LUNAR PORTABLE MAGNETOMETER

TECHNICAL SPECIFICATION

AMES
RESEARCH
CENTER

Moffett Field,
California

LUNAR PORTABLE MAGNETOMETER

TECHNICAL SPECIFICATION

D34-101

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FOR

LUNAR PORTABLE MAGNETOMETER

D34-101

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TABLE OF CONTENTS

1.0 SCOPE

1.1 This specification establishes the design requirements for Flight and Qualification models of the Lunar Portable Magnetometer (LPM).

2.0 APPLICABLE DOCUMENTS

2.1 The following documents of the issue noted form a part of this specification to the extent referenced herein. In those cases where the document listed is not dated, the latest issue in effect shall be used.

2.1.1	D34-102	Lunar Portable Magnetometer Reliability and Quality Assurance Plan
2.1.2	D34-103	Lunar Portable Magnetometer Fabrication Inspection Procedure and Record
2.1.3		Lunar Portable Magnetometer Test Procedure (To be published)
2.1.4	AHB 5328-1	ARC Preferred Parts and Materials List
2.1.5	MIL-STD-454	Standard General Requirements for Electronic Equipment
2.1.6	AHB 5328-3	Screening Inspection for Electronic Parts

3.0 REQUIREMENTS

3.1 PRECEDENCE

In case of conflict between the requirements of this specification and any reference document herein, the following requirements shall govern. Any conflict shall be promptly referred in writing to the Lunar Portable Magnetometer Experiment Manager for interpretation and clarification.

3.1.1 REQUEST FOR DEVIATION

Any change from the requirements of this specification, or applicable documents listed herein, shall be considered a design change or deviation. Request for deviation shall be submitted in writing to the LPM Experiment Manager for his approval or disapproval.

3.2 SCIENTIFIC REQUIREMENTS

The Lunar Portable Magnetometer shall have a measurement range of $\pm$ 100 gamma and $\pm$ 50 gamma with a $\pm$ one gamma accuracy. The alignment of the instrument on the Moon shall be known to within 3°. The magnetometer sensor shall be capable by means of manual rotations of reversing polarity completely so as to enable the elimination of sensor offset. One magnetic field measurement on the lunar surface is a requirement for the magnetometer described herein. Six magnetic field measurements are desired.

3.3 GENERAL INSTRUMENT DESCRIPTION

The instrument shall consist of a magnetometer sensor head consisting of three orthogonal DLK6B1 Single Axis Fluxgate Sensor assemblies (NAS2-3699), an electronics and data display package and a tripod. The sensor head and the electronics and data display package shall be connected by means of a 50 foot 32-conductor ribbon type cable. The electronics package shall consist of all electronics necessary for the operation of the magnetometer sensor. Readout shall be by means of three taut-band meters, one for each axis. Electronics shall be powered by mercury cells. Two switches shall be provided on the electronics package -- one for ON-OFF of the instrument and one for HIGH and LOW meter ranges of $\pm$ 100 gamma and $\pm$ 50 gamma. The tripod assembly shall be separate from the rest of the instrument and contain a bubble level and a sun direction indicator. The tripod shall serve as a mounting bed for the magnetometer sensor head. Figure 1 describes the general configuration of the Lunar Portable Magnetometer.

3.3.1 LUNAR SURFACE OPERATION

Suggested operation on the lunar surface is as follows:

3.3.1.1 UTILIZATION OF TWO ASTRONAUTS

(a) Subsequent to landing Astronaut #1 removes the combined sensor/cable/electronics and data display package from its stowed position.

(b) Astronaut #2 removes the tripod from its stowed position.

(c) Both Astronauts proceed to the LPM deployment position on the lunar surface.

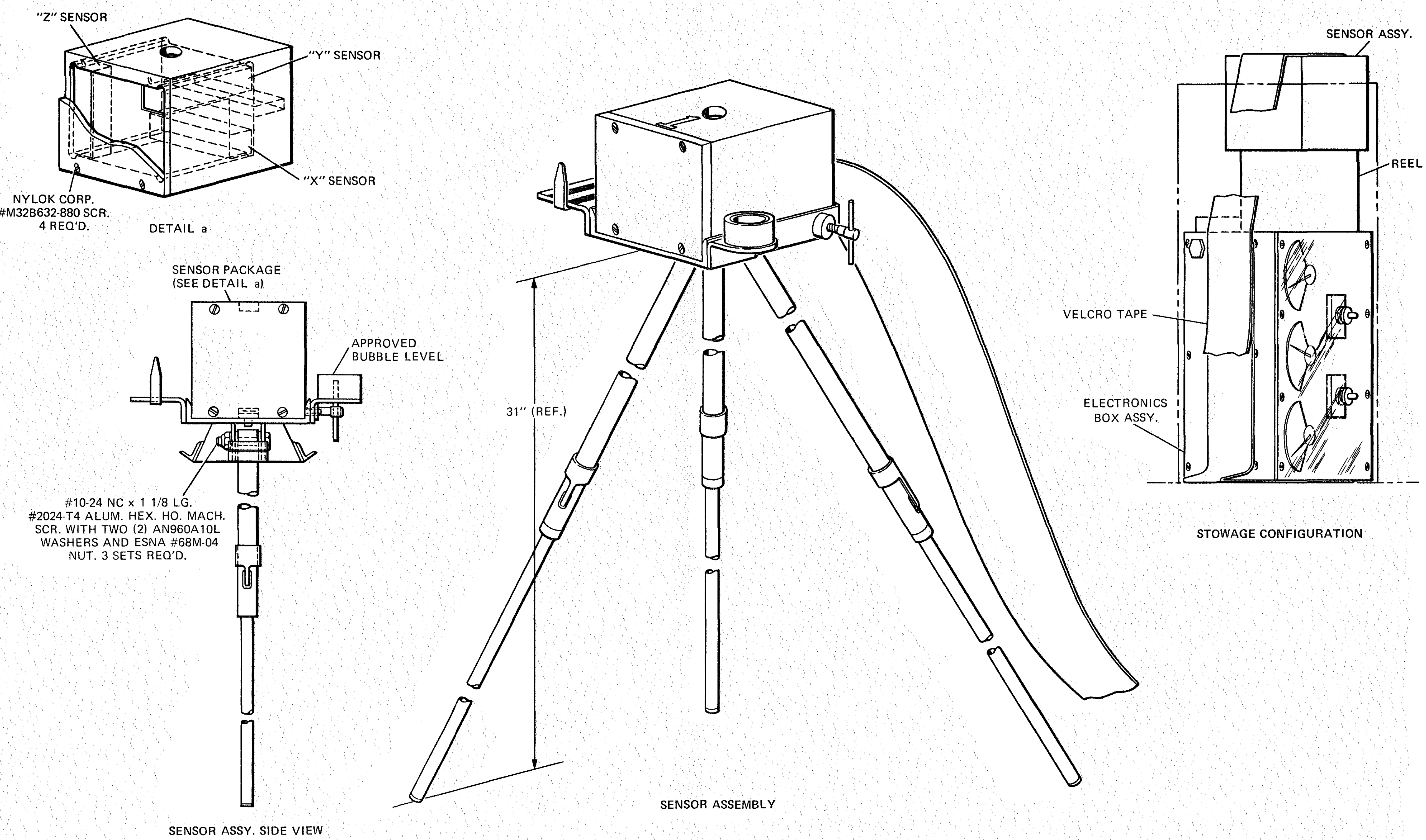

Figure 1. Portable magnetometer sensor and stowage assemblies

(d) Astronaut # 2 deploys and aligns the tripod.

(e) Astronaut # 2 holds the sensor head while Astronaut # 1, holding onto the electronics and data display package, walks away a distance of 50 feet thus deploying the cable.

(f) Astronaut # 1 extends the collapsible handle in the electronics and data display package.

(g) After ensuring that there is enough slack in the ribbon cable so as to not introduce torques or forces between the sensor head and the electronics and data display package, Astronaut # 2 mounts the sensor head in the tripod and tightens the tripod set screw on the sensor head.

(h) Astronaut # 2 walks 50 feet away from the sensor head.

(i) Astronaut # 1 turns the instrument ON, switches the range to the HIGH range, and takes a reading. He transmit this reading back to earth in realtime.

(j) Astronaut # 1 then switches to the LOW range, takes another reading and transmits this information back to earth in realtime and then switches the instrument OFF. (But note paragraph 3. 7. 2)

(k) Astronaut # 2 reapproaches the sensor head, unloosens the set screw on the tripod, rotates the sensor head 180° about the vertical axes of the instrument, retightens the set screw and walks 50 feet away.

(l) Astronaut # 1 repeats the measurement procedure described in (i) through (j) above.

(m) Astronaut # 2 reapproaches the sensor head, unloosens the tripod set screw, rotates the sensor head 180° about its X axis, reattaches the sensor head to the tripod, and walks 50 feet away from the sensor head.

(n) Astronaut # 1 repeats the steps described by (i) through (j) above.

3.3.1.2 ONE ASTRONAUT OPERATION

(a) Subsequent to the Apollo landing an Astronaut would remove the tripod from its stowed position and walk to the sensor/cable/electronics and data display package stowage area.

(b) The Astronaut would deploy the tripod and then remove the rest of the assembly from its stowed position.

(c) The Astronaut would then remove one end of the Velcro tape and then remove the sensor head and cable reel.

(d) The collapsible handle on the electronics and data display package is extended and the unit is lowered to the lunar surface by means of this handle.

(e) The sensor head would be placed in the tripod and the tripod set screw would be tightened.

(f) The Astronaut would then pick the sensor head, attached to the tripod, the cable reel and the electronics and data display package up from the lunar surface.

(g) The Astronaut would proceed to the deployment area for this experiment.

(h) The electronics and data display package would be relowered to the lunar surface by means of the collapsible handle and then the tripod would be aligned.

(i) The cable would then be unreeled and with the cable in the unreeled position the Astronaut would once again pick the electronics and data display package from the lunar surface by means of its handle and move 50 feet away from the instrument.

(k) Measurement procedures then are as described by Paragraph 3. 3. 1. 1 except that all operations would be done by one Astronaut.

3. 4 WEIGHT AND SIZE

3. 4. 1 WEIGHT

The weight of the Lunar Portable Magnetometer shall be held to a minimum, consistent with the design requirements of this specification. In any event, the total weight of the experiment including tripod shall not exceed 10 pounds.

3. 4. 2 SIZE

The overall dimensions of the Lunar Portable Magnetometer shall be as small as feasible, consistent with the design requirements of this specification. In any event the instrument shall not exceed the following:

(a) Sensor Head:	2 7/8" x 3 7/16" x 2 13/16"
(b) Electronics and Data Display Package:	4" x 5. 9" x 7. 5" - including switches
(c) Cable Reel:	3. 5" diameter, 4. 80" ht. - including handle

(d) Tripod: Stowed length 20" x 3 3/8" x 5 3/8" maximum. (See Figure 2)

3. 5 GENERAL

3. 5. 1 PARTS AND MATERIALS

Parts and materials shall be selected from Section 3 (Level 1 Parts) and Section 5 (Materials) in AHB 5328-1.

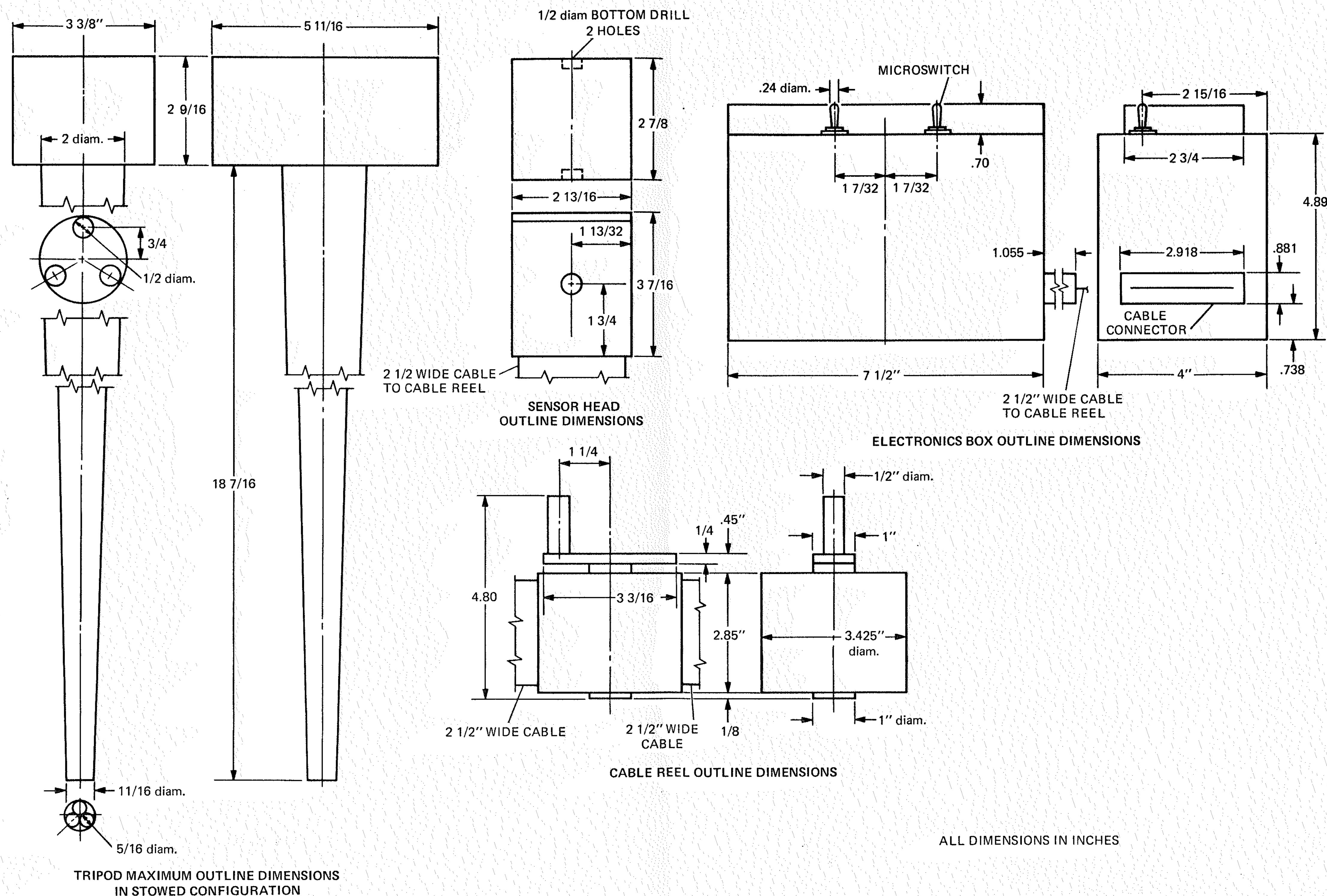

Figure 2. Portable magnetometer outline dimensions for stowage

Parts may also be obtained from other space programs (i. e., Lunar Surface Magnetometer, Pioneer Magnetometer, IMP Magnetometer, etc.). The use of magnetic, thermal, nonconducting or porous materials shall be minimized consistent with design and performance requirements. Zinc or cadmium plated components, connectors, fasteners, or materials shall not be utilized in the construction of the instruments. The LPM Experiment Manager shall be made aware of components utilized in the design. Materials that are nutrients for fungi shall not be used where it is practical to avoid them. Where used, they shall be treated with a fungicidal agent acceptable to NASA/ARC. This shall not preclude the use of materials that are nutrients for fungi in hermetically sealed assemblies and other accepted and proven products.

3.5.2 PARTS AND MATERIALS LIST

A list of all parts and materials selected shall be maintained on ARC 23 "Project Parts, Devices, and Materials List". If for any reason it should become necessary to add, subtract or make any substitutions to the list, written consent shall be obtained from the LPM Experiment Manager. The Project R&QA Manager will provide recommendations regarding the qualification and acceptability of parts and materials.

3.5.3 DISSIMILAR METALS

The use of dissimilar metals in contact, as defined in MIL-STD-454, Requirement 16, Table I, pertaining to intermetallic contact, shall be avoided wherever practicable. The LPM Experiment Manager shall be made aware of the use of dissimilar metals in contact where such use cannot be avoided or it is desirable for other reasons.

3.5.4 CONVENIENCE

Easy and ready access shall be provided to the interior parts, terminals, and wiring in the use of the LPM (as required) for adjustments, circuit inspecting, removal and replacement of parts. This paragraph need not be applied in the case of special packaging such as potted or hermetically sealed units. It shall not be acceptable to displace or remove wires, cables, parts of assemblies in order to gain access to terminals, solder connections, mounting screws, and the like. When it is not practical to avoid such construction, those parts which must be displaced or removed shall be so designated, mounted and otherwise arranged to facilitate their displacement or removal when necessary. If it is necessary to displace some other part in order to check or remove a given part, the latter shall be wired and mounted so that it can be sufficiently moved without being disconnected from its circuit.

3.5.5 LONGIVITY

The longivity of the instrument shall be as follows:

(a) Four hours minimum operating on the lunar surface (dependent upon available battery lifetime).

(b) One year shelf survivability with battery replacement only being allowed.

(c) Six-month survivability with no parts replacement.

3.5.6 RELIABILITY

The equipment shall be designed to provide the highest possible operational reliability consistent with resources and schedule limitations. Operational reliability implies survival of launch, flight to the Moon and operation on the lunar surface. High reliability is a design goal and shall be maintained through:

(a) Good engineering practice.
(b) Conservative circuit design parameters.
(c) Parts redundancy wherever feasible.
(d) Utilization of qualified parts.
(e) 100% parts screening.
(f) Strict compliance to ARC R&QA Specification D34-102.
(g) Test documentation.
(h) Developmental tests.
(i) Strict enforcement of fabrication procedures (i. e., compliance with ARC Specification D34-103).
(j) Qualification testing.
(k) Flight acceptance testing.

3.5.7 WIRE (HOOKUP)

Conductors with 19 strands shall be used wherever practicable. All conductors shall be of such cross section and temper as to provide ample and safe current carrying capacity and mechanical strength. Conductors directly associated with the primary power circuit shall be of a size consistent with excessability and weight constraints. The following wires shall be used:

(a) Flexed interwiring, no smaller than AWG22
(b) Rigid interwiring, no smaller than AWG24
(c) For AC applications the RMS working voltage shall

not exceed 25% of the RMS dialectric strength voltage.

(d) All wiring in the equipment shall, insofar as it is practical, be distinctly color coded or marked, in order to facilitate testing and the location of faults.

3.5.8 BONDING

The following bonding requirements shall be met:

(a) Bonding shall be sufficient to enable the equipment to meet the requirements for performance, safety, and interference specified herein.

(b) There shall not be more than 10 milliohms resistance between any exposed external surface of a unit and its normal mounting.

(c) Any bonding provisions shall meet the requirements of 3.5.15.

3.5.9 BATTERIES

All batteries will be redundant.

3.5.10 LOCALIZED HEATING

The instrument shall be designed in such a manner as to prevent localized hot spots. There shall be no localized hot spot more than 10° C above ambient design temperature (25°).

3.5.11 MAGNETIC CLEANLINESS

Magnetic cleanliness shall be a design consideration. Design techniques shall be utilized which reduce magnetic fields outside the instrument.

3.5.12 ELECTROMAGNETIC INTERFERENCE

The LPM, when operating in its deployed position, shall offer no electromagnetic interference to Apollo telemetry equipment. Tests shall be conducted to insure this requirement is met.

3.5.13 GROUNDS

The design and construction of the instrument shall be such that external parts shall be at spacecraft potential.

3.5.14 BATTERY SHORT CIRCUIT PROTECTION

Battery short circuit protection shall be provided by one resistor in series with each battery (see paragraph 3.6.1.2.4).

3.6 DESIGN

3.6.1 GENERAL ELECTRICAL DESCRIPTION

3.6.1.1 SECOND-HARMONIC FLUXGATE MAGNETOMETER SENSOR

The second-harmonic fluxgate magnetometer sensor is essentially a transformer with a core which is driven alternately in and out of saturation by the primary winding. The secondary, or sense winding, is wound about the entire core in such a way as to minimize coupling, both inductive and capacitive, between the primary and the secondary. Detection of magnetic fields is accomplished by the nonlinearity introduced into the core by an external field which has the effect of producing a signal in the sense winding at twice the frequency of the primary, or drive winding. An additional winding is incorporated in the fluxgate magnetometer which is wound to produce the effect of an external field. This winding is called the feedback winding. In operation the primary, or drive winding, is excited with a periodic waveform at approximately 10 kHz, which is very low in second harmonic content. The current in the drive winding causes the core material to be alternately saturated in a positive then a negative sense. The squareness of the hysteresis curve for the core material, and the symmetry of that curve, and the ease of saturation and the high permeability of the core material while not saturated, has the effect of alternately compressing field lines and then acting as if no material were present. This distortion of the field lines external to the sensor induces a voltage in the sense winding at twice the frequency of the drive signal. This second harmonic signal present in the sense winding is proportional to the amount of field lines sensed. The sensor is operated near zero field by application of a current to the feedback winding which opposes the effect of the external field on the core.

3.6.1.2 ELECTRONICS UNIT

The electronics unit is comprised of the amplifier demodulator, the drive electronics, the meter panel assembly and battery pack assembly.

3.6.1.2.1 AMPLIFIER DEMODULATOR

The amplifier demodulator (See Figure 3) is a narrow band AC amplifier having approximately 80 db gain at 14.5 kHz. The AC amplifier output is synchronously demodulated producing a DC output voltage proportional to the amplitudes of the AC voltage. This DC voltage is amplified through a narrow band amplifier and fed back to the feed back winding of the sensor. The DC amplifier sets the time response and closed-loop gain of the magnetometer system.

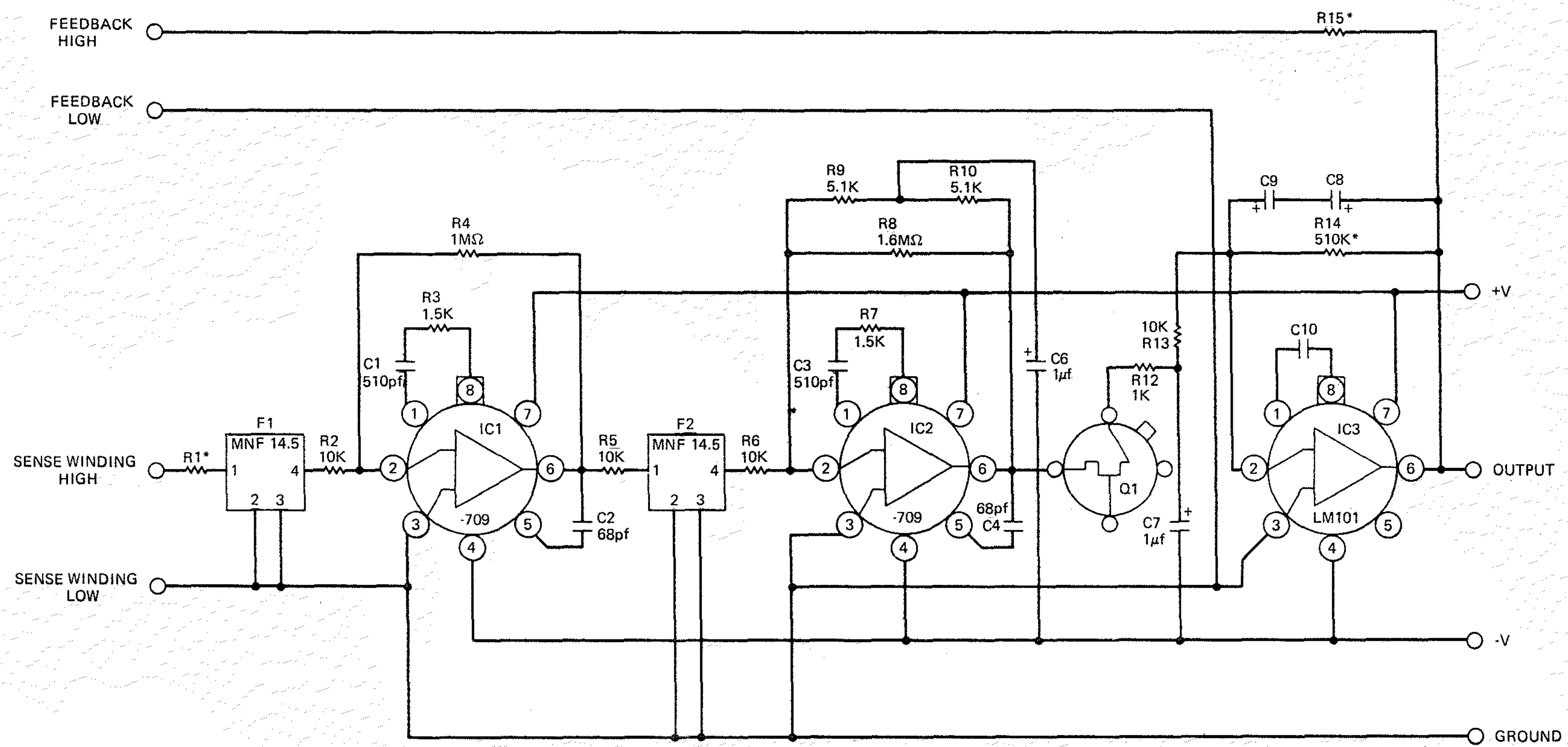

Figure 3. Amplifier demodulator

3.6.1.2.2 DRIVE ELECTRONICS

The drive electronics (See Figure 4) assembly provides both the demodulator signal and a square wave drive for the sensors. A colpitts oscillator operating at 29 kHz provides the basic timing for the system. The 29 kHz signal is amplified and squared and is used to drive a two-stage binary counter producing two frequencies: one at 14.5 kHz and one at 7.25 kHz. The 14.5 kHz signal is shaped and amplified to give a one microsecond-wide sampling pulse for the demodulator transistor in the amplifier demodulator assembly. The 7.25 kHz signal is amplified in voltage and power to produce a square wave. The symmetry of this driving square wave is held closely to eliminate any second harmonic content in the drive signal.

3.6.1.2.3 METER PANEL ASSEMBLY

The meter panel assembly consists of three taut-band one mil movement meters and associated resistors and capacitors. The resistors are used for scaling the meter to the amplifier demodulator output. The capacitor provides a time constant and a measure of damping for the meter.

3.6.1.2.4 BATTERY PACK ASSEMBLY

The battery pack assembly consists of ten 5.4 volt mercuric-oxide battery packs arranged as shown in Figure 5. The ten 5.4 volt batteries are arranged so as to provide three separate power sources with open circuit voltage of + 10.8 VDC, - 10.8 VDC and + 5.4 VDC. All battery arrangements are paralleled for complete

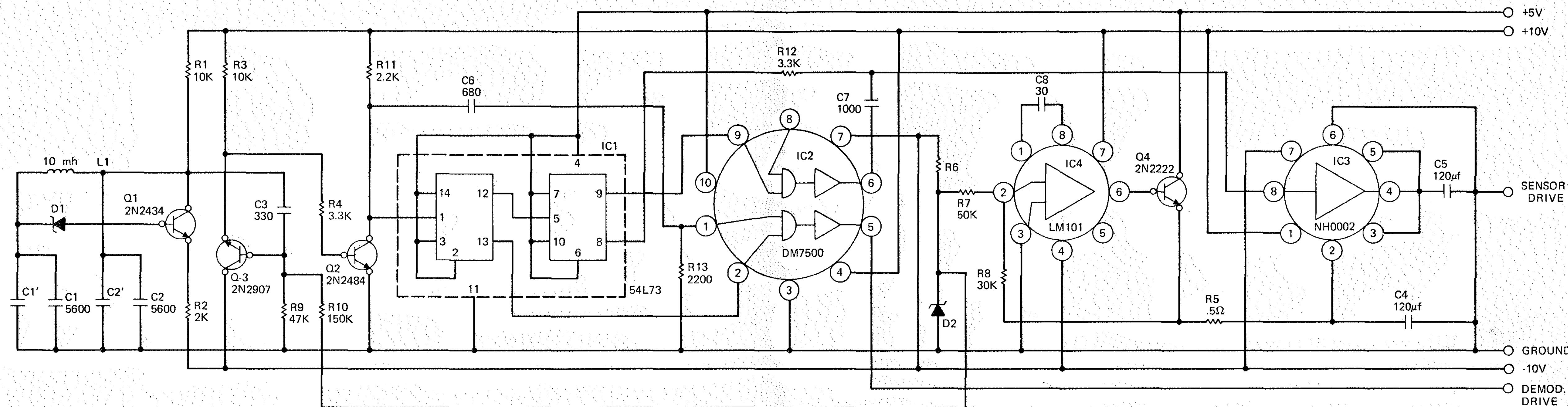

Figure 4. Drive electronics

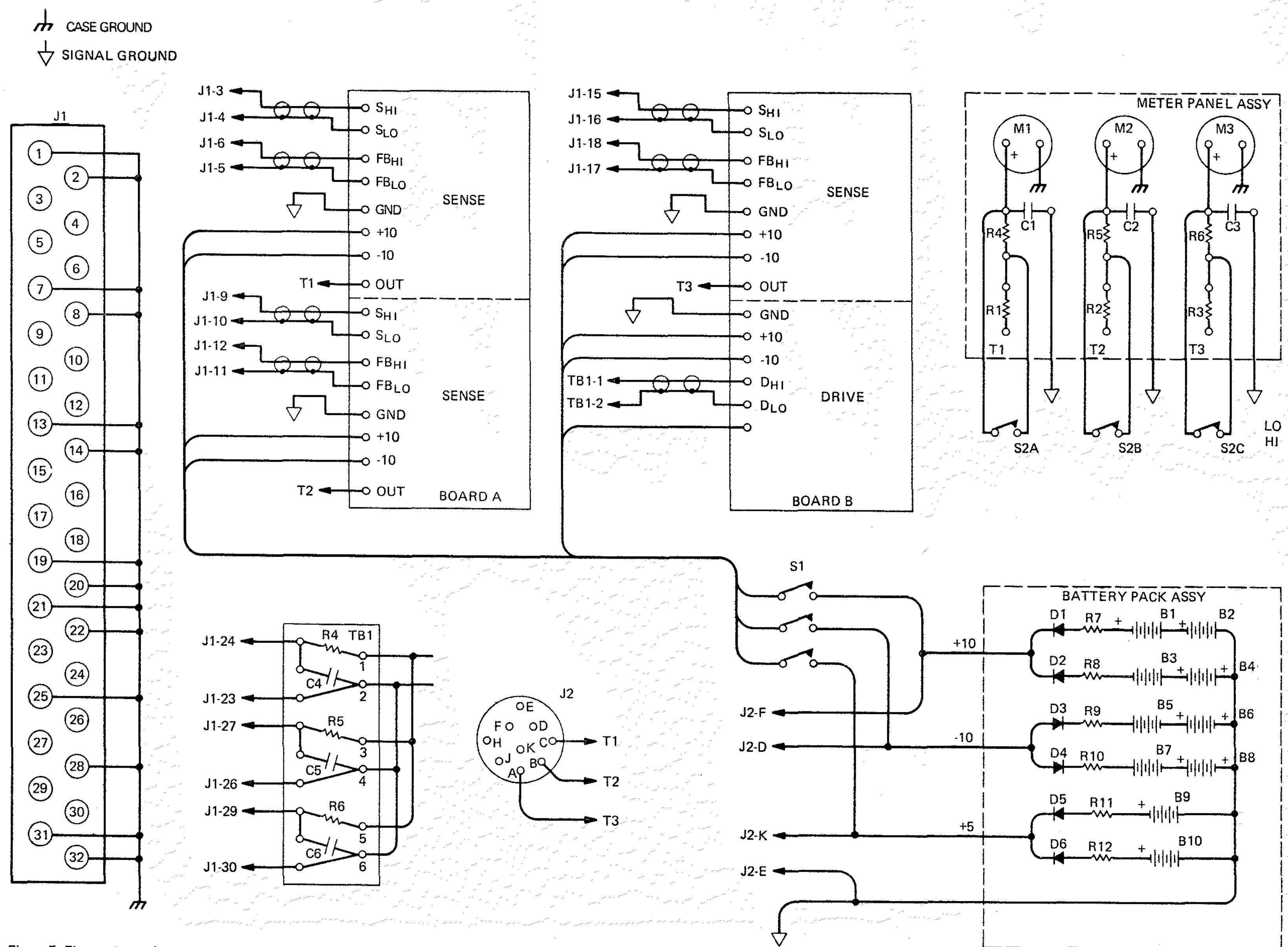

Figure 5. Electronics package

redundancy, diodes being used to isolate parallel elements should one battery set fail. In addition, each battery set is short circuit protected by a low value (~10 ohms) 1/4 watt series resistor which serves to act as a current limiter.

3.6.2 PERFORMANCE REQUIREMENTS

3.6.2.1 DYNAMIC RANGE

The instrument shall indicate magnetic field intensities of either polarity up to 100 gamma.

3.6.2.2 RESOLUTION AND ACCURACY

The instrument shall be able to indicate sensed magnetic field intensities to $\pm$ 1 gamma.

3.6.2.3 TEMPERATURE RANGE

The operating and nonoperating temperature range for the Lunar Portable Magnetometer shall be 0°C (32$\pm$F) to 50°C (122°F).

3.6.3 THERMAL DESIGN

The design temperature of all components is 25°C at a solar elevation angle of 7°. The following assumptions and/or constraints are made:

(a) The solar elevation angle upon deployment is between 7° and 30° (corresponding lunar surface temperature is -60°C and +50°C).

(b) The temperature of all components upon deployment is within the range 0°C to 50°C.

(c) The electonics subsystem and the sensor subsystem are not placed in shadow for more than a five minute period.

(d) The dominant mode of heat transfer to and from all components is by radiation.

(e) The components are isothermal.

(f) The average internally-generated heat in all components is negligible with respect to the absorbed solar radiation (i. e. , absorbed solar radiation = 3. 5 watts in sensor subsystem, 4. 2 watts in electronics).

A simple heat balance performed upon the LPM components yields the following values of the ratio of solar absorptance to emittance, (α/ε) necessary to maintain the corresponding component at an equilibrium temperature of 20°C at a solar elevation angle of 7°.

COMPONENT	TOTAL AREA / SOLAR INCIDENCE AREA	α/ε
Sensor Subsystem	6	1. 9
Electronics Subsystem	6	1. 9
Tripod	3. 1416 (π)	1. 0

At a solar elevation angle of 30° the increased thermal input from the lunar surface raises the component temperature to:

Electronics and Sensor Subsystems:	40°C
Tripod:	52°C

Selection of the thermal surfaces to achieve the desired values of α/ε were dictated by the following considerations:

(a) It is desirable to have an overall low emittance to minimize rate of temperature drop in shadow.

(b) It is desirable to utilize surfaces that have already been flight-qualified for Apollo.

The selected thermal surfaces are electro-deposited gold and S-13G white paint (silicate-treated zinc-oxide pigment in methyl-silicone binder). These two surfaces are mosaicked in such a way as to achieve the desired overall value of α/ε on each component. The values of α/ε on each component. The values of α and ε for the two thermal surfaces are:

	α	ε
Electrodeposited Gold:	0.50	0.04
S-13G White Paint	0.25	0.85

The percentages of total surface area covered by the gold and the white paint are calculated to be:

	Gold	White Paint
Sensor and Electronics	75%	25%
Tripod	60%	40%

The resulting effective solar absorptance and emittance values are:

	α eff.	ε eff.
Sensor and Electronics	.45	.24
Tripod	.40	.38

3.7 PERFORMANCE AND PRODUCT CHARACTERISTICS

3.7.1 STANDARD TEST CONDITIONS FOR PERFORMANCE MEASUREMENT

The fluxgate magnetometer shall be within its accuracy tolerance under the environmental conditions expected at the time it is used. Such means to demonstrate this include performing complete testing and calibration under several different conditions of temperature, heat flow, and other variables.

3.7.2 "PERM" ELIMINATION

Before taking the first magnetic field reading, the LPM shall be turned on for a minimum of two minutes upon initial operation on the lunar surface so as to eliminate any magnetization (PERM) of the sensor heads that may have occurred in transit.

3.8 MAINTENANCE

3.8.1 BUILT-IN TEST FEATURES

The equipment shall contain the necessary integral devices to permit pre-flight system checks of the operation of the Lunar Portable Magnetometer by means of portable ground support equipment. This shall include a separate test connector to be placed in the electronics package.

3.8.2 TEST EQUIPMENT

The design of the subsystem shall be such that the need for special test equipment for maintaining, calibrating and repairing the systems shall be kept to a minimum. The need for such special test equipment shall be subjected to the approval of the Ames Experiment Manager.

3.8.3 MAINTENANCE MANUAL

A manual describing the design, operating, and critical parameters of each functional subassembly shall be provided. Instructions for field testing including required equipment, operating procedures, and verification of operations shall be provided to the ARC Experiment Manager prior to testing of the complete instrument.

3.9 IDENTIFICATION PLATES

Each subsystem shall be identified by a part number and serial number as a minimum.

4.0 RELIABILITY AND QUALITY ASSURANCE PROVISIONS

4.1 GENERAL

Reliability and Quality assurance shall be in accordance with the LPM R&QA Plan (D34-102). Fabrication and inspection of the LPM shall be in accordance with the LPM Fabrication and Inspection Procedure (D34-103).

4.1.1 ARC SOURCE INSPECTION

The following ARC source inspections are required on all hardware:

(a) Initial Item Inspection: The first completed assembly will be inspected in order to detect and document designed deficiencies. All deficiencies will be reviewed and resultant changes incorporated into the following assemblies.

(b) In-Process Inspection: In-process inspection shall be in accordance with ARC Specification D34-103. The amount of in-process inspection provided is dependent upon the hardware complexity and final inspection assessability.

(c) Final inspection: Each LPM shall be inspected to assure that the product conforms to all the requirements specified on the applicable drawings. Each assembly shall pass a final inspection prior to testing and again prior to delivery.

4.1.2 PART SCREENING INSPECTION

All electronic parts will be electronically tested to AHB 5328-3 and accepted prior to installation. Records of screening inspection will be forwarded to the ARC Experiment Manager upon completion of testing. Parts which have been screened for other space programs do not require additional screening. However, major electrical parameters shall be checked and recorded for all parts. Test equipment shall be of sufficient accuracy and quality to permit performance of the required testing.

4.1.3 NONCONFORMING ARTICLES

All articles or materials which are found nonconforming shall be handled in accordance with the applicable paragraph in the LPM R&QA Plan (D34-102).

4.2 TESTS

4.2.1 CLASSIFICATION

The testing of the Lunar Portable Magnetometer shall be classified as follows:

(a) Developmental tests
(b) Qualification tests
(c) Flight Acceptance tests.

4.2.2 GENERAL

Developmental, qualification and acceptance tests shall be performed by ARC under the supervision of the ARC Experiment Manager or his authorized representative. Environmental levels and test sequence are outlined in the LPM R&QA Plan (D34-102).

4.2.2.1 DEVELOPMENTAL TESTS

Developmental tests are those tests conducted during development of the instrument. These are tests on parts, subassemblies, and assemblies which are designed to assure the instrument's compliance with the functional and environmental requirements delineated in this specification. All developmental tests shall be fully documented. These records shall be supplied to the ARC Experiment Manager within one week following completion of the tests.

4.2.2.2 QUALIFICATION TESTS

A qualification test shall be conducted on a completed LPM to verify that the design and mechanical integrity will survive the maximum anticipated environmental stress during pre-launch, launch, post-launch and operational phases. A document shall be prepared in which the qualification test plans, specifications and procedures are enumerated. The document shall be prepared in advance and approved by the ARC Experiment Manager and Project R&QA Manager.

4.2.2.3 FLIGHT ACCEPTANCE TESTS

A flight acceptance test shall be conducted on all LPMs to verify the mechanical integrity and operation at anticipated environmental conditions. The document for conducting the flight acceptance test shall be prepared in advance and approved by the ARC Experiment Manager and Project R&QA Manager.

5.0 PREPARATION FOR DELIVERY

5.1 CARRYING CASE

Each instrument shall be placed in a reusable carrying case meeting the following general requirements:

(a) To be constructed of wood, metal, or plastic.

(b) To be lined internally with polyurethane foam molded to the configuration of the instrument and/or assembly.

(c) To be provided with a folding carrying handle.

(d) The two halves of the carrying case to be non-separable.

(e) The carrying case to be provided with a nameplate providing identification similar to that provided for the specific instrument.

(f) Each case shall be identified with a NASA Blue Label.

(g) Each case shall contain a magnetic flux recorder.