GEMINI 8-m TELESCOPE PROJECT

Specification

SPE-ASA-G0008

TITLE: Gemini Electronic Design Specification

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GEMINI

8-M Telescopes Project

Gemini Electronic Design Specification

(Preliminary)

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Introduction to the Gemini Electronic Design Specification

Most of us who have worked for any length of time on Mauna Kea develop a real appreciation for reliable and easy to maintain equipment and instruments. Four o'clock in the morning on Mauna Kea, with temperatures around zero degrees, is not the time to discover that changing the cable between the cryostat and detector controller required the hands and dexterity of a 5 year old, a microscope to read the connector label and the strength of U of A football player -- and you still manage to skin your knuckles on the other mil-spec. connectors sticking out of the cryostat.

Consequently the Gemini Project asked ASA Automation Systems Associates to find out what common practices and approaches to electronic design and construction have been adopted amongst the Mauna Kea observatories. The result is this document "The Gemini Electronic Design Specification". As you flick through these pages, hopefully your reaction will be, "well that's obvious", and that's the point - this is supposed to be a guide to common sense and good practice. It also contains a lot of useful information like what kind of cables have been found to stiffen and degrade on Mauna Kea and what levels of static discharge can be experienced at 14,000 feet when the humidity is less than 10%. To quote from the introduction;

> *"This document is intended for use by both experienced and designers and those not so experienced in electronic design. Therefore, an effort has been made to set out fundamental guidelines for all of the expected design topics. Although experienced designers will not need to read all the sections in detail, we encourage you to at least browse through all sections which contain more fundamental topics to see the direction Gemini is taking on these issues"*

If you have better or alternative suggestions than those contained in this document -- we would like to here about them. If you feel these approaches are going to significantly drive costs up, we would like to discuss that as well.

Ultimately, from my perspective, it comes down to the science we all ultimately want to do on Gemini. On these telescopes the reliability and maintainability of instruments will be a key factor in the scientific productivity of the Observatory.

Also, please do not forget about that person, who will be sitting 14,000 feet, probably in the middle of the night, trying to get your instrument working.

Matt Mountain
Gemini Project Scientist

1. Introduction

This document gives the overall Electronic Specifications for Gemini Telescope Electronic Equipment. These specifications outline the required electrical characteristics of the equipment, including operational, design and fabrication requirements.

1.1. Scope

This document is intended to outline the overall Electronics Specifications for all electrical equipment used in the Gemini telescopes. This includes all electrical equipment mounted on or near the telescope and in the telescope control room(s). This document <u>does not</u> contain specifications for the installation of the telescope power distribution system or associated equipment.

1.2. Document Organization

This document works from the outside of the facility inward, starting with overall Site Facilities Characteristics and Requirements in Section 2. Section 3 deals with overall Operational Requirements that all equipment must meet. Sections 4 gives Detailed Equipment Specifications. Section 5 gives the Workmanship Requirements that are to be used as appropriate. Sections 6 outlines the Documentation Requirements that ensure the proper transfer of information occurs between the contractor and Gemini staff. Section 7 outlines the Quality Assurance standards required to ensure high equipment reliability and conformance to the requirements.

Within each section the topics are presented in order of importance or from the most general specifications to most the specific specifications.

For a List of Tables, see Appendix 1.

For a List of Illustrations see Appendix 2

1.3. Presentation of Duplicate Information

This document purposely contains duplicate information on selected topics in different sections. This is done for completeness and ease of use. For example, although some items on personnel safety are included in numerous sections relevant to a particular topic, these items have been collected and expanded in a section dedicated to personnel safety to ensure all the required information can be found easily.

1.4. Source Material

This document is an extraction from many standards, including UL, NEMA, EIA, ANSI-IEEE and MIL standards. In addition, the experience of many Electronic Engineers and Technicians familiar with telescope equipment has been solicited, most notably those of CFHT and Keck of Hawaii, NOAO and Gemini and MMT of Tucson, DAO of Victoria, Canada, the Royal Observatory, Edinburgh, England and others.

1.5. Level of Detail

This document is intended for use both by experienced designers and those not so experienced in electronic design. Therefore, an effort has been made to set out fundamental guidelines for all of the expected basic design topics. Although experienced designers will not need to read all sections in detail, we encourage you to at least browse through all sections which contain more fundamental topics to see the direction Gemini is taking on these issues.

1.6. Recommendations & Notation "Rec"

Where a specification has an associated recommended (but not mandatory) design or fabrication practice the notation "(Rec)" is placed beside the section title. These recommendations are found in **X**. The entries in this appendix have the same section numbers corresponding as those in the main body of this document. This appendix has its own Table of Contents and page numbers.

1.7. Standards & Specifications

1.7.1. General

The primary standards in preparation of this document have been:

1. National Electrical Code - 1990.
2. OSHA 2206, 20 CFR 1910, Safety & Health Standards.
3. NEMA ICS 1-1988 - General Standards for Industrial Control Systems.
4. UL 508, Standard for Safety - Industrial Control Equipment.
5. MIL-STD 242G, (Navy) Electronic Equipment Parts, Selected Standards.
6. MIL-STD-454, Standard Electrical Requirements for Electronic Equipment.
7. MIL-T-28800E, Test Equipment For Use With Electrical and Electronic Equipment, General Specification For.

A detailed list of all Standards used in the preparation of this document are listed in **X**.

1.7.2. Engineering Units

Metric units shall be used.

1.7.3. International Standards

Non-US laboratories will be permitted to work to International Standards in addition to or instead of certain sections of this standard provided a waiver is received in writing from Gemini.

1.8. RFP Dependent Specifications

The following specifications will be addressed on a project by project basis within the associated RFP:

Section	Description	Page Number
3.3	Service Life	8
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1.9. Interface Requirements

The following systems/subsystems require interfaces with other systems/subsystems. Therefore the designer should contact the appropriate designers of the other systems/subsystems to ensure design compatibility:

Section	Description	Page Number
3.2.1	Self Test	8
3.12	Control Panel	13
4.8.6	Connectors	19
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2. Site Facilities & Characteristics

2.1. Altitude

All equipment, including that for Cerro Pachon, shall be designed for operation at the altitude of Mauna Kea, which is 4,500 meters (14,500 feet) ASL.

2.1.1. Effects on Personnel

For personnel not familiar with working at the site altitude the following can be expected:

- shortness of breath after only minor exercise, such as walking up stairs.
- inability to concentrate on the task at hand for long periods of time.
- lack of clarity in thinking through detailed work.
- a cold environment typically below freezing.

2.2. Thermal and Humidity Environment

2.2.1. Operating Environment - Dome

The operating temperature range for inside the dome shall be -10°C to +30°C. The operating humidity range is 0% to 90%.

2.2.2. Non-Operating Environment - Storage Space

The storage temperature range shall be -30°C to +30°C. The humidity can range from 0% to 100% (condensing). The saturated conditions often occur quickly when storm systems arrive. The resulting condensation, which subsequently often freezes, is usually limited to exposed equipment surfaces.

2.2.3. Living Space

The living space temperature range shall be 0°C to 20°C, 0% to 60% humidity.

2.2.4. Computer Rooms

The operating environment for the computer rooms shall be 10°C to 15°C, 30% to 40% humidity.

2.3. Telescope Instrument Cabling

2.3.1. Instrument Ethernet LAN

This bus shall be used for interconnection of the equipment to the telescope control system. IEEE 8802.3 is the standard.

See , for this specification.

2.3.2. Instrument Non-Dedicated Coaxial Cabling

There shall be non-dedicated cabling supplied for observer use from each instrument location to the control room(s). Details of these cables will be provided by Gemini on request.

2.3.3. Instrument Fiber Optic LAN

See **X**, for this specification.

2.3.4. Fieldbus

This bus is an Allen-Bradley serial I/O system and will be used to control simple low-bandwidth systems and will be managed by VME bus interface modules.

See **X**, for this specification.

2.3.5. TBR Bus

The bus will be used for fast deterministic data transfer between the A&G and secondary mirror control, for example. It is baselined as a reflective memory system such as SCRAMnet or VMIC. EPICS device drivers will be used for the VME bus interface cards.

See **X**, for this specification.

2.3.6. Time Bus

The time bus shall be used to distribute time information throughout the telescope system. This information shall be available on 4 separate coax lines which carry IRIG B time code, 1 KHz, 100 Hz and 1 Hz signals respectively.

See **X**, for this specification.

2.3.7. Instrument Serial Link

RS 232, 422 and 482 shall not be used for interconnection to the telescope control system. This shall be accomplished via the Ethernet bus with its own cabling.

2.3.7.1. RS - 232 Interface

RS-232 may be used in a stand-alone mode for local communications, such as from a diagnostic portable computer.

Reference: EIA RS-232E.

2.4. Telescope Cooling System

The telescope shall employ a liquid cooling system for all dome mounted equipment. Each piece of equipment shall employ an air to liquid heat exchanger. The heated coolant from the equipment shall be transferred through the cable wraps, and dome plumbing to remote chillers. See Section for further information on the equipment requirements.

2.5. Telescope Electrical Power Distribution

See **X**, for this specification.

3. *General Operational Requirements*

3.1. General

This section gives Operational Electronic Requirements which must be met by all equipment. Detailed Design Requirements are given in Section 4.

3.1.1. Exceptions

The specifications within this document are intended to cover most of the electronic applications in the Gemini project. However, if one of these requirements severely impacts the performance or price of a piece of equipment, consideration will be given to modifying the requirement(s), if it can be proven that there will be no detrimental impact on either the operation or maintenance of the telescope. Each case will be examined by Gemini engineers following the submission in writing of the appropriate requested changes. No waiver shall set a precedent for the supply of any other equipment.

3.2. Reliability

The contractor shall furnish a reliability analysis or offer proven field experience demonstrating the level of reliability of the supplied system and its major subsystems.

3.2.1. Self Test Capabilities/Failure Mode Analysis

System reliability is significantly increased if the equipment is provided with Self Test capability which is typically is invoked from the operator's panel or display prior to normal use. As this capability may require the inclusion of extra sensors, and therefore extra costs, this capability shall be addressed on an individual basis for each piece of equipment.

A failure mode analysis shall be required for each piece of equipment. Although a mean time between failure for each piece of hardware is desirable, the least amount of information provided should be what will fail if a sub-system or major component fails.

3.3. Service Life

The design service life for the equipment shall be specified in the RFP.

3.4. Equipment Emanations (Rec)

The contractor shall conform to the requirements listed below for equipment emanations. Use of a qualified lab, or manufacturer's data, or developer's own measurements to confirm compliance to applicable sections is required.

3.4.1. Optical and IR Radiation

The equipment shall not emit radiation in any band used for observing.

3.4.1.1. Illumination Disable Requirements

All indicators on the exterior of the equipment shall be able to be either turned off or covered during an observing period. An example of this would be a cover that can be closed over the control panel.

3.4.1.2. Encoder Optical Shielding

All encoders shall be optically shielded to prevent infrared or visible light from emanating from the device.

3.4.2. Acoustic Noise Specification (Rec)

The OSHA requirements, section 1910.95c(1) states that the maximum recommended noise level over an 8 hour period should be 85 dB, using a standard sound level meter at slow response, A-weighted.

3.4.3. Electromagnetic Interference

Radio transmitters for telemetry shall not be used. For further information on this topic contact Bob McClaren, IFA Honolulu, at 808-956-8768.

3.4.4. Lasers

All lasers used within the United States must conform to regulations 21CFR 1040.10 and 1040.11, established by the FDA Center for Devices and Radiological Health(CDRH). For further information contact the Director (HFZ-300) Office of Compliance, Center for Devices and Radiological Health, 8757 Georgia Avenue, Silver Springs MA, 20910.

3.4.5. X-ray

X-ray emanations shall be kept below the following levels:

3.4.5.1. Human Safety

0.5 milliroentgen per hour at 5 cm from the radiating source, for a target area of 10 cm^2 which has the greatest dimension limited to 5 cm.

Reference: ANSI/ISA-S82.01 - 1988, Section 6.1.1.

3.4.5.2. CCD Delectability Limit

The emanations must be below the cosmic background level which is less than 100 counts/cm^2/hour.

3.4.6. Microwave

In the frequency range of 100 Mhz to 100 GHz. the power density shall be limited to 10mW/cm^2 at any point 5 cm from the equipment surface.

Reference: ANSI/ISA-S82.01 - 1988, Section 6.2.

3.4.7. Ozone Liberation

Any ozone liberation shall be limited to a TWA concentration of 0.1 ppm based upon a normal 8 hour workday and a 40 hour work week. Workers may be exposed to a STEL of 0.3 ppm provided the daily TWA is not exceeded at any time during the workday, even if the 8-hour TWA is equal to, or less than, 0.1 ppm.

Reference: ANSI/ISA-S82.01 - 1988, Section 6.3.

3.4.8. Ultrasonic Pressure

During normal operation the ultrasonic sound pressure level shall not be more than 110 dB above a reference level of 20 micronewtons per square meter (2 x 10^{-4} microbar or 2 pascals). Compliance is checked by measuring the sound pressure level over a frequency range of 20 KHz to 100 KHz.

Reference: ANSI/ISA-S82.01 - 1988, Section 6.4.

3.5. Storage, Handling & Transit

3.5.1. Storage Conditions

As outlined in Section , the storage temperature can range between -30°C to +30°C. The storage humidity can range from 0% to 100% condensing condensation can be expected on exposed surfaces. Therefore, a light weight cover shall protect all exposed surfaces that should not be subjected to condensation.

3.5.2. Storage/Handling Cart

This specification, although not strictly electronic in nature, is included to ensure that those aspects of the cart relevant to the Electronic Specification are included.

All instruments shall be provided with a handling cart which shall secure the instrument in a safe manner in the orientation normally used on the telescope. The cart shall be used for instrument storage and for handling while off the telescope.

Instruments intended for use at the Cassegrain focus shall be mounted on the handling cart in such a way as to not inhibit the mounting of the instrument to the Cassegrain attachment points.

The cart shall have locking, soft rubber wheels at least 150mm in diameter and, if for use at the Cassegrain focus, jack screws at each corner.

Access to the instrument by an overhead crane or other handling equipment shall not be impeded while the instrument is on the cart.

The instrument shall be capable of performing all electro-mechanical functions while on the cart. Access to connectors and power supplies for routine maintenance and troubleshooting of the instrument shall not be impeded by the cart structure.

The cart shall have at least one pair of lifting points, together with all the necessary spreader bars or specialized slings, to permit transportation of the cart plus instrument by crane.

The cart shall contain an open shelf onto which all necessary fastening hardware and tools for mounting the instrument to the telescope can be stored. This shelf should have a raised front edge to retain items within the cart.

Labels shall be affixed to the cart indicating the weight and moments about the instrument mounting face.

3.5.3. Battery Transport

If the equipment contains a battery, special considerations required for storage or transport shall be outlined.

Reference MIL-T-28800D, Section: 3.10.3.1.3.

3.5.4. Equipment Cover

All instruments shall be provided with a heavy-duty vinyl cover with full length heavy duty zippers on at least two sides. The cover shall identify the instrument with 100 mm high white letters. The cover shall be designed to fit over the instrument and its storage cart and reach within 100 mm of the floor.

3.6. Cooling & Ventilation

All dome equipment electric boxes shall be sealed and have an integral air to liquid heat exchanger, (see for further information on the heat exchange system). The equipment shall employ spill-proof disconnects to attach to the telescope cooling system.

3.7. Stand Alone Operation

All equipment and instruments shall be provided with autonomous power supplies and other hardware to allow standalone operation.

3.8. Warm-up Period

The contractor shall specify the required warm-up period for the equipment. This shall be specified in the response to the RFP in order for Gemini to assess whether or not it may have an adverse impact on the operation of the telescope. The normal operational mode is to turn the equipment on at the start of an observing run and not to turn it off until the end of the run, perhaps several weeks later

3.9. Cool-down Period

The contractor, if applicable, shall specify the required cool down period for the equipment subsequent to normal operation. This shall be specified in the response to the RFP in order for Gemini to assess whether or not it may have an adverse impact on the operation of the telescope.

3.10. Standalone Power Consumption

If the equipment requires continuous power during the non-operational periods this must be specified.

3.11. Accessory Stowage

Any accessories required for the operation of the equipment shall be stored within the equipment or within a reusable container marked for such a use which is provided by the contractor.

Reference MIL-T-28800D, Section: 3.14.3.4.f.

3.12. Control Panel

Reference: MIL-STD-28800D, Section: 3.3.3.5
Reference MIL-T-28800D, Section: 3.10.1.1.4

3.12.1. General

This panel shall be placed in an easily accessible and visible location on the equipment. If possible, the controls for all equipment devices which require operator attention should be placed on this panel. It shall not be acceptable to have a critical control inaccessible due to the telescopes orientation or the presence of another piece of equipment.

It is recommended to have the following control panel items, either at the equipment itself, if operated locally, or in the control room, if operated remotely:

- Emergency Stop Switch - This large red mushroom capped button shall be placed within easy reach of the operator and is to be used in case of a serious equipment malfunction. This maintained contact button should stay pushed in until pulled out and should be protected from accidental operation. This button should physically cut power to the devices within the equipment which could become damaged through continued operation in a fault condition.

  As per section 430-105 of the National Electrical Code - 1990, "one pole of the disconnecting means (Emergency Stop Switch in this case) shall be permitted to disconnect a permanently grounded conductor, provided the disconnecting means is so designed that the pole in the grounded conductor cannot be opened without simultaneously disconnecting all conductors in the circuit." Although this section applies to motors and motor controllers the principle holds for other energized and grounded conductors within the equipment.

- Power On-Off - This button or rotary switch shall connect and disconnect all power to the equipment. It can either be illuminated to indicate when power is applied to the equipment or have an associated pilot light to indicate a powered-up condition. The recommended color is green. If it is desired to use a momentary contact button or switch for this application then an associated power contactor or relay shall be required. This switch shall be protected against accidental contact by personnel.

  Reference: MIL-STD-454M, Requirement 1, Section: 4.4.3.5

- Graphics/Text Display - If the equipment does not communicate status and error messages to the main control computer a local display should be used for this purpose. Through the display the system software programmer can display a multitude of status messages, data and error messages, if required, that immensely assist in the operation and trouble-shooting of the device.

- Main Status Pilot Lamp - Although the graphic/text display can give status messages, it is useful to have one main pilot lamp visible from a distance that indicates when all the internal checks have been performed and that the equipment is ready for use. This lamp shall be green.

- Operator Attention Pilot Lamp - If this lamp is used it shall be placed in a conspicuous place on the equipment panel. This indicator is often used in conjunction with the graphics/text display to indicate when the operator needs to read the graphics/text display.

- Audible Alarm - An audible alarm shall be used to draw the operator's attention to the device in case of a fault which may endanger personnel.

- Other Indicators - Other indicators or controls, such as temperature, vacuum, voltage or current indicators, shall be placed on the control panel as required for operation of the equipment.

3.12.2. Selection Locking

Rotary switches, rotary adjustments and maintained contact buttons shall have a locking or detent device to keep them at the selected position.

Reference: MIL-STD-454M, Requirement 28, Section: 4.3.

3.13. Software

All software required for the dedicated control of the of the equipment shall be considered to be part of the instrument. Details of this software shall be outlined either in the Gemini Software Standards or in the Equipment RFP.

Data acquisition and user interface software is not considered part of the scope of supply unless specifically requested in the RFP.

As outlined in Section , all electrical signal and power cables shall incorporate a cable integrity signal wire. The control algorithms shall check each cable for this signal prior to operation of the equipment.

3.14. Operating and Control Modes (Rec)

A suggested set of control modes is found in **X.**

4. Detailed Electrical Design Requirements

4.1. General

All equipment shall be of modular design to facilitate repair by the replacement of spare modular assemblies. Separate sections of a piece of equipment shall not be hardwired together. Cables and/or wires with connectors shall be used to facilitate equipment disassembly and repair.

4.1.1. Removal and Replacement

Operational equipment shall be designed to have a removal and replacement cycle on the telescope of no more than four hours. It is recognized that it may take longer periods to set up the equipment in the lab prior to telescope installation.

4.1.2. Accessibility

To the maximum extent feasible, each replacement module shall be removable and replaceable without having to remove or disturb another module, assembly, component or portion of the telescope.

4.2. Standard Components

Standard Components for use in the Gemini equipment are included in **X**. All developers shall use these components unless agreed to in writing between the developer and Gemini. The intent of enforcing a standard components list is to reduce the component stock and the manpower requirements for the operation, maintenance, and trouble-shooting of the equipment on-site.

4.3. Use of Commercially Available Components

If appropriate, the use of suitable quality off-the-shelf components, assemblies and systems is highly recommended. The estimated benefits in designing a custom piece of equipment are rarely realized if a suitable piece of equipment is available off the shelf.

Order of preference in selection of components is:

- Commercial off the shelf.
- Non-commercial but widely used in similar applications/environments.
- Non commercial but already in use at Gemini.
- Unique solution.

4.4. Expandability & Excess Capacity

The supplied equipment shall have excess capacity in the following categories:

- Input/Output Points.
- Memory, RAM and Video.
- Accessory Mounting Space - if the equipment can be upgraded or devices added a a later date to alter the performance, adequate mounting space must be provided for these additions.
- Cable Conductors and associated wired up Connector Pins.
- Power Supply capacity.
- Motor torque.

The developer shall indicate the amount of expandability and excess capacity to be provided in the submitted response to the RFP.

4.5. Restricted Materials

Reference: MIL-STD-454M, Requirement 1, Section 4.8.
Reference: MIL-T-28800D, Section: 3.9.3.9.

4.5.1. Gases or Fumes

The operation of any piece of equipment shall not result in the emission of any hazardous gases or fumes. Anything not meeting this requirement, such as rotary pumps, requires a written waiver from Gemini.

4.5.2. Mercury

No mercury shall be used in any telescope equipment or apparatus, with the exception of PC computer batteries.

4.5.3. Materials that Degrade at Altitude / Ozone Degradation

It has been determined that some materials degrade at the altitude of the summit. See **X**, for a list of these materials.

4.6. Electronic Parts Derating Requirements

Electronics parts derating is employed, independently of other design criteria, to achieve an increased level of reliability in equipment by limiting the electrical and thermal stresses placed on the components. The general rule employed by telescope staff on site is to derate all components by at least 25%. In addition, electrical power dissipation should be derated to an equivalent *60°C* environment. This is due to the 40% reduced air density relative to sea level which reduces the effect of convective cooling by approximately 50%. High voltage systems should be rated for operation at an altitude of 4,500 meters (14,500 ft.).

4.7. Reference Designators

The reference designator system should keep the designators as short as practically possible. Where equipment is referenced on technical drawings the reference system should either be outlined on each drawing (if simple enough) or supplied on the first sheet of a set of drawings.

Reference: ANSI Y32.16 - 1975.
Reference: USAS Y14.15 - 1996.

4.7.1. Reference Designator Hierarchy

As an example of a designator hierarchy; basic parts such as resistors and other components are formed into subassemblies and assemblies, which are combined with other components to form units. Units are connected with other items to form groups and sets, which are linked together to form a system. The designer does not have to use these exact labels, however, the labeling for a system should be consistent and follow a definite hierarchy.

The reference designators assigned to each piece of equipment shall appear on the equipment itself and all drawings on which the equipment is displayed.

4.8. Identification & Marking of Equipment

Equipment should be permanently and legibly marked with the reference designation for each subassembly and part except for the following instances:

- when space limitation preclude such markings.
- when Gemini specifically requires that markings be omitted.
- where it is customary in industry to omit such markings for certain items.

Reference designation markings shall be located adjacent to each subassembly or part, and shall be marked on the chassis, reverse side of front panel, and other major subassemblies within the equipment. They shall be easily visible and not hidden behind components or other assemblies. The designations shall be marked in a location such that they locate the parts physically, yet remain readily visible for maintenance purposes. The primary intent of this requirement is that removal of a part or assembly should not result in the loss of the identification of its physical location.

Reference: MIL-T-28800D, Section: 3.10.3.
Reference: MIL-STD-454M, Requirement 67, Section 4.
Reference: ANSI/ISA - S82.01-1988.

4.8.1. Identification Plate

All instruments, equipment and major subsystems shall be labeled with a metal identification plate giving, at the minimum:

- Manufacturer.
- Equipment Name.
- Model.
- Serial Number.
- Power Consumption at Full Load.
- Power Type required (ie. single phase or three phase).
- Applicable Approvals.

4.8.2. Label Material & Attachment

Labels shall be made of metal or plastic unless the entire panel is silk-screened with the labels and other graphics.

All plastic and metal panel labels shall be permanently affixed with either rivets, screws or epoxy. The use of double sided tape is not acceptable.

4.8.3. Battery Warning Label

If a liquid electrolyte battery is used a battery warning label shall be clearly visible stating: "Warning - remove batteries before shipment or inactive storage of 30 days or more."

4.8.4. High Voltage

All areas containing voltages over 70 volts AC or DC shall have a "High Voltage" warning sign readily visible with the voltage stated on the sign.

Reference: MIL-T-28800D, Section: 3.10.3.1.2.
Reference: MIL-STD-454M, Requirement 1, Section: 4.7b.

4.8.5. Circuit Boards

Circuit Boards shall be labeled as to function and manufacturer.

4.8.6. Connectors

All connectors shall be labeled on the panels and on both ends of the cables.

Connector reference designators shall be assigned in accordance with the following principles:

- The movable (less fixed, such as a cable or board with a connector on it) connector of a mating pair shall be designated "P", as in "P21".
- The stationary connector of the mating pair should be designated "J" or "X", as in "J21".
- The "X" designator shall be used where the mating part is not a cable.
- The "J" designator shall be used where the mating part is a cable (see Fig. 1 below):

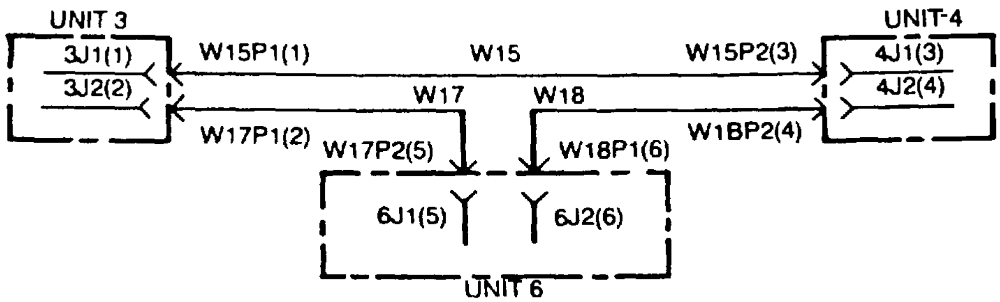


Fig. 1 - Cable Reference Designators

Reference: NEMA ICS 1-1988, Section 1-101A.5.3.5.5 (pg. 66)

Should there be more than one directly affixed connector on the mounted item, the designation of each mating mounting connectors shall consist of the following in the order listed:

- the class code letter "X"
- the basic reference designation of the mounted item (i.e. "A1").
- the basic reference designation of its mating connector on the mounted item (i.e. "P1", see Fig. 2 below):

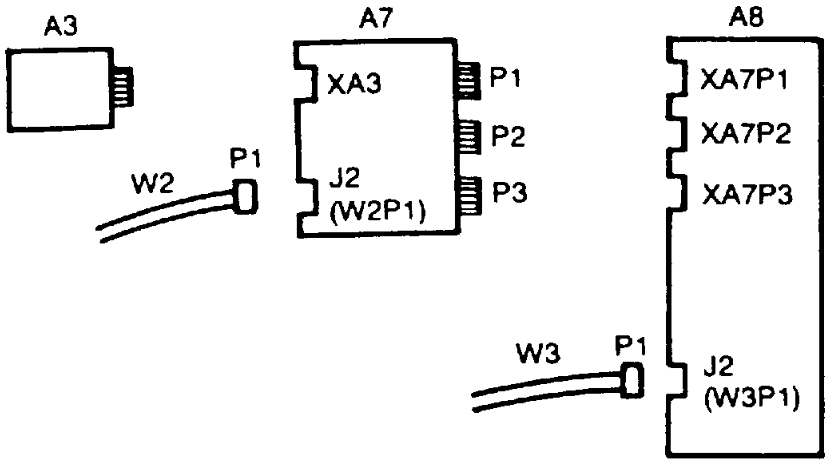


Fig. 2 - Use of X and J Designator

Reference: NEMA ICS 1-1988, Section 1-101A.5.4.5.3 (Pg. 65)

4.8.7. Circuit Breakers & Fuses

Circuit breakers and fuses shall be labeled as to their interrupting capability. This label shall also appear on the panel beside the device to allow identification of a replacement should the device be destroyed by fault level currents.

4.8.8. Switches, Knobs

The function of all knobs and switches shall be labeled.

4.8.9. Hazardous Locations

All hazards shall be clearly labeled.

4.9. Equipment Isolation (Galvanic Isolation)

The physical electrical connection of the equipment to other electrical systems, such as the telescope communications system, is not allowed, except for mains power. This is required to eliminate as many ground loops as possible. This requires that all digital communications and signal lines be optically isolated.

Typical values for galvanic isolation are:

Isolation test voltage: > 1500 VAC, 60 Hz

Isolation Resistance: > 100 M Ohms
Isolation Capacitance: < 50 pf

4.10. Signal Interconnections

4.10.1. General

The use of fiber optic cables is highly recommended in order to reduce the possibilities of ground loops. Otherwise, as noted below, the use of isolated twisted pair is recommended for interconnection.

4.10.2. Logic Signals

4.10.2.1. Signal Levels

Either 5 VDC compatible or 24 VDC shall be used for signal interconnections. The baseline is 5V TTL, other methods may be cleared with Gemini. Details of these interconnections will called out in the Preliminary Design Review. Where two pieces of equipment interface, it is the responsibility of the designer to ensure the equipment interconnections are compatible.

4.10.2.2. Interconnection methods with 5 VDC Supply

An interconnection with optical isolation is recommended in order to satisfy the galvanic isolation requirement. A single ended drive may be used for internal connection where galvanic isolation is not required, the cable length is no longer than 3 meters and the receiver has a Schmitt trigger input. For longer cable lengths not requiring isolation a differential driver should be used. The interconnection method shall be twisted pair.

4.10.2.3. Interconnection methods with 24 VDC supply

As with 5VDC systems, 24VDC systems should employ optocouplers to ensure galvanic isolation. The interconnection method shall be twisted pair.

4.10.3. Analog Signals - Interconnected Without Coaxial Cable

The Gemini baseline supply voltage of the analog driver shall be ±15 VDC. The circuits shall be isolated. Interconnection shall be twisted pair.

4.10.4. Analog Signals - Interconnected With Coaxial Cable

The interconnection with coaxial cable is allowed if all conditions that follow are valid:

- the cable length is not more than 3 meters.
- galvanic isolation is not required.

4.11. EMI Control (Ref)

4.11.1. Shielding & EMI Considerations

All devices shall be designed and fabricated to conform to Section This shall be accomplished, in part, by the following:

4.11.2. Twisted Pair

Twisted pair instrument cable shall be used outside equipment enclosures and between equipment to minimize to effects of EMI. Ribbon cable shall not be used outside equipment enclosures or in situations requiring strain relief through chassis holes.

4.11.3. Separation of Power and Signal Cables.

Power and signal cables shall be physically separated to minimize EMI into the signal cables. If possible, barriers should also separate the cables with a metal wiring tray.

4.11.4. Motor Amplifiers

All motor amplifiers shall be shielded and/or filtered to minimize the radiated EMI. Servo drives shall be disabled when not in use.

These drives may be prohibited in certain areas. Consult Gemini staff to determine the appropriate use of pulsed drives.

4.12. Equipment Mounting

Unless otherwise indicated or approved by Gemini, all telescope mounted equipment shall be mounted in standard 19" wide by 24" deep racks. Each rack mounted on the telescope or in the dome shall be sealed to allow the use of self contained air to liquid heat exchangers for temperature control. All equipment mounted in the telescope control room(s) shall be mounted in supplied 19" wide by 24" deep racks. The specifications for these racks is found in .

Reference: MIL-STD 108E - Definitions of and Basic Requirements for Enclosures for Electronic Equipment.
Reference EIA 310-D Cabinets, Racks, Panels and Associated Equipment.

4.12.1. Cable Entry

The cable entry point is the back of the rack unless otherwise indicated or approved by Gemini.

4.12.2. Use of Slides

Slides shall be required for computer room equipment but shall not be used for equipment mounted on the telescope.

4.12.3. Handling

All racks shall have lifting rings installed in appropriate locations to allow the rack to be placed in the proper location and attitude for reconfiguring the telescope equipment.

4.12.4. Chassis

Chassis front panels for telescope mounting shall be fully enclosed, with solid panels and doors over all openings. This is to accommodate the requirement that racks be sealed for the rack mounted integral cooling units.

Access panels shall be equipped with quick release captive hardware. Plastic hardware shall not be used for these applications.

4.13. Grounding (Rec)

At no time shall the telescope structure be used as a ground return for electronic equipment. See also: Section .

4.13.1. Equipment Level

The following separate grounds shall be used:

- Protective earth ground (chassis)
- Analog signal ground
- Digital signal ground
- DC protective ground(internal power supplies)
- Shield ground

These grounds shall be connected only at one point within the equipment; a lug welded to the frame close to where the mains power cable enters the equipment.

There is no requirement for a ground fault current breaker within the equipment as Gemini will have this protection installed on all power systems.

The NEC Section 430-141, Section L specifies that all non-current carrying metal parts shall be grounded to prevent the possibility of electrical shock if a live conductor accidentally contacts the metal part.

4.13.2. Subsystem Level

As mentioned in Section , it is required that there be no direct electrical connection from one subsystem to another, (i.e. equipment to telescope communications system), aside from the mains power.

4.13.3. Chassis Grounding (Bonding)

All chassis components shall be bonded together using green multiconductor wire. These connections shall terminate at the chassis ground lug near the entrance of the mains power to the chassis. All doors and other components with large movable panels shall be bonded as well.

4.13.4. Equipment Chassis Considered Effectively Grounded

Some equipment is effectively grounded through its attachment to a metal frame. An example of this would be a chassis bolted to a rack enclosure, which in turn is grounded by the green earth ground of the mains power cable. See also Section

Reference: National Electrical Code - 1990, Article: 250-58

4.14. Power Supplies & Systems

4.14.1. Voltage Transient Response

The power supply system of a piece of equipment shall be able to shield the rest of the equipment from potential damage that could be caused by variations in the supply voltage. The power supply shall be able to safely withstand momentary drop-outs and voltage spikes. As a guide to acceptable performance, MIL-T-28800D, sections 3.4.5.2.2 and 4.5.5.6.2 specifies that power supplies shall safely operate from 103.5 volts AC to 129.0 VAC. The power supply shall also withstand a 0.5 second transient of 161 VAC or dropout to 80.5 VAC and return to normal operation within 30 seconds in a fail-safe manner.

All power supplies shall be UL approved.

4.14.2. Ampacity & Current Overload Protection

4.14.2.1. General

All power systems shall employ a system of coordinated over current protection devices which shall interrupt any fault currents which occur.

Any controls which switch between alternate power sources must also switch in and out appropriate overcurrent protection devices.

At no time shall fuses or breakers be wired in parallel to achieve the required current rating (NEC 240-8)

Reference: MIL-STD-454M, Requirement 8, Section: 4.1.1

Reference: National Electrical Code - 1990, Articles: 220 & 240. It is highly recommended that this reference be studied in detail.

Reference: UL 508, Section 33

4.14.2.2. Branch Circuits and Feeder Calculations

Although, as previously stated, this specification does not apply to the electrical power system of the telescope it is prudent to apply the National Electrical Code (NEC) guidelines to the power systems of the electronic equipment.

As per NEC Section 220-3(a), continuous loads must not exceed 80% of the branch circuit rating. Therefore, for an expected 8 amp continuous load current, the overcurrent device and the wire size must be sized for 10 amps. On top of this requirement, derating factors must be applied. Where the ampacity of a conductor does not correspond with the standard ampere rating of a fuse or circuit breaker the next highest rating shall be used. (NEC 240-3, Exception No. 4).

For motor loads Table 430-152 of the NEC shall determine the value of branch circuit short circuit and ground fault protective devices.

In all protection systems the over current devices shall be coordinated such that when a fault occurs only the affected circuit is isolated. For example, a branch circuit shall not have a protective device with the same rating as the main circuit feeding the branch circuit.

4.14.2.3. Current Overload Device Selection

Although opinions among electrical designers vary on the selection of fuses vs. circuit breakers, it is commonly held that fuses are more repeatable than breakers. Circuit Breakers are more commonly used, however, because there is no danger of inserting the wrong value of fuse once an overload occurs. It is recommended, therefore, that circuit breakers be used for overcurrent protection in Gemini electronic applications. However, if an exact trip current rating is required fuses are the appropriate choice. This is due to the fact that once a breaker has been tripped several times it’s actuation point cannot be guaranteed to remain the same as the original factory setting.

4.14.2.4. Access

Any current limiting devices must be readily visible and accessible for servicing or resetting. Special tools shall not be required to reset breakers or replace fuses.

4.14.2.5. Use of Fuses

The use of copper clad steel fuse clip holders is not permitted. (MIL-P-11268L 3.10.15).

Fuses ratings are in terms of RMS, not average, line currents measured using true RMS reading equipment. The fuse rating of each fuse shall be marked next to each fuse holder. The word "Spare" shall be marked adjacent to each spare fuse holder.

Reference: MIL-STD-454M, Requirement 67, Section: 4.6, Requirement 8, Section: 4.1.2, Requirement 39.

Plug fuses and fuse holders should not be used in circuits exceeding 125 volts between conductors, except for circuits supplied by a system having a grounded neutral and having no conductor at over 150 volts to ground.

Reference: National Electrical Code - 1990, Article: 240-50.

4.14.2.6. Circuit Breakers

4.14.2.6.1. Indicating

All breakers must indicate their condition.

Reference: National Electrical Code - 1990, Article: 240-81.

4.14.2.6.2. Ungrounded Conductors

Circuit breakers shall open all ungrounded conductors of the circuit.

Reference: National Electrical Code - 1990, Article: 240-20b.

4.14.2.6.3. Marking

Circuit breakers shall be marked with their ampere rating in a manner that shall be durable and visible after installation. Such marking shall be permitted to be made visible by removal of a trim or cover.

Reference: National Electrical Code - 1990, Article: 240-83,e.

See also: MIL-STD-454M, Requirement 8, Section: 4.1.3.

4.14.2.7. Ground-Fault Protection of Equipment

The power available at the telescope will include an internal GFIC. It is not necessary to duplicate this equipment in components which receive mains power from the telescope power system.

4.14.2.8. Transient Suppression

It is required that transient suppression devices be used, especially when switching large currents or on relay coils. Not only will the EMI be reduced but the voltage spikes sent into the power systems will be reduced as well. This makes selection and coordination of the fuses and breakers easier and more accurate.

4.15. Connectors

4.15.1. Average Current Capability for Connector Contacts (Rec)

As the current ratings vary from one connector type to another depending on many factors, the exact ratings for different connector types shall be determined from the connector catalogues and qualified factory representatives and the use of the appropriate derating factors.

4.15.2. Multipole Signal Connectors (Rec)

The recommended multipole signal connector is the "MS" bayonet twist on style. Screw on type MS connectors shall not be used due the difficulty in attaching them on while wearing gloves in the typically cold telescope dome environment.

4.15.3. Environmental Considerations (Rec)

All connectors which shall be exposed to 100% humidity shall be environmentally sealed or able to resist the effects of humidity.

4.15.4. Flat Cable Terminations

The use of mass terminated insulation displacement terminations is recommended for flat cable (ribbon cable) because of its proven reliability. When replacing a damaged connector a new connector may be installed in the same position up to three times, but it is preferable to use a new location on the cable if possible.

These types of connectors typically cannot be environmentally sealed, but since this type of cable and connector shall not be used outside of equipment enclosures for the Gemini telescopes this will not present a problem.

4.15.5. Power Connectors, 115VAC, 230VAC, 400VAC

Appropriately sized MS connectors shall be used for this application. No blade type power switches shall be used on any Gemini electronic application.

4.15.6. Coaxial Connectors

Isolated BNC connectors on connector plates are used for the various communications networks within the telescope enclosure and on the telescope.

4.15.7. Optical Fiber Connectors

See for this specification.

4.15.8. Keying

All connectors, whenever possible, shall incorporate a keying scheme which prevents similar plugs from being inserted into the wrong receptacle.

4.15.9. Unused Connectors

Spare or unused connectors shall be supplied with protective caps or covers permanently attached to the cable with a small chain or flexible cord.

4.15.10. Breakout Box

The requirement for a breakout box, if required, shall be detailed in each Request for Proposal’s Statement of Work.

4.15.11. Connectors - Manufacture of

4.15.11.1. Strain Relief

All cable mounted connectors shall incorporate a strain relief and rubber bushing.

4.15.11.2. Panel Mounting

All bulkhead sockets shall be mounted on the inside of the panel to facilitate removal of the connector from the panel without unsoldering or removal of all the pins. Care is required in sizing the thickness of the panel to ensure it is not too thick to prevent the associated plug from fully engaging the socket and being able to lock in place.

4.15.11.3. Pins (Rec)

Either solder cup or crimped pin type connectors shall be used on "MS" style multi-pin connectors. The crimp pins facilitate easier field repair if the proper tools are available. The solder type pins are more commonly used for low volume work as they do not require special tools.

4.16. Cable & Wire

4.16.1. General

Reference: MIL-P-11268L, Section: 3.11.10.1.
Reference: MIL-STD-454M, Requirement 9, Section: 4.4.
Reference: National Electrical Code - 1990, Articles 420, 440, 725, 770 and 800.

4.16.2. Selection of Cable and Wire

4.16.2.1. Application

All wire and cable selection is governed by the National Electrical Code(NEC) as to applicability of use. Cable and wire is rated by various rating agencies such as the Underwriter's Laboratories (UL). All cable and wire used on the Gemini project shall be U.L. approved.

4.16.2.2. Wire Rating & Sizing(Rec)

All wire shall be sized to have no more than a 10°C temperature rise to limit the amount of heat generated within equipment. As per Section , all devices should be rated for use at 60°C for cooling, therefore all wire shall have at least a 70°C operating rating. See also Section **X**.

4.16.2.3. Core type

4.16.2.3.1. Solid

Solid copper wire is allowable for jumpers up to 7 cm. (three inches) long when unsecured and for longer lengths when secured and not subject to vibration (such as wire wrap boards).

4.16.2.3.2. Stranded

Stranded wire is required for all Gemini electronic applications except those noted in the previous section..

4.16.2.4. Insulation (Ref)

Common wire insulating materials except those noted in are acceptable.

4.16.3. Flat Cables (Ribbon Cables) (Rec)

Ribbon cable shall not be used outside an equipment enclosure as it is easily damaged.

4.16.4. Coaxial Cables (Rec)

Selection of coaxial cables should be made with regards to the impedance and attenuation at the design frequencies. The cables used at Gemini shall be specified in the appropriate communication and bus standards.

4.16.5. Power Cables

The use of a separate ground conductor is mandatory. This conductor shall not be used for a current return for any circuit other than the conduction of fault currents.

All power cables shall have sockets at the equipment end of the cable. This decreases the probability of shorting live pins if the cable is disconnected while energized.

4.16.6. Methods of Identification (Rec)

4.16.6.1. General

Cable and wire marking shall meet with the following requirements:

- It must be easily possible to identify a given cable connector with the correct equipment connector.
- The identification shall match that given on the appropriate engineering drawing.
- The identification shall be neat, legible and not damaged.
- The identification shall be permanent. Wire markers of the wrap-on type, unless covered by clear heat shrink tubing, are not permitted.

4.16.6.2. Internal Wiring

Lengths of less than 150 mm (6 inches) or less between termination points that are easily visible do not need to be labeled.

4.16.6.3. Coding & Identification of Conductors (Rec)

A single color code shall be used throughout an entire system or series of equipment models to eliminate the requirement for service personnel to return to the color coding charts continuously. Solid colors shall be used wherever possible to simplify tracing of wires. When numerous circuits are involved multiple tracer colors are acceptable.

The colors selected shall be readily distinguishable and resist fading. The color violet shall not be used since it has a tendency to be indistinguishable under certain lighting conditions.

4.16.6.4. Color Coding

A recommended coding scheme for AC wiring is (Ref: MIL-P 11268L 3.10.46.5.1):

Single Phase, 2 pole, 3 wire AC:

Black (hot)
White (neutral)
Green (ground)

Floating Single Phase, 2 pole, 3 wire AC
Gray (hot)
Gray (hot)
Green (ground)

Three Phase AC Circuits
Black (hot, phase A)
Red(hot, phase B)
Blue (hot, phase C)
White (neutral)
Green (ground)

Single Phase 2 pole, 4 wire AC (except 220 volts)
Black (hot)
Red(hot)
White (neutral)
Green (ground)

Control Circuits
AC - red
DC - blue

Reference: NEMA ICS 1, Section 1-112.63, pg. 170, 171.

Other color coding schemes are allowed but must pre-approved by Gemini. The method used must be consistent throughout the piece of equipment.

4.16.7. Cable Routing & Securing (Rec)

The cable routing shall allow for easy connection and disconnection. All cables must be secured and the use of plastic cable ducts with removable covers, such as "Panduit™" is required.

4.16.8. Through Hole Protection

Where cables and wires pass through holes in metal partitions, shields and the like, that are less than 3mm in thickness, the holes shall be equipped with suitable mechanical protection (grommet). Where the plate is thicker than 3 mm the edges of the hole must be smoothed to prevent abrasion.

4.16.9. Cable Integrity Signal Loop

All electrical signal and power cables shall have a signal loop dedicated to providing a feedback signal to the local control computer to indicate correct cable installation. This is intended to prevent operation of the equipment when all of the required cables are not in place.

4.17. Wire Terminations

4.17.1. General

The common termination methods for wires and cables are connectors, terminal strips, terminal posts, wire wrap, speedwire and wires soldered onto P.C. Boards. Wires with one end soldered onto a P.C. board must be terminated at the other end either on connectors or terminal strips. Two PCB's are not to be soldered together; this connection shall be made via connectors.

4.17.2. Terminal Strips

The acceptable types of terminal strips fully enclose the stripped wire end and secure the wire with a top mounted screw. Modular DIN-rail mounted strips, produced by many companies, are preferred because they can be installed with only as many terminations as required. All telescope mounted terminal strips shall incorporate captive screws.

4.17.3. Wire Ferrules

Wire ferrules shall be used to terminate all wires prior to insertion to a terminal block.

4.17.4. Terminal Posts & Wire Lugs (Rec)

Terminal posts are required, in conjunction with wire lugs, for chassis bonding (one part of the chassis is electrically connected to another), terminations and star points for ground systems.

4.17.5. Solderless Connections (Rec)

Wire wrap or speedwire shall be used for circuit boards under development.

4.17.6. Use of Wire Nuts

Twist-on wire connectors, commonly called wire nuts, shall not to be used.

Reference: National Electrical Code - 1990, Article: 110-14.

4.18. Maintenance, Calibration & Repair Requirements

4.18.1. Maintenance Interval

All equipment shall support a programmed adjustment and maintenance interval of 30 days or longer.

4.18.2. Required Spare Parts

The contractor shall provide a recommended spare parts list to support the specified reliability and repair philosophy.

4.18.3. Accessibility

Reference: MIL-STD-454M, Requirement 36, Section: 3.1.

4.18.3.1. Accessibility of Lamps, Fuses & Circuit Breakers

All lamps, circuit breakers and preferably fuses shall be able to be replaced or reset from the exterior of the equipment.

Reference MIL-T-28800D, Section: 3.14.1.4.c.

4.18.3.2. Accessibility for Repair & Adjustment

All items requiring regular maintenance or adjustment shall be accessible with a minimum amount of equipment disassembly.

Reference MIL-T-28800D, Section: 3.14.3.4.i,j.

4.18.3.3. Accessibility for Testing

It is highly recommended that all internal power supplies have an external test point for verification of proper supply voltages.

For circuits designed in-house all circuit board test points should be accessible with the use of an extender card. All cables attached to the card shall be long enough to allow the use of an extender card. For card boxes with front interconnection cables, it must be possible to remove the cards as well as using extender cards without a large re-cabling effort.

The interfaces required for testing shall be called out for each piece of equipment.

4.18.4. Calibration Adjustment Devices

All devices that need adjustment for the calibration procedures shall be accessible without disassembly of the equipment.

4.18.5. Self Test/Status Indicators

4.18.5.1. Systems Level

There shall be indicators on the front panel/operator interface that give the operating status of the equipment. It is recommended that all power supplies have an external indicator which shows they are operating within acceptable limits.

4.18.5.2. Board Level

Each board should have LED's that indicate whether or not an on-board fault has occurred.

4.18.6. Circuit Test Points

All circuits shall be designed with test points to facilitate trouble shooting. Documentation showing the wave forms expected at these test points should be provided if requested in the RFP.

4.18.7. Fault Isolation

The design of the equipment shall permit isolation of faults, and repair down to the lowest discrete component (resistor, capacitor, non-repairable assembly, etc.).

Reference MIL-T-28800D, Section: 3.14.3.1.

4.19. Motors & Encoders, Limits of Travel

4.19.1. Motor Selection - Types(Rec)

At the time of this writing the required motor type for various applications has not been determined. Contact Gemini for this information upon the receipt of the RFP and this document.

4.19.2. End of Travel Limit Switches

All actuators (commonly consisting of a motor and lead screw) shall incorporate four limit switches for end of travel sensing, two at each end of the travel for the device under motion. The only exception shall be for areas with a limitation on space, such as a spectrograph slit area.

The inside set of switches, one at each end, shall be software limits and shall indicate to the motion controller that the allowable limit of travel has been reached. The motion controller will then stop the travel through software. The outside set of switches, one at each end, shall be a motor power limit, and shall stop the motion of the device independently of the motion controller. If the motor under consideration is a DC servo motor then the hardware limit switches shall be wired in series with the motor. Actuation of either of these limit switches will remove power from the motor. The switch current rating shall exceed the inrush current of the motor. A diode shall be wired appropriately to the limit switch to allow the motor to be electrically driven back from the actuated limit switch position. For all other types of motors, including stepper motors, the hardware limits shall be wired according to the manufacturer's recommendations.

Limit switches shall have an expected life of at 100,000 actuations. Limit switches shall be mounted such that if the switch fails and the motor over travels the switch shall not be damaged by the actuator.

All limit switches shall wired normally closed under normal operation to provide fail-safe operation.

4.19.3. Limit Switch Actuating Devices

It is imperative that the mechanical device which trips the limit switch maintain the tripped condition of the switch even if the moving assembly coasts past the switch actuation point. If this design feature is not incorporated then the motor could become re-energized and continue its motion past the switch.

4.19.4. Hard Stops

Although not part of an electrical specification, all electrical designers shall ensure the mechanical designers have hard stops built into the equipment. No damage shall result if a motor drive continues under fault conditions to drive against the stop. Nor should the drive be able to chatter against the stop.

4.19.5. Solenoids

These devices shall be used only when the application allows momentary energization. This minimizes the generation of heat within the equipment. Electrical fail-safe brakes fall into this class of device and should be normally off when it is holding a device in a particular position. The brake shall be energized to release, the motion performed and the brake de-energized to engage. The solenoid shall have feedback devices to indicate it's position to the system controller.

4.19.6. Position Encoders (Rec)

4.19.6.1. Encoder Type

Absolute encoders shall be used on Gemini equipment. Waivers to use incremental encoders and associated homing devices shall be obtained in writing from Gemini. This may be required when the amplifier that is being used cannot support absolute encoders.

4.19.6.2. Optical Shielding

All encoders shall be optically shielded to prevent infrared or visible light from emanating from the device.

4.20. Personnel Safety Design Requirements

Some of the material presented in this section is also given in other sections of this document. As personnel safety is of paramount importance the information has been duplicated in this section in a more complete form.

Ref. MIL-STD 454M, Requirement 1.

4.20.1. Main Power Switch

The power input side of the main power switch and the incoming power line connections shall be given physical protection against accidental contact.

4.20.2. Power Indication

An external indicator, such as the power-on pilot mentioned in Section should indicate when a device is powered.

4.20.3. Lockout Capability

All equipment shall have a physical lockout capability to disable the equipment for maintenance. This can be provided through the use of lockable disconnects, Castell keys, etc.

4.20.4. Audible Alarms

All equipment shall incorporate an audible alarm to indicate, whether through motion of the device or a fault condition, that the operator must be aware of the prevailing motion or existing fault condition in order to minimize the possibility of operator injury.

4.20.5. Temperature of Exposed Surfaces

At an ambient temperature of 25°C, the operating temperature of control panels and operating controls shall not exceed 49°C. Other exposed parts subject to contact by operating personnel shall not exceed 60°C.

4.20.6. Chassis Grounding

The design of the equipment shall ensure that all external parts, surfaces and shields are at ground potential at all times during normal operation. Ground connections to shields, hinges and other mechanical parts shall not be used to complete electrical circuits. Any external connecting interconnecting cable, where a ground is part of the circuit, shall carry a ground wire in the cable terminated at both ends in the same manner as the other conductors. In no case, except in coaxial cables, shall the shield be depended for a current carrying ground connection. Static and safety grounds shall not be used to complete electrical circuits. As outlined in Section a point on the electrically conductive chassis or equipment frame shall serve as the common tie point for static and safety grounding. Chassis within the frame which are not electrically bonded to the frame shall be connected to the tie point with green wire of appropriate size (typically 16 AWG or larger). The path from the tie point to ground shall:

- be continuous and permanent.
- have ample carrying capacity to conduct safely any fault currents that may occur.

- have impedance sufficiently low to limit the potential above ground and to facilitate the operation of the over current devices in the circuit.
- have sufficient mechanical strength of the material to minimize the possibility of ground disconnection

Hinges or slides shall not be used for grounding paths. Panels and doors containing meters, switches, test points, etc., shall have a flexible green ground conductor between the door and the main chassis.

4.20.7. Shock Protection & Leakage Current

While the equipment is operating, shock protection shall be provided if the open circuit voltage between any accessible part of the equipment and ground or any other simultaneously accessible part exceeds 30 Vrms (42.4 V peak to peak), 60 VDC, or 24.8 VDC interrupted at a rate of 10 Hz. to 200 Hz.

The value of the leakage current between the accessible part and ground shall be no more than 3.5 ma when conducted with the test setup shown below:

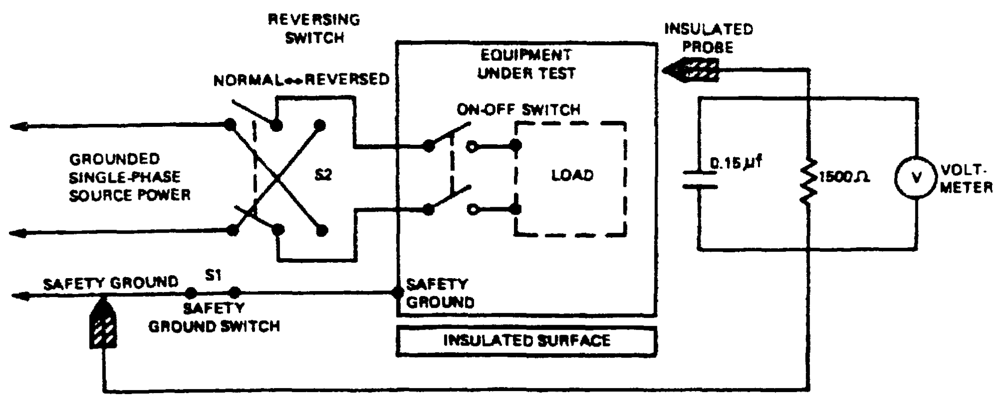


Fig. 3- Leakage Current Test Setup

Reference MIL-T-28800D, Section: 3.9.3.1.c

4.20.8. Interlocks

Panels which cover components active at 70 volts or more must be fitted with interlocks which prevent operation with the panel removed.

Circuit board power interlocks (all boards in place before power to the device is enabled) shall be provided as detailed in the Scope of Work in the RFP's.

4.20.9. Guards Shields, Permanent Insulation

All contacts, terminals and like devices having voltages between 70 and 500 volts AC rms or DC with respect to ground shall be guarded from accidental contact by personnel if such points are exposed to contact during direct support or operator maintenance. Guards or barriers should be provided with test probe holes where maintenance testing is required.

Reference MIL-T-28800D, Section: 3.9.3.7

4.20.10. Voltage Measurement

If high potentials exist within the machine, voltage divider network shall be provided to allow measurement of the voltage at a reduced potential level.

4.20.11. High Voltage Guarding

Assemblies operating at potentials in excess of 500 volts shall be completely enclosed from the remainder of the assembly and equipped with interlocks which cannot be bypassed.

4.20.12. Meter Safety

A meter should incorporate an overload bypass or alternate protection to eliminate high voltage at the meter terminals in the event of a meter failure.

Reference MIL-T-28800D, Section: 3.9.3.8

4.20.13. Accidental Contact

The equipment design shall protect personnel from accidental contact with voltages in excess of 30 volts rms AC or DC during normal operation of the equipment.

4.20.14. Hazardous Locations

All hazards shall be clearly labeled.

4.21. Electrostatic Discharge (ESD) Control

Certain areas within the Gemini complex shall be designated as Static Safe Work Areas. See , for the location of these areas. It is imperative that materials that readily hold a charge, such as photocopy paper, saran wrap, styrofoam, etc., not be used in these areas.

5. Workmanship

5.1. General

These requirements shall be used for all Gemini applications:

5.2. Materials, Parts and Processes

Materials, parts and processes shall be in conformance with best commercial standards and shall assure reliable performance.

5.3. Components - Electrical

5.3.1. Condition of

Component bodies shall meet the following requirements:

- Superficial cracks in diode envelopes that do not affect its functional performance shall be acceptable.
- Small nicks and chips in resistor bodies that do not affect its functional performance shall be acceptable.
- Capacitor welds and seals shall be intact.
- Glass headers at lead entry shall not be crazed.
- Slight surface chipping about the lead entry shall be acceptable.
- Glass headers shall not have radial cracks extending from the lead entry to the header edge.
- Small indentations in relay cases that do not affect their functional performance shall be acceptable.

5.3.2. Component Leads

Component leads shall meet the following requirements:

- Small tool marks, indentations and nicks in component leads which do not reduce the tensile strength shall be acceptable.
- Spliced component leads shall be intact and provide good electrical and mechanical bond.

5.3.3. Component Installation

Component Installation shall meet the following requirements:

- Component leads shall be free of stress and strain.

- Component leads and cases shall be insulated when in close proximity to conductors.
- Components weighing more than 14 grams (one-half ounce) or with lead length over one inch, shall be mechanically secured or bonded to a mounting surface.

Reference: MIL-T-28800D, Section: 3.3.1.5.1

5.4. Dimensions and Tolerances

Dimensions and tolerances not otherwise specified shall be compatible with the functional requirements.

5.5. Unsuitable Design

5.5.1. Use of Ribbon Cable

Ribbon cable shall not be used for permanent equipment interconnection or in any application requiring strain relief.

5.5.2. Piggy-backed Circuit Boards

One circuit board shall not be soldered on top of another. This does not apply to SBX connectors or module carriers for the use of piggy back boards. This requirement is intended to prevent the design of a system that requires the unsoldering of one board from another in order to access components on the bottom board.

Reference: MIL-STD-28800D, Section: 3.3.3.7.

5.5.3. Circuit Board Modifications

If possible, printed wiring boards shall not be modified by cutting traces or by soldering wires to the board supported only by solder. If this is absolutely required then the wires should be soldered to traces only, not to components. Any loose wires should be secured to the board with lock-tite or cyano-acrelate glues.

5.5.4. Use of Non-Standard Components

Wherever possible standard parts shall be used. See **X**.

5.5.5. Selection of Plug-In Parts

If possible, the operation of equipment shall not be dependent upon special selection of plug in parts such as jumpers, crystals, resistors of different values and solid state devices. Socketed devices such as chips are acceptable. The intent of this requirement is to prevent the operator from having to change components within the chassis in order to change the operating mode of the equipment.

Reference MIL-T-28800D, Section: 3.14.1.4.b.

5.5.6. Circuit Breakers

Circuit Breakers shall not be used as ON-OFF switches.

5.5.7. Use of Shields as Current Carrying Conductors

As outlined previous sections, shields and metallic enclosures, including the telescope structure shall not be used as current carrying conductors. The only exceptions are coaxial and triaxial cables.

5.6. Clearance

The clearance between wires and cables and heat generating parts shall be sufficient to minimize deterioration of the wires or cables.

Reference: MIL-P-11268L, Section: 3.11.10.2.

5.7. Chassis Wiring

Chassis wiring shall meet the following requirements:

- Single strand wire shall only be used for point to point wiring between adjacent terminals which cannot move relative to each other.
- Heat shrink shall be used to cover the ends of the overall insulation of cables where the insulation has been cut to expose the individual wires.
- Single strand jumpers shall be sleeved where potential shorts exist.
- Wire insulation shall not exhibit cold flow conditions.
- Wires and cables shall be positioned or protected to avoid contact with rough or irregular surfaces and sharp edges and to avoid damage to conductors or adjacent parts. (Reference: MIL-STD-454M, Requirement 9, Section: 4.4).
- Wires shall not cross over any openings required for cooling air.
- Wires should be routed to take as direct a path as practical.
- AC and DC wiring should be routed separately from each other.

- The wires should be routed either parallel or perpendicular to each other in order to obtain a neat and orderly appearance. However, wires which may be sensitive to crosstalk shall be routed away from possible EMI sources.
- Wires that follow a chassis contour shall be dressed flat on the assembly surface.
- Unused wires shall be secured into the harness.
- Wiring shall be routed to avoid contact with sharp objects or heat sources.
- Wires shall not have broken strands.
- Wiring routed between movable hinged parts shall be sleeved or jacketed.
- Wire breakouts from a bundle or harness shall not support the cable mass.
- Wire to 'floating' terminals shall have sufficient slack to allow free movement of the terminals.
- Flexible etched flat or ribbon cable shall be properly installed and move freely, as dictated by design.
- All wiring should be performed in the correct order to make assembly easier. Select and cut the wires to the proper length, strip the insulation and tin the exposed conductor, position the wire and solder, crimp or wrap the ends as required. The terminals should be wired in a definite order. First, all adjacent terminals should be connected., then the non-adjacent terminals and finally the small components are connected. There should always be enough slack left in the wires to allow a minimum of three reconnections in the event that a repair or rework must be made. In addition, this slack also permits limited movement of parts without stressing the wires and connections. Each level of wiring must be inspected before adding another level that will cover it.
- An exposed shield in close proximity to the chassis shall be covered by a vinyl sleeve to prevent potential shorts.

5.8. Cabling

5.8.1. Tension

The wire tension shall be uniform on all pins attached to the cable.

5.8.2. Routing

Cable routing shall meet the following requirements:

- Cable runs shall not mask other elements requiring access.
- Cable runs shall be properly supported when they will not support their weight in a rigid condition.
- Cable runs shall be routed in a manner to prevent them from coming in contact with moving parts, sharp objects or heat sources.
- Wire groups or bundles within a cable, approaching branch points, shall be positioned to cause the minimum amount of harness distortion.
- Wires shall be properly positioned prior to approaching the branch points in order to minimize crossovers.

5.8.3. Spot Ties

Groups of wires that are bound into harnesses having diameters less than ½ inch shall have spot ties spaced at 1-inch intervals. Groups of wires with ¾-inch diameters and above shall have spot ties spaced at 1½-inch intervals.

5.9. Connectors

5.9.1. Configuration

Connectors shall be wired in an orderly fashion to obtain an even distribution or wire tension. All wires in a connector shall equally support the cable.

5.9.2. Potting

Connector potting shall meet the following requirements:

- Connector potting shall adhere evenly and uniformly to the connectors and cable jackets.
- The potting compound shall be completely cured and free of foreign contaminants.
- The potting compound shall be confined to the potting area of the connector and shall not prohibit normal movement of the mechanical parts.
- Holes of less than 10% of the mold surface shall be acceptable.
- Potting compounds on coaxial connectors shall not extend above the shoulder surface of the back nut.

5.10. Solder Connections

This section establishes quality standards for all soldered Gemini applications.

Ref. MIL-STD 454M, Requirement 5
Reference: MIL-STD-2000
Reference: MIL-P-11268L, Section: 3.11.7.1
QQ-S 571 Solder, Lead Alloy, Tin Lead Alloy, Flux Cored Ribbon and Wire, Solid Form

5.10.1. Soldering Irons

The most reliable solder connections are achieved within a narrow range of temperature and application time. Junction temperatures of 500°F to 550°F, applied for 1 to 2 seconds produce the strongest connections. The soldering iron should be selected to produce these conditions. The soldering iron tip should be selected to have enough thermal mass to heat the joint sufficiently but not as to obscure the work, or over-heat the nearby parts or wire. For water soluble flux solder temperatures higher than those given above may be required. Consult with the manufacturer for the recommended temperature range.

5.10.2. Mechanical Connection

No electrical connection shall rely on the solder joint for mechanical strength. Solder, even when solidified, is relatively soft, and when subjected to continuous tension will cold flow, causing and increase in electrical resistance. All electrical connections shall be mechanically supported and secured before and after the solder joint is made.

5.10.3. Soldering of Terminals

Soldering of terminals shall meet the following requirements:

- Leads or tube socket terminals that are not solder filled shall have a 90 to 360 degree wrap.
- Leads to post or terminal junctions shall be secured with a minimum of a 180 degree wrap.
- Solder shall not create shorts or potential shorts to other elements.
- Solder over-flow of normal plating thickness shall be acceptable.
- Voids, pinholes or craters in the solder shall not interrupt the solder bond on any surface of the connection.
- Solder splashes shall be acceptable only when they are fused tightly to other surfaces and do not create potential shorts.
- The solder connection shall be clean and free of ash, flux, rosin residue and other contaminants.

5.10.4. Connector Solder Cups

The wires should be soldered in rows, progressing from the bottom to the top. The cups may be pre-filled with solder before any of the wires are inserted. The cup should be heated by holding the soldering iron against the side of the cup until the solder is completely melted. Keep the heat on the terminal until all of the trapped solder flux comes to the surface. The tinned wire should be slowly inserted into the molten solder until the conductor is in contact with the back wall of the solder cup. A smooth fillet should be formed between the conductor and the inner wall of the cup (see Fig. 4 below) and should not spill over the edge of the cup. Wicking of the solder up to the point of the insulation terminations acceptable. All strands of the wire must be within the solder cup.

Fig. 4 - Proper Solder Cup Fillet

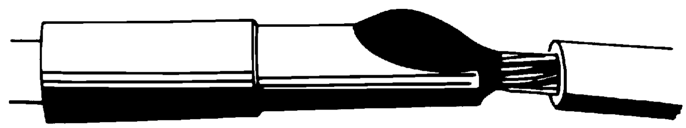


Fig. 5 - Improper Solder Cup Fillet

5.10.5. Soldering of Integrated Circuits (IC) and Flat Packs (FP)

Soldering of IC's and FP's shall meet the following requirements:

- The solder connections shall exhibit a uniform wetting action and shall contain a 360 degree fillet between the IC/FP lead and the circuit line.
- The 360 degree solder fillet shall extend upward a minimum of one-half the lead thickness.
- The solder connection shall be free of icicling solder splashes and solder bridges.
- The solder connections shall be clean and free of ash, flux, rosin residue and other contaminants.

5.10.6. Soldering of Printed Circuit Boards

- Eyelets installed in single-sided printed circuit boards shall contain a minimum solder fillet of 270 degrees.
- Eyelets installed in doubled-sided printed circuit boards shall contain a minimum solder fillet of 270 degrees on the circuitry side.
- Leads soldered to eyelets in printed circuit boards shall be secured by a 360 degree fillet of solder on the circuitry side.
- The solder connections shall have a smooth surface, with an even flow to all elements of the junction.
- The solder connections shall be clean and free of ash, flux, rosin residue or other contaminants.
- Solder splashes shall be acceptable only when they are fused tightly to other surfaces and do not create potential shorts.

- Leadless plated through interfacial holes shall exhibit clear evidence of a continuous solder flow or fill with proper wetting of the pad areas on both sides of the board.
- Solid wire may be used to complete interfacial connections in plated through or non-plated holes in the board. Wire may extend straight through the hole or be clinched over on the conductor pattern.
- Lead protrusion (clinched or straight) through a pad shall not result in a potential short.

5.11. Solderless Connections

5.11.1. Wire Wrap

Reference: MIL-P-11268L, Section: 3.11.10.7.3
Reference: EIA/RS-280-C-92 - Solderless Wrapped Electrical Connections
Reference: Wiring and Cable Designer's Handbook (See References, Section 1.6.1 in References & Recommended Practices, Gemini Telescope Electronic Design Specification

5.11.1.1. Connection Class

There are two classes of connections; Class A and Class B. Class A connections consist of a helix of continuous, solid uninsulated wire wrapped tightly around the terminal to produce a mechanically and electrically stable connection. The number of turns in the helix is dependent on the gauge of wire used. In addition to the length of uninsulated wire wrapped around the terminal, a Class A connection has an additional half turn of insulated wire to insure better vibration characteristics. The added half turn must be in contact with at least three of the sharp corners of the square terminal.

Class B connections are identical to Class A except the half turn of insulated wire is not required. Class A connections are used for vibration prone environments, such as aircraft and ships, while Class B are suitable for land based applications. Considering the changes in orientation that the telescope based instruments will be subjected to, it is recommended that all telescope mounted wire wrapped connections be Class A, while all control room applications can be Class B.

5.11.1.2. Connections

The connections shall be made so that the spacing between the turns of uninsulated wire, except for the first and last half turns, should not be greater than ½ of the nominal wire diameter. There shall not be any overlapping of the wires within the specified number of turns of uninsulated wire, except that in a Class A connection, the insulated wire may overlap the last turn of the insulated wire below it (see Fig 6 below).

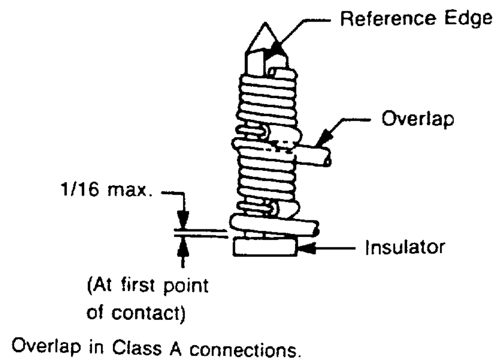


Fig. 6 - Overlap, Class A Connection

The first wrap on a terminal shall always allow for a 1/16 - inch clearance between the wrapped wire and the bottom surface of the terminal. At the termination of the last turn of a wrapped connection (end tail) the stripped wire shall not pull away from the terminal by more than on stripped wire diameter.

The minimum number of turns of the stripped wire around the terminal is given in the following table:

Table 1:

AWG Number	Minimum Number of Uninsulated Turns
26	6
24	5
22	5
20	4
18	4

Table 1- Required Wire Wraps

The minimum number of turns of insulated wire on the Class A connection is ½ turn and the maximum acceptable is 1½ turns.

To ensure that acceptable electrical and mechanical characteristics are maintained at each connection, the reduction in wire diameter due to nick, scrapes, and deformations shall not exceed the limits given in Table 2 below:

Table 2:

AWG Number	Percent of Wire Diameter Reduction
30	10
26	10
24	20
22	25
20	25
18	25

Table 2 - Allowable Wire Diameter Reductions

Prior to making a wire wrap connection the wire must meet the above criteria and the insulation must not be torn, frayed or damaged in any way.

5.11.1.3. Process

It is recommended that the wrappable terminal length provide for at least one extra wrap in addition to those wraps for production in the event that a design change is made at a later date.

5.11.1.4. Bussing

Hand wrapped connections may be bussed by strapping. Strapping consists of wrapping a continuous uninsulated wire from terminal to terminal and the required the use of a special tool. The number of turns required for strapping is the same as for Class B connections. Insulating sleeving is placed over the wire where the terminals are not adjacent and a potential for shorting exists(see Fig. 7 below)

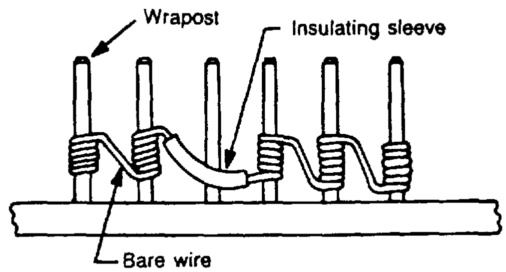


Fig. 7 - Wire wrap bussing

5.11.1.5. Inspection

The work should be examined for unsatisfactory wire-wrapped connections. Typically this inspection is done with a 5x magnifier. See for typical wire wrap faults.

5.11.1.6. Repair and Alterations

After a wire connection is completed any attempt to move or adjust it can damage the bond between the wire and the terminal. Should it become necessary to move a wire it should be completely removed and rewrapped. The completed assembly should be thoroughly cleaned and all wire clippings must be removed.

5.11.2. Wire Lugs

Wire lugs must be selected according to the wire size being used. The size and type of crimping tool must conform to the manufacturer's recommendations or the installation will result in a weakened or defective joint.

When crimping a lug, care must be taken to ensure that the part being crimped has been fitted properly into the socket of the crimping tool, and that the stripped end of the wire is fully inserted into the barrel, but not onto the face of the lug. The crimping tool must fully closed the achieve the proper crimp.

When more than one lug is placed on a post, the lugs carrying the highest current should be placed on the bottom of the stack (see Fig. 8 below).

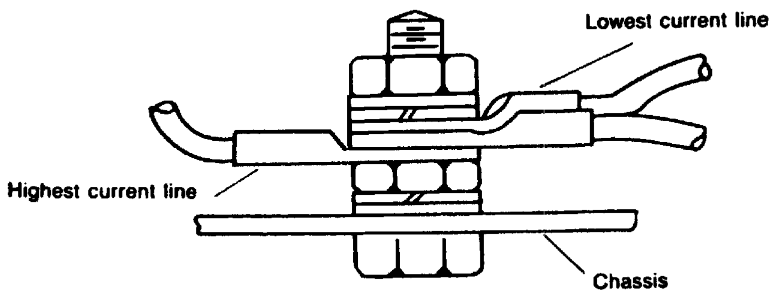


Fig. 8 - Proper Lug Installation

Lugs are designed for either solid or stranded wire and are not interchangeable.

5.11.3. Terminal Connections

Terminal connections shall meet the following requirements:

5.11.3.1. Screw Type Terminal Block Installation

- All terminations into a screw type terminal block shall incorporate a crimp ferrule over the end of the wire. This ferule is then placed into the terminal block and secured by the terminal block screw. This ensures all strands of the wire are within the terminal block and facilitates easier maintenance.
- The wire, ferrule and terminal block shall be the correct size for the application.
- The completed termination shall not be damaged.

5.11.4. Splicing

If possible wires should be cut to length to avoid splices. Under no conditions shall wires be stretched.

5.11.4.1. Solder Splices

Solder splices shall meet the following requirements:

- Splices shall be joined together by solder. It is highly desirable prior to soldering to have the splice be mechanically sound, with the two joined wires fully wrapped together.
- Completed splices shall be sleeved.
- Completed splices shall not create or be subjected to cold flow conditions.
- Soldering shall be in accordance with Section

5.11.4.2. Crimped Splices

5.11.4.2 Crimped splices shall meet the following requirements:

- Crimped splices shall be acceptable providing they are mechanically secure and electrically sound.
- Crimped splices shall be sleeved in the spliced area.
- Crimped splices shall not create or be subjected to cold flow conditions.

5.11.4.3. Spliced Component Leads

Spliced soldered component leads, such as diodes, transistor leads, etc., shall be acceptable providing the connection is sound and will not cause a potential short or problem due to heat transfer.

5.11.5. Shield Terminations

Shielding on wires and cables shall be secured in a manner that prevents it from contacting or shorting exposed current carrying parts. The ends of shielding or braid shall be secured to prevent fraying.

Reference: MIL-STD-454M, Requirement 9, Section: 4.5

5.11.5.1. Floating End Terminations

Floating end terminations shall meet the following requirements:

- Floating shields shall be terminated in the roll back and sleeve method. Completed shield terminations shall be sleeved and have the sleeving extending past the rollback.
- The completed shield termination shall be free of damage.
- there shall be no strain or flexing in the area of the shield termination.

5.11.5.2. Non-Floating Terminations

Non-floating terminations shall meet the following requirements:

- Shield terminations shall have sufficient spacing to, or insulation between, ground and the conductor so that movement of the connection will not result in a short or potential short.
- There shall be no strain or flexing in the area of the shield termination.
- Shields shall be terminated as near a possible to the conductor termination.
- The completed terminations shall be free of damage.

5.12. Printed Conductor Modules

5.12.1. Base Material

The base material shall meet the following requirements:

- Crazing shall not extend between conductors.
- the base material shall not be burned or damaged in the vicinity of eyelets or terminals.
- Warpage of the end item shall not affect fit, function or interchangability.
- Multi-layer laminates shall be free of separation or delamination or other defects which affect machineability, serviceability, or life of the end item.

5.12.2. Terminal Installation

Terminal installation shall meet the following requirements:

- Terminals and eyelets shall be properly swaged so they cannot be rotated.
- Terminals shall not be bent, broken or damaged.
- Terminals and eyelets shall contain no more than three cracks in the rolls area.

5.12.3. Circuitry and Circuit Pads

Circuitry and circuit pads shall meet the following requirements:

- There shall be no separation between the conductor and the base material.
- Scratches, pits or tool marks that reduce the conductor cross-section by less than 25% and no not expose the copper base, shall be acceptable.
- Conductors shall not be over-etched or under-etched.
- Plated through holes shall be free of epoxy smear, contaminates, voids, corrosion., and other defects which affect solderability or life of the interfacial connection.

5.13. Insulation

There should be no evidence of burns, abrading, or pinch marks in the insulation that could cause short circuits or leakage.

Reference: MIL-STD-454M, Requirement 9, Section: 5.2.

5.14. Creepage Distance

The minimum distance between live parts and grounded metal parts shall be 0.1 inches (for operation up to 250 VAC).

Reference: UL 1012, 1950 & 478.

5.15. Cleaning

After fabrication, parts and equipment shall be cleaned of smudges, loose, spattered or excess solder, weld metal, metal chips and mold release agents, or any other foreign material which might detract from the intended operation, function, or appearance of the equipment.

Reference: MIL-STD-454M, Requirement 9, Section: 4.1

5.16. Mechanical Components

5.16.1. Control Knobs

Control knobs shall meet the following requirements:

- Control knobs shall be firmly secured to the mating shaft. This precludes the use of "push-on" knobs.
- Control knobs shall not interfere with other components in any area of travel.

5.16.2. Electro-mechanical Components

5.16.2.1. Meters

Meters shall meet the following requirements:

- Dial faces shall not be damaged.
- Dial faces shall be securely installed.
- Meter needles shall not be damaged.
- Meters shall be properly secured.
- Meter housings shall not be damaged.
- Meter scales shall be legible.
- The meter movement shall operate freely without binding.
- Meters must be able to be calibrated.

5.16.2.2. Switches

Switches shall meet the following requirements:

- Rotary switches shall operate freely without binding.
- Switch contacts shall not be damaged.
- Switches shall be properly secured.
- Toggle switches shall operate freely and remain secure in either direction.
- Switch contacts shall not be corroded or contaminated.

5.16.2.3. Indicator Lamps

Indicator lamps shall meet the following requirements:

- Indicator lamps shall be intact.
- Indicator lamp holders shall be properly secured.
- Indicator lamp holders shall have the correct color lens installed.

5.16.2.4. Fuse Holders

Fuse holders shall meet the following requirements:

- Fuse holders shall not be damaged.
- The fuse holder cap shall grip the fuse securely.
- Mounted fuse holders shall have the correct fuse rating identified.

5.16.2.5. Relays

Relays shall meet the following requirements:

- Relay contacts shall be free of damage and correctly sized for the expected maximum current load.
- Relay cases and cans shall not be damaged.
- Relays shall be properly mounted as to not become loose from plug-in bases.

5.16.3. Terminal Strips

Terminal strips shall meet the following requirements:

- Terminal strips and blocks shall not be damaged.
- Terminal strips shall be properly secured.
- Terminal strip mounting screws shall be properly installed.
- Terminal strips and blocks shall be properly insulated.

5.16.4. Threaded Parts or Devices

Screws, nuts and bolts shall show no evidence of cross threading, mutilation, or detrimental or hazardous burrs, and shall be firmly secured.

Reference: MIL-STD-454M, Requirement 9, Section: 4.2

5.17. Moisture Pockets

Due to the potential condensing nature of the atmosphere at site any condensation that occurs should not be trapped or collected within the device.

Reference: MIL-STD-454M, Requirement 31, Section: 5.1.

6. Documentation

6.1. General

Documentation is considered to be part of the equipment and shall be included in the contract purchase price.

All manuals shall include the following (apart from the text):

- Title and Cover Page (contact Gemini for format).
- Table of Contents.
- List of Illustrations.
- List of Tables.
- Technical Glossary.
- Index.

All documentation shall be provided on electronic media and shall be compatible with AmiPro for text.

6.2. Drawings & Schematics

6.2.1. Format and Media

All technical drawings and illustrations shall be provided on computer media in AutoCAD or Tango compatible format and as either:

- 8½" x 11" or 11" by 17" original drawings on mylar or velum.

or as larger drawings on:

- US Standard B, C, D, or E size or European A3, A2, A1, A0 size drawing stock of mylar or velum.

or

- reproducible sepia blueprints of original mylar or velum drawings in the sizes specified above.

At least one copy of each drawing shall be provided on size A (A4) or B (A3) suitable for binding in a manual.

6.2.2. Standards

All drawings shall be numbered. The three primary standards to be used are:

- Graphical Symbols for Electrical and Electronic Diagrams, IEEE Std 315-1975, ANSI Y32.2-1975.
- Reference Designations for Electrical and Electronic Parts and Equipment, IEEE Std 200-1975, ANSI Y32.16 - 1975.
- Electrical and Electronic Diagrams, USAS Y14.15.

6.2.3. Required Drawings & Schematics

The following drawings are required:

- System Block Diagram - detailing signal flow, major subsystems and functions.
- System Component Layout - detailing component placement, cable interconnections, connector identifications and cable names.
- Detailed Wiring Interconnection Diagrams - showing connector types, connector pinouts, connector names or labels, signal and cable names and wiring color codes.
- Detailed Electronics Circuit Diagrams - indicating device numbers or labels, device types, device pinouts, all interconnections and circuit board names.
- Circuit Timing Diagrams.
- Loop Block diagrams - for all servo systems indicating components, summing points and signal paths.
- Open and closed loop gain and phase response curves (transfer functions) for all servo systems.

All changes or jumpers on circuit boards shall be highlighted

All signal paths and power runs shall be clearly identified and signal directions indicated.

All references to signals and connections form and to other drawings or devices shall be clearly identified.

Logic sense shall be consistent with the device manufacturer's symbols. The use of "inverted" logic symbols id not acceptable.

6.3. Operations Manual

An Operations Manual shall be provided which gives clear and step by step instruction as to the operation of the equipment.

6.4. Equipment Calibration Manual

The following items shall be addressed in the contractor supplied Calibration Manual.

6.4.1. Calibration Procedures

All calibration procedures shall be outlined in a step by step manner. These procedures shall include pre-calibration and post-calibration procedures such as appropriate disassembly and assembly instructions necessary to perform the required calibrations.

6.4.2. Required Calibration Equipment

All special equipment that is required to perform the calibration procedures shall be identified in the RFP.

6.4.3. Calibration Intervals

The required calibration intervals that shall be given which will ensure the equipment remains within its operational specifications. If this is not known then the contractor shall give the operational characteristics which indicate that the equipment needs to be calibrated.

6.5. Maintenance Manual

6.5.1. Maintenance Procedures

All required maintenance procedures shall be outlined by equipment suppliers.

6.5.2. Equipment Preparation

Any preparation required for a specific maintenance procedure shall be outlined.

6.5.3. Equipment Disassembly and Reassembly

If the equipment should be disassembled or assembled in a specific order or using special techniques, this information shall be supplied.

6.5.4. Periodic Maintenance Requirements

A list shall be provided showing the recommended frequency and type of maintenance to be performed.

6.5.5. Troubleshooting Tips

If the equipment has known operating characteristics which generally indicate a particular type of fault has occurred, these shall be documented and supplied.

6.6. Suggested Spare Parts List

A suggested spare parts list shall be provided which includes the part numbers and sources for the parts. Pricing does not have to be included.

6.7. Commercial Manuals

All commercial manuals which have been supplied with any commercial equipment used in the equipment shall be provided.

6.8. Commercial Drawings and Associated Lists

All commercial drawings which have been supplied with any commercial equipment used in the equipment shall be provided.

7. Quality Assurance, Testing & Training

7.1. Responsibility for Inspection & Tests

The Gemini Group Manager shall delegate this responsibility as appropriate. Details shall be provided in the Scope of Work with each RFP.

7.2. Acceptance Testing & Training

The Acceptance Testing protocol shall be supplied with each contract. In general, there shall be a preliminary Acceptance Test followed by a Final Acceptance Test. Deficiencies noted at the Preliminary Acceptance Test shall be verified as being corrected at the Final Acceptance Test.

7.2.1. Test Methods

The contractor shall submit for approval the procedures for accomplishing pre-shipment, burn-in, and on-site acceptance tests.

7.2.2. Notification

The contractor shall notify Gemini at least 48 hours in advance of testing in order to schedule an in-process inspection by Gemini quality assurance personnel at the contractor's facility.

7.2.3. Certification of Test Data and Performance

In the case where more than one unit of a particular type is to be supplied, all test and performance data supplied at the acceptance tests shall be certified as being typical of all units under test. This shall not preclude Gemini from requiring correction of equipment deficiencies subsequent to the Final Acceptance Test.

7.2.4. Contractor's Quality Assurance Plan

A QA plan shall be submitted by the contractor during the bid process for approval by Gemini. The plan shall apply to all hardware delivered to Gemini in the performance of the contract. Details of the QA plan will be provided in the RFP.

7.2.5. Configuration and Change Control

Of particular importance will be a required set of Configuration and Change Control Procedures to ensure that all requirements and suggested changes to requirements are fully understood by both the contractor and Gemini technical staff.

7.2.6. Location of Tests

7.2.6.1. Contractor's Plant

There shall be an Acceptance Test at the contractor's plant.

7.2.6.2. Telescope Site

The contractor's plant acceptance test will be followed by an Site Acceptance Test.

7.2.7. Training

The contractor will provide training sufficient to enable Gemini technical staff to:

- mount and dismount the instrument from the telescope, if required
- verify correct operation
- operate the equipment
- perform sufficient trouble shooting to identify failed subassemblies

Appendix 1- List of Tables

Appendix 2 - List of Illustrations

Appendix 3 - Technical Glossary

- Contractor: A supplier to Gemini which provides either services, equipment or both. Same meaning as "developer."
- Breakout: a group of wires exiting from a cable bundle.
- Breakout box: a box which has the appropriate connections for connecting to a cable being tested which has the individual contacts exposed internally for testing.
- Cold Flow: the ability of some materials, especially wire insulation to flow under normal operating temperatures if placed under tension or compression.
- Crazing:
- Developer: see Contractor
- Dropout: a momentary drop in supply voltage to a low level
- EMF: electromotive force
- EMI - electromagnetic interference
- GFIC - Ground Fault Interrupting device
- OEM - Original Equipment Manufacturer
- OSHA - Occupational Safety and Health Administration
- Potting - the filling of connectors with a suitable compound to prevent moisture and contamination from entering the connector.
- RFP: Request for Proposal. This is the standard form used by Gemini to solicit quotations from potential suppliers of equipment or services.

Appendix 4 - Standard Components

Appendix 5 - Telescope Power Distribution & Interconnection

Appendix 6 - Equipment Racks

Appendix 7 - TBR Bus

Appendix 8 - Instrument Ethernet LAN

Appendix 9 - Instrument Fiber Optic LAN

Appendix 10 - Allen-Bradley I/O System

Appendix 11 - TBR Bus

Appendix 12 - Time Bus

Appendix 13 - Materials That Degrade at Site Altitude

Neoprene and Viton rubber

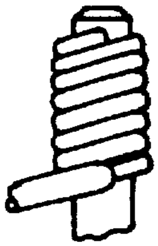
Cellular polyethylene

Wood

Appendix 14 - Integral Heat Exchanger

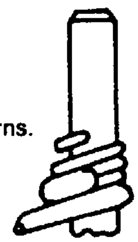
Appendix 15 - Common Wire Wrap Faults

Figures 9 to 17

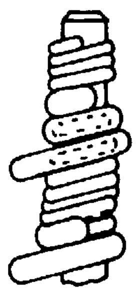


Insufficient insulation wrap for a Class A connection.

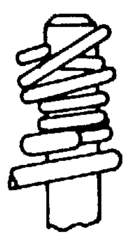
Insufficient number of turns.

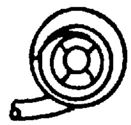


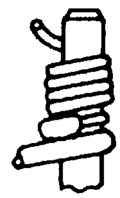
Overwrap.



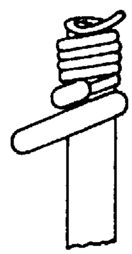
Overlap.



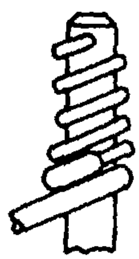




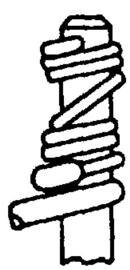
End tail.



Wrapping over the end of the terminal post.



Spiral Wrap



Open Wrap

Appendix 16 - Static Safe Work Areas

Appendix 17 - References

Commercial and U.S. Military Electrical Standards & References

Commercially Available References

1. Wiring and Cable Designer's Handbook, by Bernard S. Matisoff. Published by TAB Professional and Reference Bools, P.O. Box 40, Blue Ridge Summit, PA 17214. ISBN 0-8306-2720-0.
2. Belden Master Catalogue, Cooper Industries. Other cable manufacturers have similar catalogues.
3. Grounding and Shielding Techniques in Instrumentation, 3rd Edition, Ralph Morrison, Wiley-Interscience. ISBN 0-471-83805-5.

Commercial Electrical Standards

The following UL, EIA NEMA and ANSI-IEEE standards have been reviewed for inclusion in this specification and can be consulted for further information:

1. ANSI/ISA S82.01 - General Requirements - Safety Requirements.
2. ANSI/ISA S82.02 - Electrical and Electronic Measuring and Test Equipment.
3. ANSI/ISA S82.03 - Electrical and Electronic Process Control Equipment.
4. ANSI Y14.15 - Electrical Diagrams & Supplements.
5. NEMA AB1 - Molded Case Circuit Breakers.
6. NEMA ICS-1 - Industrial Control Systems.
7. NEMA ICS2.4 - NEMA & IEC Devices for Motor Service - a Guide for Understanding the Differences.
8. IPCS 815b - General Requirements for Soldering Electrical Interconnections.
9. UL 508 - Industrial Control Equipment.
10. UL 486A Wire Connectors and Soldering Lugs For Use With Copper Conductors.
11. UL 486 C - Splicing Wire Connectors.

Communications Standards

1. EIA RS 232E.
2. EIA RS 422A.
3. EIA RS 485A.
4. IEEE 488.
5. IEEE 802.3 Ethernet Standards

Military Electrical Standards

The Military Standards for Type III equipment , Commercial off the Shelf equipment, have been used:

1. QQ-S 571 Solder, Lead Alloy, Tin Lead Alloy, Flux Cored Ribbon & Wire, Solid Form.
2. MIL-STD 108E Definitions of and Basic Requirements for Enclosures for Electronic Equipment.
3. MIL-STD 242G(Navy) Electronic Equipment Parts, Selected Standards.
4. MIL-STD-454 Standard Electrical Requirements for Electronic Equipment.
5. MIL-STD-461D Electromagnetic Interference Characteristics Requirements for Equipment.
6. MIL-STD 681 Identification Coding and Application of Hookup and Lead Wire.
7. MIL-STD-686 Cable and Cord, Electrical, Identification, Marking and Color of.
8. MIL-STD-806 Graphic Symbols for Logic Diagrams.
9. MIL-STD-889B Dissimilar Metals.
10. MIL-STD-1472C Human Engineering Design Criteria.
11. MIL-P-11268L Parts, Materials and Processes Used in Electronic Equipment.
12. MIL-T-28800E Test Equipment for Use with Electrical and Electronic Equipment.

Appendix 18 - Recommended Practices

List of Tables

List of Illustrations

3.4. Equipment Emanations

References: MIL-T-28800E, Section 3.9.3.4. & ANSI/ISA-S82.01 - 1988, Section 6.2.

3.4.2. Acoustic Emanations

An alternate noise level limit requirement has been given by MIL-T-28800D, Test Equipment for Use With Electrical and Electronic Equipment, Section: 3.7.12, Table XI:

Table 3:

Octave Band Center Frequencies (Hz)	Octave band sound pressure levels	(dB reference: 0.002 dyne/cm^2)
	dB, 0.3 m (1 ft.) Radius From Operator's Position	dB, 7.6 m (25 ft.) Radius From Equipment Geometric Center
63	76dB	66dB
125	70	60
250	64	54
500	60	50
1000	57	47
2000	55	45
4000	53	43
8000	52	42

Table 1 - Allowable Sound Pressure Levels

It is recommended that if a sound level meter is available with the above pass band capability then the table of sound pressure levels should be used. If this device is not available then the standard meter should be used to measure the sound pressure levels.

3.12. Control Panel

3.12.1. Emergency Stop Switch

There is a debate about whether or not this switch should shut down all power within the device. Some designers prefer to keep the computer and sensors powered up to assist in the determination of the equipment fault. This has the disadvantage in that if it is the computer or sensor system which is malfunctioning then this switch is of no use. This problem can be resolved by placing the main Power On-Off switch close to the Emergency Stop switch.

3.14. Operating and Control Modes

The following modes are recommended, some of which may not be required for a particular piece of equipment:

3.14.1. Normal Operation Mode

This is the mode in which the equipment fulfills the operational requirements.

3.14.2. Self Test/Diagnostic Mode

This mode is used to diagnose problems and ensure the unit is operating within the specified limits. Inclusion of this mode is particularly recommended since troubleshooting at the site can be impaired due to the effects of the altitude on the personnel.

3.14.3. Standby - Idle Mode

This mode would power down certain portions of the system to conserve battery power, keep short-life components inactive, etc.

3.14.4. Warm-up Mode

If some components require a period to stabilize before operation this mode should be included.

3.14.5. Cool-down Mode

If some components require a period to cool down after operation prior to the system shut down this mode should be included.

3.14.6. System Reset

If the normal operational procedures fail to place a piece of equipment in the desired state, this feature should be provided to return the equipment to a known initial condition.

4.11. EMI Control

Electromagnetic interference (EMI) is the introduction of noise into a circuit through electromagnetic means from another circuit. Electromagnetic waves are composed of an electric field, or E-field, orthogonal to a magnetic field, or M-field. E-fields are generated by and are most susceptible to high impedance voltage driven circuitry such as a straight wire or a dipole. Generally, E-fields are best shielded by good conductors. H-fields are generated by and are most susceptible to low impedance current driven circuitry such as a wire loop. Generally they are best shielded by magnetic materials such as iron.

Two types of interference must be controlled; conductive and radiated. Conductive EMI is the energy that is transferred from one circuit to another by wires. This is usually addressed in the circuit design by filters and circuit grounding techniques. Radiated EMI is energy radiated through the air. This is addressed by the implementation of shielding materials and construction techniques in the design of shielded cables, enclosures and cabinets.

All Gemini electronic cables that are external to the equipment's chassis must be shielded.

Shielding attenuates the electromagnetic energy by three methods: reflection, absorption and internal reflection. Different materials affect these methods of attenuation. In addition, discontinuities in the shield act as slot antennas.

The common types of shielding are braid, conductive foil, flexible conduit and rigid conduit. Detailed effectiveness of different types of shielding can be obtained from manufacturers. For braided shielding, the effectiveness against E-filed increases with the density of the weave, but decreases with increasing frequency. The H-filed effectiveness increases with frequency and the density of the material and the permeability of the shield material. Since braid material is usually non-permeable, if magnetic shielding is required a high permeability metal strips may be wrapped around the cable.

Solid metal conduit is very effective as it completely encloses the wires. It is hard to handle, however and is heavy. Flexible conduit is easier to handle but it has tiny holes which may make it ineffective at higher frequencies.

Overall shielded zippered tubing can be procured. This is especially useful for protecting multiple twisted pair flat cables.

The shield should be connected to the shield ground and the cable end which is closest to the star point of the grounding system (where all grounds are tied together). The shield ground connection wire should be carried through all connectors in the cable and be open only at the end of the last cable in a series of connected cables. This requires that a shield conductor be provided through all junction boxes

4.13. Grounding

4.13.1. General

The following references have been consulted for this section:

- **X**, Item 1.3.
- Reference: National Electrical Code - 1990, Article: 250-42.
- Reference: MIL-P-11268L, Section: 3.11.11.
- Reference: MIL-STD-454M, Requirement 1, Section: 4.4.2.2,.3.

4.13.2. Grounding Methods & Principles

Grounding has to typically address at least four areas:

1. power reliability.
2. lightning safety.
3. reduction of ESD threats.
4. reduction of noise susceptibility.

In a typical installation, reliable system performance may seem at odds with grounding and earthing requirements. Safety grounds that tie racks together form ground loops. This is compounded by the earthing required to prevent lightning related damage. The opening of ground ties reduces noise current flow, but this runs contrary to the above needs. Compounding this problem is the fact that US law requires that PC computers by law must tie AC neutral, DC return and frame ground together at the accessory card mounting plate.

It is also sometimes impossible to obtain equipment that does not have a connection between instrument ground (DC return) and AC neutral at one point. Sometimes this can be rectified by appropriate equipment modifications, but this is a questionable practice as it may degrade the units performance and may void any warranty.

4.15. Connectors

4.15.1. Connector Current Ratings

The average current rating for contacts within connectors is as follows, assuming a 35°C rise in wire temperature at sea level is as follows:

Table 4:

Contact Size Wire Gauge	Maximum Current (Amps, Sea level 35°C wire temp rise.)
1/0	160 to 200
2	115 to 120
4	80 to 87
6	60 to 65
8	40 to 48
10	30 to 35
12	22 to 26
14	15 to 20
16	10 to 15
18	8 to 11
20	5 to 7

Table 2 - Average Contact Continuous Current Ratings

This table gives a general idea for current rating of connector contacts. As an example of how much this can vary from one connector to another the following table gives the current rating for a Cannon CA Bayonet connector at 60°C:

Table 5:

Contact Size Wire Gauge	Maximum Current (Amps)
0	160 to 200
4	115 to 120
8	80 to 87
12	60 to 65
16	40 to 48

Table 3 - Continuous Current Ratings for Cannon CA Bayonet Contacts at 60°C

Notice that this particular connector does not have contacts smaller than 16 AWG. It is very important, if using any crimp contact for a smaller wire size for which it is designed, to use wire reduction sleeves. Technical details for these sleeves are usually found in the "Accessories" section of the connector catalogue.

4.15.2. Multipole Signal Connectors - Sourcing

Difficulties are sometimes encountered in sourcing the proper MS connectors due to the large number of manufacturers and options in connector design. Should these difficulties occur, contact the Gemini staff for assistance.

4.15.3. Environmental Considerations

All connectors which shall be exposed to moisture shall be environmentally sealed. This is usually accomplished by specifying the environmentally sealed option when ordering connectors. Although it usually makes fabrication of the connector somewhat more difficult it is necessary to prevent moisture from entering the connector and subsequently freezing and damaging the connector or causing corrosion.

4.15.3.1. Potting

For connectors which do not have an environmental seal, but will be exposed to condensation, it is recommended that a connector be chosen that can be potted to prevent condensation from entering the connector.

4.15.11.3. Pin Soldering

When solder pins are used all solder cups shall be protected by a heat shrink tube. It is highly recommended that only one wire shall be soldered into each solder cup. If it is necessary, such as for jumpering pins together, then two wires can be soldered into a solder cup as long as the combined wire gauge does not exceed the maximum size appropriate for the solder cup.

4.15.11.4. Crimping

It is necessary to crimp and assemble these pins correctly or failure of a connection can occur soon after the connector is placed in service. All contractors shall contact the appropriate factory technical representatives for the correct assembly and disassembly tools for the selected pins and connectors. In addition, ensure the appropriate instruction manuals are provided which indicate the proper setup and use of the tools. These manuals also contain useful hints which can make it much easier to assemble and disassemble the connectors. At no time shall the assembler rely on technical information supplied by sales staff unless you are absolutely sure the salesperson has the required technical expertise.

It is also very important to examine all of the available hardware for the connectors and to determine it's applicability to your use. This hardware often solves a problem which is not advertised in any promotional literature but can adversely affect the reliability of your connectors. For example, for smaller wire gauges it is highly recommended that crimp inserts be placed around the wire prior to insertion into the pin. This has the effect of increasing the wire gauge and matching the internal size of the pin. If this is not done then the wire will likely break off just inside the pin, even if the correct tools are used.

The contractor shall also supply Gemini with a list of the required tools to service the connectors.

4.16. Cable and Wire

4.16.2.2. Wire Rating & Sizing

Most wire is rated by the voltage class and allowable temperature rise the wire insulation can handle without breaking down. 150V and 60°C operating temperature are the lowest ratings commonly found.

The wire should be sized according to allowable rise in temperature of the wire while carrying its continuous full load current. The following table gives the average current carrying ability for different gauges of copper wire at 25°C in still air at sea level:

Table 6:

Wire Gauge (AWG)	10°C Temp. Rise (amps)	35°C Temp. Rise(amps)
8	21	38
10	17	28
12	11	21
14	8	17
16	6.5	10
18	5	8
20	3.8	6
22	2.8	5
24	2.1	3.5
26	1.6	2.7
28	1.1	2.1

Table 4 - Typical Continuous Current Ratings for Electronic Cables.

If more than one wire is used (as in a cable), the following derating factors should be used:

Table 7:

No. of Conductors	Factors
1	1.6
2-3	1.0
4-5	0.8
6-15	0.7
16-30	0.5

Table 5 - Multiple Conductor Derating Table

The effects of altitude must be taken into account when selecting the current carrying capability of a conductor as well. Consultations with a major cable manufacturer indicates that for operation at 14,000 feet an additional derating factor of 0.85 should be used in conjunction with the above two tables. For example, for a 10°C temperature rise a 10 AWG twisted pair would be able to handle 17 x 1.0 x 0.85 = 14.45 amps.

Particular attention should be paid to the correct sizing of wire and cables extending from the control room to the various telescope instruments. These cable lengths can be several hundred feet long and have a resistance of several ohms in an 18 AWG wire size, for example. Contact Gemini for the exact length of cables required for a particular location. For example, high current loads over 5 amps this can cause a voltage drop of over 10 volts for cable losses alone.

4.16.2.4. Insulation

Insulation materials usually consist of a solid waterproof material which in some instances is covered by a braid. The primary solid insulation may be constructed from materials such as rubber, vinyl, polyethylene or fluorocarbons. The braid provides additional protection against abrasion, and carries the identification and markings. Polyethylene and similar materials are used extensively without the braided coverings.

The physical characteristics of insulation include the permissible operating temperature as outlined in Section X, mechanical strength, ease of stripping, effects of aging and resistance to vibration, moisture, flame, solvents, chemicals and fungi.

When determining the proper insulation to use in Gemini, both the upper and lower non-operating temperature limits must be considered. In addition, special attention must be paid to areas where the cables and wires will be constantly flexing in the typical operating temperature of around 0°C.

As per Section **X**, neoprene should not be used as an insulating material as it breaks down within two years.

The following table shows the operating temperatures of common insulations:

Table 8:

Insulation	Min. °C	Max. °C
PVC	-20	80
PVC (high temperature)	-55	105
Polyethylene	-60	80
Rubber	-40	75
Nylon	-55	115
Teflon TFE	-70	260
Teflon FEP	-70	200
Polypropylene	-20	105
Neoprene	-30	90
Silicone Rubber		150
Kapton HF	-70	200
Cross-linked Polyethylene	-60	135

Table 6 - Temperature Ranges of Insulation Materials

It is clear from the above table that almost all insulation materials are suitable for the Gemini environment on the basis of temperature alone. As mentioned above, the other factors which must be taken into account are degradation at altitude, flexibility, abrasion resistance and flammability. These factors should be discussed with the cable supplier's technical staff for a specific application. See Appendix 13 - Materials that Degrade at Altitude in the Design Specification for materials that should not be used.

4.16.3. Flat Cables (Ribbon Cables) - Use of

Flat cables should be used where a thin form-factor, superior flexibility and/or flex life, or the ability to transmit a large number of digital signals is required. Flat cables dissipate heat better than round cables, therefore the use of a higher resistance, smaller conductor for the same temperature rise is possible. In addition, the consistent wire positioning ensures that the electrical characteristics are more consistent without shielding.

4.16.4. Bending Radius - Coaxial Cables

Whenever coaxial cable is bent or formed, the minimum bend radius should never be less than ten times the outside cable diameter. A bend radius of less than this amount will result in cold flow of the dielectric and creeping of the inner conductor at the bend. This changes the electrical characteristics of the cable.

14.6.6. Recommended Wire Markers

It is highly recommended that the wire markers used be the Brady PermaSleeve™, or equivalent. This type of marker is a heat shrink sleeve with no seams, therefore over-heating will not separate the marker. It requires the use of a special marking equipment which costs approximately $1,500. The use of this marker gives all equipment good looking, durable marking.

4.16.7. Cable and Wiring Routing

Wire and cable routing should be planned in conjunction with the mechanical engineers early in the chassis design stage so that holes may be provided for the mounting hardware and suitable opening provided for the wires and cables.

The following guidelines should be followed:

- Insulated wires shall be formed into harnesses or cables.
- This harnessing or cabling shall be done either with specialized cable clamps, tie wraps, cable clips, zippered tubing or by lacing.
- In forming the harness or cable, the wires should formed into a circular bundle and tied together by the tie wraps, clamps or clips.
- When using zippered tubing the wires are only placed neatly into the tube prior to zipping it. No other securing is necessary within the tube.

Wires, wire harnesses or cables over 6 inches long should always be mechanically tied the chassis to prevent any movement. A wide variety of standard commercially available clamps are used for this function and come in a many sizes to suit the cables or wires being secured.

After the wires are formed in cables the following points should be taken into consideration when securing the cable with clamps:

- The number of clamping points must be sufficient to prevent any motion that may be cause abrasion to the wires or cables.
- When and externally shielded wire or cable is used, it should have a vinyl sleeve placed around the shield at the clamp area. It is often desirable to sleeve the entire length of exposed shielding to prevent potential shorting to the chassis or nearby components.
- Clamps should always be located at least one inch away from any cable breakouts to eliminate the possibility of placing a strain on the breakout.
- Clamps should never be located too close to a connector. Allowance must be made to avoid stressing the connector terminations.
- When metal clamps are used, an insulating cushion should be inserted under the clamp to prevent wire or cable damage.
- Clamps are always required on each side of a hinged assembly, except when a cable tray is used.
- Clamps should be installed at least every 12 inches on an extended cable run.
- "Sticky pads", which incorporate an adhesive to attach to a chassis panel and provide a tie wrap loop, shall not be used. Inevitably the pad comes loose from panel, leaving the cable unsecured.

Reference: National Electrical Code - 1990, Article: 110-14.
Reference: MIL-STD-28800D, Section: 3.3.3.3.
Reference: MIL-STD-454M, Requirement 9, Section: 4.4.
Reference: CFHT Design Specifications, Section: 1.5.4, .5.
Reference: MIL-STD-454M, Requirement 69, Section: 4.

4.17. Wire Terminations

4.17.4. Wire lugs

Wire lugs depend on mechanical pressure to secure wire in the lug. The advantage of this method is that higher operating temperatures are possible, ease of installation, good mechanical strength and resistance to mechanical fatigue, however, it is unlikely that the higher operating temperature will used in Gemini applications. The disadvantages of lugs is that it difficult to judge the quality of the crimp if it is not done with the proper tools.

Wire lugs are acceptable on the Gemini project only for chassis bonding and connection to OEM equipment that comes supplied with screw type terminations that require lugs.

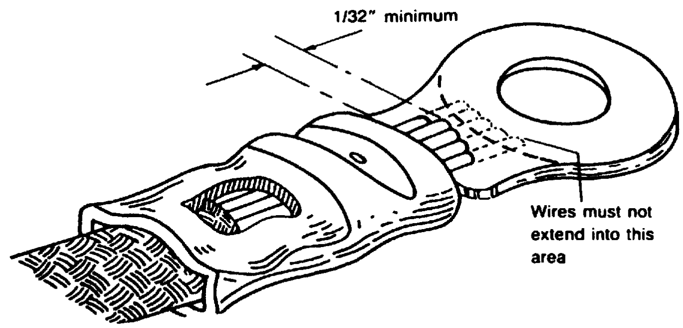


Fig. 1 - Typical Wire Lug

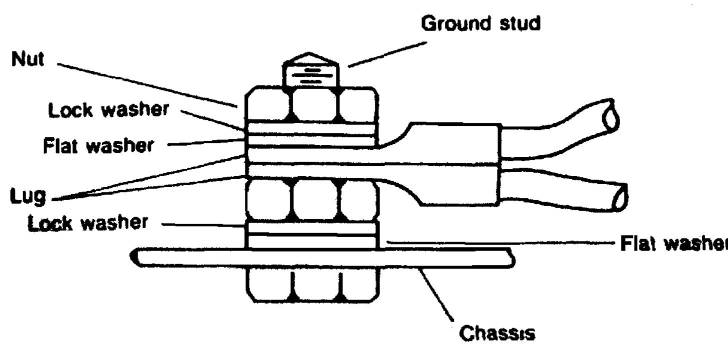


Fig. 2 - Typical Ground Stud Connection

4.17.5. Solderless Wrap (Wire Wrap)

For designs that are "fluid", and are likely to change, one of the recommended termination method is wire wrap. This type of connection has been used commercially for many years with good results, as long as the correct tools, materials and wrapping procedures are used. This type of connection has the additional benefit that by the elimination of solder, the designer avoids thermal damage to heat sensitive components and associated problems of soldering and soldering cleanup.

Most of the material in this section is extracted from Reference 1.6.1 - 1.1 in . For those designers not familiar with wire wrap it is highly recommended that a suitable reference be found to ensure the correct materials are used and the correct procedures followed. For example some of the factors which must be considered are terminal materials, dimensions, spacing and form, wire size, material, allowable elongation, etc. The following section will cover only the major points of wire wrapping.

The typical terminology used for wire wrapping is shown in Figure 3 below.

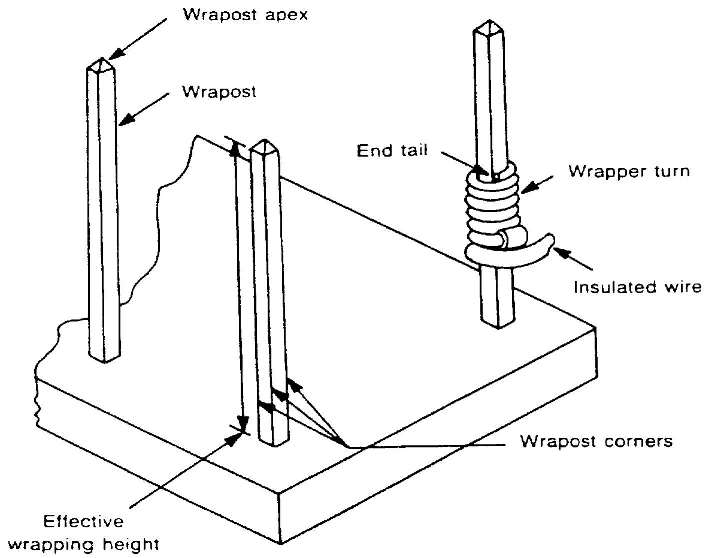


Fig. 3 - Wire Wrap Terminology

4.17.5.1. Post Type

It is recommended that square posts be used as opposed to rectangular posts for the following reasons:

- as Figure 4 shows, a rectangular post is more likely to result in too much pigtail.

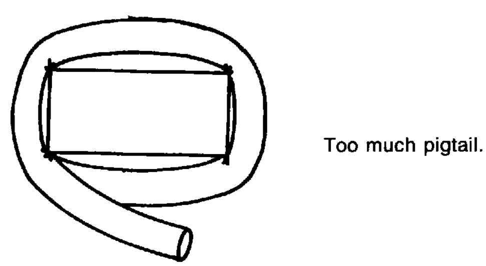


Fig. 4 - Pigtail on Rectangular Post

- a square post is more rigid during the wrapping operation.
- the square cross section has less tendency to twist around its own axis.
- the strip force values for the square cross section is usually more consistent than for other types of terminals.

- the life of the wrapping tool is extended by the use of square cross section terminals.
- most terminal posts are made of either copper, beryllium copper, plated steel, copper-nickel alloy, tinned and untinned brass, phosphor bronze, and nickel silver alloys.
- the post should be no more than 3½ times the conductor diameter.

4.17.5.2. Connection Class

There are two major types of wire wrapping connections (see Figure 5 below). Class A connections consist of a helix of continuous, solid uninsulated wire wrapped tightly around the terminal to produce a mechanically and electrically stable connection. The number of turns used is dependent on the gauge of wire used. In addition to the uninsulated wire wrapped around the post, a Class A termination has an additional _ turn of insulated wire to ensure better vibration characteristics. the added half turn of wire must be in contact with at least three of the sharp corners of the post. Class B connections do not have the extra _ turn of insulated wire. Class A connections are usually used in airborne and shipboard applications, while class B connections are acceptable for land based environments. Considering the changes in orientation that the telescope based instruments will be subjected to, it is recommended that all telescope mounted wire wrapped connections be Class A, while all control room applications can be Class B.

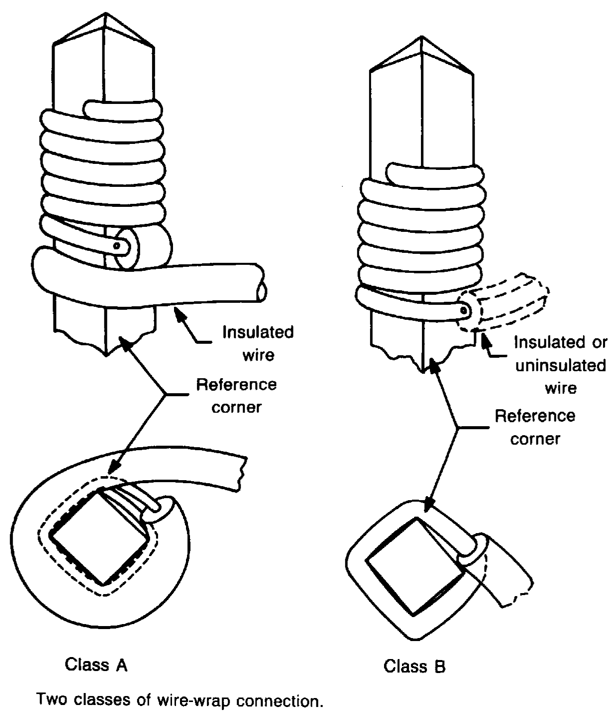


Fig. 5 - Wire Wrap Connection Class

4.17.5.3. Wire Type

Most wire wrapped connections are made using solid round wire over the posts. Stranded wire may be used in special applications where excessive flexing is expected, but it must be twisted tightly and tinned prior to the wrapping operation. The wire must be cleaned of residual flux prior to wrapping.

The wire should be selected to meet the electrical requirements (primarily allowable temperature rise for rated current) and allowable elongation. The amount of elongation allowed is to ensure the wire wrap will be firmly anchored to the post and will also unwrap if required.

4.19. Motors & Encoders, Limits of Travel

4.19.1. Stepper Motors

The advantages of stepper motor systems is that they are lower in cost than the corresponding servo system. Stepper motors also have an inherent "holding torque" which can be used to maintain a rotary position of no other torques are present on the motor shaft. If other torques are applied to the motor shaft a fail-safe brake should be used to maintain the shaft position and the motor can be de-energized. This method has the advantage of not using any power to maintain a rotary position, therefore minimizing the generation of heat.

If stepper motors are used with encoders, the line resolution of the encoder must be smaller than the motor step size to prevent oscillation of the encoder outputs as the motor settles to a position.

DC Servo Motors

Servo motors are most appropriate for fine position servo and velocity servo work. The advantage of DC servos is that the motor position is known at all times and that a following error can easily be programmed to monitor the condition of the moving assembly. The corresponding disadvantages of this type of system is the more complex motor amplifiers and associated servo control software. D.C. servo motors should not be used to maintain a rotary position at a single point. In this application since the motor is not moving there is little back EMF, allowing large currents to flow which could rapidly heat up the motor.

4.19.6. Incremental Encoder Homing Switch

If an incremental position encoding device is used the servo system will need to be homed upon power-up since there is no guarantee that the position of the system has not changed since it's last use. Some servo systems employ a separate home limit switch to indicate when the system is in a known "home" position. All motions are then referenced from this home position. A complication with this approach is that upon power-up, unless another absolute position encoding device is being used in conjunction with the incremental encoding device, there is often no way to know which way to send the system to search for the home switch. This condition can occur upon a power failure, for example, in which the servo system had not been able to return the moving assembly to its home or stowage position. In this situation the moving assembly would have to be moved in either one direction or the other to search for the home switch. If a end of travel limit switch is encountered prior to the home switch, the system would have to reverse the direction of travel and once again search for the home switch. Some designers dispense with the home switch and always drive the system in the same direction until an end of travel limit switch is encountered. Since the position of this switch is known it is used as a home switch. Either approach is acceptable.

4.19.6.1. Shaft Mounted Encoders

Encoders can either be mounted on the motor shaft or an associated rotary axis. For motor shaft mounting, the use of factory mounted shaft encoders is recommended. As the clearance between the encoder disk and the pickups is only a few thousandths of an inch, any misalignment upon installation will rapidly result in failure of the encoder.

Belt or Gear Driven Encoders

If a different ratio of motor turns to encoder turns is required the encoder can be mounted on a separate shaft and either a belt or set of gears chosen to give the required change in rotary gearing. If this encoding technique is used the designer must be very careful to minimize the backlash in the system. Any appreciable amount of backlash makes servo tuning very difficult and the servo performance unreliable. This is because the backlash momentarily unloads the servo motor. It is highly recommended, for high accuracy systems, that if a gear or belt mounted encoder is used, then a motor shaft mounted encoder also be used. The motor mounted encoder should be used for motor speed control and the second encoder used for final position verification and adjustment.

Encoding Disk Material

Encoder disks are usually made of metal or glass. The metal disks have a low resolution as they depend on punching or etching small slots in the disk to pass the light from the LED to the detector. However, these encoders are very rugged. Glass disk encoders have finer graduations etched on them, but are much more fragile. For the typical low vibration telescope environment glass disk encoders are suitable for most of the of the applications. Care should be taken if using kit encoders to ensure the disk is placed on the encoder shaft squarely and in the correct position to prevent the disk from rubbing against LED or the pickup while the encoder is rotating.

5.0 Human Engineering

A Human Engineering Plan will be part of the Gemini Telescopes System. The requirements to be detailed and the form of analysis to be performed are detailed below. The plan is TBD.

0.0.0.1 Human Engineering Requirements

A. range of acoustic noise, vibration, acceleration, shock and impact
B. protection form thermal, mechanical, electrical, electromagnetic, visual and other hazards
C. adequate space for personnel, clothing, and equipment during operation and maintenance
D. acceptable personnel accommodations for seating, rest, etc.
E. provisions for minimizing stress effects and fatigue
F. specific tasks
G. people and machine interfaces
H. procedures
I. training and experience
J. interaction with team members
K. management and organizational behavior

0.0.0.2 Human Engineering Task Analysis

A. information required by the operator/maintainer, including cues for task initiation
B. information available to the operator/maintainer
C. evaluation process
D. decision reached after evaluation
E. action taken
F. body movements required by action taken
G. work space envelope required by action taken
H. work space available
I. location and condition of work environment
J. frequency and tolerances of action
K. time base
L. feedback informing operator/maintainer of the adequacy of actions taken
M. tools and equipment required
N. number of personnel required, their specialty and experience

O. job aids or references required
P. communication required, including type of communication
Q. special hazards involved
R. operator interaction where more than one crew member is involved
S. operational limits of personnel performance
T. operational limits of machine and software

0.0.1 Environmental Compatibility

The contractor shall conform to the requirements listed below for equipment emanations. Use of a qualified lab, or manufacturer's data, or developer's own measurements to confirm compliance to applicable sections is required.

0.0.1.1 Electromagnetic Compability

0.0.1.1.1 Classifications of EMC

There are four general classifications of EMC:

1. Radiated emissions
2. Conducted emissions
3. Radiated Susceptibility
4. Conducted Susceptibility

0.0.1.1.2 EMC Design Requirements

Areas specifically addressed will be:

A. electrical bonding and grounding
B. shielding
C. transient control
D. radiated signal control
E. interference and susceptibility prediction
F. cable considerations

0.0.1.1.3 Radio

Radio transmitters for telemetry shall not be used. For further information on this topic contact Bob McClaren, IFA Honolulu, at 808-956-8768.

0.0.1.1.4 Microwave

In the frequency range of 100 MHz to 100 GHz, the power density shall be limited to $10 mW/cm^2$ at any point 5 cm from the equipment surface.

0.0.1.1.5 Optical and IR Radiation

The equipment shall not emit radiation in any band used for observing.

Illumination Disable Requirements

All indicators on the exterior of the equipment shall be able to be either turned off or covered during an observing period. An example of this would be a cover that can be closed over the control panel.

Encoder Optical Shielding

All encoders shall be optically shielded to prevent infrared or visible light from emanating from the device.

0.0.1.1.6 X-ray

X-ray emanations shall be kept below the following levels:

Human Safety

0.5 milliroentgen per hour at 5 cm from the radiating source, for a target area of 10 cm^2 which has the greatest dimension limited to 5 cm

CCD Detectability Limit

The emanations must be below the cosmic background level which is less than 100 counts/cm^2/hour.

0.0.1.1.7 Lasers

All lasers used within the United States must conform to regulations 21CFR 1040.10 and 1040.11, established by the FDA Center for Devices and Radiological Health (CDRH). For further information contact the Director (HFZ-300) Office of Compliance, CDRH, 8757 Georgia Avenue, Silver Springs MA, 20910.

0.0.1.2 Acoustic Compability

0.0.1.2.1 Noise Levels

The OSHA requirements, section 1910.95c(1) states that the maximum recommended noise level over an 8 hour period should be 85dB, using a standard sound level meter at slow response, A-weighted.

0.0.1.2.2 Ultrasonic Pressure

During normal operation the ultrasonic sound pressure level shall not be more than 110dB above a reference level of 20 micronewtons per square meter (2 x $10^{-}4$ microbar or 2 pascals). Compliance is checked by measuring the sound pressure level over a frequncy range of 20kHZ to 100kHz.