigned to the signal.

3.1.5.9 Signal Output Pins 21706

Signal pins **shall** be assigned so as to be located as far as practical from the power input and power return pins.

3.1.5.10 Signal Ground Pins 21707

At least two signal ground pins **shall** be assigned on the same connector as the signal output pins.

3.1.5.10.1 Signal Ground Pins-1 21708

Signal ground pins **shall** be tied together internal to the component.

3.1.5.11 Spare Pins

Where practical, a minimum of 10% spare pins **will** be provided per connector.

3.1.5.12 Connector Location and Identification 21710

All connectors **shall** be clearly and uniquely identified with appropriate labeling or marking standards.

3.1.5.12.1 Connector Location and Identification-1 21711

All unit connector locations, orientation, and identification **shall** be defined on the unit Interface Control Drawing (ICD)/Source Control Drawing (SCD).

3.1.5.13 Connector Keying 21712

Wherever possible and whenever damage to flight equipment can result, connectors **shall** be selected and keyed to preclude incorrect connections.

3.1.5.13.1 Connector Keying-1 21713

All unit connectors keying **shall** be designated in accordance with the unit ICD/SCD.

3.1.5.14 Test Connectors 21714

Wherever possible, signals required for spacecraft level test or diagnostic purposes **shall** be routed through dedicated test connectors on shielded wires.

3.1.5.14.1 Test Connectors-1 21715

Test connectors **shall** have protective electromagnetic shielded covers installed at all times when the test connector is not in active use.

3.1.5.14.1.1 Test Connectors-2 21716

The shielded covers **shall** be capable of withstanding the launch and orbital environments.

Additional requirements are redacted for export.

3.1.5.15 Flight Plugs and Locations

Redacted for export.

3.1.6 Command, Telemetry, and Data Interfaces

Command, telemetry, and data interfaces between other subsystems and the TT&C subsystem are implemented via two possible paths; the first is via a direct connection to a dual MIL-STD-1553B data bus and the second is via standard analog and digital interfaces with RIUs.

3.1.6.1 1553 Bus Interfaces 21719

Components interfacing directly to the MIL-STD-1553B bus **shall** conform to the MIL-STD-1553B data protocols, formats, and timing.

3.1.6.1.1 1553 Bus Interfaces-1 21720

All components interfacing with the data bus **shall** use a transformer coupled stub.

3.1.6.1.2 Data Bus-1 21721

Direct coupling shall not be allowed.

3.1.6.1.3 Protocol Limitations 21722

All units on the MIL-STD-1553B bus **shall** implement all of the protocols required by MIL-STD-1553B except as delineated in the following subparagraphs.

3.1.6.1.3.1 Protocol Limitations-1 21723

The only onboard component that **shall** perform the bus controller or monitor function is the OBC.

3.1.6.1.3.2 Protocol Limitations-2 21724

All other components **shall** function as remote terminals (RT) only.

3.1.6.1.3.3 Protocol Limitations-3 21725

The format of message and data transmissions will vary between components and details **shall** be defined in the component specifications and the TT&C subsystem specification.

3.1.6.1.3.4 Protocol Limitations-4 21726

All units on the Bus **shall** implement odd parity on their RT address to satisfy the requirements of Paragraph 30.3 of MIL-STD-1553B, Notice 2.

3.1.6.1.3.5 Protocol Limitations-5 21727

User-defined subaddresses **shall** be within the range of 10000 to 11101.

3.1.6.1.3.5.1 Protocol Limitations-6 21728

Subaddresses 11110 and 11111 **shall** be reserved and implemented for Data Wrap-around and Mode Codes, respectively.

3.1.6.1.3.6 Broadcast Messages 21729

Response to Broadcast Messages are optional and **shall** be described in the component performance specification.

3.1.6.1.3.6.1 Broadcast Messages-1 21730

In accordance with MIL-STD-1553B, an RT with the broadcast option **shall** set the "Broadcast Command Received" bit in the status word and suppress the status word.

3.1.6.1.3.7 Status Word Implementation 21731

All units on the Bus **shall** respond with Status Words per MIL-STD-1553B requirements.

3.1.6.1.3.7.1 Status Word Implementation-1 21732

The definition and implementation of Status word bits **shall** be per Table IV. Specific unit-level applications of these bits are redacted for export.

Table IV MIL-STD-1553B Status Word Implementation Requirements

Bit(s)	Feature/Mode	Implementation Requirements
1-3	Sync	As required by MIL-STD-1553B
4-8	RT Address	Assigned MIL-STD-1553B Remote Address

3.1.6.1.3.7.1.1 Status Word Implementation-2 21733

9	Message Error	**Shall** be set to a logic one by all Units in response to a received illegal or unimplemented Command or Subaddress.

3.1.6.1.3.7.1.2 Status Word Implementation-3 21734

10	Instrumentation	**Shall** be set to a logic zero by all RTs and a logic one by the Bus Controller to identify a Status Word and Command Word, respectively.

3.1.6.1.3.7.1.3 Status Word Implementation-4 21735

11	Service Request	**Shall** be set to a logic one to indicate that the RT is requesting service.

3.1.6.1.3.7.1.3.1 Status Word Implementation-5 21736

11	Service Request	Specific uses of this bit **shall** be defined in the unit Performance Specification.
12-14	Reserved	As required by MIL-STD-1553B

3.1.6.1.3.7.1.4 Status Word Implementation-6 21737

15	Broadcast Command Received	**Shall** be set to a logic one to indicate that a Broadcast Command has been received.

3.1.6.1.3.7.1.4.1 Status Word Implementation-7 21738

15	Broadcast Command Received	Units **shall** not respond to Broadcast Commands in any manner except for setting this Status Word bit.

3.1.6.1.3.7.1.5 Status Word Implementation-8 21739

16	Busy	**Shall** be set to a logic one to indicate that the RT is unable to act on the message received from the Bus Controller.

3.1.6.1.3.7.1.5.1 Status Word Implementation-9 21740

16	Busy	Specific uses of this bit **shall** be defined in the unit Performance Specification.

3.1.6.1.3.7.1.6 Status Word Implementation-10 21741

17	Subsystem Flag	**Shall** be set to a logic one to indicate an internal failure in the RT or that the data requested may not be valid.

3.1.6.1.3.7.1.6.1 Status Word Implementation-11 21742

17	Subsystem Flag	Units **shall** use this bit to indicate detectable internal failures or conditions resulting in the potential of incorrect operation or corruption of MIL-STD-1553B data as defined in the unit Performance Specification.

3.1.6.1.3.7.1.7 Status Word Implementation-12 21743

18	Dynamic Bus Cntl Acceptance	**Shall** not be implemented and permanently set to a logic zero by all units on the MIL-STD-1553B Bus.

3.1.6.1.3.7.1.8 Status Word Implementation-13 21744

19	Terminal Flag	**Shall** be set to a logic one to indicate RT fault as a result of self-test.

3.1.6.1.3.7.1.8.1 Status Word Implementation-14 21745

19	Terminal Flag	**Shall** be set to a logic zero permanently if RT does not contain any self-test feature. .

3.1.6.1.3.7.1.8.2 Status Word Implementation-15 21746

19	Terminal Flag	Units **shall** use this bit to indicate fault conditions as a result of any implemented self-test features as defined in the unit Performance Specification.
20	Parity	As required by MIL-STD-1553B

3.1.6.1.3.8 Mode Code Implementation 21747

MIL-STD-1553B Mode Codes **shall** be implemented as delineated in Table V. Additional unit-level implementation requirements are redacted for export.

Table V MIL-STD-1553B Mode Code Implementation Requirements

3.1.6.1.3.8.1 Mode Code Implementation-1 21748

#	Command	Implementation Requirements
0	Dynamic Bus Control	**Shall** be an Illegal RT Command.

3.1.6.1.3.8.1.1 Mode Code Implementation-2 21749

0	Dynamic Bus Control	RTs **shall** respond by setting the Message Error bit in their Status Word to a logic one.

3.1.6.1.3.8.2 Mode Code Implementation-3 21750

1	Synchronize	Units **shall** respond with a Status Word.

3.1.6.1.3.8.2.1 Mode Code Implementation-4 21751

1	Synchronize	Additional actions or responses **shall** be documented in the component performance specification.
2	Transmit Status Word	As required by MIL-STD-1553B.

3.1.6.1.3.8.3 Mode Code Implementation-5 21752

3	Initiate Self-Test	**Shall** cause the RT to perform Self-Test if the RT contains a Self-Test feature.

3.1.6.1.3.8.3.1 Mode Code Implementation-6 21753

3	Initiate Self-Test	For Units not containing a Self-Test feature, response **shall** be no action taken other than responding with a Status Word.

3.1.6.1.3.8.3.2 Mode Code Implementation-7 21754

3	Initiate Self-Test	Units **shall** implement this Command per the definition above as per the unit Performance Specification.
4	Transmitter Shutdown	As required by MIL-STD-1553B.
5	Override Transmitter Shutdown	As required by MIL-STD-1553B.
6	Inhibit Terminal Flag Bit	As required by MIL-STD-1553B.

7	Override Inhibit Terminal Flag Bit	As required by MIL-STD-1553B.

3.1.6.1.3.8.4 Mode Code Implementation-8 21755

8	Reset RT	**Shall** reset the MIL-STD-1553B logic in RTs.
9-15	Reserved	As required by MIL-STD-1553B.

3.1.6.1.3.8.5 Mode Code Implementation-9 21756

16	Transmit Vector Word	Units **shall** perform no action in response to this Command other than responding with a Status Word.

3.1.6.1.3.8.6 Mode Code Implementation-10 21757

17	Synchronize	Units **shall** respond with a Status Word.

3.1.6.1.3.8.6.1 Mode Code Implementation-11 21758

17	Synchronize	Additional actions or responses **shall** be documented in the component performance specification.
18	Transmit Last Command	As required by MIL-STD-1553B.

3.1.6.1.3.8.7 Mode Code Implementation-12 21759

19	Transmit BIT Word	Units with BIT (Built-In-Test) **shall** respond by sending an appropriately defined Data Word indicating the result of BIT.

3.1.6.1.3.8.7.1 Mode Code Implementation-13 21760

19	Transmit BIT Word	Units without BIT **shall** perform no action other than responding with a Status Word.

3.1.6.1.3.8.7.2 Mode Code Implementation-14 21761

19	Transmit BIT Word	Units **shall** respond as specified above per the unit Performance Specification.

3.1.6.1.3.8.8 Mode Code Implementation-15 21762

20	Selected Transmitter Shutdown	**Shall** be an Illegal RT Command.

3.1.6.1.3.8.8.1 Mode Code Implementation-16 21763

20	Selected Transmitter Shutdown	RTs **shall** respond by setting the Message Error bit in their Status Word to a logic one.

3.1.6.1.3.8.9 Mode Code Implementation-17 21764

21	Override Selected Transmitter Shutdown	**Shall** be an Illegal RT Command.

3.1.6.1.3.8.9.1 Mode Code Implementation-18 21765

21	Override Selected Transmitter Shutdown	RTs **shall** respond by setting the Message Error bit in their Status Word to a logic one.

3.1.6.1.3.8.10 Mode Code Implementation-19 21766

22 to 31	Reserved	**Shall** be an Illegal RT Command.

3.1.6.1.3.8.10.1 Mode Code Implementation-20 21767

22 to 31	Reserved	RTs **shall** respond by setting the Message Error bit in their Status Word to a logic one.

3.1.6.1.4 Non Cross-Strapped Interface 21768

Internally redundant components that are not cross-strapped to the bus shall have separate taps from both the A-bus and B-bus for each side of the component. Figure 4 illustrates the interface.

3.1.6.1.4.1 Non Cross-Strapped Interface-1 21769

Where both sides of a redundant component may operate simultaneously, the non cross-strapped interface **shall** be used.

3.1.6.1.4.1.1 Non Cross-Strapped Interface-2 21770

Different RT addresses shall be assigned to each redundant side. In the event that both sides cannot be powered simultaneously, because of command interlock, the two redundant sides may be assigned the same RT address on a spacecraft (implemented redundantly).

3.1.6.1.4.2 Non Cross-Strapped Interface-3 21771

In the case of components that are not internally redundant, the interface in Figure 4 **shall** be utilized, but only with Side A; Side B is not applicable to such RTs.

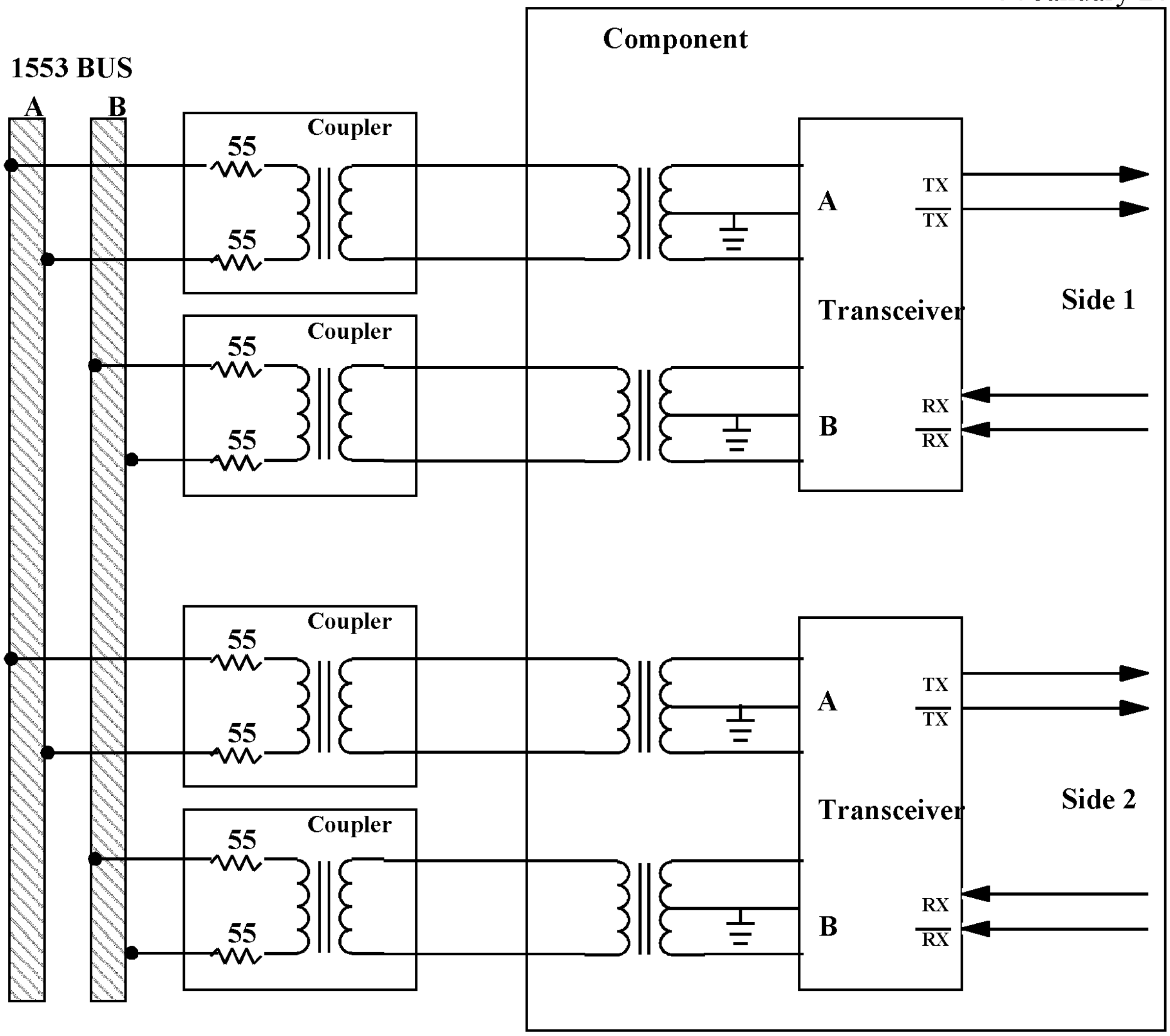


Figure 4 1553 Bus Non Cross-strapped Interface

3.1.6.1.5 Cross-Strapped Interface 21772

Internally redundant components that are cross-strapped to the bus shall have one pair of taps from both the A-bus and B-bus to handle both sides of the component. Figure 5 illustrates the interface.

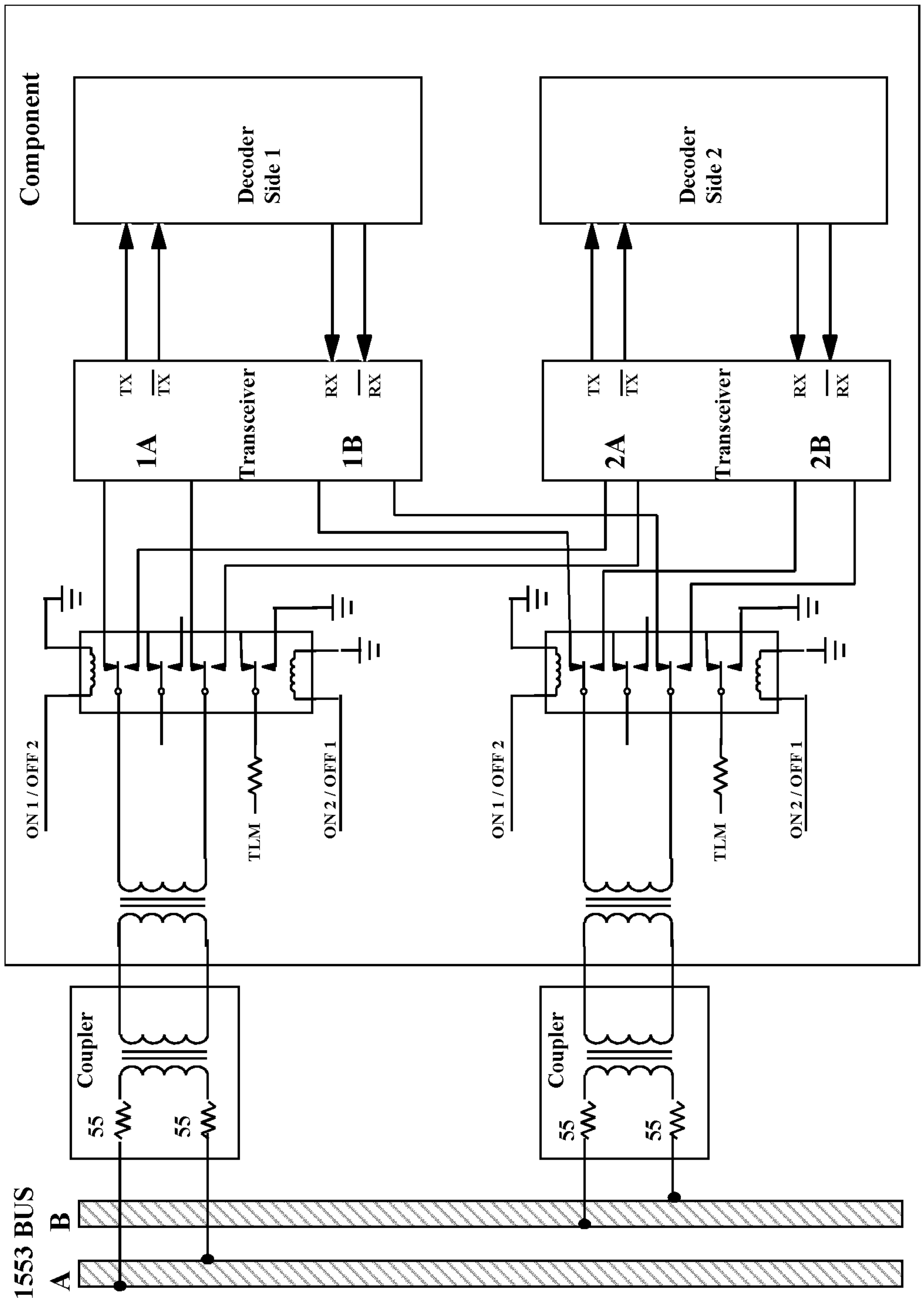


Figure 5 1553 Bus Cross-strapped Interface

3.1.6.1.5.1 Cross-Strapped Interface-1 21773

The same RT address shall be assigned to each redundant side of the component. The RT address is a five-bit code that is assigned at spacecraft level, and implemented by terminating connector pins high or low in the wiring harness.

3.1.6.1.5.1.1 Cross-Strapped Interface-2 21774

A sixth pin **shall** be provided for odd parity on the RT address.

3.1.6.1.5.1.2 Cross-Strapped Interface-3 21775

The address pins **shall** be implemented independently for each redundant side of the RT.

3.1.6.1.5.2 Cross-Strapped Interface-4 21776

Identical 1553 bus transactions (RT address, subaddresses, and data words) **shall** be used regardless of whether side –1 or side –2 of the RT is powered / connected.

3.1.6.1.5.3 Cross-Strapped Interface-5 21777

The relay drive command pulses that turn the RT sides on and off, and that connect each side to the 1553 bus, **shall** be configured per Table XII.

Table XII On/Off Command and 1553 Bus Relays Truth Table

Command Pulse	EPC-1 On/Off	EPC-2 On/Off	1553 Prime Bus Relay	1553 Backup Bus Relay
Side-1 ON	ON	(off)	Select Side-1	Select Side-1
Side-2 ON	(off)	ON	Select Side-2	Select Side-2
Side-1 OFF	OFF	-	-	-
Side-2 OFF	-	OFF	-	-

3.1.6.1.6 Remote Terminal (RT) Operation 21778

The RT responses **shall** be predictable and immediately available upon switch-on.

3.1.6.1.6.1 Remote Terminal (RT) Operation-1 21779

If the RT contains a microcomputer, it **shall** not require "care and feeding" to load code or data, nor to go through several steps to be ready to execute commands and collect telemetry, although provisions may be made for updating firmware and data.

3.1.6.1.6.2 Remote Terminal (RT) Operation-2 21780

The RT **shall** be self-clocking.

3.1.6.1.6.2.1 Remote Terminal (RT) Operation-3 21781

The RT sha**ll** not rely on an external frequency or time reference for its activity on the 1553 bus.

3.1.6.1.6.3 Remote Terminal (RT) Operation-4 21782

In accordance with paragraph 4.3.2 "Bit priority" of MIL-STD-1553B, in all fields and sub-fields transmitted serially over the 1553 bus, the most significant bit **shall** be transmitted first in time.

3.1.6.1.6.3.1 Remote Terminal (RT) Operation-5 21783

Data word transmission bits shall be as follows: bits 1-3 are sync, bits 4-19 contain a 16-bit data word, and bit 20 is parity.

3.1.6.1.6.3.2 Remote Terminal (RT) Operation-6 21784

Bit 4 **shall** be the most-significant end of the 16-bit word.

3.1.6.1.6.4 Remote Terminal (RT) Operation-7 21785

In accordance with paragraph 4.4.1.3 "Terminal fail-safe" of MIL-STD-1553B, the remote terminal **shall** contain a time-out, implemented in hardware, to ensure that no signal transmission exceeds 800 microseconds. Such protection against "babbling terminal" is critical to isolating the fault from the bus, as further transactions on the 1553 bus are required to switch power from the offending RT. The failed terminal with such a fail-safe timer may produce an 800-microsecond transmission every time the terminal receives a valid command.

3.1.6.1.6.4.1 Remote Terminal (RT) Operation-8 21786

The Bus Controller shall ensure that transactions to switch power to the offending RT are at least 1.6 milliseconds after any normal scheduled transactions with the RT.

3.1.6.1.6.5 Selection of Command Execution Within the RT Via 1553 Bus 21787

The RT may implement configurable data registers, which control the internal states (for example, subfunction enable/disable, gain or level settings). Registers within the RT, selected by subaddress, may be loaded directly by the Bus Controller, using transactions with a single data word (preferred) or with two data words. Messages to the RT **shall** not require more than two data words.

3.1.6.1.6.5.1 Selection of Command Execution Within the RT Via 1553 Bus-1 21788

Mode codes **shall** not be used for this type of control.

3.1.6.1.6.5.2 Selection of Command Execution Within the RT Via 1553 Bus-2 21789

It shall be possible to update these registers immediately after receipt of a prior update.

3.1.6.1.6.5.3 Selection of Command Execution Within the RT Via 1553 Bus-3 21790

This command type **shall** not need the Busy bit.

3.1.6.1.6.5.4 Selection of Command Execution Within the RT Via 1553 Bus-4 21791

Pulse commands are actions that the RT will take over a time interval consistent with Figure 17. Any pulse command that the RT produces **shall** be completely specified by a single 1553 transmission containing the allocated RT address, a subaddress, and one 16-bit data word.

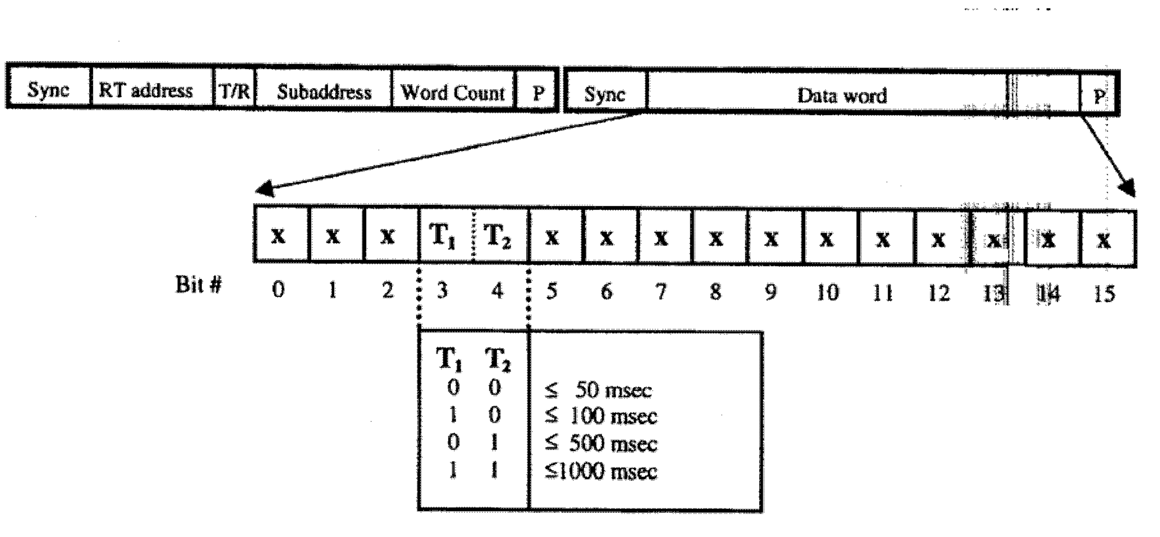


Figure 17 Pulse Command Format Constraint

3.1.6.1.6.5.4.1 Selection of Command Execution Within the RT Via 1553 Bus-5 21793

Subaddress 29 [11101] **shall** be used for any pulse commands.

The bit pattern of the single-word pulse command is constrained as shown in Figure 17, where bits 3 and 4 specify the maximum pulse duration.

3.1.6.1.6.5.5 Selection of Command Execution Within the RT Via 1553 Bus-6 21794

Every serial command, and any other command type that the RT implements, **shall** be completely specified by a single transmission containing the allocated RT address, a subaddress, and either one or two 16-bit data words. Different subaddresses may be used for different commands.

3.1.6.1.6.5.6 Selection of Command Execution Within the RT Via 1553 Bus-7 21795

If only one command may be processed at a time by a subaddressed circuit, then after the immediate Status Word reply in which the RT acknowledges receipt of the command, the RT **shall** set the Busy bit in any subsequent Status Words associated with similar commands, until the command execution is complete. The number of subaddresses, each of which has the potential to be "busy", must be coordinated with the TT&C subsystem and with Flight Software.

3.1.6.1.6.5.6.1 Selection of Command Execution Within the RT Via 1553 Bus-8 21796

The busy state of a command subaddress **shall** not affect telemetry operations.

3.1.6.1.6.5.6.2 Selection of Command Execution Within the RT Via 1553 Bus-9 21797

Status Words for telemetry requests and reads **shall** not indicate "busy" state because of overlap with extended execution of a command. It is expected that most commands would complete execution within 50 milliseconds. Longer commands may be accommodated but this must be distinguishable in the bit patterns.

3.1.6.1.6.6 Telemetry Acquisition From the RT Via 1553 Bus 21798

Any registers within the RT, selected by subaddress and constantly available without set-up time, may be read directly by the Bus Controller, using a single transaction. In such a transaction, the RT is commanded to transfer the register contents at a particular subaddress. It is preferred that only one dataword be read back from each subaddress. If an RT stores more than one 16-bit dataword at a subaddress, the word order should be coordinated with the TT&C subsystem and with Flight Software.

Telemetry reports other than register read-back **shall** be obtained from the RT using two 1553 bus transactions, both under the control of the Bus Controller (BC):

- Telemetry Request, by which the BC supplies an address to the RT
- Telemetry Response, during which the RT returns the data to the BC

Two methods are available for these transactions:

- Analog / Discrete Telemetry Readings:

3.1.6.1.6.6.1 Telemetry Acquisition From the RT Via 1553 Bus-1 21799

- The BC supplies a Telemetry Request, consisting of the allocated RT address ("RT"), a subaddress, and one 16-bit data word supplied to the RT. The RT shall reply immediately with its Status Word, and begin to acquire the telemetry reading.

3.1.6.1.6.6.2 Telemetry Acquisition From the RT Via 1553 Bus-2 21800

- The RT **shall** be ready within 400 microseconds of the completion of the request transaction.

3.1.6.1.6.6.3 Telemetry Acquisition From the RT Via 1553 Bus-3 21801

- The BC requests a Telemetry Response consisting of one word from the same RT Address ("RT") and he same subaddress. No data word is supplied to the RT at this time. The RT **shall** respond immediately with its Status Word, followed by a single 16-bit data word.

3.1.6.1.6.6.4 Telemetry Acquisition From the RT Via 1553 Bus-4 21802

- Serial Telemetry Readings:

  - The BC supplies a Telemetry Request, consisting of the allocated RT address ("RT"), a subaddress, and one 16-bit data word supplied to the RT. The RT **shall** reply immediately with its Status Word, and begin to acquire the telemetry reading.

3.1.6.1.6.6.5 Telemetry Acquisition From the RT Via 1553 Bus-5 21803

- The RT **shall** be ready with the serial response word in less than 900 microseconds of the completion of the request transaction.

3.1.6.1.6.6.6 Telemetry Acquisition From the RT Via 1553 Bus-6 21804

- The BC requests a Telemetry Response consisting of one word from the same RT address ("RT") and the same subaddress. No data word is supplied to the RT at this time. The RT **shall** respond immediately with its Status Word, followed by a single 16-bit data word.

3.1.6.1.6.6.7 Analog Telemetry Function 21805

The RT **shall** make measurements of analog parameters such as voltage, current, RF power, temperature and angle.

3.1.6.1.6.6.7.1 Analog Telemetry Function-1 21806

To accomplish this, the RT **shall** use an analog-to-digital (A/D) converter, and appropriate signal conditioning circuits. The requirements that must be met by the RT analog telemetry circuit are as follows.

3.1.6.1.6.6.7.2 Analog Telemetry Function-2 21807

Digitization: The A/D converter **shall** provide at least 8 bits.

3.1.6.1.6.6.7.2.1 Analog Telemetry Function-3 21808

The digital reading **shall** increase monotonically as the analog input increases.

3.1.6.1.6.6.7.3 Analog Telemetry Function-4 21809

Linearity: The A/D converter linearity over the range **shall** be no worse than half of one Least Significant Bit (LSB) for an 8-bit converter, and no worse than one LSB for a converter having more than 8 bits.

3.1.6.1.6.6.7.4 Analog Telemetry Function-5 21810

Random Access: Analog telemetry readings may be made in any order, including immediate repetitions for dwell. The RT **shall** not constrain the order.

3.1.6.1.6.6.7.4.1 Analog Telemetry Function-6 21811

Each analog telemetry reading **shall** be made individually, without grouping.

3.1.6.1.6.6.7.4.2 Analog Telemetry Function-7 21812

Any constraint on the order shall be listed in the component specification, and dispositioned by systems engineering as a GIS exception.

3.1.6.1.6.6.7.5 Analog Telemetry Function-8 21813

Response Format: The analog readings returned to the Bus Controller **shall** be left-justified within the 16-bit word, having most significant bit first, and zero-filling remaining bits at the end of the word (right-most, last in time). See Figure 18.

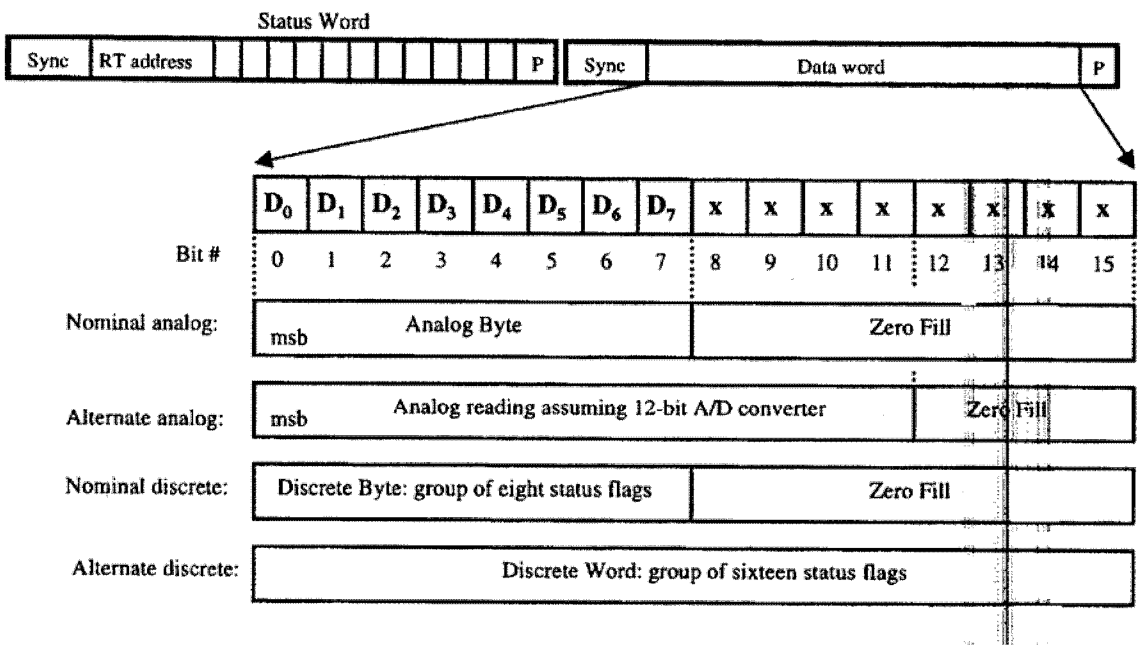


Figure 18 Telemetry Response Dataword Format

3.1.6.1.6.6.7.6 Analog Telemetry Function-9 21814

Response Time: The RT **shall** complete an analog telemetry measurement and be ready to respond over the 1553 bus within 400 microseconds. During the interval between request and read transactions, unrelated transactions may occur on the 1553 bus.

3.1.6.1.6.6.7.7 Analog Telemetry Function-10 21815

Dwell: It **shall** be possible to read the same analog channel at high rates, for dwell purposes.

3.1.6.1.6.6.7.7.1 Analog Telemetry Function-11 21816

The maximum rate **shall** be constrained only by the 1553 bus transactions, with their 400-microsecond delays.

3.1.6.1.6.6.7.8 Analog Telemetry Function-12 21817

Accuracy: The RT analog telemetry measurement accuracy **shall** be budgeted as follows for the cases when the RT is providing the analog-to-digital conversion only (digitization accuracy), and when the RT is reporting on its own internal parameters (end-to-end system accuracy). In each case, the uncertainty percentages refer to the telemetry digitization range, are combined using Root-Sum-Square, and apply after any necessary initial calibrations.

	Digitization	**End-to-end**
Active analog (BOL ambient)	±0.7 %	±1 %
Active analog (EOL, over temperature)	±1 %	±3.2 %
Passive analog temperature (EOL)	±1.2 %	±3.2 %

3.1.6.1.6.6.7.9 Analog Telemetry Function-13 21818

Self-Calibration: The RT **shall** provide precision voltage references that can be measured with the A/D converter.

3.1.6.1.6.6.7.9.1 Analog Telemetry Function-14 21819

As a minimum, voltages **shall** be provided near each end of the normal working range. This will allow conversion accuracy to be checked.

3.1.6.1.6.6.7.9.2 Analog Telemetry Function-15 21820

In the event that the A/D converter measurements change towards end of life in either offset or gain slope, the calibration channel measurements shall allow these errors to be compensated.

3.1.6.1.6.6.8 Discrete Telemetry Function 21821

The RT **shall** make measurements of discrete status flags such as equipment on/off and switch close/open. The signal conditioning done by the RT and the payload may be adapted as required by the equipment supplier(s). The requirements that must be met by the RT discrete telemetry circuit are as follows.

3.1.6.1.6.6.8.1 Discrete Telemetry Function-1 21822

Grouping: The RT **shall** report discrete telemetry readings in groups of eight bits, or alternatively in groups of sixteen bits. It is not necessary to re-adjust the composition of the byte or word.

3.1.6.1.6.6.8.2 Discrete Telemetry Function-2 21823

Response Format: For eight-bit reports, the data of interest **shall** be presented in the most significant byte of the 16-bit data word returned to the Bus Controller (first in time).

3.1.6.1.6.6.8.2.1 Discrete Telemetry Function-3 21824

The following eight bits **shall** be zero-filled. See Figure 18.

3.1.6.1.6.6.8.3 Discrete Telemetry Function-4 21825

Response Time: The RT **shall** complete a group of discrete telemetry measurements and be ready to respond over the 1553 bus within 400 microseconds. During the interval between request and read transactions, unrelated transactions may occur on the 1553 bus.

3.1.6.1.6.6.8.4 Discrete Telemetry Function-5 21826

Random Access: Discrete telemetry byte or word readings may be made in any order. The RT **shall** not constrain the order.

3.1.6.1.6.7 Actuator Functions 21827

The RT may control antenna positioning mechanisms and actuators and one-time deployments. In each case, the RT actions **shall** be controllable over the 1553 bus.

3.1.6.1.6.7.1 Actuator Functions-1 21828

Actuator circuitry **shall** be independent of pulse commands and of telemetry acquisition, to the greatest extent possible, so that actuator control can overlap with other commands and telemetry.

3.1.6.1.6.7.1.1 Actuator Functions-2 21829

The actuator **shall** be self-clocked within the RT, such that the Bus Controller can configure for motion, then rely on the RT to complete the expected sequence.

3.1.6.1.6.7.1.2 Actuator Functions-3 21830

The RT shall accept a new configuration at any time, and suspend any action in progress to begin the new operation. The state of the control circuit may be queried for telemetry by the Bus Controller at any time.

3.1.6.1.6.7.2 Actuator Functions-4 21831

One time deployment actions **shall** be deemed hazardous commands.

3.1.6.1.6.7.2.1 Actuator Functions-5 21832

One time deployment action shall require two independent circuit inhibits, each separately commanded, to complete the operation. Such operations are typically composed of one or more Enables, and a Fire command.

3.1.6.1.6.7.2.2 Enable States 21833

The preceding Enable states **shall** be available in telemetry.

Detailed 1553 formats for actuator functions should be coordinated with the TT&C subsystem and with Flight Software.

3.1.6.2 Command and Logic Interfaces 21834

All critical and switching circuits **shall** be designed so as to be immune to noise pulses on signal lines, signal returns, power bus, power returns, and spacecraft structure.

3.1.6.2.1 Command and Logic Interfaces-1 21835

Spacecraft grounding, signal routing, and harnessing **shall** be designed in accordance with 20032596 and paragraphs 3.1.3 and 3.1.7 herein.

3.1.6.2.2 Command and Logic Interfaces-2 21836

Commands **shall** be delivered either as relay driver pulses, latching relay contact closures, or as logic level commands (restricted use) to solid state circuitry in units.

3.1.6.2.2.1 Command and Logic Interfaces-3 21837

Commands which load digital data **shall** be delivered in the form of a serial bit stream to solid state circuitry in units.

3.1.6.2.3 Command and Logic Interfaces-4 21838

Establishment of a unit operating mode **shall** not depend on a previous state of the unit.

3.1.6.2.3.1 Command and Logic Interfaces-5 21839

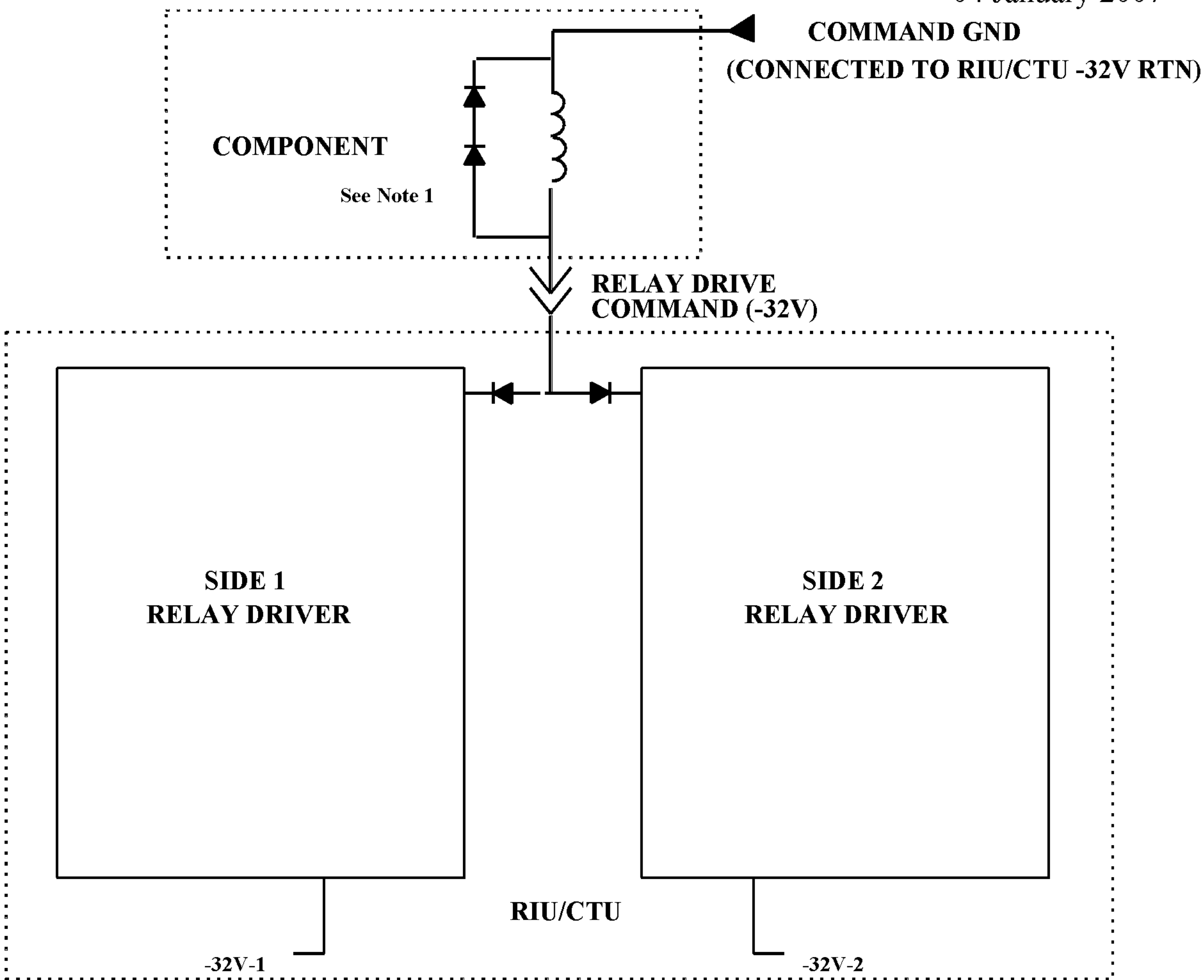
Establishment of a unit operating mode **shall** not require a particular sequencing of commands other than unit turn on.

3.1.6.2.4 Relay Drive Commands 21840

Relay driver commands are provided for opening and closing relays or controlling on/off switching circuits in spacecraft equipment.

The relay driver interface is shown in Figure 6 and **shall** have the following characteristics:

• On level	Per Table VI
• Off state	Driver leakage current < 100 μA
• Pulse duration	0.04 , 0.1, 0.5, or 1.0 _ .010 seconds from RIU (Programmable via cmd) 0.018 to 0.026 seconds from CTU (fixed)
• Turn-on (Fall) time	2.0 mS maximum
• Turn-off (Rise) time	0.5 mS maximum, 50 ohm load 2.0 mS maximum, 6.4 kohm load
• Sink current	500 mA maximum, high current interface 250 mA maximum, low current interface
• Fault current limit	550 ±30 mA



Notes:
1) Transient suppression diodes across relay coils shall be 1N6510 or equivalent
2) Tolerance on -32V supply is ±10%

Figure 6 Relay Driver Command Interface

Table VI Relay Driver Interface On Voltage vs. Load Current

Load Current (mA)	Worst Case On Voltage Low Current I/F (V)	Worst Case On Voltage High Current I/F (V)
0	-35.0 (max)	-35.0 (max)
10	-32.3 (max)	-32.3 (max)
100	-26.3 (min)	-26.5 (min)
200	-25.7 (min)	-26.0 (min)
250	-25.2 (min)	-25.8 (min)
500	N/A	-25.0 (min)
Note: Minimum and maximum refer to voltage across load		

3.1.6.2.5 Relay Drive Command Receiver Circuit 21841

Users of relay driver commands may be relays or on/off switching circuits. Both circuits **shall** meet the requirements for the relay drive command interface defined in paragraph 3.1.6.2.4 and the following requirements:

3.1.6.2.5.1 Relay Drive Command Receiver Circuit-1 21842

- Transient Rejection: Users **shall** not respond to a ±20V damped sinusoidal transient at 1 MHz on either the command or command ground line.

3.1.6.2.5.1.1 Relay Drive Command Receiver Circuit-2 21843

- Transient Rejection: Solid state circuits **shall** not respond to an individual pulse of full voltage (-32V) of duration less than 1 millisecond.

3.1.6.2.5.2 Relay Drive Command Receiver Circuit-3 21844

- DC Offset Rejection: Solid state command receivers **shall** not permit spurious switching to arise from DC levels of less than ±8V.

3.1.6.2.5.3 Relay Drive Command Receiver Circuit-4 21845

- Transient Suppression: Inductive loads (> 1 mH) such as relay coils **shall** suppress the transient turn off of the command with redundant diodes as shown in Figure 6.

3.1.6.2.6 Deleted

3.1.6.2.7 Logic Level Interface 21847

Logic Level Interfaces **shall** use the Differential Interface circuit as shown in Figure 7. The circuit may be configured for cross-strapped or non-cross-strapped applications.

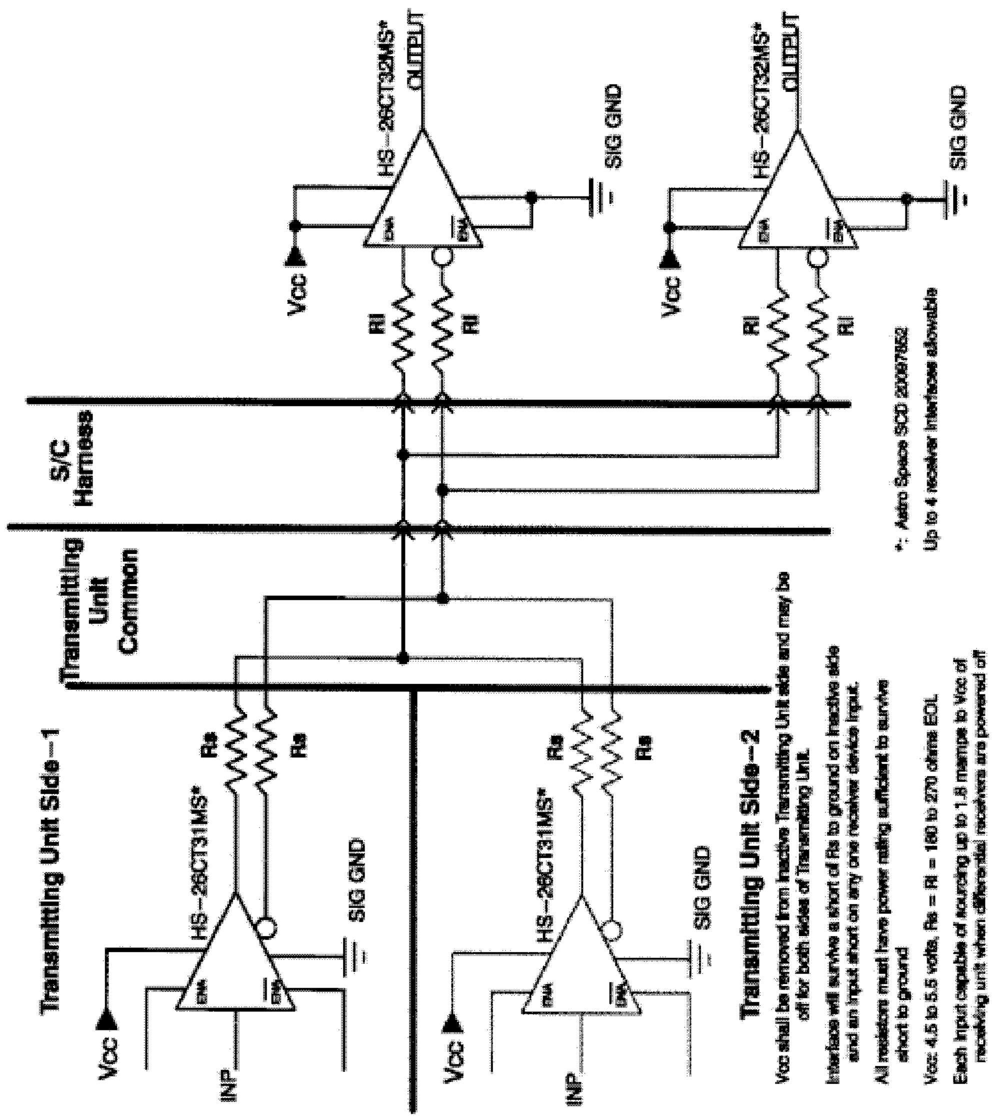


Figure 7 Differential Logic Interface

Note: Usage of this interface is restricted to certain bus components.

3.1.6.2.7.1 Logic Level Interface-1 21848

Logic polarity for control signals **shall** be such that the "active", "on" or "enable" state **will** be indicated by zero volts at the points labeled "INP" and "OUTPUT" in the Figure (negative true).

3.1.6.2.7.2 Logic Level Interface-2 21849

All data transmissions utilizing this interface **shall** utilize positive true logic (logic "1" representing on or active, "high" voltage level).

3.1.6.2.7.3 Logic Level Interface-3 21850

Transmitting units **shall** be configured such that either one or neither differential driver is powered and actively driving at any time.

3.1.6.2.7.4 Logic Level Interface-4 21851

For circuits where both transmitting units may be unpowered, the receiving unit **shall** guarantee that the output of its receiver is pulled to the inactive state during this condition.

3.1.6.2.7.5 Logic Level Interface-5 21852

The interface **shall** accommodate one to four receivers.

3.1.6.2.7.6 Logic Level Interface-6 21853

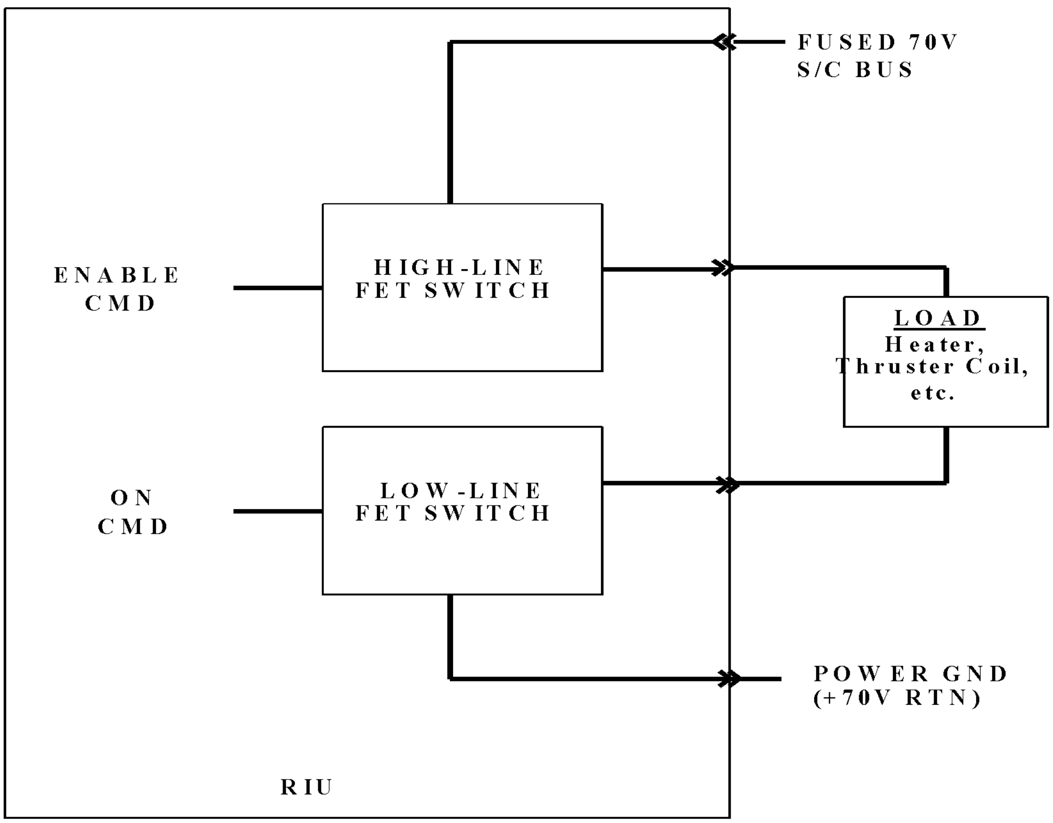
The interface **shall** be tolerant of a direct short to ground of one inactive driver or any one receiver input (i.e. all non-failed interface components and the interface itself **will** continue to function). Usage is restricted to assigned Bus interfaces.

3.1.6.2.8 High-Line FET Switch Interface 21854

The High-Line FET Switch Interface **shall** be used to switch the Spacecraft Power Bus (70 Volts) in response to an Enable command to spacecraft loads such as Heaters, Thruster Coils, etc.

3.1.6.2.8.1 High-Line FET Switch Interface-1 21855

This interface **shall** be used in conjunction with the Low-Line FET Switch Interface (in the same RIU connector) as defined in Paragraph 3.1.6.2.9. A block diagram of the interface configuration is shown in Figure 9A.



OUTPUT CHARACTERISTICS

1) **Output = 1 Amp maximum (continuous)**
2) **Max FET Impedance at 1 Amp: 0.35 Ohms (high switch), 0.54 Ohms (low switch)**
3) **Rise/Fall Time = 3 to 100 microseconds**
4) **Off State Leakage = 1 mAmp max**

Figure 9A FET Switch Interface Configuration

Figure 9B Deleted

3.1.6.2.8.2 High-Line FET Switch Interface-2 21856

The characteristics of the power switched to the load **shall** be as follows:

- Voltage:

  +67.9 volts minimum; +69.6 volts typical; +71.0 volts maximum

- Rise/Fall Time:

  3 to 100 microseconds

- Maximum Current:

  1 Amp continuous

3.1.6.2.8.3 High-Line FET Switch Interface-3 21857

Users **shall** provide the characteristics of any load inductance to A2100 Systems Engineering.

Additional information about this interface is redacted for export.

3.1.6.2.9 Low-Line FET Switch Interface 21858

The Low-Line FET Switch Interface **shall** be used to switch the Power Ground (Spacecraft Power Bus return) in response to an On command to spacecraft loads such as Heaters, Thruster Coils, etc.

3.1.6.2.9.1 Low-Line FET Switch Interface-1 21859

This interface **shall** be used in conjunction with the High-Line FET Switch Interface (in the same RIU connector) as defined in Paragraph 3.1.6.2.8.

Additional information about this interface is redacted for export

3.1.6.3 Telemetry 21860

Each telemetry signal **shall** be presented at the unit-to-harness interface as shown in Figure 10.

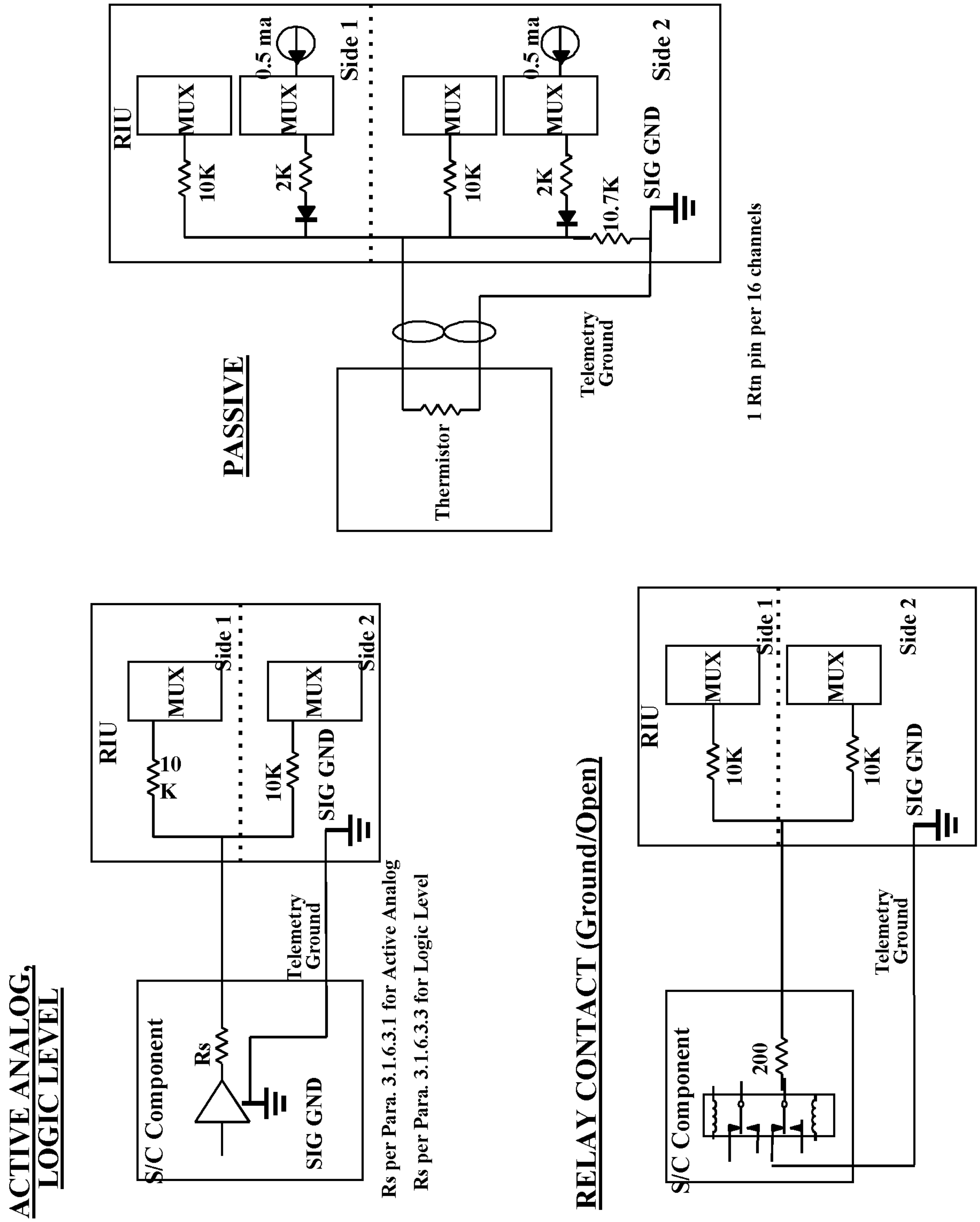


Figure 10 Telemetry Cross-strapping

3.1.6.3.1 Telemetry-1 21861

For internally redundant units, Active Analog and Logic Level telemetry signals **shall** be provided as isolated outputs from each side.

3.1.6.3.1.1 Telemetry-2 21862

Isolation between the two RIU sides **shall** be at least 10 K ohm.

3.1.6.3.1.2 Telemetry-3 21863

The telemetry signal interfaces **shall** comply with the requirements in the following sections.

3.1.6.3.1.3 Telemetry-4 21864

Grounding and shielding requirements **shall** be in accordance with paragraph 3.1.3.

3.1.6.3.2 Telemetry-5 21865

For all telemetry words, the first bit transmitted **shall** be the Most Significant Bit (MSB) and **will** be designated bit 0.

3.1.6.3.2.1 Telemetry-6 21866

Within each telemetry frame, 256 words **shall** be transmitted.

3.1.6.3.2.2 Telemetry-7 21867

The first word in each frame **shall** be designated word 0.

3.1.6.3.3 Active Analog Telemetry 21868

Active analog telemetry signals **shall** comply with the following requirements:

- Voltage:
  0.0 to +5.1 volts, 8-bit, LSB = 20 mV (standard telemetry transmission)
  Other optional telemetry transmission modes are allowed, including:
  0.0 to +10.2 volts, 8-bit, LSB = 40 mV
  0.0 to +10.2375 volts, 12-bit LSB = 2.50 mV

- Source Impedance to desired voltage (source unit powered):
  180 ohm minimum
  1 kohm maximum

- Source Impedance to signal ground (source unit unpowered):
  180 ohm minimum
  15 kohm maximum

- Source Failure Overvoltage:

  -15.0 to +25.0 volts (any condition)

3.1.6.3.3.1 Active Analog Telemetry-1 21869

Telemetry signal bandwidth shall not exceed 200Hz unless documented in the component performance specification.

3.1.6.3.3.2 Active Analog Telemetry-2 21870

The RIU **shall** have the following characteristics:

- Input Impedance:
  5 Mohm, minimum

- Multiplexer Gate Failure Output Current:
  ±1.5 ma driven from a +15V supply in the RIU with 10K ohm series impedance

- Low-pass filtering for analog signals:
  Four pole, 15.0 kHz nominal cutoff frequency, 40 dB rejection at 50 kHz

3.1.6.3.3.3 Active Analog Telemetry-3 21871

The overall system accuracy **shall** be better than ±1% under BOL ambient conditions, including any calibrations, except as specified in A2100 Bus Performance Specification.

3.1.6.3.3.3.1 Active Analog Telemetry-4 21872

The overall system accuracy, including any calibrations, **shall** be better than ± 3.2% of full scale at EOL over the full operating temperature range of the unit.

3.1.6.3.3.3.2 Active Analog Telemetry-5 21873

The telemetry system contribution to the overall system error **shall** not exceed 0.7% at BOL and 1.0% at EOL for active analog telemetry or 1.2% for passive analog telemetry over the full operating temperature range.

3.1.6.3.3.3.3 Active Analog Telemetry-6 21874

The telemetry source contribution to the overall system error **shall** not exceed 0.7% at BOL and 3.0% at EOL over the full operating temperature range.

3.1.6.3.4 Passive-Analog Telemetry 21875

A passive input is used for a resistive sensor such as a thermistor. At the time a passive input is being sampled, the RIU **shall** output to the sampled sensor a constant current of 0.5 ma ±0.8% EOL to generate a telemetry voltage in the same range as for the analog telemetry specified in Section 3.1.6.3.3.

3.1.6.3.4.1 Passive-Analog Telemetry-1 21876

The line capacitance from the telemetry sensor to the RIU **shall** be limited to 1000 pF. The CS and CW thermistors are in parallel with a 10.7 KΩ (kOhm) (nominal) resistor in the RIU.

3.1.6.3.4.1.1 Passive-Analog Telemetry-2 21877

A thermistor type 311P18-07S7R6 **shall** be used to sense temperatures in the range -34°C to +110°C.

3.1.6.3.4.1.1.1 Passive-Analog Telemetry-3 21878

This constant current temperature sensor **shall** be designated “Standard Range” (CS).

3.1.6.3.4.1.2 Passive-Analog Telemetry-4 21879

A thermistor type 20009426P107 **shall** be used to sense temperature in the range -5°C to +150°C.

3.1.6.3.4.1.2.1 Passive-Analog Telemetry-5 21880

This constant current temperature sensor **shall** be designated ‘Wide Range’ (CW).

3.1.6.3.4.1.3 Passive-Analog Telemetry-6 21881

A sensor type 2280061-7 **shall** be used to sense temperature in the range -240°C to +400°C.

3.1.6.3.4.1.3.1 Passive-Analog Telemetry-7 21882

This constant current temperature sensor **shall** be designated ‘Platinum Range’ (CP).

Other thermistor types may be used. Only the CS, CW, and CP thermistors may be used for on-board control of heaters by flight software.

3.1.6.3.5 Digital Discrete Telemetry 21883

Digital discrete inputs are accepted in two forms: ground/open and digital logic level. These inputs **shall** have the following characteristics:

Ground/open type:

- Logic "0" (off or inactive):
  Signal ground through a source impedance of 200 ohm. +10%
  May be zero ohms for RF switches not having internal resistors.
  In no case may this include a diode or bipolar transistor in series to ground.

- Logic "1" (on or active):
  Open circuit with source impedance greater than 2 Mohm

Logic level type:

- Logic "0" (off or inactive):
  -1.0 to +1.5 Volts

- Logic "1" (on or active):
  +3.5 to +15.0 Volts

- Source impedance:

3.1.6.3.5.1 Digital Discrete Telemetry-1 21884

200 ohm minimum, maximum 20k ohm to ground when in Logic "0" state or when the source unit is unpowered, and **shall** guarantee +3.5V into 9k ohm load to ground when in Logic "1" state

Both types:

- Source Failure Overvoltage:

  -15.0 to +25.0 volts (any condition) for RIU inputs
  -0.5 to +25.0 volts (any condition) for CTU inputs

- Channel Leakage:

  Less than 0.1mA feedback to source Current

- RIU Input Impedance:

  Greater than 5 Mohm, not sampled
  Greater than 20 Kohm, sampled

3.1.6.3.5.2 Digital Discrete Telemetry-2 21885

- Multiplexer Gate:

  RIU **shall** limit current fed back to a failed telemetry source to +1.5 mA.

- Source Capacitance:
  100pF, excluding cables (assume 500 pF for cable capacitance)

3.1.6.3.6 Bidirectional Serial Bus 21886

Over a bidirectional serial bus, the RIU **shall** transfer 32 bits of data and collect 16 bits of data from all users.

3.1.6.3.6.1 Bidirectional Serial Bus-1 21887

The interface **shall** consist of a gated 66.7 kHz clock, enable (active at least one cycle before the first rising edge on the clock line), a transmit/receive line, and one data line in each direction (transmit and receive). The terms “transmit” and “receive” are defined relative to the RIU for this interface.

3.1.6.3.6.1.1 Bidirectional Serial Bus-2 21888

The transmit data, clock, enable, and transmit/receive signals **shall** use the interface shown in Figure 8.

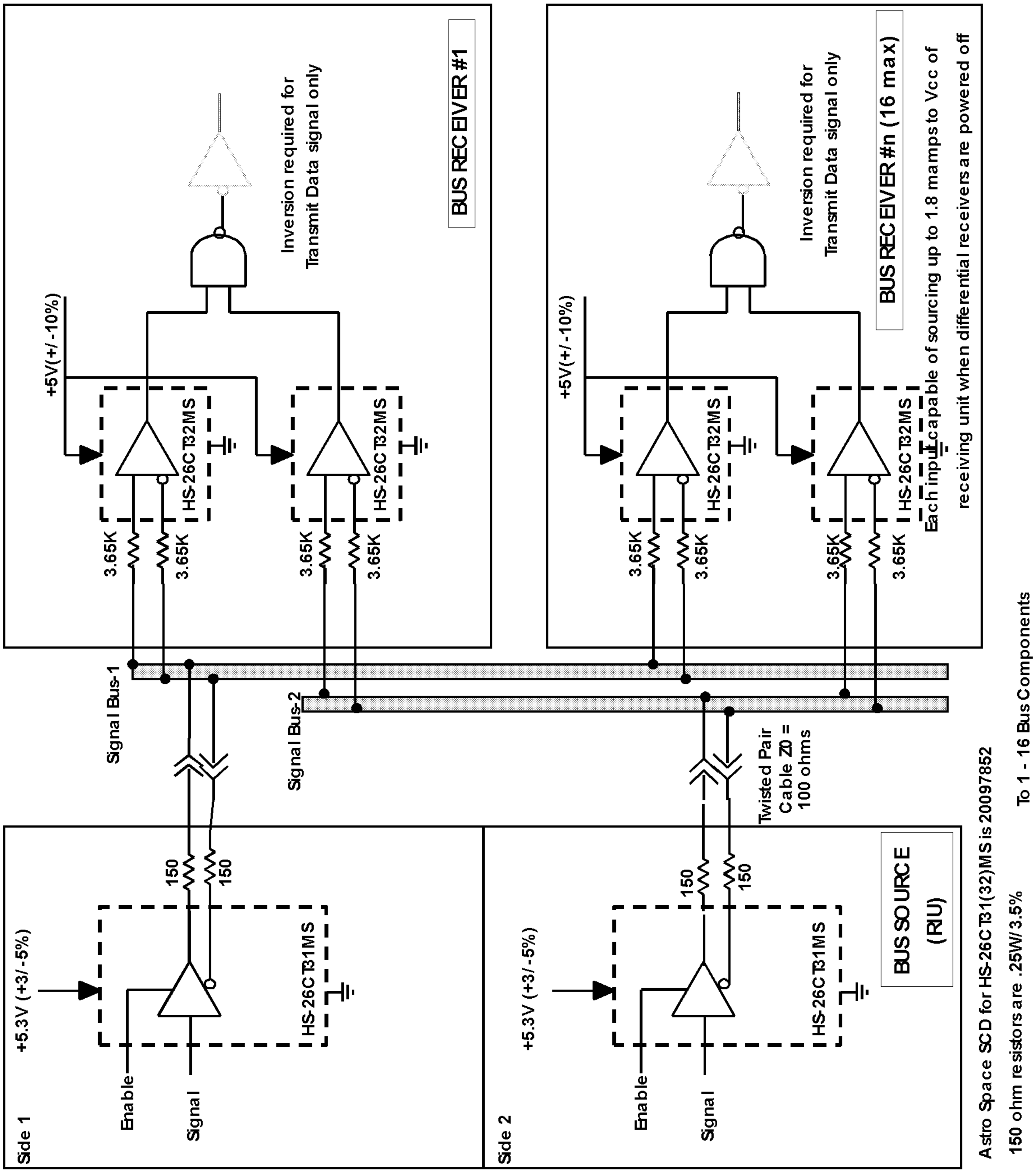


Figure 8 Bidirectional Bus Interface (RIU to User)

3.1.6.3.6.1.2 Bidirectional Serial Bus-3 21889

The receive data signals **shall** use the interface shown in Figure 11.

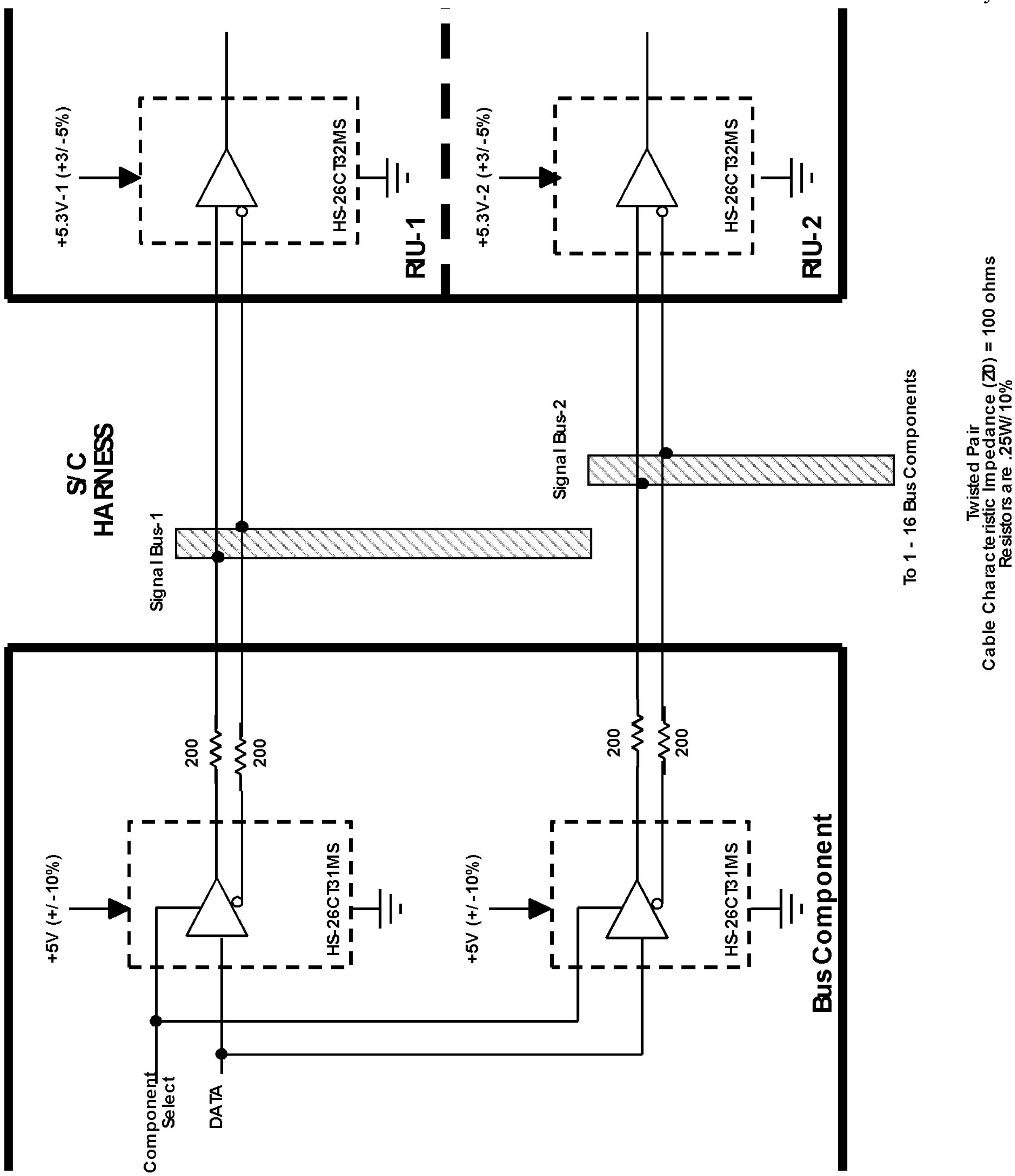


Figure 11 Bidirectional Bus Interface (User to RIU)

3.1.6.3.6.1.3 Bidirectional Serial Bus-4 21890

The timing **shall** be as specified in Figure 12.

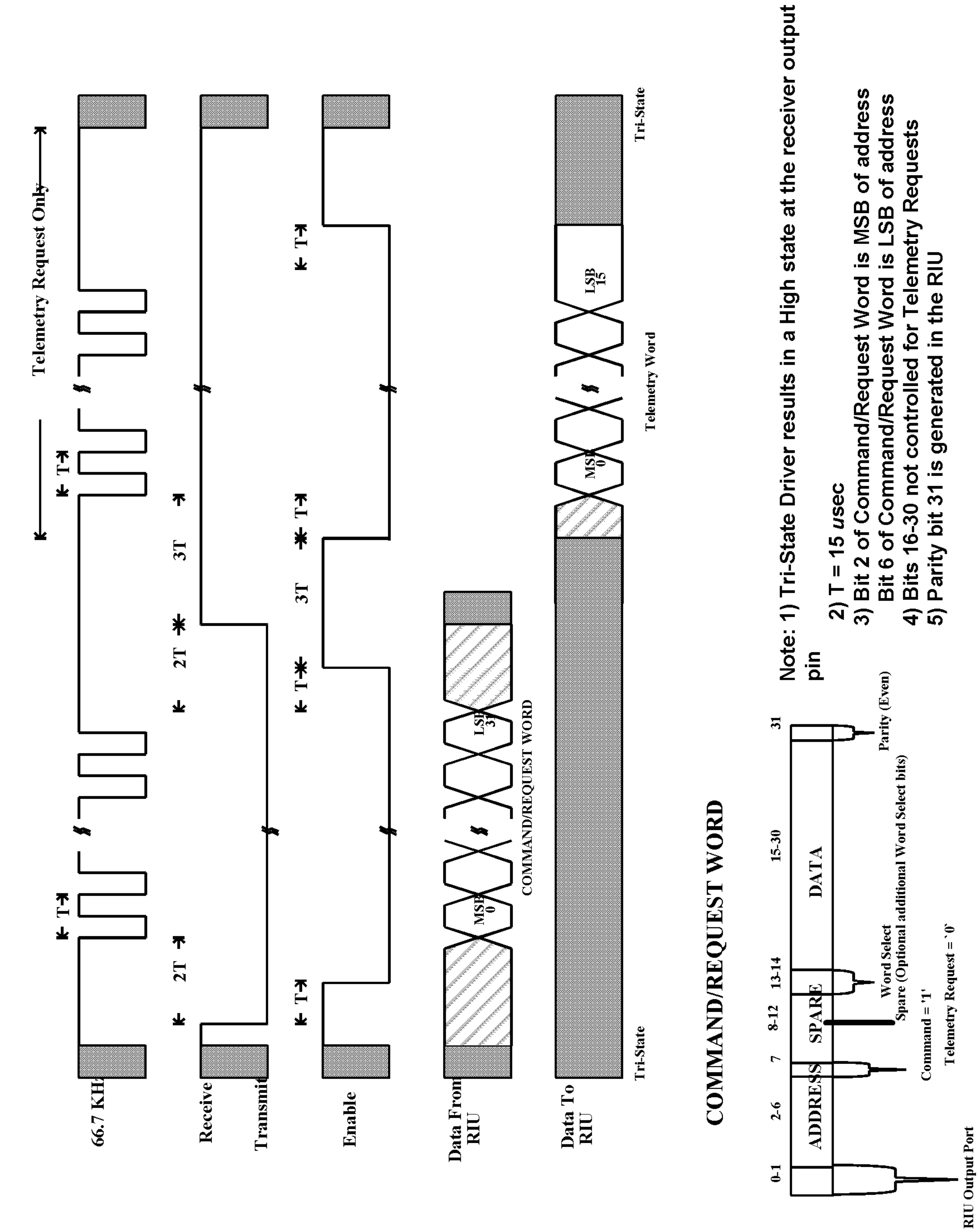


Figure 12 Bidirectional Serial Bus Timing

3.1.6.3.6.1.4 Bidirectional Serial Bus-5 21891

The transmit/receive line **shall** always go high for at least one clock cycle after each transmission even if there are consecutive commands.

3.1.6.3.6.1.5 Bidirectional Serial Bus-6 21892

All line receivers **shall** include input circuitry such that when the bus is in the inactive state (high impedance) the output **will** be a logic '1'.

3.1.6.3.6.1.6 Bidirectional Serial Bus-7 21893

The 16 bits of return data **shall** only occur on bit 7 being a logic '0'.

3.1.6.3.6.1.7 Bidirectional Serial Bus-8 21894

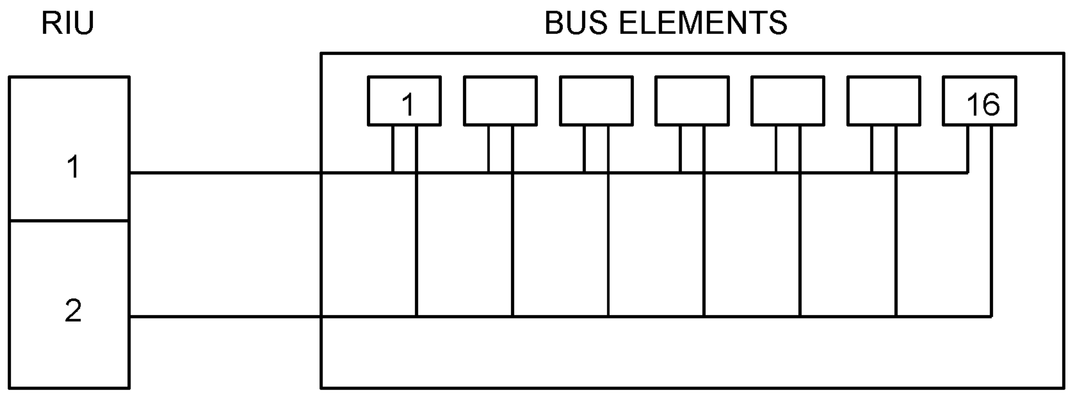
All data transmissions utilizing this interface **shall** utilize positive true logic (logic "1" representing on or active, "high" voltage level).

3.1.6.3.6.1.8 Bidirectional Serial Bus-9 21895

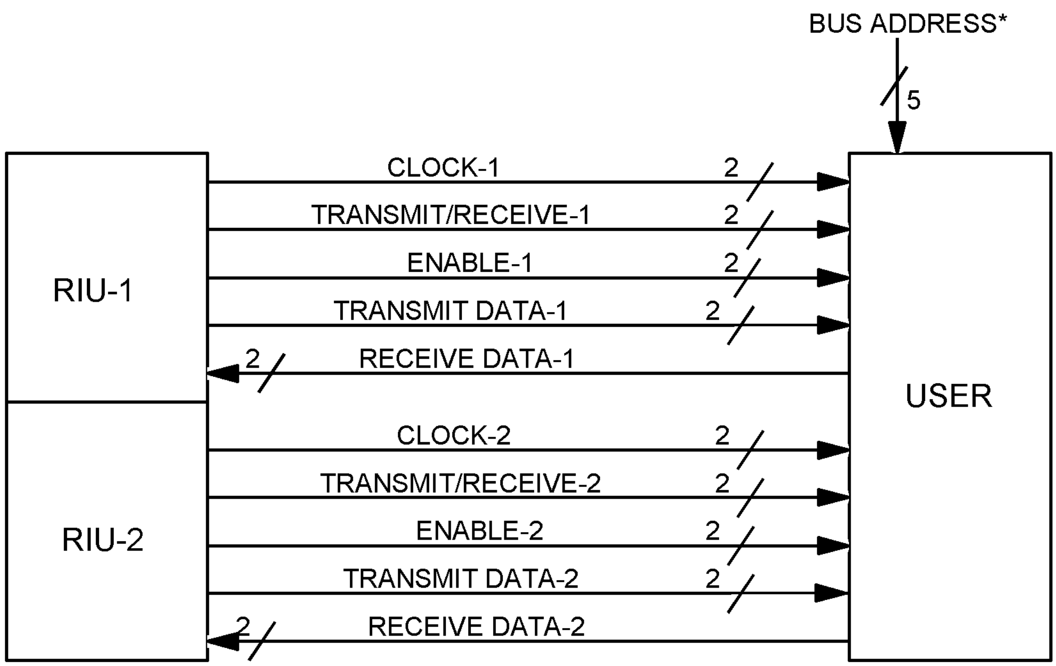
The RIU **shall** tri-state all output drivers between messages.

3.1.6.3.6.2 Bidirectional Serial Bus-10 21896

The users **shall** be connected to the bus as shown in Figure 13.



Note: The interconnection between bus elements takes place in S/C harness



* Configured by S/C Harness

Figure 13 Serial Bus Architecture

3.1.6.3.6.2.1 Bidirectional Serial Bus-11 21897

Each implementation of a bidirectional serial bus **shall** be capable of servicing up to 16 users.

3.1.6.3.6.2.2 Bidirectional Serial Bus-12 21898

One side of the RIU **shall** always be powered off.

3.1.6.3.6.3 Bidirectional Serial Bus-13 21899

Each user **shall** implement connector pins which allow the spacecraft wiring harness to program the bidirectional bus address.

3.1.6.3.6.3.1 Bidirectional Serial Bus-14 21900

This **shall** be provided independently for internally redundant units. Five connector pins are required, corresponding to, and named for, bits 2 through 6 of the bidirectional command/request transmission (see Figure 12), where bit 2 is the first in time, and most significant.

3.1.6.3.6.3.2 Bidirectional Serial Bus-15 21901

For new designs, the default state of these programming pins **shall** be logic one, pulled high internally by 3K to 33K ohms. They may be programmed as logic zero by terminating externally to ground at a dedicated signal ground pin provided by the component.

3.1.6.3.6.4 Bidirectional Serial Bus-16 21902

The command word from the RIU shall utilize even parity over the entire 32 bit transmission.

3.1.6.3.6.4.1 Bidirectional Serial Bus-17 21903

Upon detecting a parity error, users **shall** discard the transmitted command.

3.1.6.3.6.5 Bidirectional Serial Bus-18 21904

Users **shall** discard any commands that are not exactly 32 bits in length.

3.1.6.3.7 Failure Protection 21905

Telemetry points **shall** be fail-safe such that any single failure in any of the following **will** not cause the unit within which the telemetry point is located to malfunction in any way:

- the telemetry circuitry
- failures at the interface within the limits specified in section 3.1.6.3.3 for active analog circuits
- failures at the interface within the limits specified in section 3.1.6.3.5 for digital circuits
- shorts to ground at the interface.

3.1.6.3.7.1 Telemetry Protection Against External ESD 21906

Analog telemetry signals, including temperature sensors, which originate outside the main spacecraft structure (typically on solar array and reflector appendages) are a potential ESD threat to the RIU. A circuit path **shall** be provided, using limiting diodes, to divert positive or negative discharges to structure. The circuit path should be located close to the entry point of the signal into the main spacecraft body.

3.1.6.3.7.1.1 Telemetry Protection Against External ESD-1 21907

The circuit path shall limit the transient at the RIU to the overvoltage range in Paragraph 3.1.6.3.3.

3.1.6.3.7.1.2 Telemetry Protection Against External ESD-2 21908

Telemetry calibration information **shall** be adjusted as needed at system level.

3.1.6.3.8 Telemetry Calibration 21909

Units **shall** be tested to determine the transfer characteristics of each active analog telemetry point.

3.1.6.3.8.1 Telemetry Calibration-1 21910

The testing **shall** be in accordance with the unit performance specification.

3.1.6.3.8.2 Temperature Testing of Active Analog Telemetry Circuits 21911

A minimum of one unit (may be the qualification unit or the Prototype) **shall** have active analog telemetry circuits tested at the required hot, cold, and ambient temperature plateaus.

3.1.6.3.8.2.1 Temperature Testing of Active Analog Telemetry Circuits-1 21912

If these tests reveal that the telemetry point is temperature sensitive such that the results do not meet the allowable accuracy at any temperature with respect to any other temperature over life, then additional testing shall be performed at all three plateaus for each flight unit. If the telemetry point is not temperature sensitive, then each flight unit may characterize its analog telemetry points at ambient temperature only.

3.1.6.3.8.2.2 Temperature Testing of Active Analog Telemetry Circuits-2 21913

Telemetry points provided expressly for indicating temperature **shall** be subjected to the full range of temperatures necessary to provide the required test data.

3.1.6.3.8.2.3 Temperature Testing of Active Analog Telemetry Circuits-3 21914

If the sensor is internal to a unit, the temperature range **shall** be restricted to the allowable temperature range of that unit.

3.1.6.3.8.2.4 Temperature Testing of Active Analog Telemetry Circuits-4 21915

The sensor **shall** use a standard calibration curve.

3.1.6.3.8.3 Test Data Required 21916

Test data **shall** be provided for each unit to completely characterize each telemetry point.

3.1.6.3.8.3.1 Test Data Required-1 21917

As a minimum for simple transfer characteristics, test data **shall** include readings taken at 0.5V increments of the telemetry voltage for analog data.

3.1.6.3.8.3.2 Test Data Required-2 21918

This **shall** be repeated in all operating modes affecting the telemetry point.

3.1.6.3.8.3.3 Test Data Required-3 21919

For more complex transfer characteristics, additional data **shall** be taken as required to describe the characteristic; e.g., for a non-linear function with a steep slope, the test data increment may have to change to 0.2V or 0.1V of telemetry.

3.1.6.3.8.4 Test Data Accuracy 21920

The test data supplied **shall** comply with the following requirements for accuracy.

3.1.6.3.8.4.1 Test Data Accuracy-1 21921

Temperature: For other than temperature telemetry points, the test temperature specified for the data **shall** be accurate to within 2°C of the actual test temperature.

3.1.6.3.8.4.1.1 Test Data Accuracy-2 21922

For temperature telemetry points, the test temperature specified for the data **shall** be accurate to within 0.5°C.

3.1.6.3.8.4.2 Test Data Accuracy-3 21923

Voltage: All telemetry voltage readings recorded **shall** be accurate to within 0.4%.

3.1.6.3.8.4.3 Test Data Accuracy-4 21924

Current: All current readings recorded **shall** be accurate to within 0.4% or l mA, whichever is greater.

3.1.6.3.9 Subcommutated Telemetry

Redacted for export.

3.1.6.4 Test Points 21926

Test points between any unit and the Spacecraft Test Station **shall** be one of the following types:

- Analog per Paragraph 3.1.6.4.1 or 3.1.6.4.3
- Logic Level per Paragraph 3.1.6.4.2
- MIL-STD-1553B
- RS-422-A

3.1.6.4.1 Analog Test Points, Spacecraft Output 21927

Analog test points shall comply with the following:

- Signal Level: 0 to +5.1 volts nominal, +10.0 volts maximum
- Output Configuration: Single ended, dc coupled, referenced to signal ground
- Output Impedance: 2 Kohm minimum, l0 Kohm maximum
- Load Impedance: 10 Mohm minimum
- Accuracy: 0.1% of voltage being measured when driving minimum load impedance
- Overvoltage due to failure mode: -0.7 volts to +10.7 volts

3.1.6.4.2 Digital Test Points 21928

All spacecraft input and output digital test points **shall** comply with the logic level interface requirements specified in Paragraph 3.1.6.2.7 for a non–cross–strapped configuration.

3.1.6.4.3 Analog Test Points, Spacecraft Input

- Signal Level: 0 to +5.1 volts nominal, +10.0 volts maximum

- Input Configuration: Single ended, dc coupled, referenced to signal ground

3.1.6.4.3.1 Analog Test Points, Spacecraft Input-1 21930

Overvoltage due to failure mode: **Shall** be tolerant of any voltage level from -0.7 volts to +10.7 volts with no degradation in performance to any redundant units during the time the stimulus is applied.

3.1.6.4.3.1.1 Analog Test Points, Spacecraft Input-2 21931

Unit **shall** also prevent degradation in performance of any other part of the spacecraft after the stimulus is removed.

3.1.6.4.4 Failure Protection 21932

Test points **shall** be fail-safe such that a single point failure to ground in the test point circuitry, the send or receive interfaces, or GSE equipment **will** not cause the unit within which the test point is located to malfunction in any way while the failure is present or after it is removed.

3.1.6.5 Launch Vehicle Command and Telemetry Interface

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3.1.6.6 Sensor Data Interfaces 21934

Unique signal interfaces may be employed between the RIU and the Earth Sensors, and between the RIU and the Sun Sensors, as defined in this section. The signals are commands, telemetry, and instrument data. Serial clock and data signals **shall** be conveyed in twisted shielded pairs, where the second wire in each pair is signal ground, and the shield connects to chassis ground.

3.1.6.6.1 Sensor Data Interfaces-1 21935

Each entire wiring bundle **shall** be over-wrapped with a grounded metallic shield.

3.1.6.6.2 Earth Sensor Data Interface 21936

Interfaces between the ESA and RIU **shall** be of the three types shown in Figure 15.

Figure 15 Deleted

3.1.6.6.2.1 Earth Sensor Data Interface-1 21937

Pulse commands from the RIU to the ESA **shall** have the following characteristics:

Active state: low voltage 0V +/- 0.65V while the RIU sinks up to 2 mAmp from the ESA termination.

Inactive state: open collector at the RIU, pulled up to +5V at the ESA.

Pulse width: active for 40 msec +/- 1 msec.

3.1.6.6.2.2 Earth Sensor Data Interface-2 21938

Discrete telemetry from the ESA to the RIU **shall** have the following characteristics:

Active state (logic one): +3.5V to +11.0V.

Inactive state (logic zero): -1.0V to +1.5V.

Source impedance: 2 kOhms to 15 kOhms.

Receiver threshold: +2.6V +/- 0.3V.

Received Impedance: 100 kOhms minimum.

3.1.6.6.2.3 Earth Sensor Data Interface-3 21939

Instrument data **shall** be read at 8Hz intervals.

3.1.6.6.2.3.1 Earth Sensor Data Interface-4 21940

The ESA **shall** indicate fresh data is available by activating the Inhibit signal for 2 msec.

3.1.6.6.2.3.2 Earth Sensor Data Interface-5 21941

The RIU **shall** read the data within 14 msec.

3.1.6.6.2.4 Earth Sensor Data Interface-6 21942

Serial data and Inhibit signals from the ESA to the RIU **shall** have the following characteristics:

Active state (logic zero): low voltage 0V +/-0.65V while the ESA sinks up to 2 mAmp from the RIU termination.

Inactive state (logic one): open collector at the ESA, pulled up to +5V at the RIU.

3.1.6.6.2.5 Earth Sensor Data Interface-7 21943

The Serial Clock signal from the RIU to the ESA **shall** have the following characteristics:

Active state: low voltage 0V +/-0.65V while the RIU sinks up to 2 m Amp.

Inactive state: open collector at the RIU, pulled up to +5V at the ESA.

Clock burst frequency: 7812 Hz, for 28 bits, 50% duty cycle, active low for 64 microsec.

3.1.6.6.2.6 Earth Sensor Data Interface-8 21944

The ESA **shall** advance to the next data bit on the rising clock edge.

3.1.6.6.2.6.1 Earth Sensor Data Interface-9 21945

The RIU **shall** read data bits on the falling clock edge.

3.1.6.6.3 Sun Sensor Data Interface 21946

The serial interface between the SSA and RIU **shall** be as shown in Figure 16.

Clock and Enable signals are generated by the RIU, and the sun sensor responds with Data.

Circuit characteristics are:

> Active state: high voltage +12V +/- 4V, source series impedance 2 kOhm, receiver impedance (to ground) 20 kOhm or greater.
>
> Inactive state: low voltage 0V +/- 1V, pulled down to ground by source resistor 10 kOhm and by receiver resistor 20 kOhm.
>
> Receiver threshold: 6V +/- 3V.

Clock burst frequency: 7812 Hz, for 32 bits, 50% duty cycle.

Figure 16 Deleted

3.1.6.6.3.1 Sun Sensor Data Interface-1 21947

The SSA **shall** advance to the next data bit on the falling clock edge.

3.1.6.6.3.1.1 Sun Sensor Data Interface-2 21948

The RIU **shall** read data bits on the rising clock edge.

3.1.7 Spacecraft Harness

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Table VII Deleted

3.1.7.1 Harness Sizing Philosophy

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3.2 Mechanical Interface

3.2.1 Unit Physical Characteristics

3.2.1.1 Interface Control Drawing 21953

Each unit **shall** have an Interface Control Drawing (ICD)/Source Control Drawing (SCD) containing the following information as a minimum:

Overall dimensional envelope
Dimensional main body envelope
Mounting area (in^2)
Nominal and maximum thermal dissipations
Interface bolt size and quantity
Interface hole size and locations, including tolerances
Thickness of mounting feet
Field of view requirements (if applicable)
Special accessibility/stayouts for connector installation, alignment, or other operation
Connector(s) location
Connector type and designation
Center of mass location
Deleted
Part Number
Volume (if applicable)
Weight
All features of the baseplate design include items such as cavities, pockets, vent paths, counterbores and countersinks, and abutted baseplate elements (slice seams).
Mounting method
Surface finish
Temperature sensor locations

3.2.1.1.1 Interface Control Drawing-1 21954

A CAD model of the unit ICD/SCD generated with the SDRC Ideas program **shall** be provided to the A2100 Mechanical Architect for incorporation into the spacecraft model.

3.2.1.2 Unit Weight 21955

The weight allocation for each unit **shall** be controlled by A2100 Systems Engineering.

3.2.1.2.1 Unit Weight-1 21956

Deviations **shall** be requested via Weight Change Notice for formal approval.

3.2.1.2.2 Unit Weight-2 21957

Unit mass **shall** be measured to an accuracy of ±1%.

3.2.1.3 Unit Center of Mass 21958

Center of mass locations **shall** be calculated to an accuracy of 2.54mm (0.10 inch) in any direction.

3.2.1.4 General 21959

All units **shall** use only approved parts from the site specific APL20098029.

3.2.1.4.1 General-1 21960

Materials and Processes selection and control **shall** be in accordance with PN20095414.

3.2.1.5 Units with Waveguide Interfaces 21961

Any unit which has internal moving or rotating parts and an external waveguide interface, **shall** utilize a protective waveguide window within the component to prevent debris from entering the waveguide opening.

3.2.1.5.1 Units with Waveguide Interfaces-1 21962

Use of the window **shall** be evaluated from an RF performance and power handling standpoint for all applications.

3.2.2 Unit Mounting

3.2.2.1 Mounting Technique 21964

Each unit **shall** be mounted to the spacecraft by means of mounting bolts passing through flanges located on the unit, and mating with captive threaded hardware.

3.2.2.1.1 Mounting Technique-1 21965

Means **shall** be provided for positive locking of the fasteners against rotation.

3.2.2.1.2 Mounting Technique-2 21966

The mounting bolt size **shall** be No. 8-32.

3.2.2.1.3 Mounting Technique-3 21967

The hole pattern **shall** be defined by the unit and spacecraft designers in accordance with the load capacity required to satisfy unit level vibration tests, thermal tests, and stayout zones. If loads permit, mounting bolts should be limited to four.

3.2.2.1.4 Mounting Technique-4 21968

The minimum centerline spacing between mounting bolts **shall** be 0.625 inches.

3.2.2.1.5 Mounting Technique-5 21969

All mounting feet of a given unit **shall** have a thickness of 0.100 + 0.005 inches, except as provided for below.

3.2.2.1.6 Mounting Technique-6 21970

In cases where the 0.100 foot thickness cannot be accommodated due to other driving requirements (thermal, EMI/EMC, radiation shielding), all mounting feet for the unit **shall** have a thickness of 0.350 + 0.005 inches.

3.2.2.1.7 Mounting Technique-7 21971

For all unit designs, the assumed strength capability of the honeycomb inserts **shall** be not more than 90.7 kg (200 lbs.) in shear; and 68.0 kg (150 lbs.) in tension.

3.2.2.1.8 Mounting Technique-8 21972

Screws with different threads **shall** be of different size to prevent damage resulting from insertion into wrong holes.

3.2.2.1.8.1 Mounting Technique-9 21973

For a given unit, all fasteners for covers **shall** be of the same size and all case fasteners **will** be of the same size.

3.2.2.2 Mounting Surfaces 21974

For all units requiring a thermal interface filler, the mounting surface(s) **shall** be flat (coplanar) per Table VIII with a unit flatness of 0.005 in. per 12 in. That is:

⏥	A (See Table) 0.005/12

Table VIII Unit Mounting Surface Flatness

Box Length	12	24	36	48
Flatness "A"	0.005	0.010	0.015	0.020
Note: All dimensions are in inches.				

3.2.2.2.1 Mounting Surfaces-1 21975

For all other units, mounting surface(s) **shall** be flat (coplanar) within 0.008 in.

3.2.2.2.1.1 Mounting Surfaces-2 21976

The roughness of the baseplate mounting surface **shall** not exceed 125 microinches.

3.2.2.2.1.2 Mounting Surfaces-3 21977

Mounting surfaces of units **shall** be electrically conductive (i.e., unpainted), with an electrical contact resistance of 0.5 ohm or less per square inch.

3.2.2.2.2 Mouning Surfaces-4 21978

The component baseplate design **shall** preclude any path for mounting adhesive to enter the internal cavities of the box.

3.2.2.2.2.1 Mounting Surfaces-5 21979

In cases where component design requires special features such as countersinks or counterbores for fasteners in the baseplate, abutted baseplate elements (slices), electronic components exposed at the mounting interface, etc., these features **shall** be clearly identified on the component OCD and listed as an exception per Paragraph 1.2 of this document.

3.2.2.3 Mounting Hole Positional Tolerance 21980

Unit mounting hole locations **shall** be:

ø.196 + .005/- .001 (in.); | ⌖ | **Ø.010 Ⓜ** | **A** | **B** | **C** |

The unit hole tolerance may be relaxed as follows with the corresponding increased hole size diameter:

ø.199 + .005/- .001 (in.); | ⌖ | **Ø.013 Ⓜ** | **A** | **B** | **C** |

ø.201 + .005/- .001 (in.); | ⌖ | **Ø.015 Ⓜ** | **A** | **B** | **C** |

ø.204 + .005/- .001 (in.); | ⌖ | **Ø.018 Ⓜ** | **A** | **B** | **C** |

3.2.2.3.1 Mounting Hole Positional Tolerance-1 21981

The maximum unit hole diameter **shall** not exceed ø.209 inches.

3.2.2.4 Fastener Clamp Load 21982

The unit mounting lug **shall** exhibit no permanent deformation after being exposed to a fastener clamp load up to, and including, 580 lbs.

3.2.3 Unit Alignment

3.2.3.1 Alignment Establishment

Redacted for export.

3.2.3.2 Alignment Measurement 21985

Units requiring alignment measurement **shall** provide a 5-sided alignment reference cube with at least a 645.2 mm^2 (l $in.^2$) area per surface, fixed mirror, or mounting provisions for separate optical tooling containing an alignment reference flat as delineated in the unit performance specification.

Additional requirements are redacted for export.

3.2.3.3 Optical Tooling 21986

Units which require separate optical tooling to define the alignment reference flat **shall** provide the optical tooling for alignment measurement on the spacecraft.

3.2.4 Mechanisms

3.2.4.1 Operations 21988

Units employing electro-mechanical devices **shall** be designed to minimize static and dynamic disturbances to the spacecraft platform.

3.2.4.1.1 Operations-1 21989

The dynamic characteristics of all such mechanisms **shall** be detailed in the unit performance specification.

3.2.4.2 Caging 21990

Mechanisms requiring caging **shall** be capable of being caged remotely or by insertion of temporary locking devices for spacecraft balance and handling operations.

3.2.4.2.1 Caging-1 21991

The unit **shall** not require power to maintain a caged condition.

3.2.4.2.2 Caging-2 21992

The caging mechanism **shall** be capable of restraining all motions in accordance with the accelerations specified in the A2100 Component Environmental Test Specification, 20032724.

3.2.4.3 External Properties 21993

Mechanisms whose motions are exposed to the external environment **shall** not cause the external thermal properties of the spacecraft to vary as a function of position of the mechanism.

3.2.5 Viewing Apertures

Redacted for export.

3.2.6 Dynamic Characteristics 21995

Box assemblies **shall** be designed to a minimum natural frequency of 100 Hz.

3.2.7 Unit Finishes

3.2.7.1 External Finish 21997

Units **shall** be finished in accordance with the thermal constraints delineated in Section 3.3.

3.2.7.1.1 External Finish-1 21998

The unit mounting surface **shall** be finished in accordance with Section 3.2.2.2.

3.2.7.2 Corrosion Protection 21999

Metallic material corrosion prevention **shall** be in accordance with PN20095414.

3.2.8 Venting 22000

Provisions **shall** be included for adequate venting in all compartments to maintain internal and external pressure equilibrium, except where unit design requires a sealed unit.

3.2.8.1 Venting-1 22001

A minimum total aperture of 48 mm^2 (0.075 $in.^2$) **shall** be provided per 28,317 cm^3 (cubic foot) of unit volume.

3.2.8.2 Venting-2 22002

No less than 32.26 mm^2 (0.05 $in.^2$) of total aperture **shall** be provided in any unit, with no individual aperture being less than 0.487 mm^2 (0.00075 $in.^2$).

3.2.8.3 Venting-3 22003

Venting methods **shall** be consistent with shielding requirements specified in 20032596.

3.2.9 Outgassing Materials 22004

Nonmetallic and metallic material selection and control **shall** be in accordance with PN20095414.

3.2.10 Interchangeability 22005

Units **shall** be designed so that functionally identical units are fully interchangeable.

3.2.11 Storage 22006

Units **shall** be capable of being stored for a period of up to 5 years under the following conditions:

- +17 to +27°C
- Up to 60% relative humidity

3.2.12 Protective Covers 22007

Protective covers to preclude entrance of foreign particles to sensitive areas and to preclude damage during the handling, assembly, integration, and test of the unit **shall** be provided.

3.2.12.1 Protective Covers-1 22008

Protective covers not required for environmental shielding on-orbit (damage protective) **shall** be designed to be removed prior to final spacecraft assembly.

3.2.12.2 Protective Covers-2 22009

Such items **shall** be color coded in a red finish and labeled accordingly.

3.2.13 Maintainability 22010

All units **shall** be designed so that they are factory repairable by the replacement of a part or module.

3.2.13.1 Maintainability-1 22011

All units **shall** be designed so that they can be replaced without adjustments.

3.2.13.2 Maintainability-2 22012

All units **shall** be designed so that only standard tools are needed for mounting or adjustment.

3.2.13.3 Maintainability-3 22013

Each unit **shall** be designed for installation and removal from the spacecraft without disassembly of the unit.

3.2.13.3.1 Maintainability-4 22014

All mounting bolts **shall** be accessible from the top, or equipment side of the spacecraft mounting surface.

3.2.13.3.2 Maintainability-5 22015

Spacecraft test connectors, flight plugs, and temporary vacuum seals **shall** be readily accessible with the unit integrated into the spacecraft.

3.2.14 Spacecraft Reference Coordinate System

The spacecraft reference coordinate system is defined as shown in Figure 14.

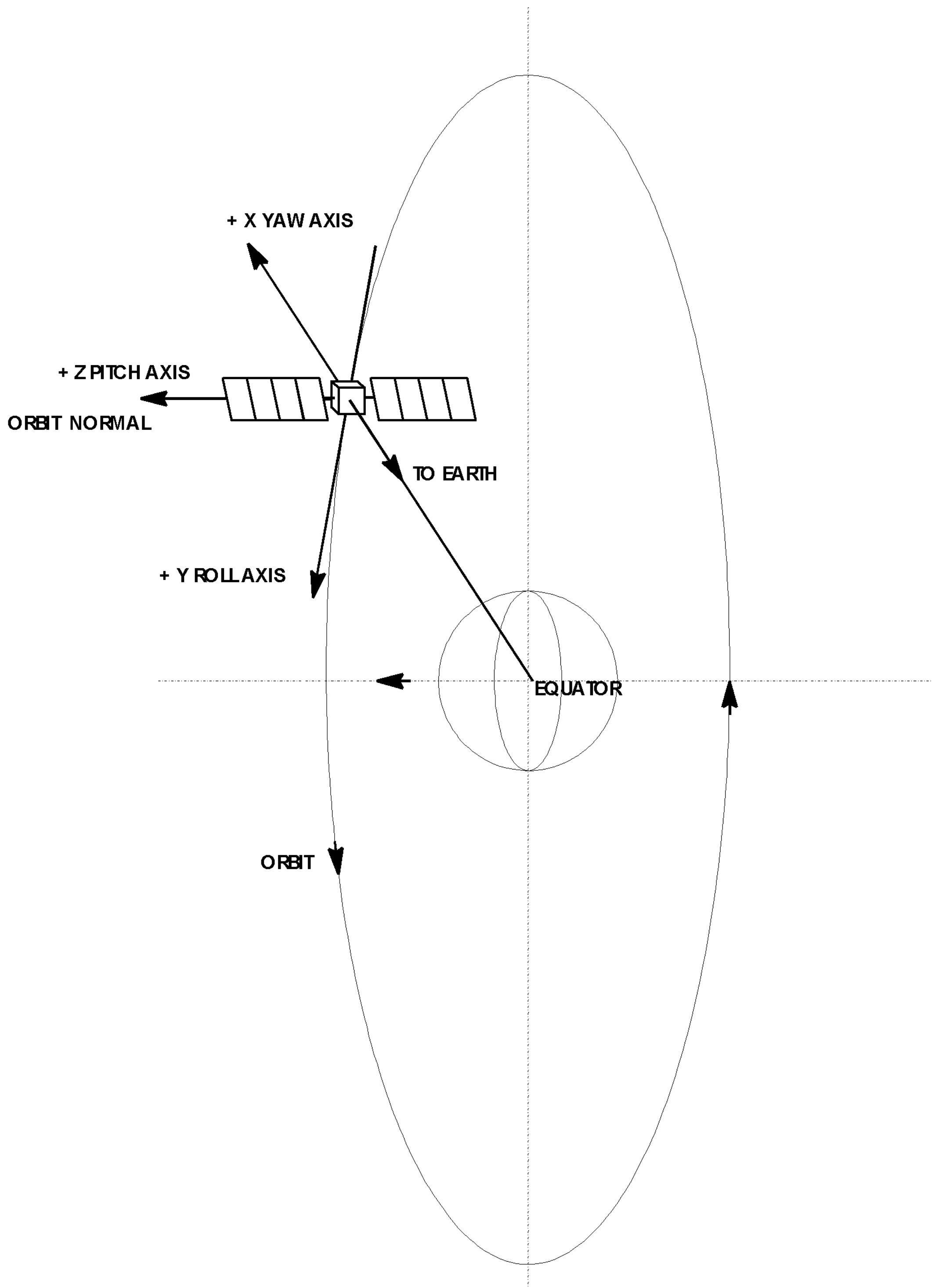

Figure 14 Spacecraft Reference Coordinate System

3.3 Thermal Interface

3.3.1 General 22018

Unit thermal dissipations **shall** be transferred to the spacecraft via conductive coupling at the mounting surface interface and/or radiation from the unit to its surroundings.

3.3.2 Unit Temperatures 22019

Each A2100 unit **shall** be designed to perform within specifications while operating within its qualification temperature range.

3.3.2.1 Unit Temperatures-1 22020

Each unit **shall** also be designed to be switched on without damage within its start-up temperature range, and to withstand exposure to its survival temperature range while in a non-operational state.

3.3.2.2 Unit Temperatures-2 22021

Components fully enclosed within the spacecraft thermal blanketing system **shall** be designed to perform within all specifications when subjected to one 15 degree and one 7.5 degree temperature swing per day and eighty-eight 15 degree eclipse diurnal swings per year for 15 years about an average component baseplate temperature of 45 degrees C.

3.3.2.3 Unit Temperatures-3 22022

Components (fully or partially) exposed directly to space environments **shall** be designed to perform within all specifications when subjected to predicted diurnal swings as defined by A2100 Systems Engineering.

3.3.2.4 Unit Temperatures-4 22023

These requirements **shall** be applied to demonstrate positive margin for any fatigue sensitive device attachments within components when subjected to the cumulative ground assembly and test thermal cycles plus the on-orbit diurnal cycles stated above.

3.3.2.5 Unit Temperatures-5 22024

The thermal subsystem design **shall** limit component baseplate diurnal temperature swing to less than or equal to 15 degrees per day except for the eighty-eight days of eclipse per year, where two diurnal swings less than or equal to 15 degrees will be allowed.

3.3.2.5.1 Unit Temperatures-6 22025

Secondary diurnal swings due to shadowing or other effects **shall** be limited to one swing per day less than or equal to 7.5 degrees.

3.3.2.5.2 Unit Temperatures-7 22026

The average component baseplate temperature **shall** be less than 45 degrees C.

3.3.3 Internal Spacecraft Radiative Environment 22027

The average internal radiative environment experienced by units inside the spacecraft during the transfer orbit **shall** be between -24°C and +30°C.

3.3.3.1 Internal Spacecraft Radiative Environment-1 22028

During the operational orbit, the temperature **shall** be between -24°C and +61°C.

3.3.4 Unit Mounting 22029

The unit Interface Control Drawing and Performance Specification **shall** delineate the unit mounting method.

3.3.4.1 Unit Mounting-1 22030

Units mounted with interface filler **shall** achieve an interface conductance of between 0.5 $W/in^2{}°C$ for the hot case and 3.0 $W/in^{2°}C$ for the cold case.

3.3.5 Unit Surface Finishes 22031

All units, excluding circuit boards within chassis, **shall** be conductive and grounded as specified in 20099181.

3.3.5.1 Unit Surface Finishes-1 22032

The external finish of that portion of a unit within the spacecraft **shall** have a total normal emittance of 0.85 or greater, unless specified otherwise in the unit performance specification and approved by A2100 Systems Engineering.

3.3.5.2 Unit Surface Finishes-2 22033

The unit Interface Control Drawing and Performance Specification **shall** delineate the surface finish.

3.3.6 Heaters/Temperature Sensors 22034

Heaters **shall** be required on units where the spacecraft environment causes the unit to operate at a temperature lower than that delineated in the A2100 Component Environmental Test Specification.

3.3.6.1 Heaters/Temperature Sensors-1 22035

Definition of heater hardware mounted on units **shall** be contained in the unit Interface Control Drawing and Performance Specification.

3.3.6.2 Heaters/Temperature Sensors-2 22036

For every unit, a location **shall** be specified for temperature monitoring, representative of the baseplate average temperature.

3.3.6.2.1 Heaters/Temperature Sensors-3 22037

The location of the baseplate temperature sensor **shall** be documented in the unit ICD/SCD.

3.3.6.2.2 Heaters/Temperature Sensors-4 22038

A minimum of one flight sensor **shall** be installed at this location.

3.3.6.2.3 Heaters/Temperature Sensors-5 22039

The flight sensor shall be an integral part of the unit design.

Additional requirements are redacted for export.

3.3.7 External Coatings / MLI

Redacted for export.

3.3.8 Heat Pipe Panels

Redacted for export

3.3.9 Thermal Dissipations 22042

Nominal and maximum unit thermal dissipations **shall** be defined in the unit ICD/SCD and Performance specification.

3.3.9.1 Thermal Dissipations-1 22043

The definition **shall** be in the form of a table or graph if significant (>2 watt) differences in dissipation occur as a function of temperature, season, time of day, or spacecraft operating configuration. The definition may consist of a mathematical equation or algorithm to calculate the dissipation from one or more input parameters.

3.3.9.2 Thermal Dissipations-2 22044

Units whose heat is rejected via conductive coupling to a radiator panel **shall** have a local dissipation of no more than 0.5 W/in^2 of baseplate area or, 1.0 W/in^2 if the unit is mounted on a heat pipe panel.

3.3.9.2.1 Thermal Dissipations-3 22045

Units which are not mounted to a radiator **shall** have a local dissipation of no more than 0.15 W/in^2 of baseplate area if the total dissipation is less than 8 watts or 0.10 W/in^2 if the total dissipation is greater than or equal to 8 watts.

3.3.9.2.2 Thermal Dissipations-4 22046

Internally mounted units whose heat is rejected via radiation from the unit housing **shall** dissipate no more than 0.04 W/in^2 of unit radiating area.

Allowable exceptions to the general guidelines are as follows:

- TWT Collectors: 4.5 W/in^2, 45 W maximum
- SSPA Heat Sink: 5.0 W/in^2, 30 W maximum

3.3.10 External Radiation Sources 22047

The solar flux incident on an external surface normal to the sun vector **shall** have a value of 0.840 to 0.915 W/in^2 (1300 to 1420 W/m^2).

3.4 Magnetic Interface

3.4.1 Residual Magnetic Dipoles 22049

Each unit **shall** be designed to have a residual dipole of less than 0.2 atm^2 except for TWTs.

3.4.1.1 Residual Magnetic Dipoles-1 22050

The TWTs sha**ll** be designed to have a residual dipole of less than 0.9 atm^2.

3.4.1.2 Residual Magnetic Dipoles-2 22051

If the unit's predicted residual dipole exceeds this value, the designer or subcontractor **shall** request a written waiver from A2100 Systems Engineering.

3.4.1.3 Residual Magnetic Dipoles-3 22052

The request (in writing) **shall** describe the magnitude and direction of such a dipole.

Additional requirements are redacted for export.

3.4.2 Deleted

3.5 Environmental Interface 22054

All unit level designs **shall** meet the requirements of the A2100 Component Environmental Test Specification, 20032724.

3.5.1 Environmental Interface-1 22055

All subsystem and system level designs **shall** meet the requirements of the customer specific Comprehensive Test Plan.

3.5.2 Space Radiation Environments 22056

All units, harnesses, thermal control surfaces and spacecraft **shall** be designed to comply with requirements specified in 20099181, A2100 Survivability and Spacecraft Charging Requirements.

3.6 Ordnance Interface

3.6.1 Ordnance Devices

Redacted for export.

3.6.2 Maximum Current

Redacted for export.

3.6.3 All Fire Time

Redacted for export.

3.6.4 Bridge Wire Isolation

Redacted for export.

3.6.5 Installation Requirements

Redacted for export.

3.6.6 Test Capability

Redacted for export.

3.6.7 Safety Ground

Redacted for export.

3.6.8 Safety Short

Redacted for export.

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4 TEST INTERFACES

4.1 General Testing Requirements 22069

All units **shall** be tested in accordance with the A2100 Component Environmental Test Specification, 20032724 and in accordance with PN20032524.

4.1.1 Functional Testing 22070

All units **shall** be designed to allow complete functional testing in an ambient or thermal (vacuum) environment, and to allow testing of all operating modes including fully loaded operation of dc/dc converters and high voltage power supplies.

4.1.1.1 Functional Testing-1 22071

This requirement **shall** be met to allow assessment of the unit and spacecraft EMI interfaces.

4.1.1.2 Functional Testing-2 22072

In the event the flight lifetime would be compromised by such tests, dummy loads **shall** be supplied to simulate the unit under the conditions defined.

4.1.2 Pyrotechnic Device Testing

Redacted for export.

4.1.3 Unit Substitution 22074

There **shall** be no scheduled replacement of unit assemblies, units, or parts after the final spacecraft pre-shipment test at Lockheed Martin.

4.1.3.1 Unit Substitution-1 22075

No unit connectors interfacing with the spacecraft harness **shall** require disconnection for routine testing at the launch site.

4.1.4 Special Fault Conditions 22076

Units **shall** be capable of surviving, without permanent degradation, sudden termination of input power when operating in any mode.

4.1.4.1 Special Fault Conditions-1 22077

Turn on/turn off within one command cycle **shall** not cause damage to the units.

4.1.4.2 Special Fault Conditions-2 22078

There **shall** exist no failure mode which can result from any sequence of commands to the unit.