MAY 1968

FINAL REPORT

ACTIVE PRIMATE SIMULATOR

by

A. S. Iberall, C. Beckman, D. Lulejian, F. Pavone, E. Pikalow

prepared under

Contract No. NASW-1638

by

GENERAL TECHNICAL SERVICES, INC.

UPPER DARBY, PENNSYLVANIA 19082

for

NATIONAL AERONAUTICS

AND

SPACE ADMINISTRATION

WASHINGTON, D.C.

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GENERAL TECHNICAL SERVICES, INC.
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TABLE OF CONTENTS

FOREWARD

The staff of General Technical Services would like to take this opportunity to express their deep appreciation of the role played by W. F. Barrows of Ames Research Center, NASA, in the successful implementation of this project.

Without his enlightened and intelligent guidance and cooperation and without his willingness to participate in the design and debugging phases of the project at the "shirtsleeves" level, the project could hardly have been completed successfully within the impossibly short time schedule and within the budget allocated to this program,

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

I. INTRODUCTION:

This final report covers the development of an Active Primate Simulator which has been designed to simulate the small primate to be used in the 30 day Biosatellite flight. The entire program was on a crash emergency basis since the schedule associated with it required completion by June 30, 1967. Initial conversations with the sponsor (National Aeronautics and Space Administration, Biosatellite Project) began during the first week of April, 1967, and a contract was signed on or about May 23, 1967. The first prototype was completed June 30, 1967 and was delivered to Ames Research Center on July 5, 1967, the first working day after June 30. Initial testing and evaluation were performed at Ames Research Center by Mr. W. F. Barrows as a result of which changes were incorporated in the final prototype.

The final Active Primate Simulator was delivered to Ames along with the test system (AGE) on August 2, 1967, The Active Primate Simulator and the Test System for the Active Primate Simulator was tested and accepted at Ames Research Center at that time. The equipment was then delivered to the Biosatellite Project, General Electric Company, 3198 Chestnut Street, Philadelphia, Pa., on or about August 15, 1967.

After several months of testing and use at the General Electric facility, the second model of the Active Primate Simulator, containing a number of refinements and improvements was delivered on November 17, 1967. Since November, 1967, a number of additional refinements were incorporated in both simulators and in the Test System (AGE) to conform with G.E. - NASA specifications which had not been finalized at the time of initiation of the project and to provide for easier maintainability. Changes were made to insure interchangeability of battery packs between Unit #1 and Unit #2 and to simplify removal of a discharged battery pack and replacement with a freshly charged battery pack. Since each simulator has a spare battery pack associated with it, a total of 4 battery packs were supplied with the two simulators, thus providing a sufficient back up battery capability for long time duration test schedules.

This report describes the final specification which formed the basis of the work statement, the significant design problems and the technical approach used in the solution of these problems.

The description of the Active Primate Simulator system and its associated Test System (AGE) is then covered. Test results and operating experience to date are also included.

II. DISCUSSION OF SPECIFICATION

The original work statement for the project consisted of NASA Document No. 883-11-14, entitled, "PROJECT BIOSATELLITE - FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATORS", Rev. 1, March 1967. During the course of the project, this specification was supplanted by GTS Rev. 2, dated May 3, 1967. The final specification which contains all the revisions that have occurred since March, 1967 is dated February 1, 1968. The final specification for the Active Primate Simulator can be found in Appendix A of this final report.

The purpose of the Active Primate Simulator is to simulate a number of primate physiological parameters and to stimulate the signal conditioners interfacing with the primate in the space capsule. A number of documents and drawings form part of the simulator specification. These documents and drawings cover the specifications of materials, coatings and methods of construction to be used, the various interconnection interfaces, and the geometric constraints applicable to the simulator case dimensions. A number of UCLA and USC drawings are included as well as the final GTS Drawings which describe the Active Primate Simulator.

Sections 1.0 to 3.5.5 of the subject specifications are all fairly standard and have been complied with in a satisfactory manner.

Section 3.6, which covers the performance of the Active Primate Simulator deserves some discussion. The electrical requirements of the Active Primate Simulator are described in section 3.6 and are detailed in Figure 1, Appendix A, entitled, "Active Simulator Electrical Requirements".

The most difficult of the electrical requirements is the EEG requirement for a 10 microvolt peak-to-peak sine wave signal having a maximum peak-to-peak noise level of 2.5 microvolts. The source impedance of the EEG signal is shown in the circuit diagram in Figure 1, Appendix A, and consists of two 100,000 ohm resistors, one in each leg of the signal output lines. Therefore, the source impedance of the EEG signal is 200,000 ohms. Realizing this low noise level is a theoretically difficult problem because the high source resistance of the signal generates a high Johnson noise level. The electrical requirements of the EOG and EMG channels were fairly straightforward and easy to obtain.

The GSR and temperature channels consisted of switchable networks of precision resistors and were readily realizable.

The EKG/ZPG channels were also simple to simulate.

The blood pressure channels consisted of precision resistance bridges and again they presented no particular problem.

In order to insure that the simulator could be fitted within the defined envelope provided in the capsule, it was necessary that the case of the simulator should be no greater than 16 inches by 7 inches by 4 inches. This imposed a severe space problem since the oscillators required to generate the 3 sinusoidal signals were quite large and since the simulator batteries were required to operate for at least 24 hours without recharging. The volumetric requirements were difficult to satisfy. It was necessary to use silver-zinc batteries which require special handling and treatment to meet this requirement.

The following additions and improvements were incorporated in the final simulator; these features, which were not called for in the original specification, are being made part of the final specification. Paragraphs 3.6.1.8 to 3.6.1.14cover these changes. These additions include incorporation of low current pilot lights for "Power-On" and "Charge Cycle" indications, electrically interlocking the "Power-On" and "Charge Cycle" switches, provision for a battery test switch, a battery test meter, interchangeable plug-in battery packs, an EMI see-through door for both EMI shielding and protection from accidental changes of the control settings, a battery cell test connector, a battery test connector and a voltage regulator test connector.

The operating service conditions listed in paragraphs 3.7 are quite modest and offer no problems. The non-operating service conditions (par.3.8) were also compatible with the active primate simulator performance capability for these conditions.

The design of the simulator will enable it to meet the required goal of 2,000 hours life with reasonable servicing and replacement of parts. High reliability military and industrial components were used throughout.

The storage life requirement of 2 years can be satisfied if the batteries are stored dry during this period.

The Active Primate Simulator weighs about 15 pounds, which is well within the 30 pound weight limit specification.

Paragraph 3.10, which covers the AGE requirements, was complied with in a satisfactory manner as will be described in a later section of this report. The Test System for the Active Primate Simulator (AGE) was designed to perform all necessary check-out and calibration procedures on the Active Primate Simulator and also has the capability to recharge the battery either in or out of the Simulator.

EMI tests were performed on the Simulator by Interference Measurements Laboratory of New York City on June 27, 1967. The first prototype unit passed these tests satisfactorily as will be evidenced by the attached test report by this company.

The Final Specification for the Active Primate Simulator, Appendix A, dated February 1, 1968 thus becomes the work statement for the design and construction of the Active Primate Simulator and its associated test equipment.

III. DISCUSSION OF DESIGN PROBLEMS - TECHNICAL APPROACH

A. Active Primate Simulator Design Problems.

1. Low Level Signals - Allowable Electrical Noise Levels.

The most severe problem encountered in the development of the Active Primate Simulator was the specification for the EEG signal quality. This requirement called for three sinusoidal frequencies of 0.5 HZ, 3.0 HZ and 35 HZ of 10 microvolts peak-to-peak amplitude and an allowable noise level of 2.5 microvolts peak-to-peak. The EEG signals have a source impedance requirement of 200,000 ohms. Since the 3 generated signals cover a bandwidth of from zero to 35 HZ, it was estimated and verified experimentally that the 100 HZ bandwidth instrumentation system to be used would provide negligible attenuation at 35 HZ. It was also assumed that the noise requirements would have to be met over the zero to 100 HZ band.

The first noise source to be investigated was the thermal agitation noise or Johnson noise of the 200,000 ohm source resistance of the EEG signals. The magnitude of the thermal agitation noise depends on the resistance across which the noise is developed, the absolute temperature of the resistance, and the bandwidth of the system involved. The well known quantitative relations are as follows:

$$E \text{ (RMS)} = 2\sqrt{kTR(f_2 - f_1)} \qquad (1)$$

Equation 1 above is the quantitative relationship for the RMS value of the voltage developed across the resistance. We are of course concerned with the peak-to-peak value of this voltage. For a perfect sine wave the peak-to-peak value would be 2.828 times the RMS value of the voltage. For wave forms of random and arbitrary nature, the peak-to-peak value could be anywhere from the value of 2.828 times the RMS value to as high as 20 times the RMS value. We have estimated that a good compromise for this factor would be 4 times the RMS value of the voltage. Therefore,

$$E \text{ (P-P)}, = 4\,E\text{(RMS)} = 8\sqrt{kTR(f_2 - f_1)} \qquad (2)$$

k = Boltzmann's constant = 1.374 x 10-23 joules/degree K

T = temperature = 300° K (room temperature)

R = resistance = 200,000 ohms

Substituting these values in equation 2 above, we then get

$$E\ (P\text{-}P) = 2.3 \times 10^{-6} \text{ volts} \quad \text{or}$$

$$E\ (P\text{-}P) = 2.3 \text{ microvolts}$$

The minimum theoretical value for the thermal agitation noise voltage for 200,000 ohms is therefore 2.3 microvolts peak-to-peak which is just about equal to the 2.5 microvolts peak-to-peak maximum noise level called for by the specification. The specification for the Simulator therefore calls for a noise level close to the theoretical minimum noise level and does not allow noise contributions from sources other than the source resistance of the EEG signal generators.

It was the opinion of the NASA project personnel that the lowest realizable noise level would be that approximately equal to the noise signal generated by a shielded 200,000 wire wound resistance.

A 200,000 ohm wire wound resistance was placed in a small shielded enclosure with extremely short shielded leads terminated with coaxial connectors. This was then used as the standard against which the performance of the Simulator was measured. As will be seen from discussions in a later section, these requirements were met very closely by using extreme care in the construction of the shielded enclosure for the Simulator and in the cabling between the enclosure and the measuring system. All measurements had to be taken with extreme care. The use of unshielded wire and clip-leads were found to result in hundreds of microvolts of noise. All terminations and connections had to be made with coaxial connectors and all cables had to be constructed of shielded cable. Great care was necessary with regard to grounding procedures.

2. Battery Requirements

The Active Primate Simulator specification called for a self-contained battery power pack having the capability of operating the Simulator continuously for a 24 hour period. The total current and voltage requirements for the Simulator are approximately 0.3 amperes at 12.0 volts. Therefore, a battery having a minimum capacity of 7.5 ampere hours would be required to operate the Simulator over a 24 hour period without interruption and without recharging.

A survey of commercially available batteries was made and it was found that the silver zinc storage battery was the only type of battery capable of meeting both the watt-hour requirements and the volume requirements of the Simulator. A number of companies manufacture this type of battery; however, the Electric Storage Battery Company was the only company able to satisfy our delivery schedule. Therefore, the Electric Storage Battery Company S-7.5 cell was selected for this application.

Silver zinc batteries have to be handled very carefully. The procedures for storage, charging and discharging must be followed rigorously. The ESB S-7.5 battery has a nominal shelf life rating of 6 months after filling with electrolyte. With refrigeration, the non-operating shelf life can be extended to 9 months.

In order to confirm the published ratings of the ESB, S-7.5 battery, a test run was made on a battery pack consisting of 5 cells in series with a discharge current between 0.35 and 0.4 amperes. The total discharge time to a point where the voltage began to decrease below 7.5 volts was 30 hours (1.5 v/cell). Another test was run on a single cell which had been activated for 8 months prior to subject test and had undergone approximately 30 charge-discharge cycles. This cell performed satisfactorily for 21 hours. This was considered to be excellent performance since the rated non-operating shelf life of the S-7.5 cell is only 6 months; the cell had not only exceeded rated non-operating shelf life by two months but had also undergone 30 charge-discharge cycles during the 8 month period.

The S-7.5 silver zinc battery has a discharge characteristic which varies from an initial fully charged value of 1.8 volts to a final value of 1.5 volts. The 1.5 volt level is reached after the battery is 25% discharged. The cell voltage remains at 1.5 volts for the duration of the useful discharge cycle; when the cell voltage begins to drop below 1.5 volts it is then necessary to recharge the battery.

The power supply requirements for the oscillators are plus 6 volts and minus 6 volts. These voltages must be regulated to at least ± 1%.Two 5 cell battery packs were utilized to provide these voltages. Each battery pack supplied an initial voltage of 9 volts which decreased to 7.5 volts during the discharge. An automatic voltage regulator is required for each battery pack so that a 6 volt ± 1% output is provided while the input voltage varies from 9 volts to 7.5 volts. A miniature automatic voltage regulator, the super/reg, manufactured by Trio Laboratories, Plainview, New York, was selected to satisfy this requirement. The Trio Laboratories super/reg is described in the following section.

3. Automatic Voltage Regulator

A market search was made to obtain information on miniature automatic voltage regulating devices to satisfy the requirement described above.

The Trio Laboratories' super/reg device was selected; this compact, hermetically sealed unit provided voltage regulation to better than one part in a thousand or ± 0.1%. The super/reg is similar to an ordinary zener diode in that the unit is a two terminal device having the ability to maintain a precise DC voltage across its terminals despite wide variations in the voltage applied to it. Unlike the ordinary zener, the super/reg permits adjustment of its regulated output voltage over a $\pm$ 10% range about the nominal voltage value, without derating or degrading its characteristics. The device has almost negligible zener impedance and is roughly 100 times more immune than conventional zeners to temperature fluctuation and self-heating effect. The particular super/reg selected for this application regulates over a current range of 0.01 amperes to 3 amperes. A variation of several parts in 6,000 was observed when the load current was varied from the zero to the full load current of 0.3 amperes. The unit occupies a volume of less than 1 cubic inch and was easily fitted into the simulator package.

4. Oscillators

One of the major requirements of the Active Primate Simulator was to provide sinusoidal electrical signals at three frequencies and at three voltage levels. The three frequencies specified are: 0.5 HZ, 3.0 HZ, and 35 HZ.

It was decided that individual plug-in oscillators of the hermetically sealed type would provide the best solution to this problem. A number of manufacturers were contacted who manufacture hermetically sealed plug-in oscillators. Of the manufacturers contacted, only one seemed to be capable of meeting the volumetric requirements, the electrical performance requirements and the required delivery schedule. This manufacturer, Fork Standards Inc. of West Chicago, Illinois, manufacturers a line of temperature-compensated, bimetallic tuning fork oscillators. Standard, off-the-shelf oscillators range in frequency from 50 HZ on up. Therefore, the frequencies required for the Active Primate Simulator called for a special development job; in particular the two lower frequency oscillators were quite difficult to design and fabricate.

The approach used by Fork Standards was as follows:

The 0.5 oscillator was constructed of two tuning forks, one having a resonant frequency of 800 HZ and the other having a resonant frequency of 804 HZ. These two basic frequencies were divided down to 100 HZ and 100.5 HZ. The two lower frequencies were then subtracted, giving the desired result of 0.5 HZ.

The 3 HZ oscillator was constructed of two tuning fork oscillators having natural frequencies of 1000 HZ and 1006 HZ. These two frequencies were divided down to 500 HZ and 503 HZ, which were then subtracted giving a resultant frequency of 3 HZ.

The 35 HZ oscillator was constructed of one tuning fork having a natural frequency of 1120 HZ. A five-step division by two then gave the desired result of 35 HZ.

Solid state amplifier and filter circuits were incorporated in the oscillator to meet the necessary amplitude and distortion requirements.

The initial models of the three oscillators were received in time to complete the first model of the Active Primate Simulator. During the course of checking out the first prototype of the Simulator, a number of design defects were observed in the three oscillators. These design defects are as follows:

a. It was found that the low level EEG channels were picking up the basic tuning fork frequencies by inductive coupling. This problem was solved by replacing the brass cases of the oscillators with steel cases to provide a modest amount of magnetic shielding. Other steps that were taken to alleviate this condition were the elimination of wire wound resistors, which were acting as pick-up coils and the relocation of the plug-in oscillators so that they were as widely separated as possible from the low level EEG circuits. A 1/8 inch thick steel plate, inserted between the plug-in oscillators and the EEG circuits also greatly reduced this inductive coupling.

b. The specifications for the Active Primate Simulator require three voltage amplitude outputs at three different signal frequencies to simulate EEG, EOG, EMG and EKG. Voltage divider networks are used to obtain the three voltage amplitudes. Depending upon the setting of the various voltage dividers the oscillator outputs can see a load which might vary from a minimum of 10 K to a maximum of 30 K. The early models of the oscillators were extremely sensitive to this load variation; it was found that their voltage output varied as much as 10% as the load resistance varied from minimum to maximum.

Since the tolerance specification on voltage amplitude was $\pm$ 1% this performance was entirely unacceptable. In order to correct this difficulty, emitter follower circuits were designed and installed into the oscillator circuits. This modification eliminated this problem completely; further tests indicated that with load variation from a minimum of 10 K to a maximum of 30 K, the output voltage of the oscillators remained well within the specified tolerance of $\pm$ 1%.

c. In order to obtain precise final adjustment of the amplitude of the oscillator outputs, it was necessary to have the manufacturer install adjustment controls into the oscillators that were accessible from the outside of the steel cases.

After these various changes were made, the hermetically sealed plug-in, tuning fork oscillators performed quite satisfactorily. Tests indicated tolerances of 0.1% for frequency stability, 1% for amplitude stability and less than 2% distortion.

5. Shielded Enclosure for Active Primate Simulator

During the early phases of the Active Primate Simulator Development Program, there was quite a bit of discussion as to whether this device was intended to be a Simulator or a calibration system. One opinion called for the development of a completely unshielded device since that more nearly represented the actual conditions that exist in a live primate. The opposite opinion was that the Active Primate Simulator should really be a calibration device and should be as heavily shielded as was feasible. After concurrence from NASA-Ames personnel, the latter approach was taken by General Technical Services, Inc.

Since the EMI specifications were not available at the time of the inception of the program, it was decided that the best possible shielding should be provided that would be compatible with the volumetric and weight requirements of the system. It was decided that this task should be subcontracted to one of the manufacturers who specialize in the design and construction of shielded enclosures. Technical Wire Products, Inc. of Cranford, New Jersey, a company which manufacturers a line of shielding products under the name of Tecknit, was selected for this task.

The shielded enclosure was constructed of aluminum of 0.050 inches thickness and was plated with a conductive irridite finish. EMI gasketing was utilized throughout to provide for RFI leakage control. A maximum of shielding effectiveness was provided due to the combination of the aluminum enclosure and the RFI gasketing.

The various switches and controls that operate the Active Primate Simulator system are mounted on the front panel. These switches and controls and other devices on the front panel can act as either sources or receivers of EMI. In order to eliminate the possibility of any front panel EMI problems, it was decided to use an EMC glass door. The see and shield EMC glass door was provided with EMI gasketing to provide further EMI protection. EMC glass is a laminated plexiglas material, having electrically non-polarized mesh laminated between the two plexiglas sheets. The EMC glass door provides a suitable compromise between visibility and electrical shielding. The EMC glass is approximately 90% transparent and provides about 65% of the shielding effectiveness of an all metal panel.

In addition to providing EMI shielding, the EMC glass door has the added advantage of mechanically protecting the sensitive controls and switches on the front panel, when the instrument is being handled. Accidental changes in the settings of the various controls are minimized by the protection afforded by this door.

6. Instrumentation

As was discussed in a previous section, the Active Primate Simulator must generate a 10 microvolt peak-to-peak sinusoidal signal with a noise voltage of no greater than 2.5 microvolts peak-to-peak. One of the most difficult problems encountered in this program was obtaining instrumentation capable of making measurements at this low level without introducing noise levels of the same order of magnitude as the maximum allowable noise level of the Simulator. In order to make adequate measurements, it is usually necessary to have an instrument which is at least 10 times better than the tolerance requirements of the parameter to be measured. On this basis, it would be necessary to provide instrumentation that had a noise-level of 0.25 microvolts peak-to-peak or less. The instrumentation should be capable also of making this measurement over a 0-100 HZ bandwidth on a signal whose source resistance is 200 kilohms. This high source resistance provides another difficult instrumentation problem.

It was not possible to find a commercially available instrument that was capable of satisfying these specifications. One low level, low-noise amplifier was found that seemed to be suitable for this application from the published literature. This particular amplifier had a gain adjustable from 200 to 1,000,000 and advertised a 0.005 microvolt RMS noise-level. Unfortunately, these performance characteristics were only applicable over the extremely narrow bandwidth of 0.1 HZ to 1 HZ and for signals having a source impedance of 100 ohms or less. The noise and drift for this particular amplifier approximately doubled for each 2,000 ohms of source resistance.

Since it seemed impossible to completely satisfy this particular specification without going into a major research and development program far beyond the scope of the contract, it was decided to use the best commercially available instrumentation. The two instruments selected to satisfy this need were the Tektronix, Model 1A7 low-level plug-in amplifier and the Keithley, Model 103, ultra-low noise preamplifier. These instruments do not meet the required performance specifications which are believed to be beyond the present day state-of-the-art.

a. Tektronix, Type 1A7, Plug-in Amplifier.

The type 1A7 is a high gain, low noise, adjustable bandwidth, DC coupled, differential amplifier. This unit is designed for use in all Tektronix, 530, 540, 550 and 580 series oscilloscopes.

The maximum sensitivity of the 1A7 is 10 microvolts/cm. The maximum bandwidth is DC to 500 KHZ; however, the bandwidth adjustment used for all measurements on the Active Primate Simulator Project was DC to 100 HZ.

The input noise is 3.3 microvolts RMS maximum over the DC to 500 KHZ bandwidth. Drift is less than 200 microvolts per hour with ambient temperature and line voltage constant; temperature drift is less than 150 microvolts per degree C.

With the input of the 1A7 grounded the wide band noise signal was observed to be about 20 microvolts peak-to-peak. With the bandwidth reduced from DC - 500 KHZ to DC - 100 HZ, the peak-to-peak noise signals were reduced to one to two microvolts. These noise values are, of course, very close to the specified simulator values of 2.5 microvolts peak-to-peak. Since the 1A7 appeared to be the best low level, low noise amplifier that was commercially available, this unit had to be used to make the necessary simulator measurements.

b. Keithley Model 103 Amplifier

The Model 103 Amplifier is an ultra low noise preamplifier with an adjustable bandwidth of 0.1 HZ to 100 KHZ and with gains of 100 and 1,000. The amplifier features a normal and a low noise mode of operation. In the normal position, the input impedance is 10 megohms. In the low noise position, the input impedance is 100 K. Since the Active Primate Simulator generates 200 K source impedance, EEG signals, it was necessary to work exclusively in the normal mode of operation, since the low noise position would present an overload to the simulator. With the input grounded the noise signal generated by the Model 103 amplifier was on the order of 2 to 3 microvolts peak-to-peak. This value is in the specified range of the maximum allowable noise level of the Active Primate Simulator.and therefore can not really be qualified as an adequate instrument. However, the 103 seems to be the only commercially available unit whose performance is even close to the required noise levels.

The Keithley Model 103 Amplifier was designed into the test system for the Active Primate Simulator (AGE) in order to enable the user of the AGE system to work with commonplace 10 mv/cm oscilloscope amplifiers. The normal position with a gain setting of 1,000 was used exclusively. The bandwidth selected was 0.1 HZ to 100 HZ.

B. Test System for Active Primate Simulator (AGE) - Design Problems

1. System Philosophy.

Paragraph 3.10 in the final specification states that AGE (Aerospace Ground Equipment) shall be provided to perform all necessary check-out and calibration of the Simulator as defined in the subject specification. The AGE should be capable of connecting to all electrical Simulator outputs and should provide the necessary circuitry to make the desired parameters available to standard readout equipment such as oscilloscopes, meters, etc.

The AGE equipment designed and fabricated by General Technical Services meets all the requirements set forth in this paragraph of the specification. The basic philosophy was to provide as much self sufficiency as was feasible in the test system. The only additional equipment that is required is a standard cathode ray oscilloscope with a 10 millivolt/cm sensitivity. Additional calibration and cross checking capability is available if a 10 microvolt/cm plug-in amplifier can also be provided with the cathode ray oscilloscope.

Some of the features of the Test System for the Active Primate Simulator are as follows:

a. A high quality digital voltmeter capable of measuring D.C. voltages, A.C. voltages and resistance to an accuracy ± 0.01% is incorporated in the system.

b. A precision ultra low noise amplifier is incorporated in the system together with its power supply. This permits the use of conventional oscilloscopes with commonplace 10 mv/cm plug-in amplifiers.

c. A precision D.C. power supply, operable in either a constant voltage or a constant current mode is incorporated in the system. The D.C. power supply provides power to charge the silver zinc storage batteries, to energize the blood pressure circuits and to activate the 64 KHZ and 240 KHZ oscillators used to calibrate the EKG/ZPG circuitary.

d. All of the above three instruments can be used independently as general purpose laboratory instruments by proper adjustment of front panel controls and use of the readily accessible binding posts.

e. A completely automatic charge and discharge system for servicing the high energy density silver zinc batteries is incorporated in the test system. Silver zinc batteries require very precisely controlled charge, discharge, and storage procedures. For example, the charging rate for the 7.5 ampere hour battery must be set at no greater than 0.5 amperes. The individual cell voltages must not exceed 2.1 volts during the charging process. The charging process is automatically switched off when the cell voltage reaches 1.97 to 2.1 volts.

f. A separate battery discharge fixture has been supplied with the Test System which allows each individual cell to be discharged to zero volts at the proper current discharge rate.

g. A high quality, low level, switching system has been provided to switch the various electrical inputs and outputs to their proper read-out device or stimuli sources.

h. A panel type voltmeter and ammeter is incorporated to continuously monitor power supply voltage and current. The precision digital voltmeter can also be switched in to verify these panel meter measurements to ± 0.01% accuracy and with NIXIE digital readout. The digital voltmeter can also be switched to the individual battery cell voltages so that they can be individually monitored to insure that all cells are uniform and that no individual cell voltage exceeds 2.1 volts during charge.

i. The Test System has been found to be completely capable of checking out and calibrating all performance functions of the Active Primate Simulator. It has also been found to be a useful tool in debugging and trouble shooting the Active Primate Simulator. The test system can also be used as a general purpose laboratory instrument.

2. Low Level Switching System

Two general approaches were considered with regard to the design of the low level switching system. The first approach called for a miniature low level, solid state amplifier for each of the 15 channels that generate low level signals. This approach was carefully investigated and subsequently rejected since it was found that all miniature, commercially available, solid state amplifiers brought to our attention during this investigation had noise ratings much greater than the specified 2.5 microvolt peak-to-peak noise level.

In fact, even the expensive bench type, low level amplifiers such as the Keithley 103 and other low level amplifiers of the precision laboratory variety cannot provide noise performance better than several microvolts peak-to-peak for the source impedance and bandwidth conditions specified for the simulator.

The second approach to this problem was the use of high quality, rotary selector switches. It was reasoned that a high quality contact with a heavy wiping action using precious metal alloys for switch contacts should give performance equivalent to or better than the miniature connectors that are to be used in the final operational system to transmit the low level signals from the live primate to the signal conditioning amplifiers.

As a result of a thorough market search, a Leeds and Northrup Type 31, sixteen position rotary selector switch was chosen for this application. The 16 position switch combines a molded acrylonitrile shaft and molded alkyd wafers to assure superior mechanical reliability. The switch is designed to assure low, stable contact resistance of less than 0.001 ohms with contact variations of 0.0005 ohms or less. The stationary contacts are made of fine silver, and self adjusting, multiple leaf brushes are of a durable silver alloy. A heavy wiping action assures good performance under dry circuit conditions. These switches have thermal emf's of less than 1 microvolt and a life expectancy of 1,000,000 operations or greater. The switch action is easily adjustable from loose to firm operation by means of an adjusting screw. The switches are totally enclosed to keep out dust and dirt.

One minor problem was encountered in the use of the switches due to the capacitance between switch positions which is approximately 2.0 picofarads. The original design of the AGE equipment provided a feature which permitted the 2.8 volt peak-to-peak A.C. oscillator output signals to be switched to an oscilloscope readout. The purpose of this feature was to monitor the A.C. signals being generated by the three plug-in oscillators. Low level signals are connected to switch positions adjacent to these relatively high level voltage signals. The 2.0 picofarad coupling capacitance induced a several hundred microvolt spurious signal in these adjacent low level channels. It was therefore necessary to eliminate the oscillator output measuring capability from the AGE unit.

Field experience to date has indicated that the elimination of this feature has not been at all critical and that once the oscillators are set up and adjusted they remain stable. In any case, if the oscillators do require adjustment, it is necessary to remove the back panel of the Simulator to make these adjustments. With the back panel removed, the oscillator output terminals are then readily available for monitoring on the cathode ray oscilloscope.

All our tests and operating experience to date have proven that the selection of a simple, straightforward low level switching system was correct. There is no measureable difference between low level EEG signals observed directly from the output of the Simulator thru shielded cables and high quality BNC connectors and those signals observed thru the AGE unit and the type 31 low level, rotary selector switch system. We have experienced no difficulties with the use of this low level switching system.

3. Measurements Using the Tektronix 1A7 Low Level Plug-In Amplifier

In this mode of operation, the low level signals are connected directly into the AGE system and are switched by means of the low level switching system to output terminals which are connected by shielded cable to the Tektronix 1A7 amplifier. Considerable difficulty was encountered using this technique during the initial stages of testing of the AGE system. These difficulties have been eliminated by using shielded cable with coaxial connectors throughout and by repairing a number of open shield connections inside the AGE cabinet.

Special adapter cables had to be constructed with built in load resistances to insure that each selected signal was terminated with the proper load resistance. The use of the 1A7 10 microvolt/cm plug-in amplifier does provide an excellent calibration check of the other measuring technique which is described in the next section.

4. AC Measurements Using the Keithley 103 Low Level Amplifier

In order to insure that the AGE system will be compatible with standard laboratory oscilloscopes, it was decided to incorporate a low level amplifier into the AGE system. As was previously discussed, the Keithley 103 Amplifier was selected for this application.

Using a gain setting of 1000 on the Keithley 103 Amplifier, it is then possible to use the AGE system with standard 10 mv/cm sensitivity oscilloscopes; these oscilloscopes are usually available in all laboratories. The Tektronix 1A7 Amplifier discussed in Section 3 above, eliminates the need for the Keithley 103; however, 1A7 Amplifiers are generally not available in most laboratories. For this reason, the Keithley 103 Amplifier was designed into the AGE system; this will enhance the general purpose capability of the Test System.

5. D.C. Voltage, A.C. Voltage, Resistance and Impedance Measurements

a. D.C. Voltage Measurements

It is necessary to make a number of D.C. voltage measurements to satisfy all the performance requirements of the Active Primate Simulator and its associated Test System. The digital voltmeter which forms part of the AGE system can be manually switched to make all of these measurements; several panel type meters are also included to continually monitor battery voltage and battery current during the battery charging mode. D.C. measurements are required for the following tasks:

(1) Adjustment of the voltage of the power supply output to 11 volts D.C. to actuate the blood pressure circuits.

(2) Adjustment of the D.C. power supply to 12 volts D.C. to provide D.C. power to the two plug-in oscillators (64 KHZ and 240 KHZ) which are used to measure and calibrate the ZPG circuitry.

(3) Measurement of the output of the voltage regulator circuits.

(4) Measurement of the D.C. voltage and D.C. current during the battery charging mode.

(5) Measurement of the individual battery cell voltages.

(6) Measurement of the output voltage of the blood pressure circuits.

b. A.C. Voltage Measurements

The A. C. measurement capability of the AGE system is used for the measurement of the output voltage and current of the 60 HZ supply, the 64 KHZ supply and the 240 KHZ supply. These A.C. measurements are necessary to calibrate the ZPG circuit.

c. Resistance Measurements

The resistance measuring capability is utilized to check out the temperature circuits and the GSR circuit. These circuits are switchable precision resistor networks. The resistance measurement capability is also used to check the source resistance of the EEG circuits, the EOG circuits, the EMG circuits, the EKG/ZPG circuits and the six blood pressure circuits. The ability to make these measurements to a precision of 0.01% has been invaluable for trouble shooting and debugging. The digital voltmeter is therefore used as a general purpose tool for performing fault isolation of the simulator.

d. Impedance Measurements

When calibrating the Active Primate Simulator it is necessary to measure the A.C. impedance of the ZPG circuit. This impedance value is determined by means of the 60 HZ, 64 KHZ, and 240 KHZ current and voltage measurements. The ZPG impedance parameters can be determined from these measurements by calculation.

The impedance of the ZPG circuit at 240 KHZ is approximately 250 ohms. The RZ resistance which is part of this impedance is changed by means of a pushbutton switch from 0 to 10 ohms or 0 to 20 ohms during normal simulator use, The 10 ohms and 20 ohm values must be measureable to ± 2% of these values. To realize this accuracy, it is necessary to measure the overall ZPG impedance at 240 KHZ to an accuracy of ± 0.2 ohms for the 10 ohm change and to ± 0.4 ohms for the 20 ohm change. Therefore, an A.C. measurement accuracy of at least ± 0.1% is required. The Dana digital voltmeter is capable of providing this precision for A.C. measurements. Measurements made with the Dana digital voltmeter at 240 KHZ for RZ values of 0, 10 ohms, and 20 ohms indicate good correlation with results obtained by independent measurements of the 10 ohm and 20 ohm resistances.

6. Battery Charge and Discharge Functions

An automatic battery charging circuit was incorporated into the AGE system. The battery charging circuit contains an adjustable precision D.C. power supply which can operate in either a constant current or constant voltage mode and a meter relay with adjustable high and low cut-off contacts. The two battery packs are charged in series and the meter relay is set to interrupt the charging process at 20 volts. This results in an average cell voltage of 2.0 volts. This value is slightly below the 2.1 volts per cell which is the maximum allowable cell voltage for the S-7.5 battery. It is necessary to discontinue charging at this point to allow for minor cell voltage variations.

An automatic battery discharging circuit was also included in the AGE system but it was found that the need for the discharge feature disappeared when the battery discharge fixture was constructed.

The battery discharge fixture consists of ten 0.5 ohm resistors in series, each of which is connected across an individual cell. This is a simple, inexpensive device and provides the added advantage of relieving the AGE system for other service when batteries are being subjected to a let down discharge which is necessary prior to storage.

IV. DESCRIPTION OF ACTIVE PRIMATE SIMULATOR SYSTEM

A. Block Diagram - Active Primate Simulator - GTS9008

1. Battery and Associated Circuitry

The battery and associated circuitry produce two nominal voltages, plus 7.5 volts and minus 7.5 volts. These voltages are unregulated and vary from an initial value of 9 volts toa final value of 7.5 volts. The power on switch, the power indicator lamp and access points to the individual battery cells complete this section of the circuit.

2. Battery Test Circuit

The battery test circuit consists of a spring return to center, double pole, double throw switch which places a 0.5 ampere load across each of the 7.5 volt battery packs. A battery test meter is also provided with the "operate" limits and "recharge" limits indicated on the meter face. The spring return to center switch prevents the operator from accidently leaving the battery test circuit activated; this would discharge the battery.

3. Battery Charging and Discharging Circuit

The Battery Charging and Discharging circuit consists of an input connector to the battery, a switch to connect the batteries to the charger input connector and a pilot light to indicate that the battery is being charged.

The charging switch is interlocked to prevent battery power from being applied to the Simulator while the charging circuit is in operation.

4. Voltage Regulator Circuits

The voltage regulator circuits consists of Two Trio Laboratories super/reg two terminal devices which provide + 6 volts and - 6 volts to the oscillator package.

5. Oscillator Package

The oscillator package consists of the three plug-in oscillators which supply frequencies of 0.5 HZ, 3.0 HZ and 35 HZ.

6. Grounding System #1

Grounding system #1 permits the common lead of the oscillator packages to be returned to either case ground or to a terminal which can be connected to an external ground of the user's choice. Grounding system #1 also has the capability of inserting various values of resistance between the common and selected ground (0 ohms, 1,000 ohms, 10,000 ohms, and 50,000 ohms).

7. Frequency Controls

The frequency controls consist of a system of selector switches which permit any one of the three frequencies to be selected for any one of the four groups of output channels

8. Amplitude Controls

The amplitude controls consist of a system of selector switches designed to switch any one of three voltage amplitudes to each of the four groups of circuits.

9. EEG Circuits

There are ten channels of EEG signals, all operated in parallel.

10. EOG Circuits

There are two channels of EOG circuits operated in parallel.

11. EMG Circuits

There are two channels of EMG circuits operated in parallel.

12. EKG and ZPG Circuit

There is one combined EKG/ZPG Circuit

13. ZPG Controls

The ZPG Controls consist of a switch for adjusting the Rz value to either 10 ohms or 20 ohms and a shorting push-button to short-circuit either the 10 ohm or the 20 ohm value of Rz.

14. Grounding System #3

Grounding System #3 consists of the ground circuits for the shields in the head cable and the head connector.

15. Grounding System #2

Grounding System #2 is concerned with the grounding of the shields in the body leads cable.

16. Blood Pressure Circuits

There are 6 channels of blood pressure circuits. The blood pressure circuits consist primarily of D.C. excited resistance networks.

17. GSR Circuit

There is a single GSR circuit which consists of three precision resistance values each of which can be selected by a rotary selector switch.

18. Temperature Circuits

There are two temperature circuits, each consisting of a three precision resistor network, selectable by a rotary selector switch.

B. Schematic Wiring Diagram - Active Primate Simulator - GTS9009

The Active Primate Simulator Circuitry will be described in detail in this section: The circuit schematic is shown in Drawing GTS9009.

1. Battery and Associated Circuitry

This section consists of the two 5 cell battery packs, B1 and B2. Each individual battery voltage is accessible through connectors JJ10 and JJ9. JJ9 is connected to the battery when the charger switch, S2 is turned on. This accounts for all battery terminals, with the exception of the Common, which is available at a number of convenient access points. Two fuses F1 and F2 protect the battery and its associated circuits from accidential short circuits. The battery pack which is mounted in a stainless steel case, can be easily removed from the Simulator by disconnecting connectors JJ11 and JJ12.

2. Battery Test Circuit

The Battery Test Circuit consists of a spring return to center double pole, double throw switch, a 0 to 10 volt D.C. meter and a 15 ohm load resistor. The battery test switch, S3 is set to one position to test the positive battery and to the other position to test the negative battery. The 15 ohm load resistor, R1, places a 0.5 ampere drain on the battery when the battery voltage is at its nominal voltage of 7.5 volts and a proportionately higher current drain for a freshly charged battery. Since the normal rated load current supplied by the battery is of the order of 0.3 amperes, the test procedure is on the conservative side. Meter M1, the 0 to 10 volt D.C. voltmeter has a red zone for the "recharge" condition and a green zone for the "operate" condition.

3. Battery Charging and Discharging Circuit

The battery charging and discharging circuit consists of the charger switch S2, which is a three pole, double throw switch, the pilot light, PL1 and the charger input connector, JJ9. The charger switch S2 must be in the "off" position in order for power to be supplied to the main power switch S1, which provides power to the Simulator. It is therefore impossible to operate the Simulator when the charger switch S2 is in the "on" position.

4. Voltage Regulator Circuits

The positive voltage regulating circuit consists of R6, a 4.7 ohm dropping resistor, VR1, the super/reg voltage regulator and R4, a 100 K trimming resistor. The variable resistor R4 is used to precisely adjust the voltage output of the voltage regulator. The positive voltage regulator also supplies power for PL2, the main power indicator light. The negative voltage regulator circuit is identical to the positive voltage regulator circuit with the exception that it does not have to supply power to a pilot light. A small Microdot connector JJ6 provides access to the + 6 volt and the - 6 volt voltage output terminals so that these voltages can be monitored during trouble shooting and adjustment procedures.

5. Oscillator Package

The oscillator package consists of three Fork Standards plug-in oscillators, f1 (0.5 HZ), f2 (3 HZ), and f3 (35 HZ). Switches S4, S5, and S6 permit each individual oscillator to be turned on or off. Radio frequency suppression circuits are connected across the output terminals of each of the three oscillators.

6. Grounding System #1

Grounding System #1 consists of a switching system which permits control of the grounding conditions of the oscillator common circuit. S18, the common ground selector switch permits the ground to be switched to either Simulator case ground or external ground. The external ground point is also connected to pin "K" of Connector JJ2 which is used for the EMG and EKG common ground and pin "K" of Connector JJ3 which is used for the EEG common ground. Switch S17, the EEG, EMG, and EKG ground resistance selector switch permits four values of resistance to be inserted into the common return to ground circuit. These four values are 0 ohms, 1000 ohms, 10,000 ohms, and 50,000 ohms.

7. Frequency Controls

The frequency controls consist of 4 individual three position rotary selector switches. Switch S7 supplies any one of the three frequencies to the 10 EEG circuits. Switch S8 switches any one of the three frequencies to the 2 EOG circuits. Switch S9 selects any one of the three frequencies for the 2 EMG circuits. Switch S10 supplies any one of the three frequencies to the EKG/ZPG circuit.

The EKG/ZPG frequency control circuit also has 3 voltage dividers associated with it, one for each frequency. This was found necessary due to the variable loading effect of the ZPG circuit on the output of the EKG channel at the 35 HZ frequency. The 0.5 HZ voltage divider and the 3.0 HZ voltage divider consist of resistors R30, R32 and R29, R31, respectively, and are equal, indicating that there is negligible change in the amplitude level when switching from 0.5 HZ to 3.0 HZ. The 35 HZ voltage divider consists of a fixed resistor R23 and a variable resistor R11. The variable resistor must be adjusted to insure that the EKG output voltage at 35 HZ is equal to the EKG voltage output at 0.5 HZ and 3.0 HZ.

8. Amplitude Controls

The amplitude controls consist of four 3 position rotary selector switches connected to supply one of three voltage amplitudes to the EEG, EOG, EMG, and EKG circuits. Switch S11, the EEG amplitude selector switch selects one of three voltage amplitudes for the 10 EEG circuits. Switch S12, the EOG amplitude selector switch, selects one of three voltage amplitudes for the 2 EOG circuits. Switch S13, the EMG amplitude selector switch, switches one of three voltage amplitudes to the 2 EMG circuits. Switch S14, the EKG amplitude selector switch provides one of three voltage amplitudes to the EKG Circuit. There are three individual voltage dividers for each selector switch, as well as three individual trimming potentiometers for fine adjustment of each voltage amplitude. Most of the resistors are metal film precision resistors. In certain cases wire wound precision resistors have been used.

9. EEG Circuits

The EEG circuits consist of 10 individual channels with a 100 K precision resistor in each of the two legs of each channel. Therefore, each EEG circuit has a source resistance of 200 K.

10. EOG Circuits

The EOG Circuits consist of 2 channels which are derived from 3 terminals - one common and two outputs. The circuit arrangement for the EOG circuits is somewhat different from that of the EEG circuits and the EMG circuits.

11. EMG Circuits

There are two EMG channels, each of which contains two 50,000 ohm precision resistors. Therefore, the output impedance of each of the EMG channels is 100 K.

12. EKG and ZPG Circuit

There is a single EKG Channel with a 25,000 ohm series resistance in each leg of the circuit. Therefore, the source resistance of the EKG circuit is 50,000 ohms, plus the 1,000 ohm value of the voltage divider resistor. The ZPG network is in parallel with the EKG output leads.

13. ZPG Controls

The ZPG controls consist of the ZPG resistance selector switch S15 and the Rz shorting pushbutton S16. One position of switch S15 places a 20 ohm resistance in the ZPG network, the other position of switch S15 places a 10 ohm resistance in the ZPG network. Pushbutton S16, when in the non-operating position shorts out the Rz resistor of 10 ohms or 20 ohms as selected by switch S15. When the Rz shorting pushbutton S16 is operated the appropriate resistance value is inserted into the ZPG network.

14. Grounding System #3

Grounding System #3 connects the EEG, EOG and EMG shields in the head cable and the head connector to the Simulator Case Ground.

15. Grounding System #2.

Grounding system #2 connects all the shields of the body leads to Switch S28, the Body Leads, Grounding Selector Switch. The body leads shields can then be switched by means of S28, which is a single pole, double throw switch to either the Simulator case ground or external ground. The body leads shields are also connected to pin H of connector JJ5.

16, Blood Pressure Circuits

There are six channels of blood pressure circuits. Each channel consists of a 350 ohm bridge circuit with a 25,000 ohm variable resistor across its diagonal. There is a three position rotary switch to allow for selection of the Rc value which is in parallel with one of the 350 ohm legs of the bridge. The input voltage to the bridge is approximately 1 volt, which is derived from an 11 volt circuit thru a 3.5K series resistance. With the selector switch set on the infinity resistance position, the 25K variable resistor is adjusted to give 0 output. When the rotary switch is adjusted to an Rc value of 80.6K or 40.2K, the output from the blood pressure circuit should lie somewhere between 0 and 3 millivolts. The blood pressure circuits performed as expected.

17. GSR Circuit

The single channel GSR circuit consists of 3 Rx resistance values and selector switch S25, which can select any one of three precision resistance values.

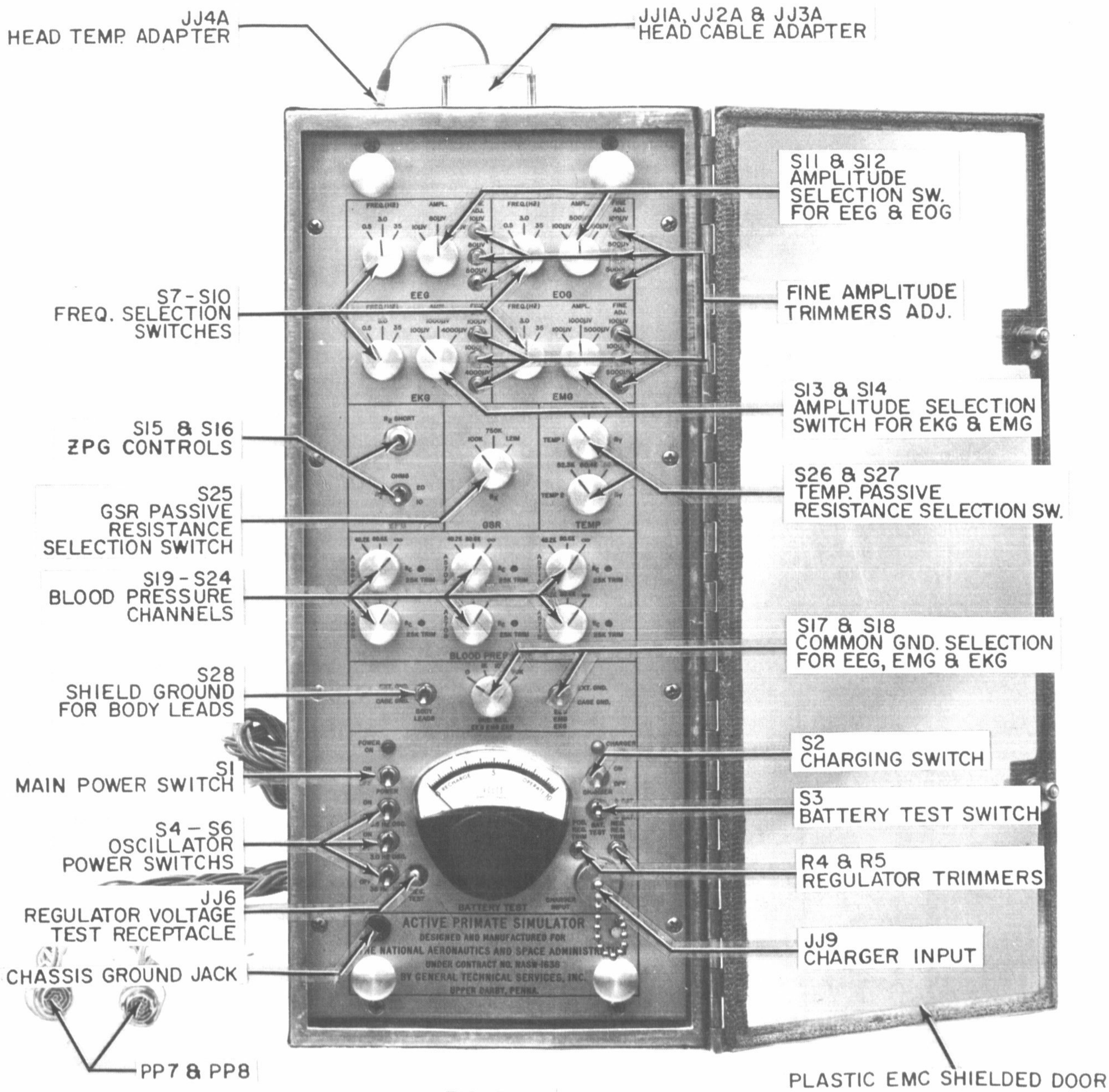


FIGURE I

SIMULATOR NO.2 - FRONT PANEL

18. Temperature Circuits

There are two channels of temperature circuits. Each temperature circuit consists of an Ry Resistance selector switch S26, S27, which is capable of selecting any one of three precision resistance values.

C. Description of Simulator Front Panel

The front panel of Simulator #2 is shown in Figure 1. The head temperature adapter JJ4A and the head cable adapter JJ1A, JJ2A and JJ3A can be seen at the top of the Simulator. The four Frequency Selector switches, S7, S8, S9 and S10, are located at the top of the panel. The four Amplitude Selector switches, S11, S12, S13 and S14, are each located to the right of its associated frequency selector switch. The 12 Amplitude fine trimmer controls are also located at the top of the front panel and are screwdriver adjustable. The ZPG Controls, S15 and S16, the GSR Resistance Selector Switch and the two Temperature Resistance Selector switches are shown on the next level. The six Blood Pressure controls are located on the next level. S28, S17, and S18, the Ground Control switches are located below the Blood Pressure controls.

The lower section of the control panel contains the power controls, including the main power switch, the three oscillator power switches, the charging switch, the battery test switch, the two regulator trimmers which are used for fine adjustment of the regulator output voltages, the regulator voltage test receptacle, the charger input connector and a banana jack for case ground.

The EMC shielded door is shown in the open position. The EMC shielded door has two latches in order to insure that the EMI gaskets are tightly in place when the door is closed. Other views of the Active Primate Simulator in various stages of disassembly are shown in the Operating and Maintenance Manual.

V. DESCRIPTION OF TEST SYSTEM FOR ACTIVE PRIMATE SIMULATOR (AGE)

The Test System for the Active Primate Simulator was designed to test, fault isolate and calibrate the Active Primate Simulator. All the necessary equipment to perform these functions are contained in the Test System, with the exception of the Tektronix Oscilloscope. The Test System was designed to make this testing procedure as simple as possible for the user of the Active Primate Simulator. Three standard pieces of laboratory equipment were incorporated into the Test System; the Dana Digital Voltmeter, the Keithley Low-level Amplifier, and the Lambda Power Supply. The front panel of the Test System is arranged in such a way so that any one of these three pieces of laboratory equipment can be used as general purpose laboratory equipment.

A. Simplified Block Diagram - Test System for Active Primate Simulator (AGE) - GTS9011

1. Digital Voltmeter

The digital voltmeter is switched to various sections of the system by means of the SS panel (selector switch panel).

2. Keithley Power Supply

The Keithley power supply supplies highly regulated D.C. power to the Keithley Amplifier.

3. S.S. Panel

The Selector Switch Panel contains the selector switches which are used for distributing the various signal voltages and power voltages to all sections of the system.

4. Keithley Amplifier

The low-level Keithley Amplifier receives signals from the Selector Switch panel, amplifies these signals and routes them to the readout device, the cathode ray oscilloscope. The oscilloscope is not shown on GTS9011.

5. Oscillator Supply

The oscillator supply contains the two plug-in oscillators (64 KHZ and 240 KHZ) and the 60 cycle step down transformer. These three frequencies are used to make impedance measurements of the ZPG Circuit.

6. Lambda Power Supply

The Lambda regulated power supply provides the various D.C. voltages and currents required for powering the plug-in oscillators, the blood pressure circuits, and the battery charging system.

7. Test Panel

The Test Panel contains the receptacles which receive all signals from the Simulator and which supply various excitation voltages to the Simulator. All incoming and outgoing signals are routed through the test panel.

8. Power Panel

The Power Panel contains all the power switches, meters, and power control devices to operate the test system.

B. Block Diagram - Test System for Active Primate Simulator (AGE) - GTS9012

This Block Diagram is a more detailed block diagram of the Test System for the Active Primate Simulator.

1. Dana Digital Voltmeter

The Dana Digital Voltmeter is used to measure A.C. volts, D.C. volts and ohms.

2. Keithley Power Supply

The Keithley Power Supply is used to supply D.C. power to the Keithley low level amplifier. When making low level oscilloscope measurements, it is necessary to operate the auxiliary power switch shown on the right hand side of the block diagram. This disconnects all 60 HZ power to the Test System, excepting the Keithley power supply. The auxiliary power switch is located at the rear of the Test System cabinet and was found to be necessary since it was impossible to adequately shield the low level circuits from the 110 volt A.C. power circuits connected to the front panel. Therefore, when making low level oscilloscope measurements, A.C. power is supplied to the Keithley Power Supply only.

3. Selector Switch Panel

The selector switch panel contains both signal switching networks and power switching networks. The signal switching networks receive all signals generated by the Active Primate Simulator (shown in block diagram form to the left of the dotted line) and distributes them to the Dana Digital Voltmeter, the Keithley Amplifier and the Tektronix Oscilloscope. The power switching network system receives power imputs from the Lambda Power Supply, the 60 HZ Supply, the 64 KHZ Supply and the 240 KHZ Supply. The power switching system also provides 12 volts D.C. to the 64 KHZ and 240 KHZ oscillators. The 11 volt D.C. blood pressure circuits supply is switched from the power switching networks, through the signal switching networks to the blood pressure circuits. The necessary power for the battery charging circuit and the load resistance for the battery discharging circuit are switched by the power switching networks. The voltage regulator output voltage and the individual battery cell voltages are connected to the power switching network and then switched to the Dana Digital Voltmeter. The power switching network has the capability to switch all incoming signals to the Dana Digital Voltmeter for precision measurement and calibration.

4. Keithley Amplifier

The Keithley low level Amplifier is used if desired, to amplify low level signals originating at the Active Primate Simulator so that they can be observed and calibrated by a conventional 10 mv/cm sensitivity cathode ray oscilloscope. As indicated in the block diagram, the low level signals can be switched directly to the oscilloscope provided a 10 microvolt/cm sensitivity oscilloscope is available.

5. Oscillator Supply

The oscillator supply provides three signals of different frequencies, (60 HZ, 64 KHZ and 240 KHZ) to the power switching network, which in turn switches them through the signal switching network to the ZPG circuit for measurement of ZPG impedance. The 64 KHZ and 240 KHZ are generated by two plug-in oscillators. The 60 HZ supply is derived from the A.C. line through a step-down transformer.

6. Lambda Power Supply

The Lambda Power Supply provides adjustable D.C. voltage and current to the power switching network, which in turn redistributes this D.C. power to the oscillator supply, to the signal switching networks for activation of the blood pressure circuits and to the battery charging circuit.

7. Test Panel

The test panel is not shown on GTS9012; however, the dotted line on the left hand side of the block diagram illustrates the function of the test panel. All receptacles used to connect the Active Primate Simulator to the Test System are located on the test panel.

8. Power Panel

The Power Panel is illustrated by means of the block, entitled "A.C. Power Switching Controls". Switches, meters,pilot lights and a fuse post are located on the Power Panel, which will be described in detail in the next section.

C. Schematic Diagram For Test System for Active Primate Simulator (AGE) - GTS9013

1. DVM

The digital voltmeter can be used directly as a general purpose laboratory instrument through its binding posts, BP6-1 and BP6-2. The digital voltmeter terminals are connected to terminals 2 of SS3-1 and SS3-2, and to the wipers of SS3-3 and SS3-4. When this four level selector switch SS3 is in position 2, the digital voltmeter is connected to the wipers of SS1-1 and SS1-2, a two level 16 position switch. The digital voltmeter can then be switched to each of the 10 EEG outputs, (EEG1 to EEG10 inclusive) or to each of the 2 EMG outputs (EMG1 and EMG2).

When SS1 is at position 16 the digital voltmeter is then connected to the wipers of SS2-1 and SS2-2 so that the resistances of EOG1, EOG2, EKG/ZPG, the 6 blood pressure circuits (BP1 to BP6 inclusive), the GSR circuit, Temperature 1 and Temperature 2 can be measured. When the blood pressure circuits are supplied with 11 volts D.C. the DVM is then switched to the millivolt range so that the 0 to 3 millivolt signals generated by the blood pressure circuits can be measured and calibrated.

The DVM is also connected to the wipers of SS3-3 and SS3-4 where it is used to measure 60 HZ voltage and current, 64 KHZ voltage and current, and 240 KHZ voltage and current. These six measurements supply the information necessary to exactly compute the parameters of the ZPG impedance network.

SS3 switches the digital voltmeter to the battery voltage (position 9 on switch SS3). Position 10 on switch SS3 is the battery cell test position. The battery cell test position connects the digital voltmeter to the wipers of SS5 (a two level, 12 position switch). Switch SS5 then connects the digital voltmeter to each of the 10 battery cell voltages.

Selector switch SS3 connects the digital voltmeter to the positive voltage regulator terminals, the negative voltage regulator terminals, the power supply output voltage, and the power supply output current.

2. Keithley Power Supply

The Keithley Power Supply is shown connected to the A.C. line cord supplying the Test System. The Keithley Power Supply can be turned off from a switch located on its front panel. It is not controlled by the main power switch as are the other A.C. powered devices in the Test System.

3. Selector Switch System

The switching system consists of 5 selector switches; SS1 and SS2 are primarily concerned with switching of the low level signals generated by the Simulator. SS1 is a two level, 16 position switch and SS2 is a 4 level, 16 position switch. SS1 switches the 10 EEG signals and the 2 EMG signals to either the digital voltmeter for measurement of resistance or to the low level, cathode ray oscilloscope measuring system. Selector switches SS3, SS4 and SS5 are primarily concerned with the switching of power voltages and currents for purposes of measurement and calibration. The functions of switches of SS3 and SS5 were described in detail in Section C-1 above.

Switch SS4 is concerned with the switching of the Lambda Power Supply D.C. power to the various devices requiring D.C. power. Position 1 provides 11 volts D.C. to the blood pressure circuits, position 2 supplies 12 volts D.C. to the oscillator supply, position 3 provides 0.5 amps constant current to the battery charging circuit and position 4 provides D.C. power to binding posts BP5-1 and BP5-2 for general purpose laboratory use.

4. Keithley Amplifier

The Keithley Amplifier is shown connnected via a cable to connector J20, which in turn is connected to position 1 on selector switch SS3. Resistors R211, R212, R213 and R214 adjust the input resistance to the specified 1 megohm resistance value. The input impedance of the Keithley Amplifier is 10 megohms for each leg or a total of 20 megohms leg-to-leg. Therefore the total input resistance as seen by the Active

Primate Simulator is slightly less than 1 megohm. Position 1 of Selector Switch SS-3 can be directly connected to the Tektronix Oscilloscope by means of another cable connecting directly to Connector J20.

5. Oscillator Supply

The oscillator supply consists of f1 and f2, the two plug-in oscillators and transformer TT1, which provides 3.15 volts, 60 HZ. The two plug-in oscillators, f1 and f2 require a center tapped, 12 volt supply which is obtained from the Lambda Power Supply through a voltage divider circuit consisting of two 20 ohm resistors. The voltage outputs of the three A.C. supplies are measured by means of SS-3 and the digital voltmeter. The three current measurements are made by means of three 100 ohm precision resistors, R203, R204 and R205. It was found necessary to insert R206, a 270 ohm resistance, in series with position 4 of SS3-3 so that the 60 HZ current could be measured without momentarily short circuiting the 60 HZ supply. The need for this was caused by the fact that SS3 is a shorting type selector switch supplied by the 60 HZ power derived directly from the line; therefore even a momentary short circuit could create considerable damage. This was not necessary in the case of the 64 KHZ oscillator and the 240 KHZ oscillator, since their internal impedances are high enough to prevent large short circuit currents.

6. Lambda Power Supply

The Lambda Power Supply is provided with its own voltage and current controls and is more fully described in the Manual supplied with the unit. Switch S9 modifies the Lambda Power Supply operation from a constant voltage mode to a constant current mode. The Lambda Power Supply provides D.C. voltage for the blood pressure circuits, the oscillators, the battery charging circuit and to binding posts BP5-1 and BP5-2 for general purpose laboratory use.

7. Test Panel

The Test Panel contains all the input connectors which are cable connected to the Active Primate Simulator. These connectors are all shown on the left hand side of the wiring diagram. Connectors J1, J2 and J3 represent the head cable receptacle. Connector J4 is the head temperature connector. Connector J5 is the body leads receptacle. Connector J6 is the Voltage Regulator Test Receptacle. Connectors J7 and J8 are the blood pressure and EKG/ZPG receptacles. Connector J9 is the charger output connector. Connector J10 is the battery cell voltage connector. The 10 connectors, J1 to J10 inclusive, are all located on the Test Panel and are used to connect the Simulator via 7 cables to the Test System. The head cable connects to connectors J1, J2, J3 and J4.

8. Power Panel

The Power Panel contains devices for the control and measurement of power into the Test System. S6, the main power switch, is used to turn on A.C. power to the digital voltmeter, the Lambda Power Supply and the 60 HZ power supply which is part of the oscillator supply, S10, the auxiliary power switch, is located at the rear of the Test System cabinet and prevents 60 HZ power from arriving at the front panel where it would be in proximity to the low level signals being switched by the selector switches. This was found to be necessary to minimize stray 60 HZ pick-up.

A three ampere slow blow fuse is easily replaceable from the front panel.

Switch S9 permits the Lambda power supply to be switched from a constant voltage mode to a constant current mode.

Switch S1 switches the battery circuit from the charge to the discharge mode. The discharge function is no longer necessary since it is more convenient to use separate discharge fixtures. The discharge fixtures perform the discharge function inexpensively and efficiently and release the more expensive Test System for other uses. Push buttons S7 and S8 are the discharge and charge activating pushbuttons, respectively.

Meters M1 and M2 are used to monitor the D.C. current and voltage supplied by the Lambda Power supply. Meter M3 is an adjustable meter relay which automatically controls the battery charger. This adjustment is set at 20 volts and when the 10 cell battery reaches this value, the battery charger is automatically disconnected.

Switches S2, S3, S4 and S5 permit the user to connect the common returns and the various shield systems to chassis ground or to any desired ground circuit. Switch S2 controls the EKG shield grounding circuit. Switch S3 controls the six blood pressure shields grounding circuit. Switch S5 controls the body leads shields grounding circuit. Switch S4 controls the EKG, EEG, EMG, common returns grounding circuit.

D. Active Primate Simulator Under Test

Figure 2 shows the Active Primate Simulator under test. The Test System for the Active Primate Simulator, the Simulator and the Test Oscilloscope are shown in this figure. The various cables required to test and calibrate the Simulator can be seen in this photograph.

The DVM Input Cable connects the output of the selector switch panel to the digital voltmeter. The Keithley Amplifier Input Cable connects the output of the selector switch panel to the input of the Keithley Amplifier. When this cable is removed, the output of the selector

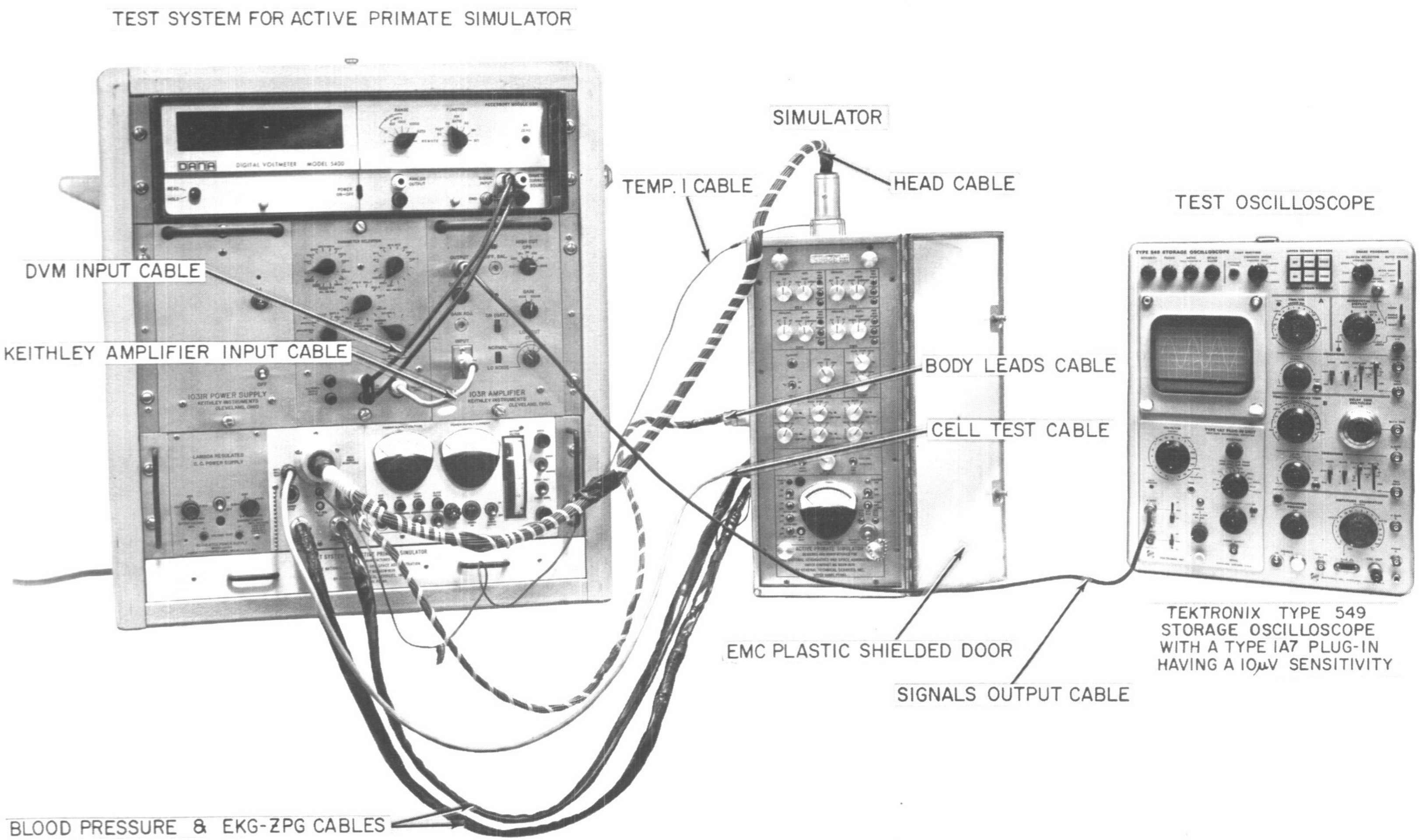


FIGURE 2
ACTIVE PRIMATE SIMULATOR
UNDER TEST

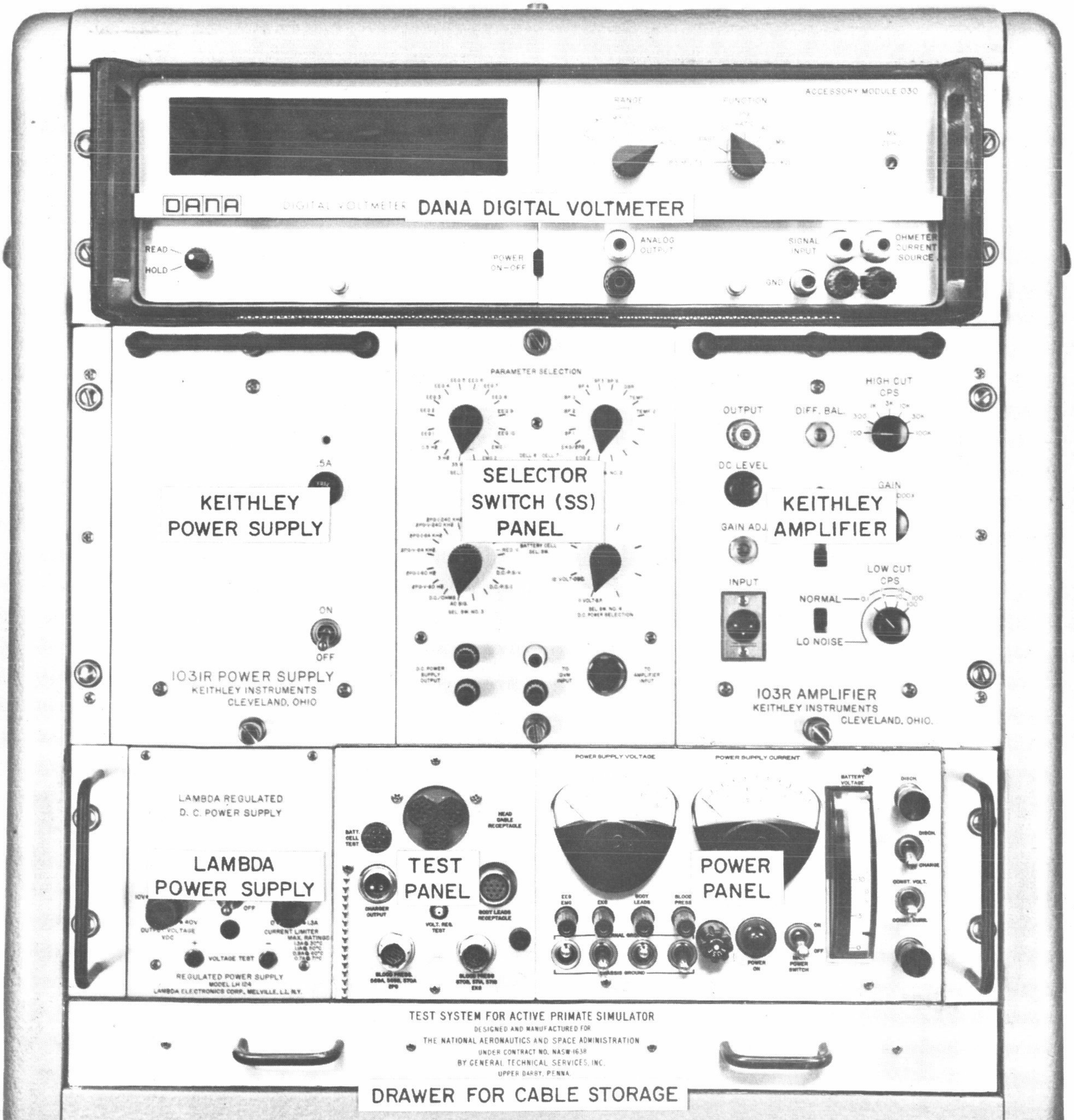


FIGURE 3
TEST SYSTEM FOR ACTIVE PRIMATE SIMULATOR

switch panel can be connected directly to the test oscilloscope. The Blood Pressure - EKG/ZPG Cables, the Temperature 1 Cable, the Head Cable, the Body Leads Cable and the Cell Test Cable are all shown connected to the Active Primate Simulator. Other cables not shown are the Voltage Regulator Test Cable and the Battery Charger Cable. The Signals Output Cable is shown connected from the output of the Keithley Amplifier to the test oscilloscope.

E. Front Panel - Test System for Active Primate Simulator (AGE)

Figure 3 shows the front panel for the Test System and its operating controls. The operating controls have been described in previous sections. The three major sections slide out on chassis slides and each individual subassembly can be removed for service. There is a drawer for storage of cables and accessories.

VI. TEST RESULTS AND OPERATING EXPERIENCE

A. EMI Tests

The following report prepared by Interference Measurements Laboratory, Inc. describes the EMI Tests that were made on the Simulator. The conclusions state that the Simulator does not radiate any perceptible radio interference and is not susceptible to RF field intensities of the order of 1 volt per meter throughout the spectrum of 15 KHZ to 400 MHZ.

INTERFERENCE MEASUREMENT LABORATORY, INC.

RADIO INTERFERENCE TEST REPORT

NO. 911

ON

SIMULATOR

GENERAL TECHNICAL SERVICES, INC.

Upper Darby, Pa.

JUNE - 1967

P.O. No. 1678

"INTERFERENCE MEASUREMENT LABORATORY, INC.

OBJECT:

The GENERAL TECHNICAL SERVICES, INC. requested the INTERFERENCE MEASUREMENT LABORATORY, INC. perform radio interference radiation and susceptibility measurements on a Simulator to determine compliance with requirements that it shall not malfunction when equipment is operating in an electromagnetic environment in the r.f. spectrum extending throughout the range of 15 KHz. to 400 MHz.

DATE AND LOCATION OF INVESTIGATION:

This investigation was conducted at the Laboratory in a screened room on 27 June 1967.

DESCRIPTION OF TEST ITEM:

Simulator — Portable - Battery Powered.

TEST INSTRUMENTS:

14 KHz. to 250 KHz.	Stoddart Radio Interference and Field Intensity Meter NM-10A	S.N. 219-15 Cal. 5/22/67
150 KHz. to 25 MHz.	Stoddart Radio Interference and Field Intensity Meter NM-20B	S.N. 185-46 Cal. 5/20/67
20 MHz. to 400 MHz.	Stoddart Radio Interference and Field Intensity Meter NM-30A	S.N. 165-60 Cal. 5/15/67

PROCEDURE:

The Simulator was placed on a copper ground plane on a table in the shielded room. The control panel of the test item was positioned facing the radiating antenna located one foot from its perimeter so that maximum r.f. field intensity would illuminate the control panel which was the most susceptible surface for r.f. leakage.

Antennae for the radio frequency field intensity instruments were located at approximately the same distance from the transmitting antenna and were oriented for maximum response on major lobe of radiation pattern. The NM-10A and NM-20B field intensity instruments were calibrated using their standard rod antennae. The NM-30A was calibrated using the standard tuned dipoles.

Measurements were made of the radiated interference emanating from the Simulator while in normal operation and also for r.f. transients which might arise during switching operations on the control panel.

During the susceptibility phase of these tests readings were taken at the calibrated frequencies recorded in the results and in addition the output waveforms were monitored to detect evidence of malfunction as the r.f. fields of the transmitters were swept through the frequency range of 15KHz. to 40 MHz.

RESULTS:

The observed data are recorded in the Tabulated Results.

CONCLUSIONS:

The Simulator does not radiate any perceptible radio interference and is not susceptible to r.f. field intensities of the order of 1 volt/m. throughout the spectrum of 15 KHz. to 400 MHz.

INTERFERENCE MEASUREMENT LABORATORY, INC.

N. I. Wolk - Director

INTERFERENCE MEASUREMENT LABORATORY, INC.

GENERAL TECHNICAL SERVICES, INC.

SIMULATOR BATTERY PORTABLE

RADIATED INTERFERENCE

Freq. - MHz.	Ambient	R.F. Transients (uvs./m)	Field Intensity (Volts/m)	O'scope
.015	10	-	0.75	-
.025	10	-	0.5	-
.04	10	-	0.12	-
.06	7	-	1	-
.16	4	-	0.5	-
.2	5	-	1	-
.25	5	-	1.25	-
.3	5	-	1	-
.5	5	-	0.5	-
1	3	-	1	-
3	2	-	0.9	-
5	2	-	0.6	-
10	1	-	0.3	-
15	1	-	0.3	-
20	1	-	0.94	-
40	1	-	0.375	-
50	1	-	0.52	-
80	1	-	0.44	-
100	1	-	0.52	-
150	1	-	0.5	-
200	1	-	0.285	-
250	1	-	0.21	-
300	1	-	0.435	-
350	1	-	0.63	-
400	1	-	0.59	-

NOTE: "-" Indicates no perceptible reading

INTERFERENCE MEASUREMENT LABORATORY, INC.

AUXILIARY INSTRUMENTS:

Oscilloscope Tektronix Type 531A S.N. 026554

Bridge Oscillator General Radio Type 1330-A S.N. 1446 5 KHz. to 50 MHz.

Signal Generator Hewlett-Packard Type 608-D S.N. 4511 10 MHz to 420 MHz."

B. Oscilloscope Tests

1. Oscillator Outputs

Figures 4, 5 and 6 are the oscillograms of the outputs of the three oscillators. The peak-to-peak values are close to the specified 2.83 volts and the wave forms are sinusoidal and of the proper frequency.

2. Noise Signal - Tektronix 1A7

Figure 7 shows the noise signal of the Tektronix 1A7 with its input grounded and with the filter set for D.C. to 100 HZ bandwidth. The peak-to-peak noise signal is observed to be 1 to 2 microvolts. This is quite close to the specified maximum allowable noise voltage of 2.5 microvolts peak-to-peak.

3. Noise Signal - Keithley 103

Figure 8 shows the noise signal voltage of the Keithley 103 with its input grounded, cascaded with the Textronix 1A7. The 103 is set for a 0.1 - 100 HZ bandwidth and a gain of 1000; the 1A7 is set for a bandwidth of DC-100 HZ. For this set of conditions a 2 microvolt peak-to-peak noise signal with a predominant frequency of the order of 180 HZ can be observed.

4. Noise Signal - 200K Metal Film Resistor (Shielded) (Tektronix 1A7)

Two 100K metal film resistors connected in series were placed in a small shielded enclosure and connected by means of shielded cable and a coaxial connector to the Tektronix 1A7 plug-in amplifier. With the 1A7 bandwidth set for D.C. - 100 HZ, a 4 microvolt peak-to-peak signal can be observed in Figure 9.

5. Noise Signal - 200K Metal Film Resistor (Shielded) (Keithley 103 into Tektronix 1A7)

Using the same shielded precision resistors as were used in Section 4 as the input signal, the noise voltage, observed in Figure 10, was 4 microvolts peak-to-peak with the Keithley 103 amplifier cascaded into the Tektronix 1A7. The noise data observed in Figures 9 and 10 will be used for comparison with the noise signals generated by the unactivated EEG channels.

6. EEG Noise Signals - Various Conditions

Figures 11, 12 and 13 are oscillograms of the EEG noise signals for various conditions including the Tektronix 1A7 alone and the Keithley 103 cascaded with the Tektronix 1A7. The magnitude of the noise voltage generated was approximately 4 microvolts peak-to-peak. This coincides almost exactly with that observed in Figures 9 and 10. Therefore the noise signals observed on the EEG channels are approximately equivalent to the noise signals observed under the ideal conditions described in Figures 9 and 10.

7. EOG Noise Signals - Various Conditions

Figures 14, 15 and 16 show the oscillograms of the noise voltages generated under various conditions by one of the EOG channels. The magnitude of the EOG noise signal was 5-6 microvolts peak-to-peak. This is considerably less than the specified limit of 30 microvolts peak-to-peak.

8. EMG Noise Signals - Various Conditions

Figures 17, 18 and 19 show the EMG Noise signals under various conditions. A noise voltage magnitude of 4-5 microvolts peak-to-peak was observed; this compares favorably with the specified value of 30 microvolts peak-to-peak.

9. EKG Noise Signal - Various Conditions

Figures 20, 21 and 22 show the EKG noise signal under various conditions. The magnitude of the EKG noise signal is in the 6-8 microvolt peak-to-peak range. This compares favorably with the specified value of 50 microvolts peak-to-peak.

10. EEG Signals - Tektronix 1A7 - Various Voltages And Frequencies

Figures 23 to 31 inclusive show the oscillograms of the EEG signal as observed directly from the Tektronix 1A7 plug-in amplifier. The three frequencies (0.5 HZ, 3.0 HZ and 35 HZ) at the three specified amplitudes (10 microvolts, 80 microvolts and 500 microvolts, peak-to-peak) are shown in Figures 23 to 31.

11. EOG Signals - Tektronix 1A7 - Various Voltages and Frequencies

Figures 32 to 40 inclusive show oscillograms of the EOG signals at the three specified frequencies of 0.5 HZ, 3.0 HZ and 35 HZ and at the three specified amplitude levels of 100 microvolts, 500 microvolts and 5000 microvolts peak-to-peak.

12. EMG Signals - Tektronix 1A7 - Various Voltages and Frequencies

Figure 41 to 49 inclusive are oscillograms of the EMG signals at the specified frequencies of 0.5 HZ, 3.0 HZ and 35 HZ and at the specified amplitudes of 100 microvolts, 1000 microvolts and 5000 microvolts peak-to-peak.

13. EKG Signals - Tektronix 1A7 - Various Voltages and Frequencies

Figures 50 to 58 inclusive are oscillograms of the EKG signals at the frequencies of 0.5 HZ, 3.0 HZ and 35 HZ and at amplitudes of 100 microvolts, 1000 microvolts and 4000 microvolts, all peak-to-peak.

14. Oscillograms of all Signals Using the Keithley 103 Cascaded with the Tektronix 1A7

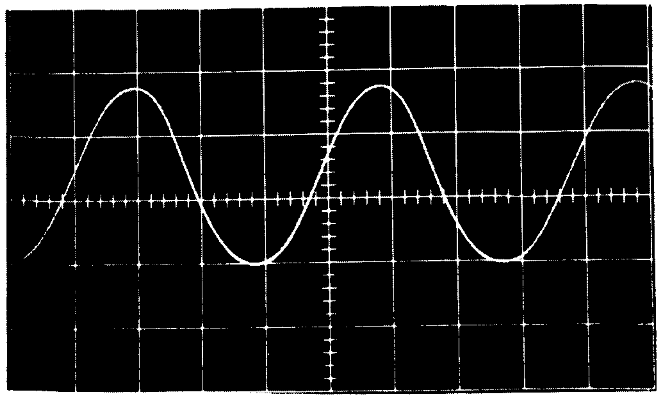
All oscillograms taken in Sections 10 to 13 were repeated using the Keithley 103 cascaded with the Tektronix 1A7. These oscillograms are shown in Figures 59 to 94 inclusive. No appreciable differences were observed.

Note: All large divisions on the following photographs of the oscilloscope reticule are centimeters.

Figure 4.

Oscillator Output
0.5 HZ

1 v/cm

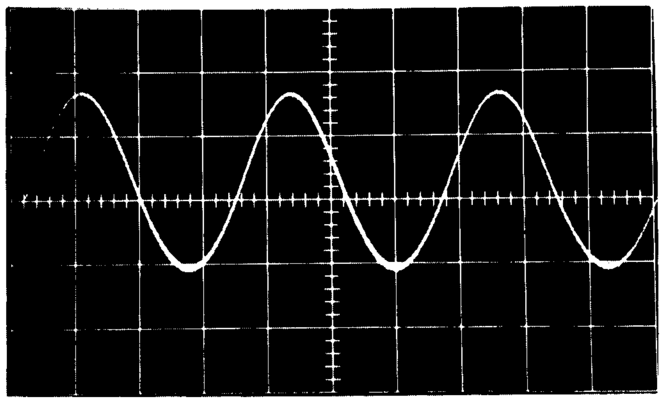


500 msec/cm

Figure 5.

Oscillator Output
3.0 HZ

1 v/cm

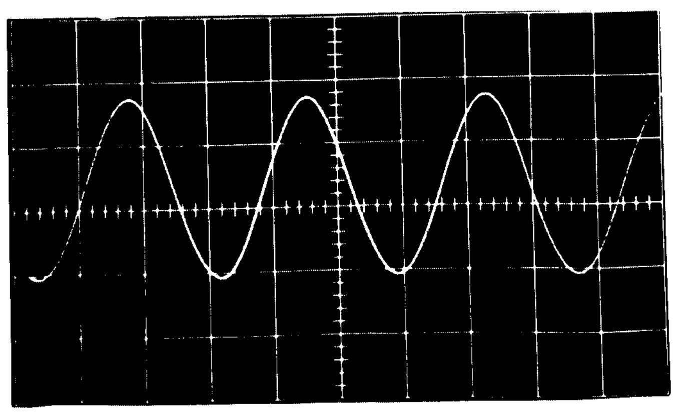


100 msec/cm

Figure 6.

Oscillator Output
35 HZ

1 v/cm

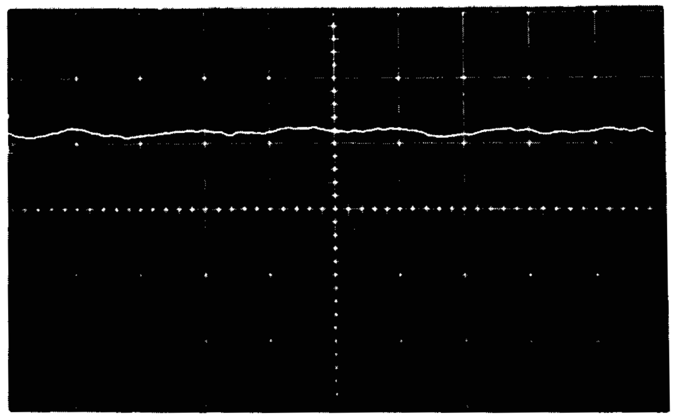


10 msec/cm

Figure 7.

Noise Signal
Tektronix 1A7
Input Grounded
1A7 (DC-100 HZ)

$10 \frac{\mu v}{cm}$

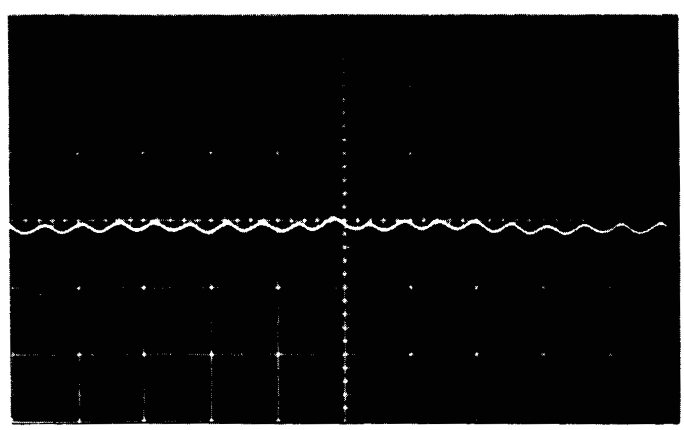


10 msec/cm

Figure 8.

Noise Signal
Keithley 103 **into**
Tektronix 1A7
Input Grounded
103 (0.1-100 HZ) (G=1000)
1A7 (DC-100 HZ) ($10 \frac{mv}{cm}$)

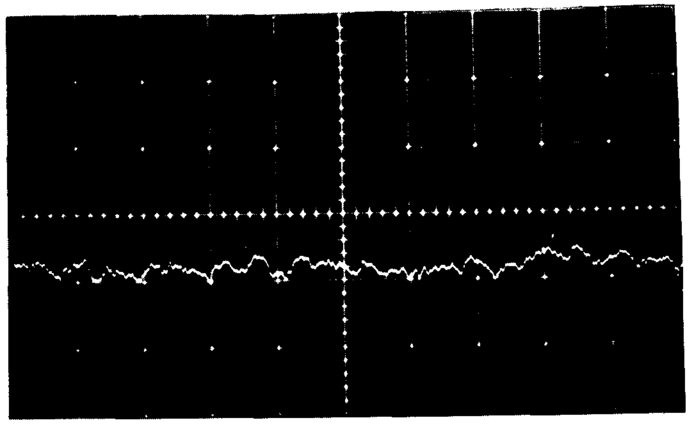
$10 \frac{\mu v}{cm}$



10 msec/cm

Figure 9.

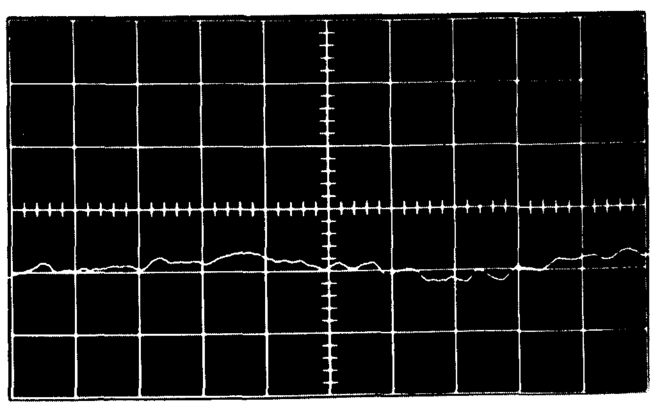
Noise Signal $10\ \frac{\mu v}{cm}$
200K Metal Film
Resistors (Shielded)
Tektronix 1A7 (DC-100 HZ)



10 msec/cm

Figure 10.

Noise Signal
200K Metal Film $10\ \frac{\mu v}{cm}$
Resistors (Shielded)
Keithley 103 into
Tektronix 1A7
1A7 (DC - 100 HZ) $(10\ \frac{mv}{cm})$
103 (0.1 - 100 HZ) (G=1000)

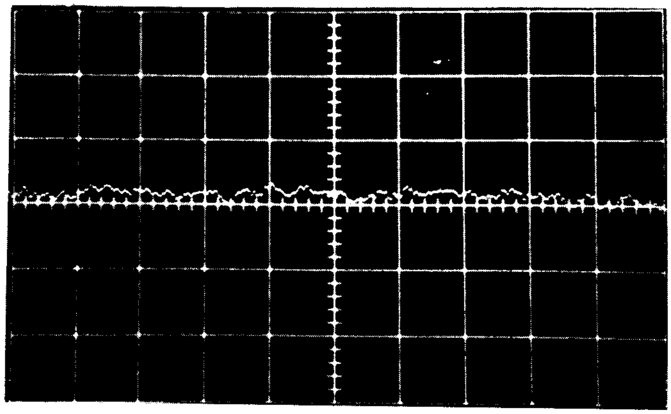


10 msec/cm

Figure 11.

EEG Noise Signal
Tektronix 1A7
1 Megohm Load
1A7 (DC - 100 HZ)

10 $\frac{\mu v}{cm}$

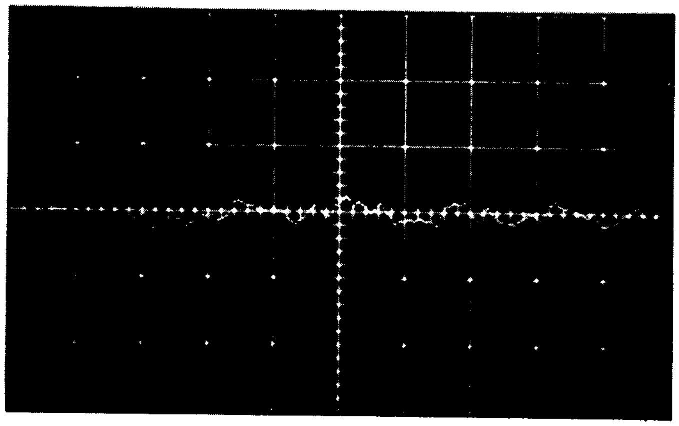


10 msec/cm

Figure 12.

EEG Noise Signal
Tektronix 1A7
2 Megohm Load
1A7 (DC - 100 HZ)

10 $\frac{\mu v}{cm}$

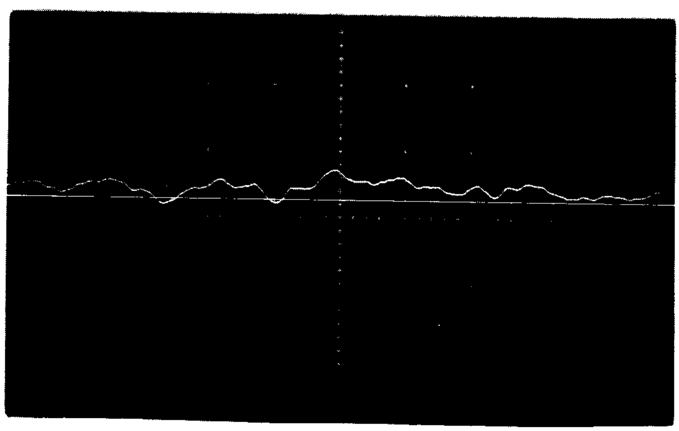


10 msec/cm

Figure 13.

EEG Noise Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) (10 $\frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G=1000)

10 $\frac{\mu v}{cm}$

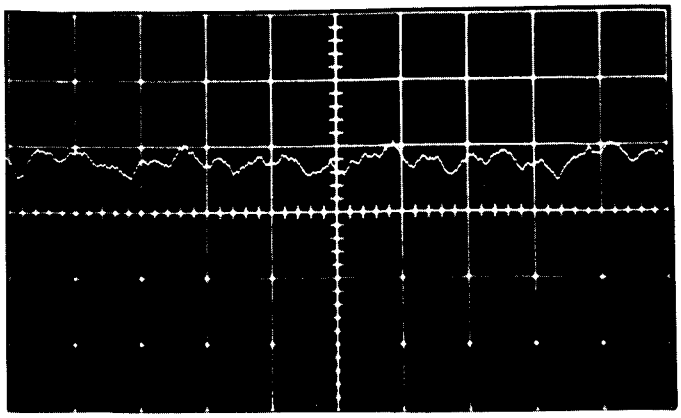


10 msec/cm

Figure 14.

EOG Noise Signal
Tektronix 1A7
1 Megohm Load
1A7 (DC - 100 HZ)

10 $\frac{\mu v}{cm}$

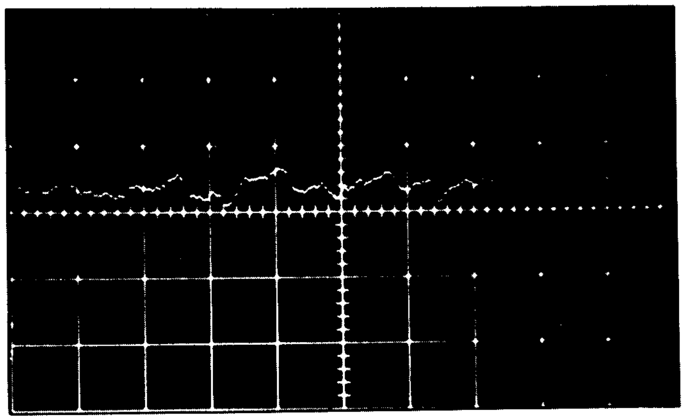


10 msec/cm

Figure 15.

EOG Noise Signal
Tektronix 1A7
2 Megohm Load
1A7 (DC - 100 HZ)

10 $\frac{\mu v}{cm}$

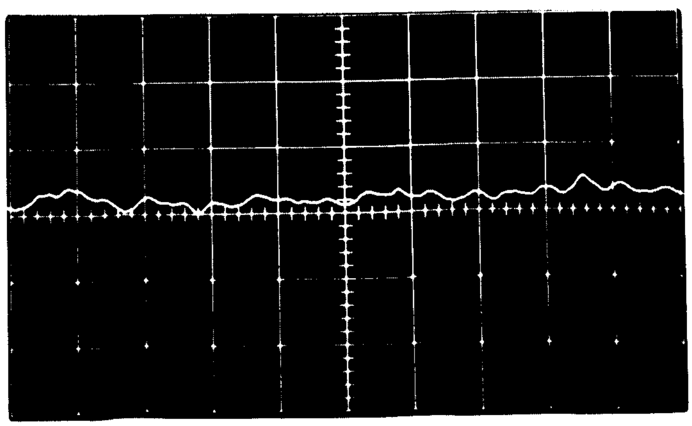


10 msec/cm

Figure 16.

EOG Noise Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ ($10 \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

10 $\frac{\mu v}{cm}$

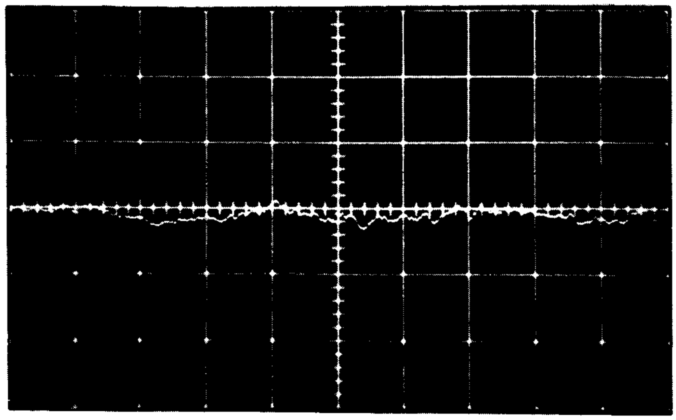


10 msec/cm

Figure 17.

EMG Noise Signal
Tektronix 1A7
1 Megohm Load
1A7 (DC - 100 HZ)

$10 \frac{\mu v}{cm}$

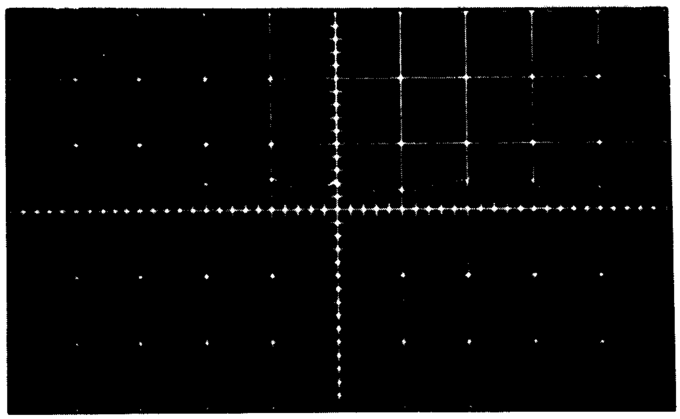


10 msec/cm

Figure 18.

EMG Noise Signal
Tektronix 1A7
2 Megohm Load
1A7 (DC - 100 HZ)

$10 \frac{\mu v}{cm}$

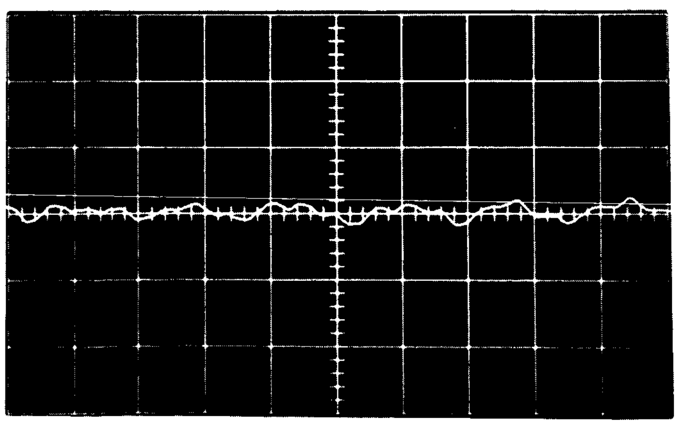


10 msec/cm

Figure 19.

EMG Noise Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($10 \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1,000)

$10 \frac{\mu v}{cm}$

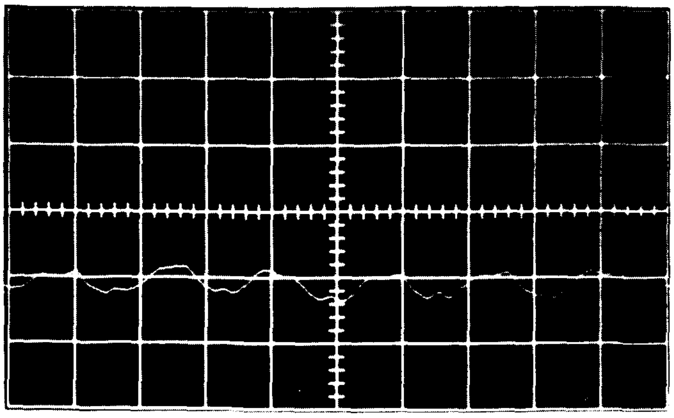


10 msec/cm

Figure 20.

EKG Noise Signal
Tektronix 1A7
251K Load
1A7 (DC - 100 HZ)

$10\ \frac{\mu v}{cm}$

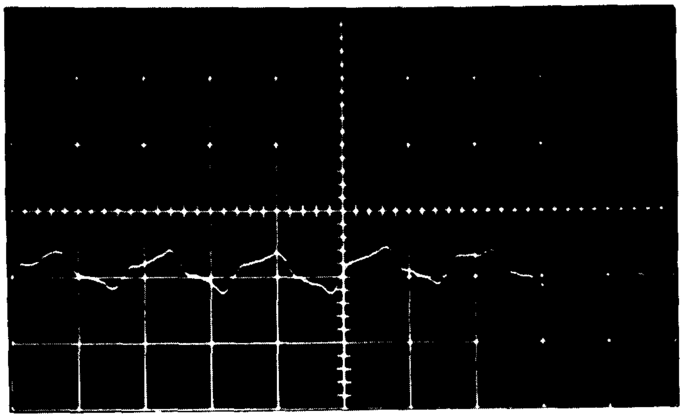


10 msec/cm

Figure 21.

EKG Noise Signal
Tektronix 1A7
2 Megohm Load
1A7 (DC - 100 HZ)

$10\ \frac{\mu v}{cm}$

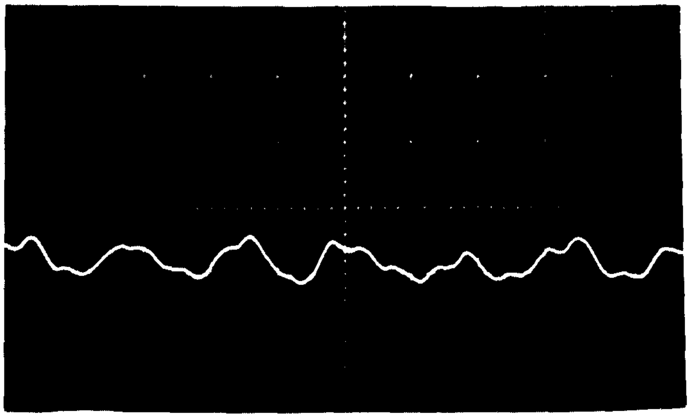


10 msec/cm

Figure 22.

EKG Noise Signal
Keithley 103 into
Tektronix 1A7 (251K Load)
1A7 (DC - 100 HZ ($10\ \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

$10\ \frac{\mu v}{cm}$

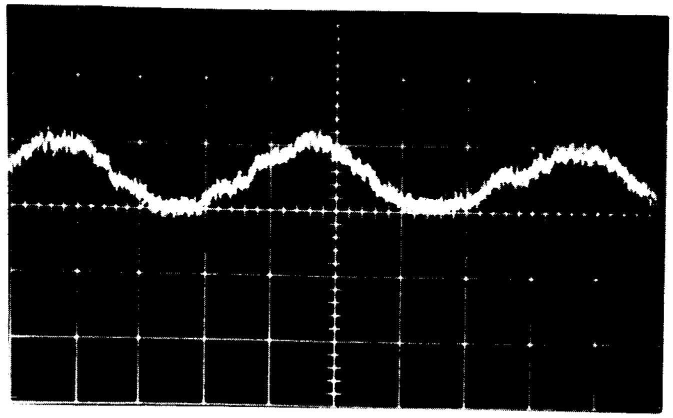


10 msec/cm

Figure 23.

EEG 0.5 HZ
10 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

10 $\frac{\mu v}{cm}$

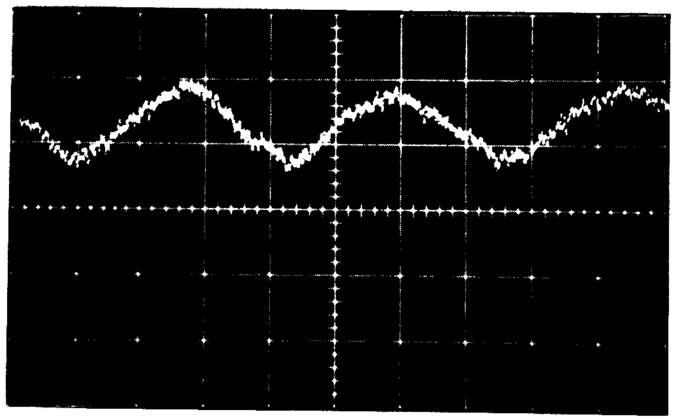


500 msec/cm

Figure 24.

EEG 3.0 HZ
10 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

10 $\frac{\mu v}{cm}$

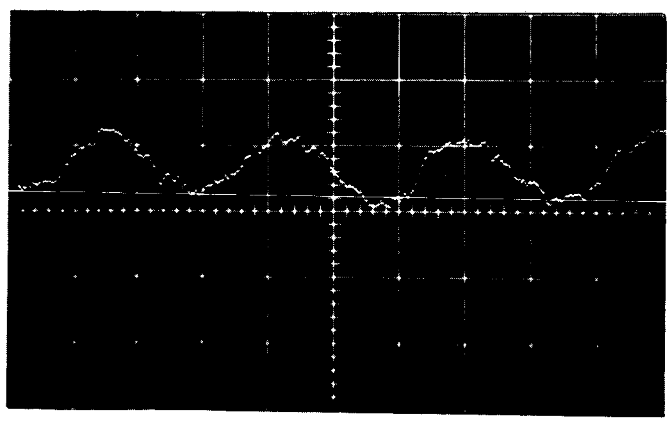


100 msec/cm

Figure 25.

EEG 35 HZ
10 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

10 $\frac{\mu v}{cm}$

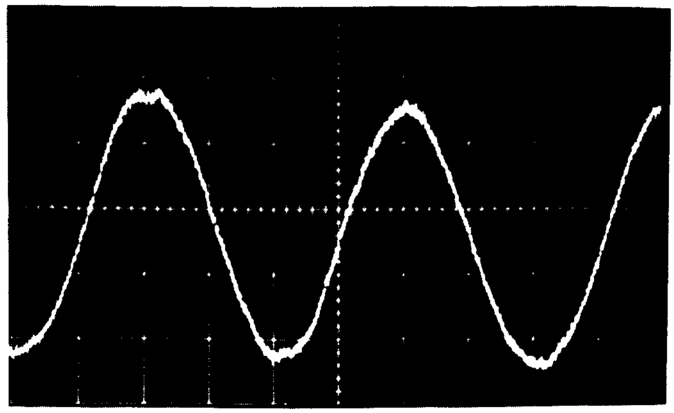


10 msec/cm

Figure 26.

EEG 0.5 HZ
80 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

20 $\frac{\mu v}{cm}$

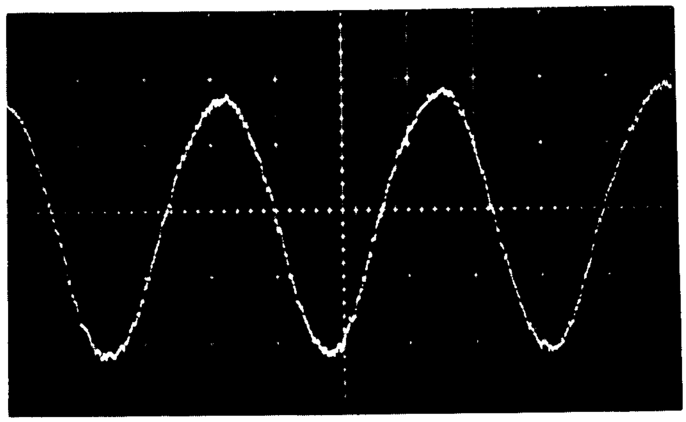


500 msec/cm

Figure 27.

EEG 3.0 HZ
80 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

20 $\frac{\mu v}{cm}$

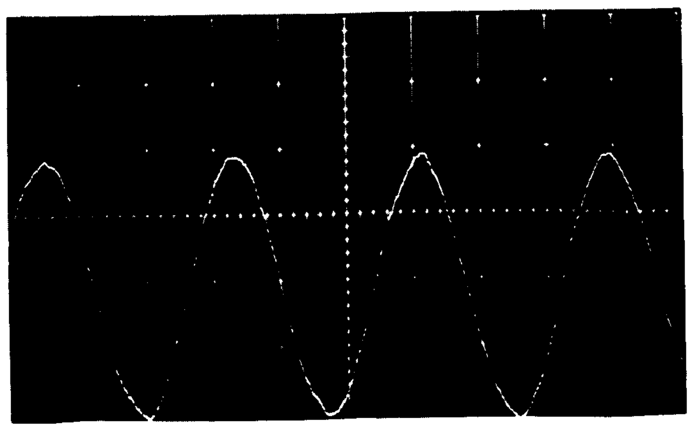


100 msec/cm

Figure 28.

EEG 35 HZ
80 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

20 $\frac{\mu v}{cm}$

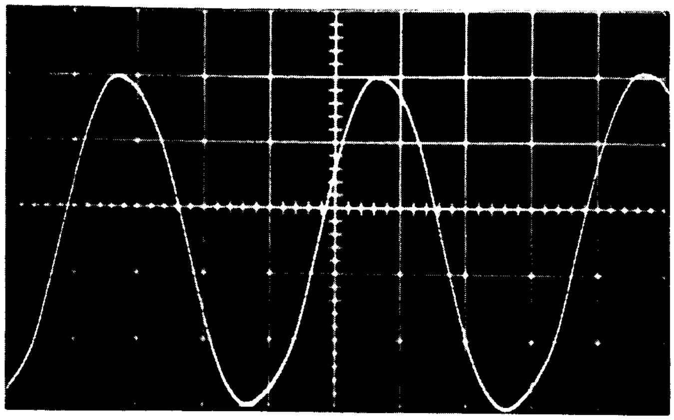


10 msec/cm

Figure 29.

EEG 0.5 HZ
500 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

100 $\frac{\mu v}{cm}$

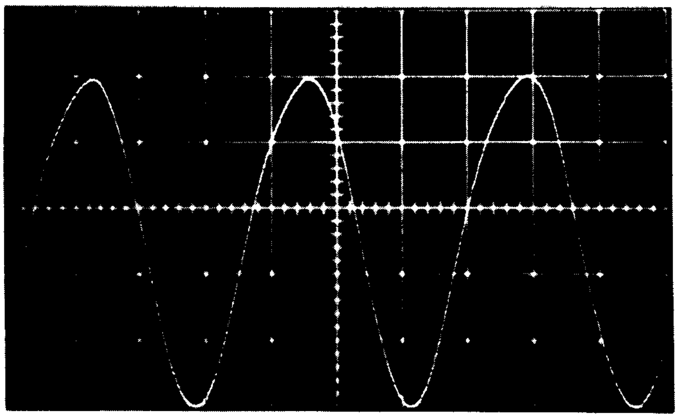


500 msec/cm

Figure 30.

EEG 3.0 HZ
500 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

100 $\frac{\mu v}{cm}$

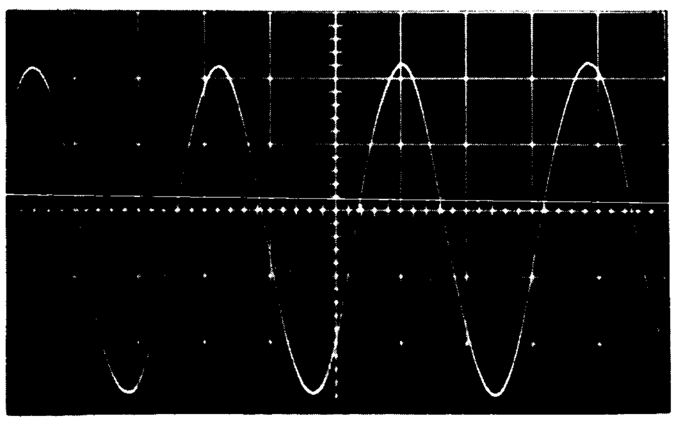


100 msec/cm

Figure 31.

EEG 35 HZ
500 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

100 $\frac{\mu v}{cm}$

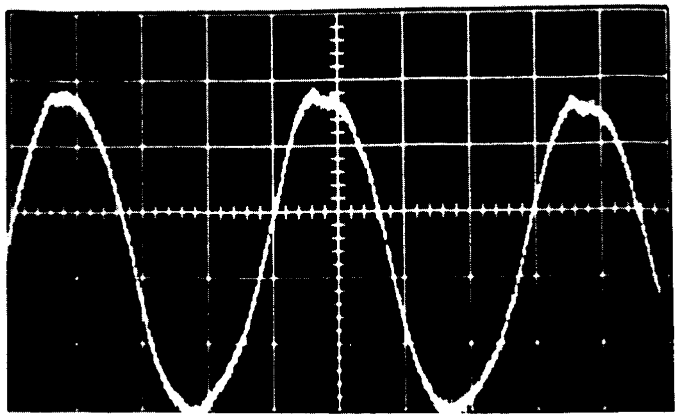


10 msec/cm

Figure 32.

EOG 0.5 HZ
100 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

20 $\frac{\mu v}{cm}$

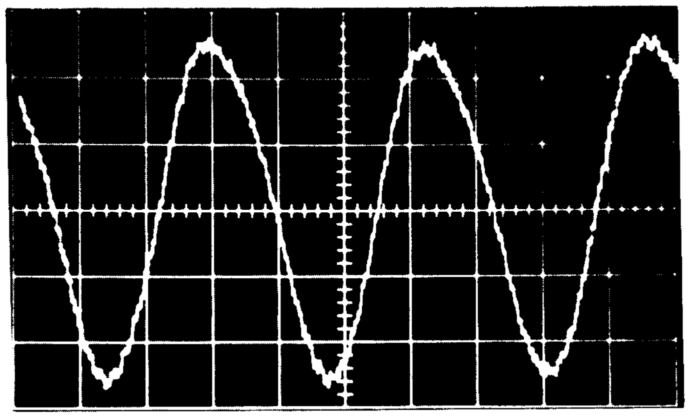


500 msec/cm

Figure 33.

EOG 3.0 HZ
100 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

20 $\frac{\mu v}{cm}$

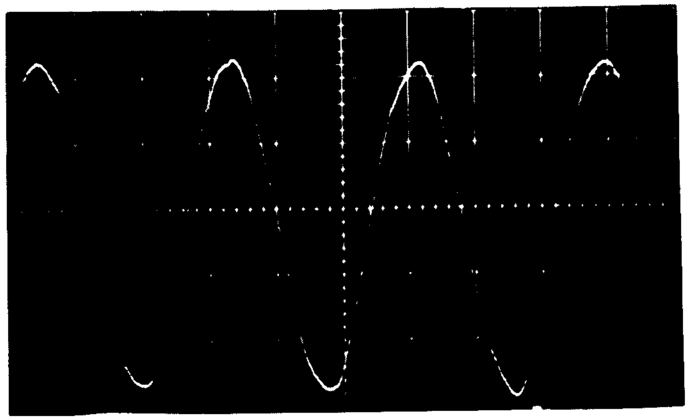


100 msec/cm

Figure 34.

EOG 35 HZ
100 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

20 $\frac{\mu v}{cm}$

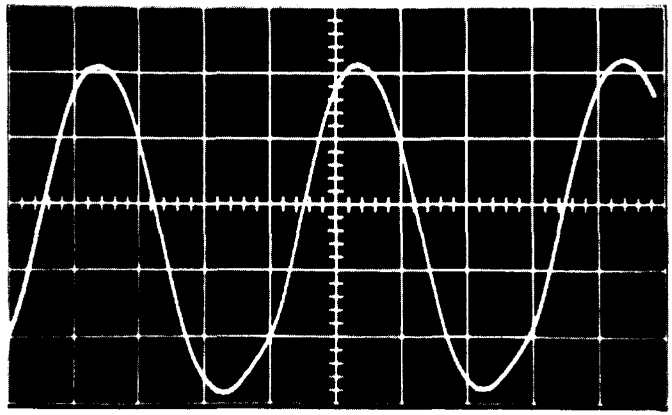


10 msec/cm

Figure 35.

EOG 0.5 HZ
500 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

100 $\frac{\mu v}{cm}$

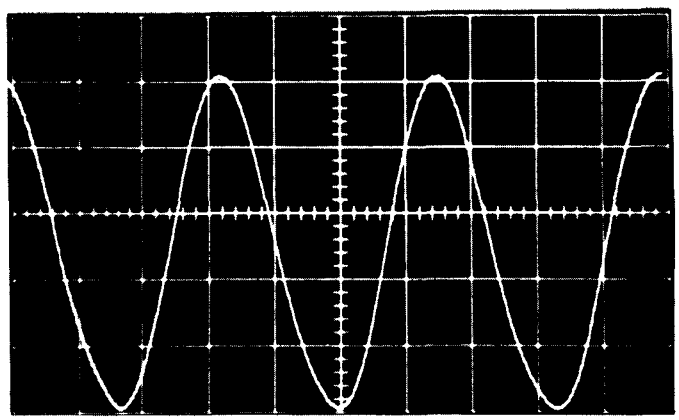


500 msec/cm

Figure 36.

EOG 3.0 HZ
500 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

100 $\frac{\mu v}{cm}$

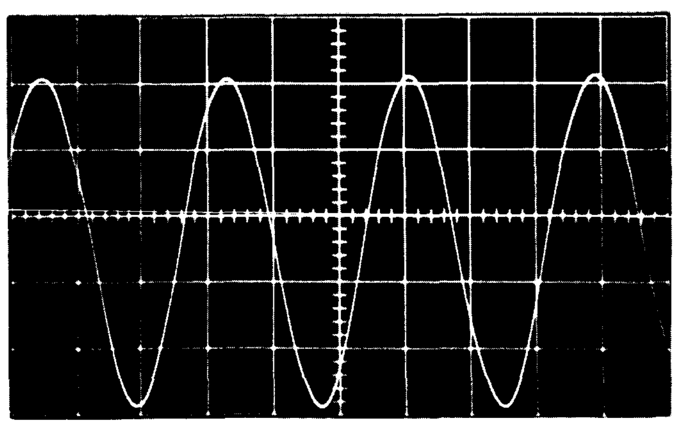


100 msec/cm

Figure 37

EOG 35 HZ
500 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

100 $\frac{\mu v}{cm}$

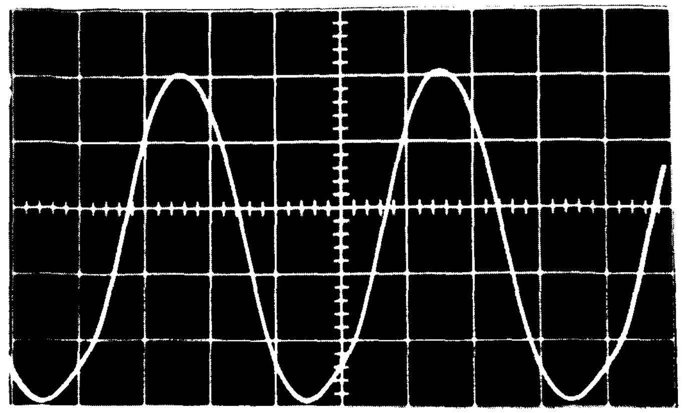


10 msec/cm

Figure 38.

EOG 0.5 HZ
5000 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

$1 \frac{mv}{cm}$

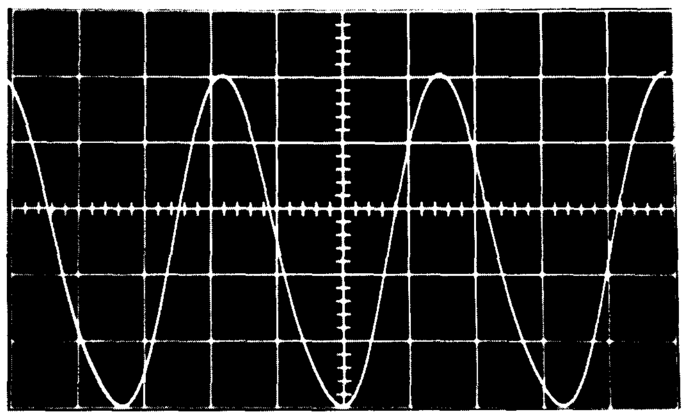


500 msec/cm

Figure 39.

EOG 3.0 HZ
5000 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

$1 \frac{mv}{cm}$

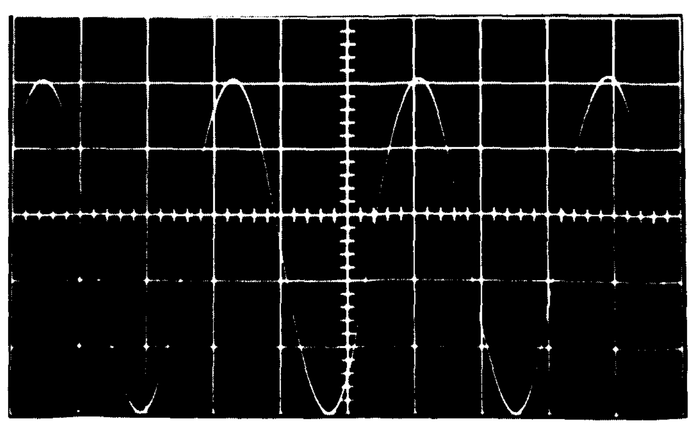


100 msec/cm

Figure 40.

EOG 35 HZ
5000 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

$1 \frac{mv}{cm}$

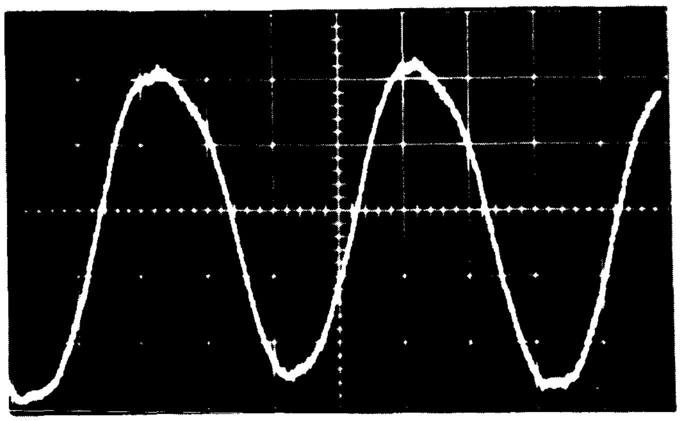


10 msec/cm

Figure 41.

EMG 0.5 HZ
100 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

20 $\frac{\mu v}{cm}$

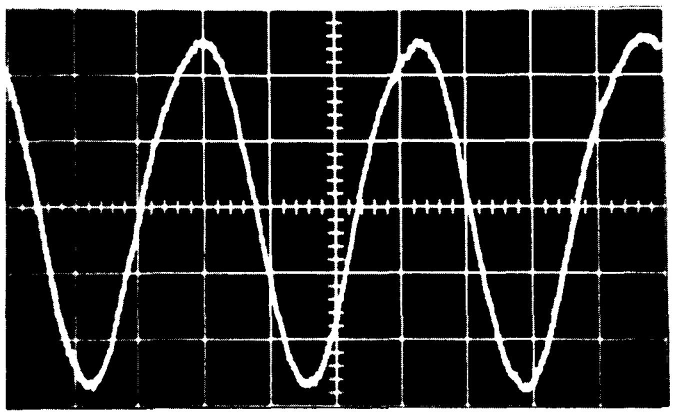


500 msec/cm

Figure 42.

EMG 3.0 HZ
100 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

20 $\frac{\mu v}{cm}$

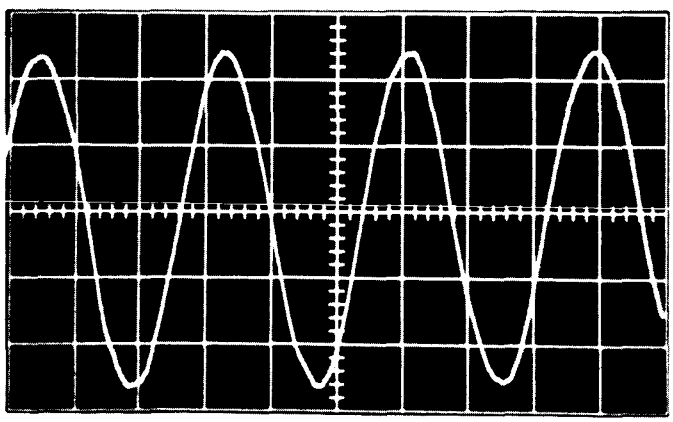


100 msec/cm

Figure 43.

EMG 35 HZ
100 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

20 $\frac{\mu v}{cm}$

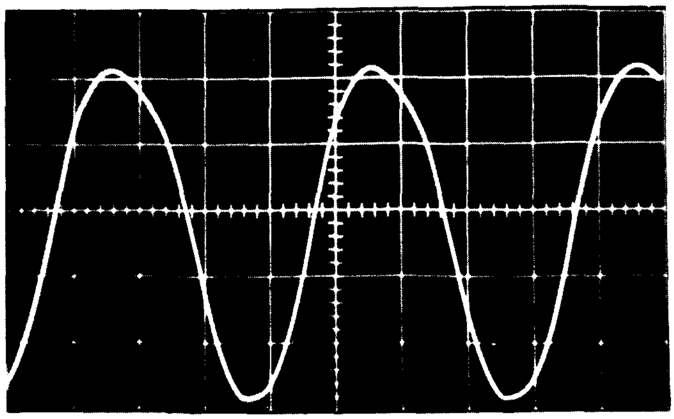


10 msec/cm

Figure 44.

EMG 0.5 HZ
1000 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

200 $\frac{\mu v}{cm}$

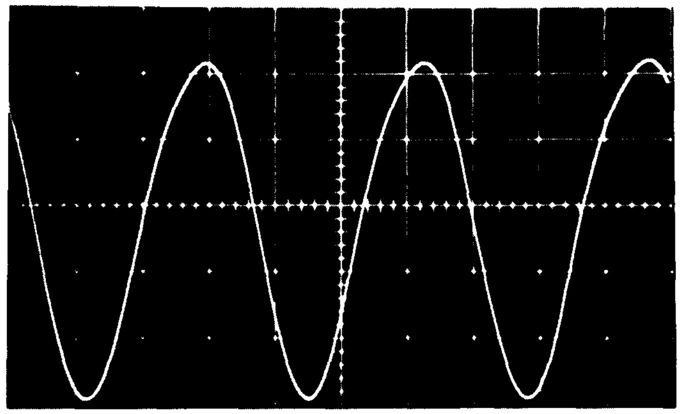


500 msec/cm

Figure 45.

EMG 3.0 HZ
1000 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

200 $\frac{\mu v}{cm}$

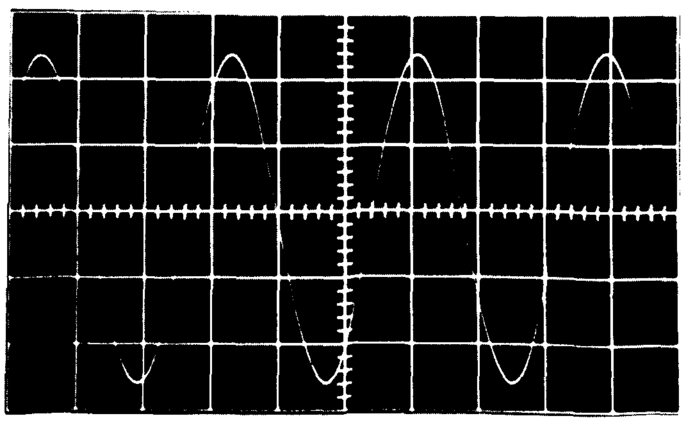


100 msec/cm

Figure 46.

EMG 35 HZ
1000 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

200 $\frac{\mu v}{cm}$

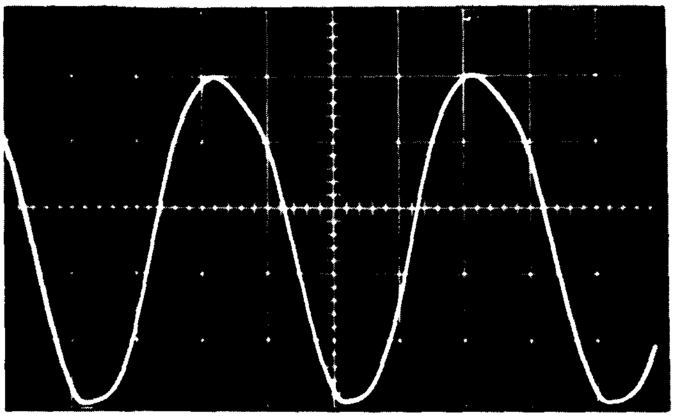


10 msec/cm

Figure 47.

EMG 0.5 HZ
5000 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

$1 \frac{mv}{cm}$

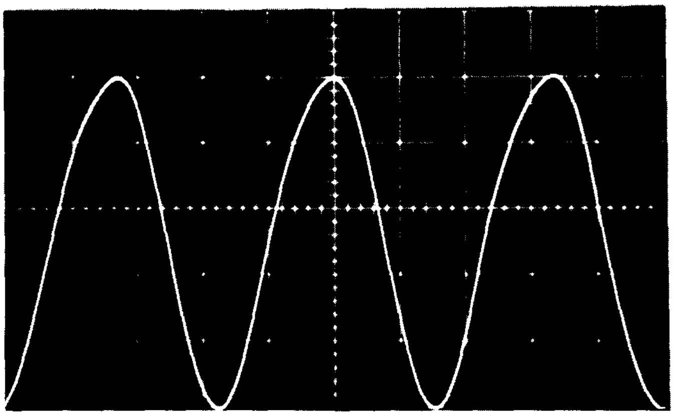


500 msec/cm

Figure 48.

EMG 3.0 HZ
5000 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

$1 \frac{mv}{cm}$

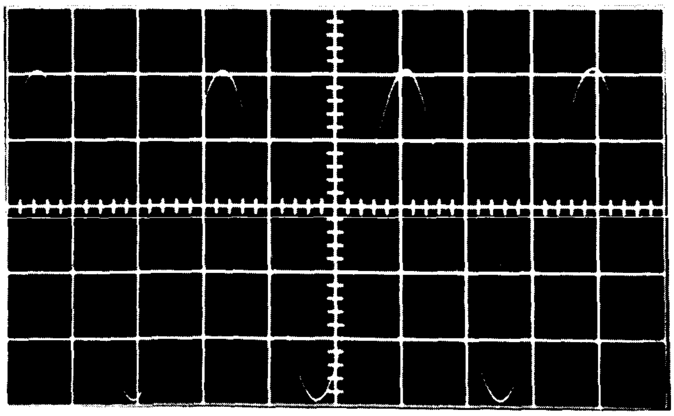


100 msec/cm

Figure 49.

EMG 35 HZ
5000 Microvolt P-P Signal
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)

$1 \frac{mv}{cm}$

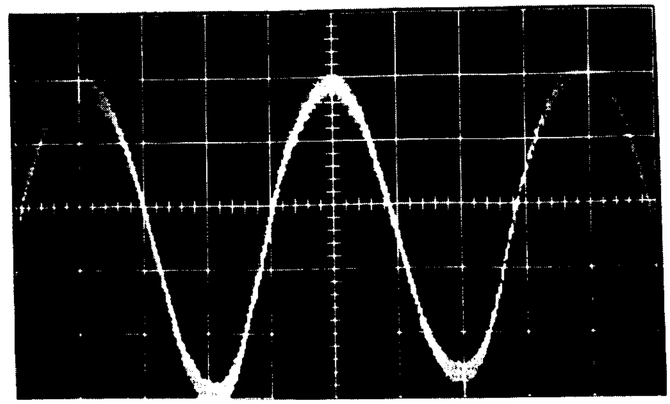


10 msec/cm

Figure 50.

EKG 0.5 HZ
100 Microvolt P-P Signal
Tektronix 1A7 (251K Load)
1A7 (DC - 100 HZ)

20 $\frac{\mu v}{cm}$

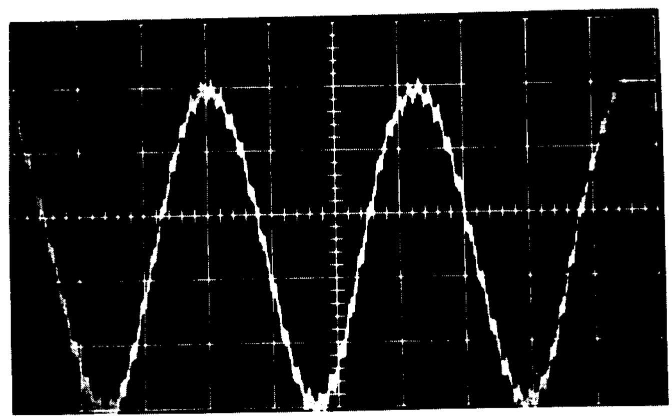


500 msec/cm

Figure 51.

EKG 3.0 HZ
100 Microvolt P-P Signal
Tektronix 1A7 (251K Load)
1A7(DC - 100 HZ)

20 $\frac{\mu v}{cm}$

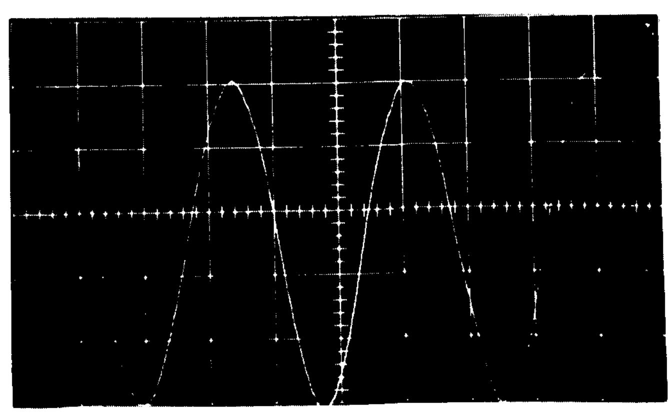


100 msec/cm

Figure 52.

EKG 35 HZ
100 Microvolt P-P Signal
Tektronix 1A7 (251K Load)
1A7 (DC - 100 HZ)

20 $\frac{\mu v}{cm}$

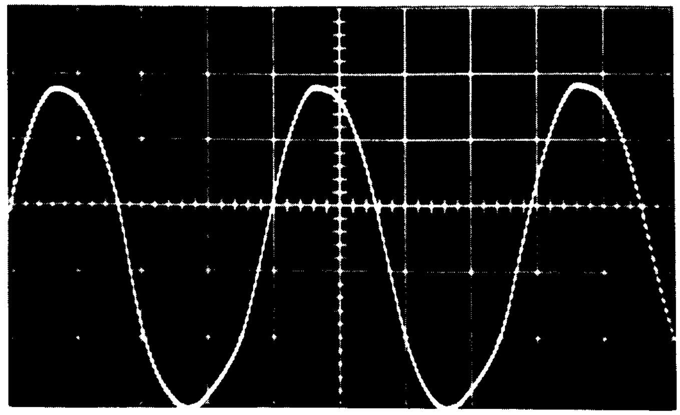


10 msec/cm

Figure 53.

EKG 0.5 HZ
1000 Microvolt P-P Signal
Tektronix 1A7 (251K Load)
1A7 (DC - 100 HZ)

200 $\frac{\mu v}{cm}$

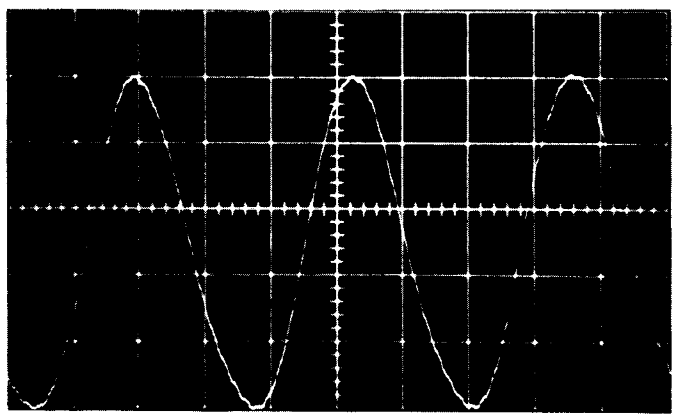


500 msec/cm

Figure 54.

EKG 3.0 HZ
1000 Microvolt P-P Signal
Tektronix 1A7 (251K Load)
1A7 (DC - 100 HZ)

200 $\frac{\mu v}{cm}$

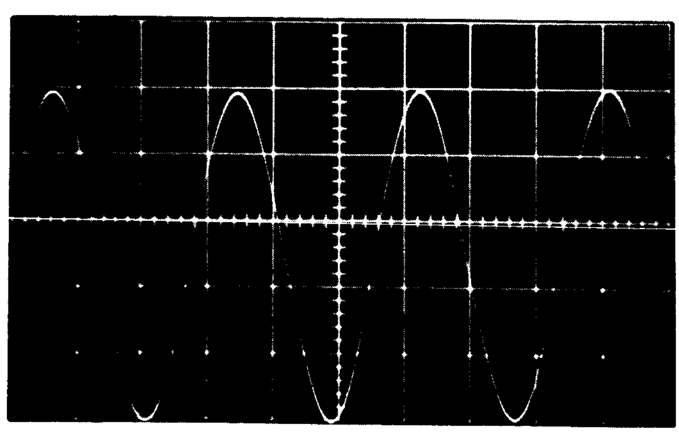


100 msec/cm

Figure 55.

EKG 35 HZ
1000 Microvolt P-P Signal
Tektronix 1A7 (251K Load)
1A7 (DC - 100 HZ)

200 $\frac{\mu v}{cm}$

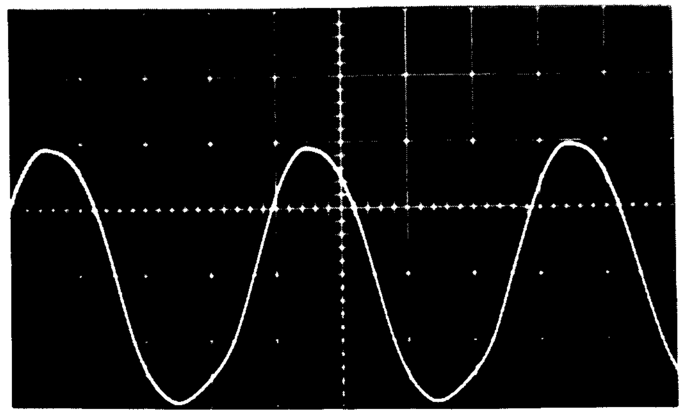


10 msec/cm

Figure 56.

EKG 0.5 HZ
4000 Microvolt P-P Signal
Tektronix 1A7 (251K Load)
1A7 (DC - 100 HZ)

1 $\frac{mv}{cm}$

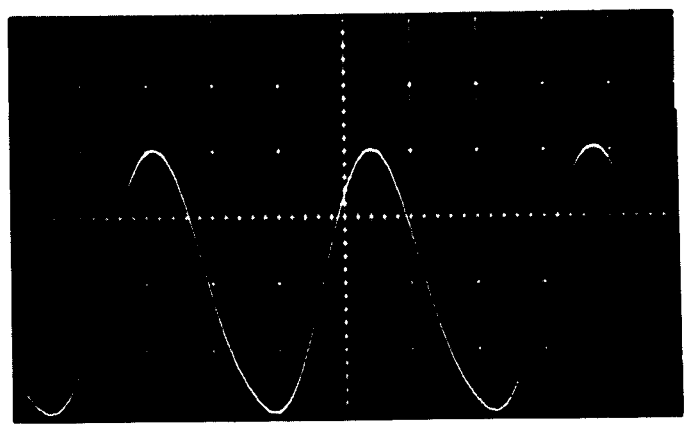


500 msec/cm

Figure 57.

EKG 3.0 HZ
4000 Microvolt P-P Signal
Tektronix 1A7 (251K Load)
1A7 (DC - 100 HZ)

1 $\frac{mv}{cm}$

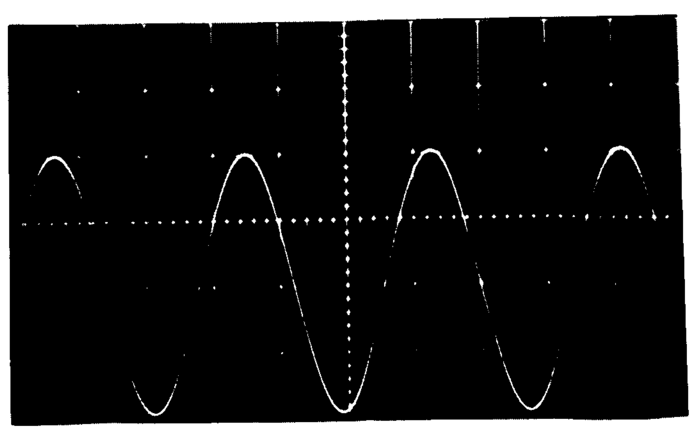


100 msec/cm

Figure 58.

EKG 35 HZ
4000 Microvolt P-P Signal
Tektronix 1A7 (251K Load)
1A7 (DC - 100 HZ)

1 $\frac{mv}{cm}$

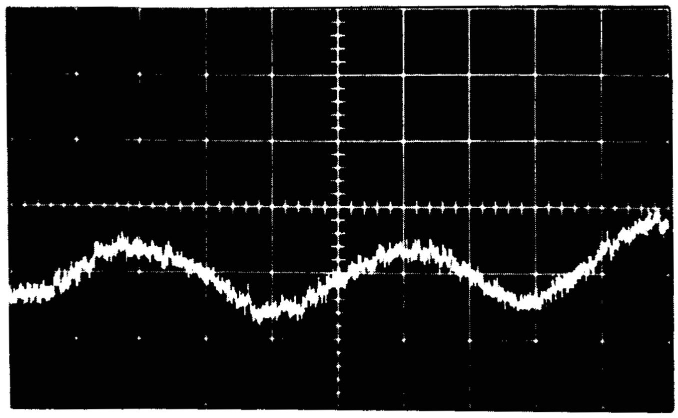


10 msec/cm

Figure 59.

EEG 0.5 HZ
10 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($10\ \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

$10\ \frac{\mu v}{cm}$

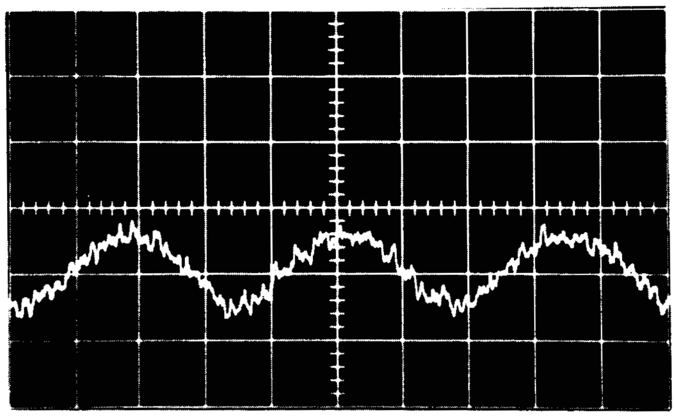


500 msec/cm

Figure 60.

EEG 3.0 HZ
10 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ ($10\ \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

$10\ \frac{\mu v}{cm}$

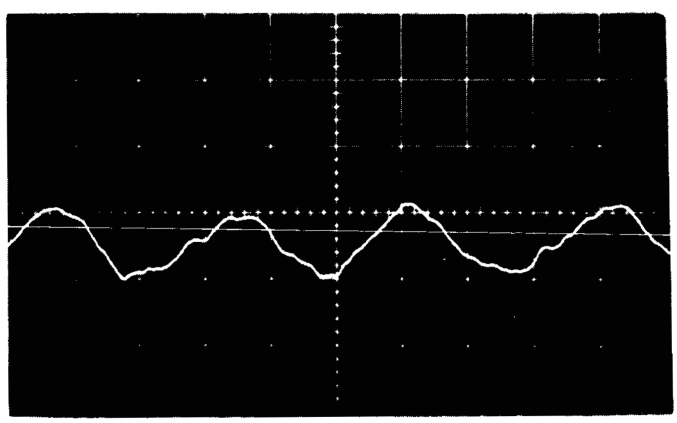


100 msec/cm

Figure 61.

EEG 35 HZ
10 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($10\ \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

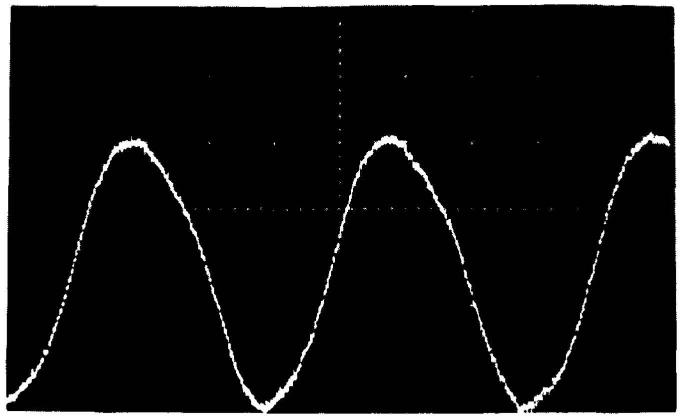
$10\ \frac{\mu v}{cm}$



10 msec/cm

Figure 62.

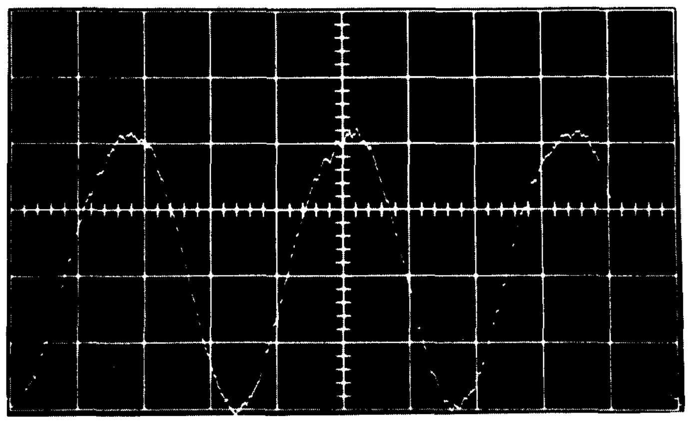
EEG 0.5 HZ $20 \frac{\mu v}{cm}$
80 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($20 \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)



500 msec/cm

Figure 63.

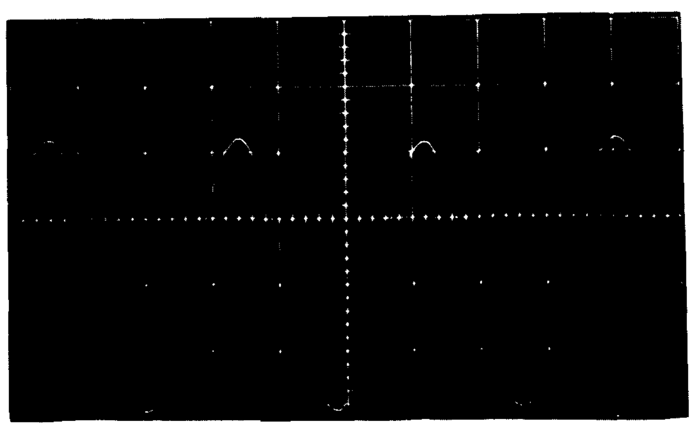
EEG 3.0 HZ $20 \frac{\mu v}{cm}$
80 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($20 \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)



100 msec/cm

Figure 64.

EEG 35 HZ $20 \frac{\mu v}{cm}$
80 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($20 \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

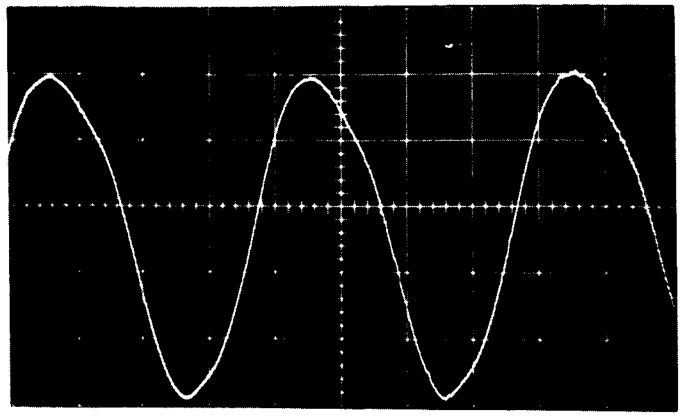


10 msec/cm

Figure 65.

100 $\frac{\mu v}{cm}$

EEG 0.5 HZ
500 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($100\ \frac{mv}{cm}$)
103 (0.1- 100 HZ) (G = 1000)

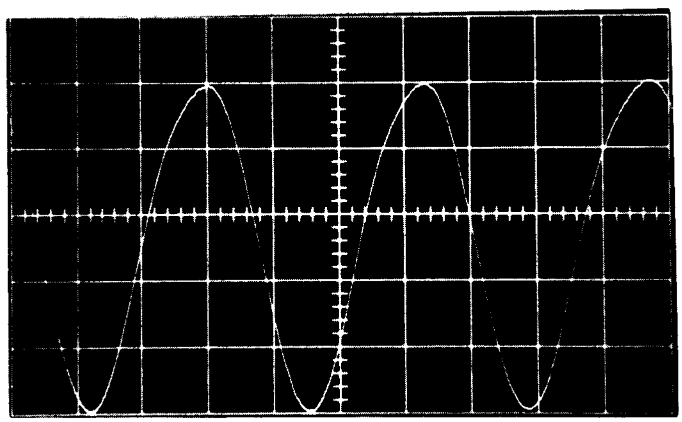


500 msec/cm

Figure 66.

100 $\frac{\mu v}{cm}$

EEG 3.0 HZ
500 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ)($100\ \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

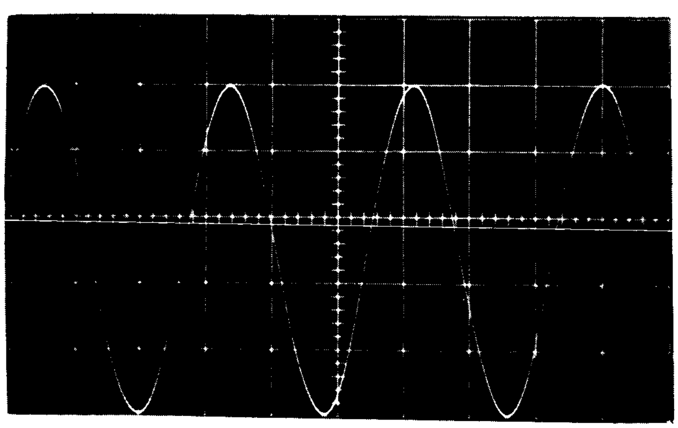


100 msec/cm

Figure 67.

100 $\frac{\mu v}{cm}$

EEG 35 HZ
500 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ ($100\ \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

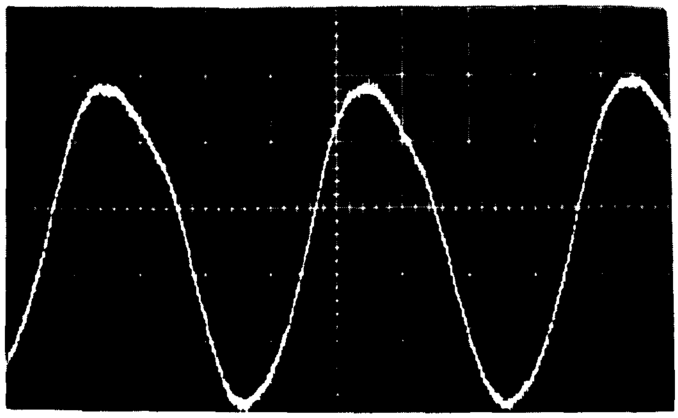


10 msec/cm

Figure 68.

$20\ \frac{\mu v}{cm}$

EOG 0.5 HZ
100 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($20\ \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

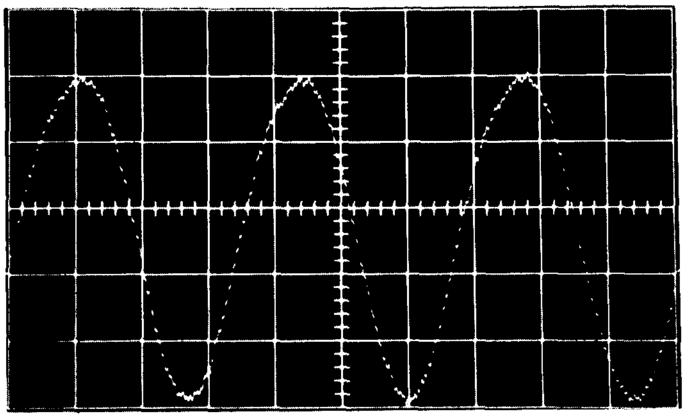


500 msec/cm

Figure 69.

$20\ \frac{\mu v}{cm}$

EOG 3.0 HZ
100 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC-100 HZ)($20\ \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

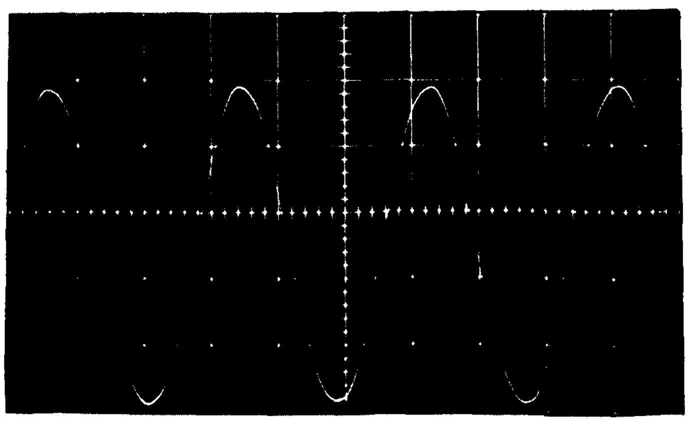


100 msec/cm

Figure 70.

$20\ \frac{\mu v}{cm}$

EOG 35 HZ
100 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($20\ \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1,000)

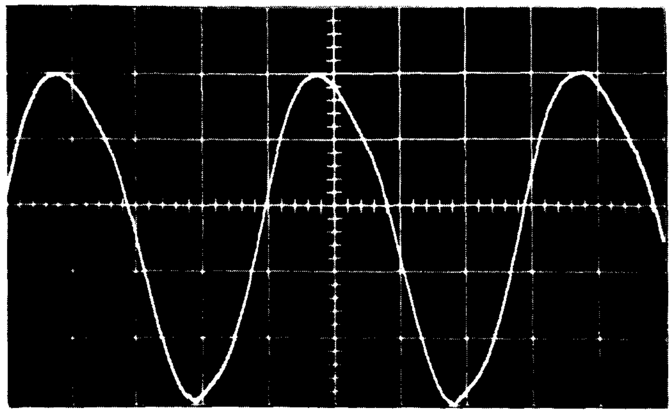


10 msec/cm

Figure 71.

EOG 0.5 HZ
500 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($100\ \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

$100\ \frac{\mu v}{cm}$

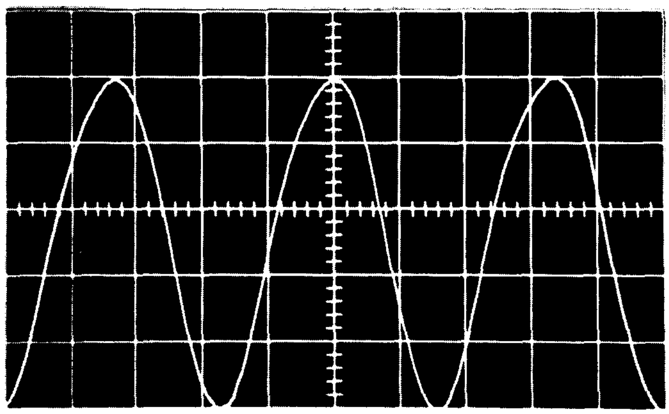


500 msec/cm

Figure 72.

EOG 3.0 HZ
500 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($100\ \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G= 1000)

$100\ \frac{\mu v}{cm}$

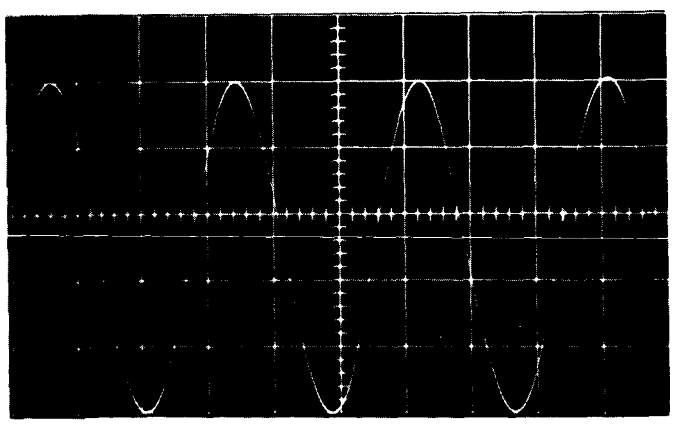


100 msec/cm

Figure 73.

EOG 35 HZ
500 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($100\ \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

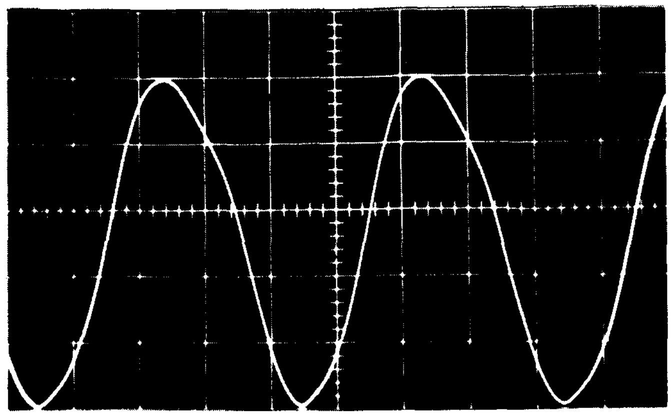
$100\ \frac{\mu v}{cm}$



10 msec/cm

Figure 74.

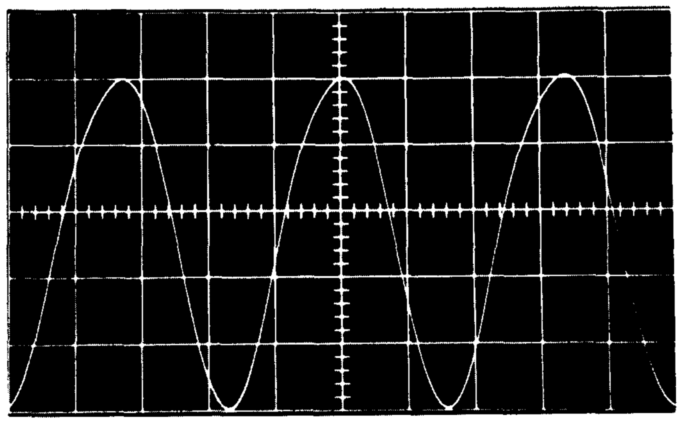
EOG 0.5 HZ $1 \frac{mv}{cm}$
5000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) $(1 \frac{v}{cm})$
103 (0.1 - 100 HZ) (G = 1000)



500 msec/cm

Figure 75.

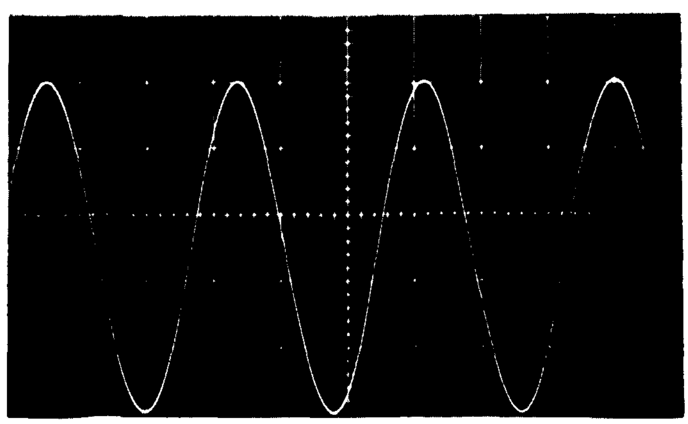
EOG 3.0 HZ $1 \frac{mv}{cm}$
5000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) $(1 \frac{v}{cm})$
103 (0.1 - 100 HZ) (G = 1000)



100 msec/cm

Figure 76.

EOG 35 HZ $1 \frac{mv}{cm}$
5000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) $(1 \frac{v}{cm})$
103 (0.1 - 100 HZ) (G = 1000)

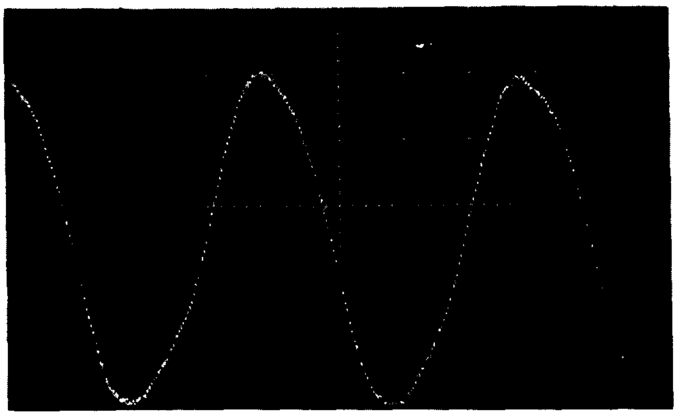


10 msec/cm

Figure 77.

EMG 0.5 HZ
100 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) (20 $\frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

20 $\frac{\mu v}{cm}$

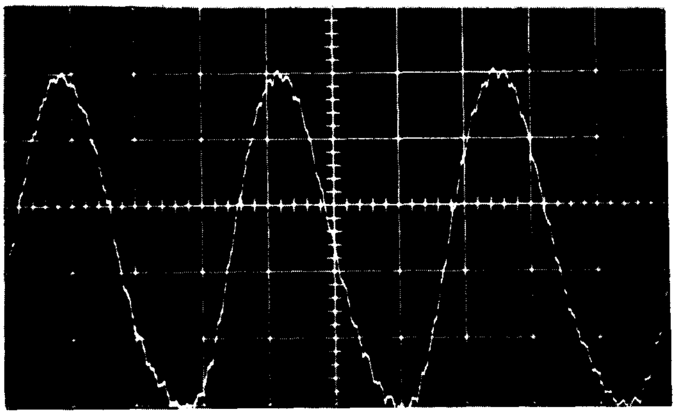


500 msec/cm

Figure 78.

EMG 3.0 HZ
100 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ (20 $\frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

20 $\frac{\mu v}{cm}$

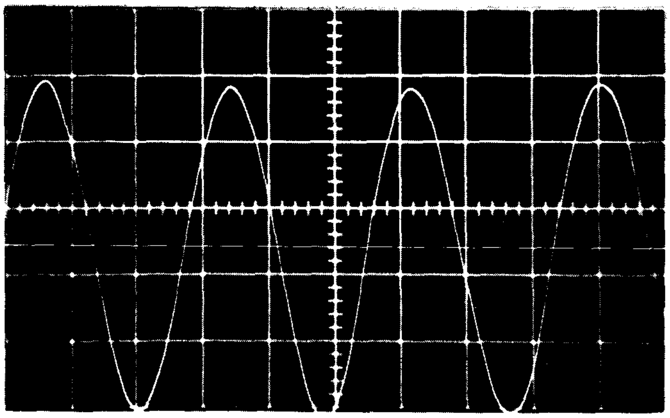


100 msec/cm

Figure 79.

EMG 35 HZ
100 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) (20 $\frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G=1000)

20 $\frac{\mu v}{cm}$

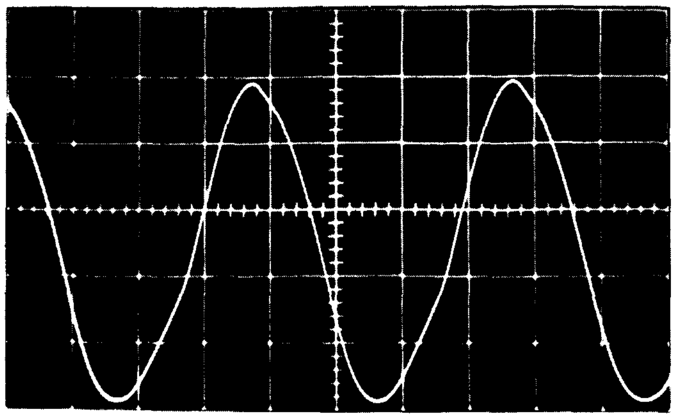


10 msec/cm

Figure 80.

EMG 0.5 HZ
1000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) (200 $\frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

200 $\frac{\mu v}{cm}$

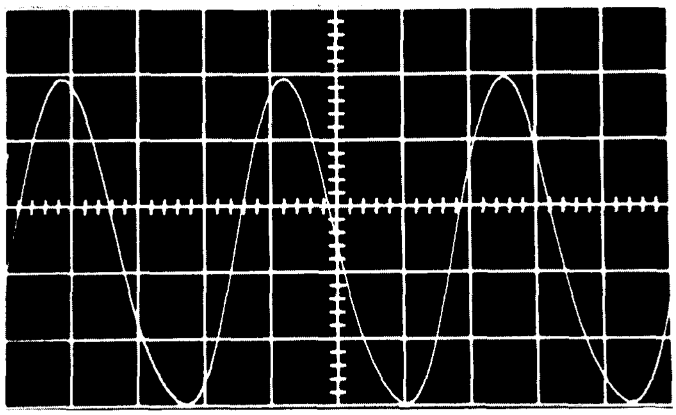


500 msec/cm

Figure 81.

EMG 3.0 HZ
1000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) (200 $\frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

200 $\frac{\mu v}{cm}$

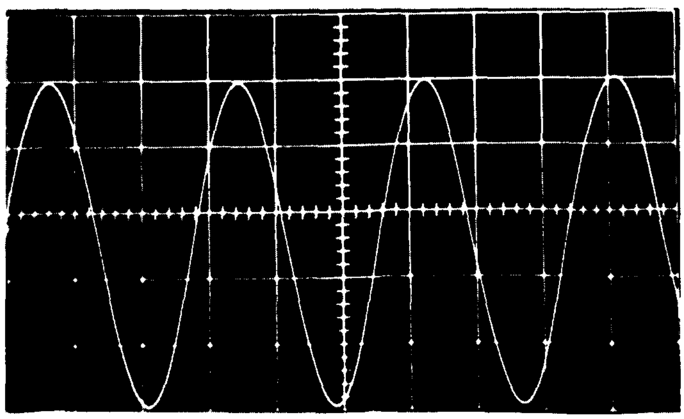


100 msec/cm

Figure 82.

EMG 35 HZ
1000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) (200 $\frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

200 $\frac{\mu v}{cm}$

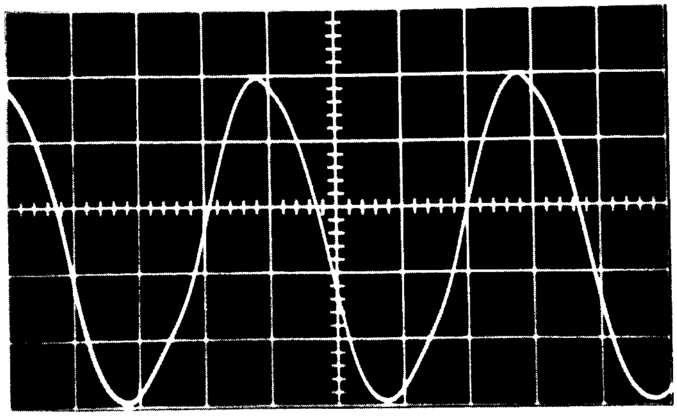


10 msec/cm

Figure 83.

EMG 0.5 HZ
5000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($1 \frac{v}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

$1 \frac{mv}{cm}$

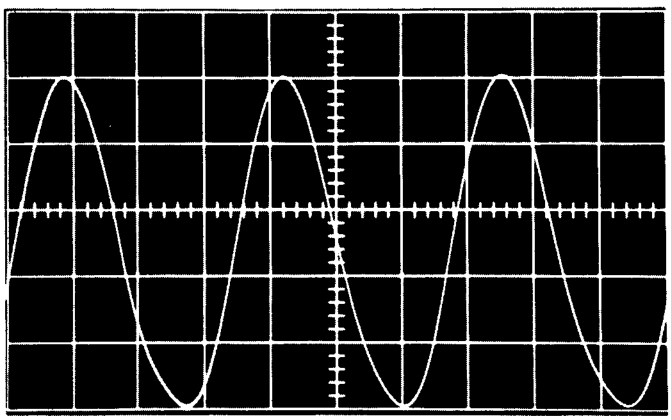


500 msec/cm

Figure 84.

EMG 3.0 HZ
5000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($1 \frac{v}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

$1 \frac{mv}{cm}$

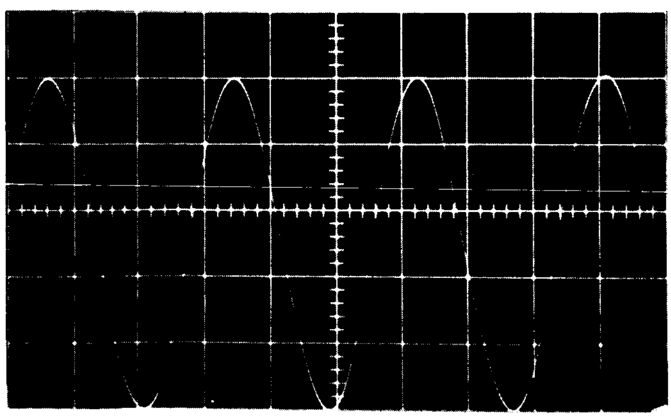


100 msec/cm

Figure 85.

EMG 35 HZ
5000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (1 Megohm Load)
1A7 (DC - 100 HZ) ($1 \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

$1 \frac{mv}{cm}$

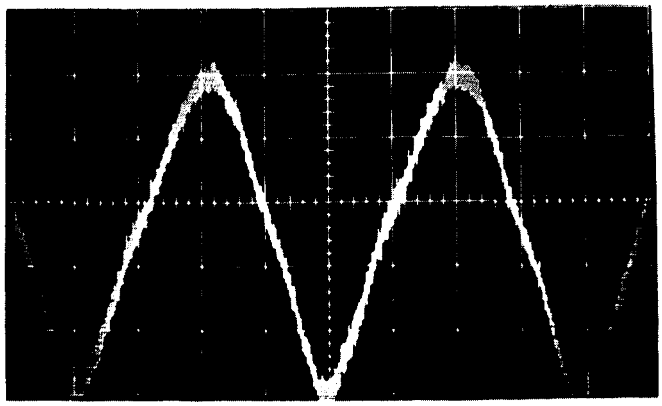


10 msc/cm

Figure 86.

$20 \frac{\mu v}{cm}$

EKG 0.5 HZ
100 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (251K Load)
1A7 (DC - 100 HZ ($20 \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

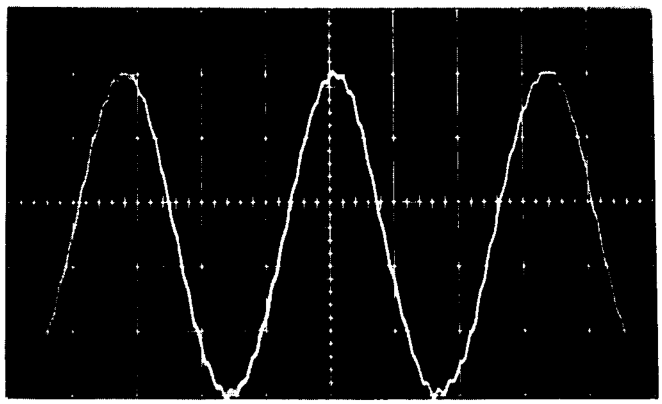


500 msec/cm

Figure 87.

$20 \frac{\mu v}{cm}$

EKG 3.0 HZ
100 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (251 K Load)
1A7 (DC - 100 HZ) ($20 \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

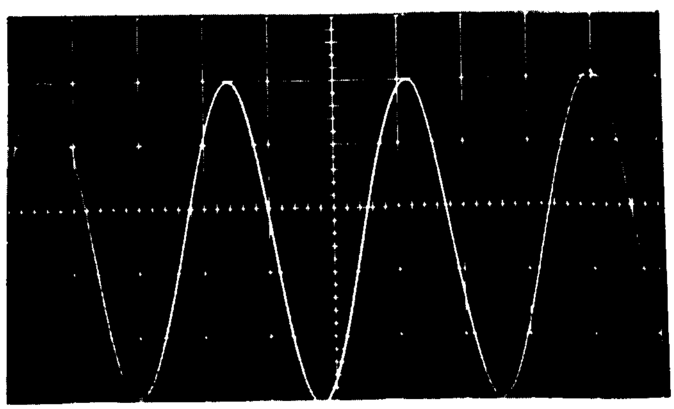


100 msec/cm

Figure 88.

$20 \frac{\mu v}{cm}$

EKG 35 HZ
100 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (251 K Load)
1A7 (DC - 100 HZ) ($20 \frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

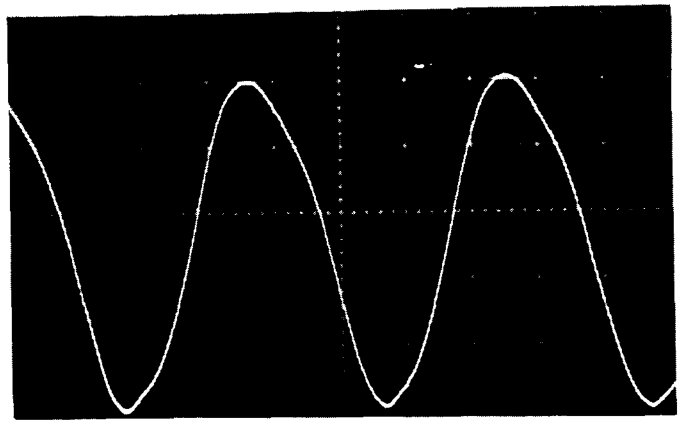


10 msec/cm

Figure 89.

EKG 0.5 HZ
1000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (251 K Load)
1A7 (DC - 100 HZ) (200 $\frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

200 $\frac{\mu v}{cm}$

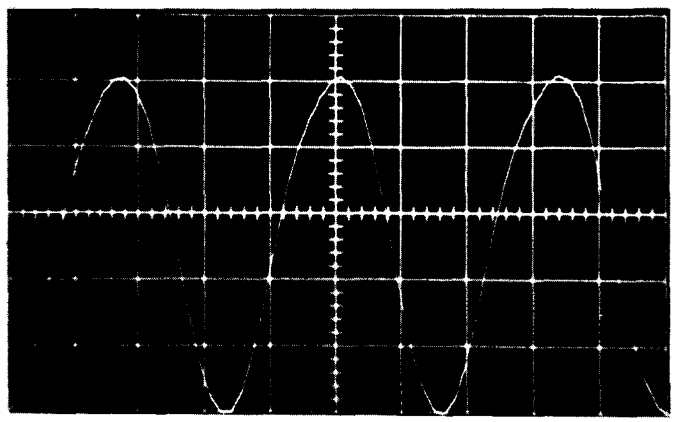


500 msec/cm

Figure 90.

EKG 3.0 HZ
1000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (251 K Load)
1A7 (DC - 100 HZ)(200 $\frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

200 $\frac{\mu v}{cm}$

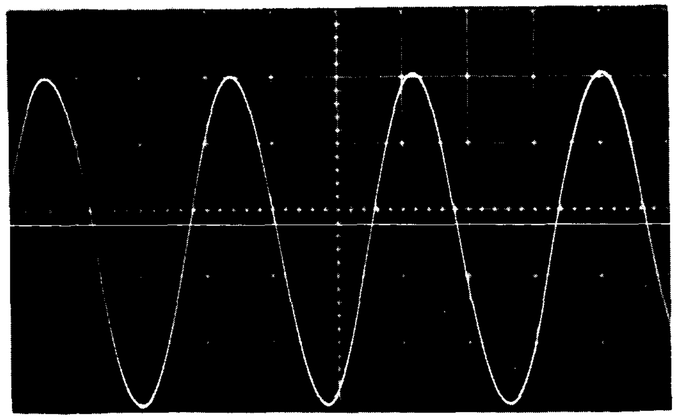


100 msec/cm

Figure 91.

EKG 35 HZ
1000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (251K Load)
1A7 (DC - 100 HZ) (200 $\frac{mv}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

200 $\frac{\mu v}{cm}$

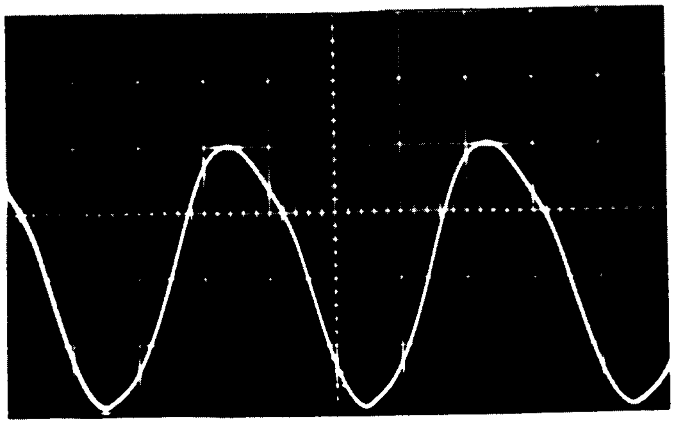


10 msec/cm

Figure 92.

EKG 0.5 HZ
4,000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (251 K Load)
1A7 (DC - 100 HZ) ($1 \frac{v}{cm}$)
103 (0.1 - 100 HZ) (G = 1000)

$1 \frac{mv}{cm}$

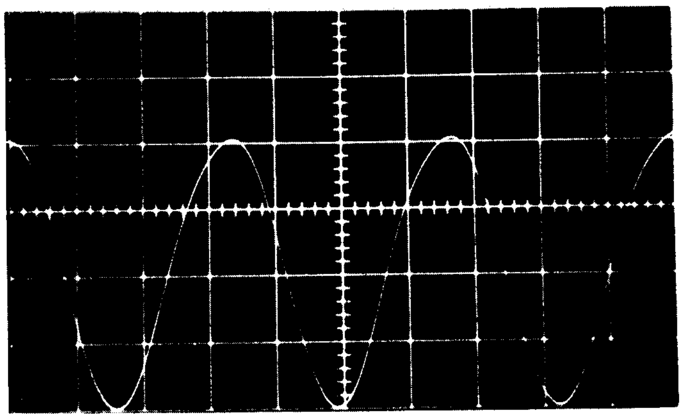


500 msec/cm

Figure 93.

EKG 3.0 HZ
4000 Microvolt P.P Signal
Keithley 103 into
Tektronix 1A7 (251 K Load)
1A7 (DC - 100 HZ) ($1 \frac{v}{cm}$)
103 (0.1 - 111 HZ) (G = 100)

$1 \frac{mv}{cm}$

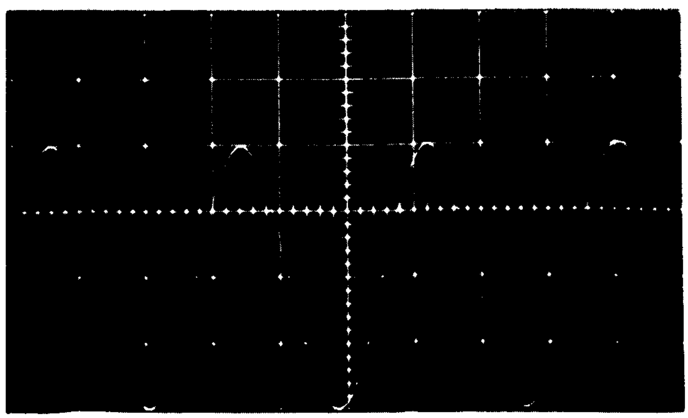


100 msec/cm

Figure 94.

EKG 35 HZ
4000 Microvolt P-P Signal
Keithley 103 into
Tektronix 1A7 (251 K Load)
1A7 (DC - 100 HZ) ($1 \frac{v}{cm}$)
103 (0.1 - 100 HZ) (G=1000)

$1 \frac{mv}{cm}$



10 msec/cm

C. Other Tests on Active Primate Simulator

1. Voltage Regulator Tests

A voltage regulation test was made on the Trio Laboratory's miniature, automatic voltage regulators (super/reg) under actual operating conditions in the Active Primate Simulator. The load was varied from no load to full load and the change in output voltage was observed. The total change in voltage for a zero to full load change in current was approximately one part in 2,000. The load was varied by switching off the three oscillators and turning them on sequentially until all three oscillators were operating simultaneously. It was concluded from these test results that the performance of the super/reg automatic voltage regulators was more than adequate to meet the requirements of the Active Primate Simulator.

2. A.C. Signal Tests

During the early phases of A.C. signal testing, a number of high frequency ripple components were observed. These spurious ripple signals were identified by their frequencies and traced to 3 major sources.

a. Tuning Fork Frequencies (1140 HZ, 100 HZ and 800 HZ)

The three fundamental tuning fork frequencies were a direct cause of the spurious high frequency ripple signals. A number of steps were taken to completely eliminate these spurious high frequency signals. These steps were as follows:

(1) The oscillators were redesigned to minimize the output of the fundamental tuning fork frequencies. The major circuit modification was the incorporation of additional filtering.

(2) The original brass cases were replaced by steel cases to provide magnetic shielding and minimize the amount of flux leakage.

(3) A steel plate was inserted between the tuning fork oscillators and the low level circuits in Model #1. In Model #2 the tuning fork oscillators were placed a sufficient distance away from the low level circuits to eliminate the need for the steel plate magnetic shield.

(4) It was found that the high value, wire wound resistors were acting as pick-up coils due to the large number of turns of resistance wire required by the high value resistors. All wire wound resistors were replaced by metal film resistors which have much fewer turns and therefore much lower induced voltages. In all cases the replacement of the wire wound

resistors by metal film resistors completely eliminated the high frequency pickup problem. Model #2 was constructed entirely of metal film resistors and in addition, as mentioned previously, the plug-in oscillators were located a maximum distance away from the low level circuits.

b. 35 HZ Oscillator

During the initial tests it was discovered that spurious 35 HZ signals were observed in several of the EEG circuits. This was discovered to be due to capacitive coupling in the Test System (see "III B 2," p.14), and inductive coupling to the low level, high resistance circuits in the Active Primate Simulator (as in "a(4)" above). As was mentioned previously, the elimination of the 2.828 volt peak-to-peak oscillator voltages from the low level selector switches in the Test System eliminated the 35 HZ Test System problem and the replacement of wire wound resistors by metal film resistors as well as careful mechanical layout of the critical components eliminated the 35 HZ pickup problem in the Active Primate Simulator.

c. Power Line Frequency (60 HZ)

During initial checkout and debugging, 60 HZ pickup problems were severe. These were largely eliminated by careful shielding and grounding techniques and by complete separation of the 60 HZ power conductors in the Test System from the low level circuits.

3. ZPG Measurements

ZPG impedance measurements were made at 240 KHZ. With Rz set at 0 ohms, the overall impedance was 253 ohms; with Rz set at 10 ohms, the overall impedance was 263 ohms; with Rz set at 20 ohms, the overall impedance was 273 ohms, The change in the computed ZPG impedance values check quite closely with the directly measured values of Rz.

4. Tests on Blood Pressure Channels

Tests on the blood pressure circuits resulted in the following measurements for resistance and voltage.

The overall bridge resistance value, which was computed to be 350 ohms, was measured to be approximately 352 ohms, The additional 2 ohms was traced to the resistance of the 6 feet of wire in the blood pressure cable.

With the Rc resistance selector switch set at the infinity position, the 25,000 ohm potentiometer was adjusted to give zero voltage output with 11 volts supplied to the blood pressure network through a 3.5K series resistor. With the Rc selector switch set at the 80.6 K position a reading of 1.3 millivolts was obtained and with the Rc selector switch set at the 40.2 K position, a reading of approximately 2.6 millivolts was obtained. The readings were similar for all 6 blood pressure circuits.

D. Operating Experience

As a direct result of operating experience with the Active Primate Simulator at the General Electric facility the following changes, corrections and improvements were made to the Simulator:

1. Banana Jack type plug-in grounds were incorporated in both the Simulator and the Test System. This provided greater convenience in connecting the cathode ray oscilloscope ground to either the Simulator ground or the Test System ground.

2. All trimmer potentiometers were rewired so that clockwise rotation of the trimmer controls results in an increase in voltage at the output terminals.

3. A number of wire wound resistors were replaced by metal film resistors in Model #1 in order to reduce noise, pickup and ripple. Model #2 was constructed entirely of metal film resistors. The use of metal film resistors minimized the problems due to pickup.

4. The trimmer potentiometers in the EEG 10 microvolt channel and the EKG 100 microvolt channel were increased in value in order to provide a greater range of amplitude adjustment.

5. The series resistances in the voltage regulator circuits were changed in order to give improved voltage regulator performance.

6. The Fork Standards plug-in oscillators were returned to the manufacturer, in order to make the following modifications and improvements.

a. Emitter follower circuits were incorporated into the oscillators in order to minimize the effect of loading on the oscillators.

b. The brass cases were replaced with steel cases in order to provide a modest amount of magnetic shielding to reduce the high frequency ripple present in the low level EEG circuits due to the fundamental tuning fork frequencies.

c. The high frequency ripple in the oscillator output voltages was substantially reduced by circuit redesign, improved filtering and other circuit modifications.

d. Externally available amplitude controls were added to the plug-in oscillators so that they could be individually adjusted.

7. As a direct result of oscillator circuit modifications, high frequency parasitic oscillations were observed in the oscillators. The parasitic oscillations were eliminated by the addition of RF suppression circuits.

8. A clamp was added to the external battery connector in order to provide strain relief.

9. The Spectrol selector switches were replaced by positive snap action Alco selector switches. This was done because the Spectrol selector switches were delicate and difficult to adjust.

10. One side of Temperature #1 channel was grounded to the AGE chassis. This greatly reduced the noise on this channel.

11. The value of the charging pilot light series resistance was decreased in order to increase the brightness of the lamp for better visibility.

12. The DPDT battery test switch was replaced by a spring return to center switch to eliminate the possibility of accidently discharging the battery.

13. The frequency selector switching circuits were simplified by using a single deck instead of a three deck switch, since the power interlock circuitry originally incorporated in the frequency switching circuits to conserve battery power were found to be unnecessary.

14. A head connector extension adapter was constructed to allow the UCLA head cables to be easily plugged into the recessed head connector receptacle of the Active Primate Simulator.

15. A short extension cable was made up for the Temperature #1 cable to provide for more convenient connection.

16. Jiffy connectors were incorporated in the body leads cable. A microdot connector was used for the Temperature #2 channel in the body leads cable. Similar changes were made in the AGE cables to conform with the changes in the body leads cable.

17. The oscillator package for Simulator #2 was placed at the bottom of the Simulator instead of the top as in Model #1. This further reduced crosstalk and pickup in the low level EEG channels.

18. Picofuses of 5 ampere, 125 volt capacity were installed in both of the simulators. The use of these fuses will minimize the possibility of accidental short circuits on the battery packs, which can cause considerable damage due to the high short circuit current capacity of these batteries.

19. A 1/32 inch thick sheet of plexiglass was cemented to the front surface of each battery case to prevent contact with the front panel terminals and wiring. All other surfaces were insulated with Lamart

T-18 Teflon Vinyl Laminate. The mounting details of the battery pack for Model #1 were modified so that all four battery packs are interchangeable with respect to both Simulator #1 and Simulator #2. These mounting modifications will make it almost impossible to install the battery pack incorrectly, since the battery pack will be capable of being installed in only one way. These changes were made to simplify the replacement of discharged battery packs during extended tests.

20. Two battery let down discharge fixtures were supplied with the Simulators, in order to insure that each battery cell discharges to zero voltage. The let down discharge fixtures consist of a bank of ten 0.5 ohm resistors connected in series and attached to suitable connectors to allow for easy connection to the battery power pack.

21. A log sheet was attached to the back surface of each battery case, having the following information:

a. Battery Pack Serial No.
b. Filling Date
c. Date of Each Letdown Discharge

22. When a single cell in a given battery pack has failed and the battery pack is shown to be close to the end of its life (i.e., close to the 6 month rated shelf life), the entire battery pack will be replaced, instead of replacing the single failed cell. This procedure has been instituted in order to minimize the "down time" caused by single cell failure in a battery pack which is known to be close to the end of its specified life. In the event of a single cell failure on a new battery pack, the cell will be replaced and not the entire battery pack.

23. It was observed during test and calibration procedures that, to get agreement between measurements taken by the Tektronix 1A7 Amplifier and measurements taken by the Keithley 103 Amplifier, it was necessary to provide adapter cables with resistance networks to compensate for the input impedances of the instruments. When the adapter cables are properly installed, identical load impedances are seen by the signal generators using either the 1A7 or the 103 Amplifiers and the readings obtained by both instruments were in substantial agreement.

E. Acceptance Tests

1. Hi-pot Tests

During the General Electric acceptance tests, 3 failures were found during hi-pot test on the Test System and one failure during the Simulator hi-pot test. These four hi-pot failures were due to partial shorting between the shield and the center conductor of the shielded cables. After repairs were made, both the Test System and the Simulator passed the hi-pot test satisfactorily.

2. EMI Tests

It was noticed during EMI testing that the Simulator was radiating very low level 270 MHZ oscillations. This was traced to the oscillators and was probably due to the oscillator emitter follower circuit.

According to General Electric personnel, the frequency was high enough and of a sufficiently low level to be disregarded. Therefore, in the opinion of General Electric personnel, the results of the EMI tests on the Active Primate Simulator were considered satisfactory.

APPENDIX A

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR

PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)

GENERAL TECHNICAL SERVICES, INC., Rev. 3, February 1, 1968

TABLE OF CONTENTS

LIST OF FIGURES

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968

APPENDIX A

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968.

This final specification was derived from NASA Document #883-11-14 after a series of visits and telephone conferences with Mr. W. F. Barrows, Ames Research Center, NASA, Moffett Field, California, and after several months of field experience with the system at General Electric's Biosatellite facility at 3198 Chestnut Street, Philadelphia, Penna.

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968.

1.0 Scope - This specification covers one type of primate simulator used to (1) simulate various primate parameters and (2) stimulate the signal conditioners interfacing with the primate. The simulator type and quantities required, is identified as follows:

(1) Active Simulator, 2

2.0 Applicable Documents

MIL-STD-130B Identification, Marking of M.S. Military Property, 4/24/62.
MS-33586 Metals, Definition of Dissimilar.
Electromagnetic Compatibility Test Specifications.
Finishes and Coatings.
Wiring and Electrical Connectors, AGE.
Preparation for Delivery.

2.1 NASA/ARC Documents

Document #883-11-10, BIOSATELLITE Experiment Technical Requirements.

2.2 NASA/ARC Drawings

A 12774, UCLA Experiment Interconnect Diagram
A 12766, USC Experiment Interconnect Diagram
A 12779, Restraint Couch Interface
A 12780, Primate Interface
A 12876, Primate Urine and Feces Collection Interfaces
A 12885, USC Heparin Block.

2.3 GTS Drawings

GTS-9008, Block Diagram: Active Primate Simulator
GTS-9009, Schematic Wiring Diagram: Active Primate Simulator
GTS-9010, Connector Diagram: Active Primate Simulator.

2.4 In case of a conflict between this specification and the above referenced documents, this specification shall take precedence.

3.0 Requirements

3.1 Acceptance Requirements - The simulators furnished under this specification shall be tested to satisfy the Acceptance Test Requirements in Section 4.

3.2 Reliability of the hardware connected to or interfacing with the simulators shall not be degraded when used with the simulators.

3.3 Materials

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968.

3.3.1 Selection of Parts, Materials, and Processes

Parts shall be selected to meet the functional requirements of this specification and shall meet the environmental stresses defined in this specification and referenced applicable documents.

3.3.2 Materials

Materials used shall be of a type, grade, and quality which is sufficient to ensure the proper operation of the simulators in conformance with this specification.

3.4 Protective Treatment - When materials used in the construction of the simulators are subject to deterioration when exposed to climatic and environmental conditions likely to occur during service usage, they shall be protected against such deterioration in a manner that will in no way prevent compliance with the performance requirements of this specification.

3.5 Design and Construction - This component shall be of the design and construction specified on this specification.

3.5.1 Safety Provisions - Provisions for the safety of personnel shall be incorporated to the maximum extent possible with regard to anticipated operating conditions and the capability of operating personnel.

3.5.2 Maintenance Provisions - Ease and simplicity of maintenance shall be a general design objective. Components and parts requiring frequent maintenance or adjustment shall be as accessible as possible.

3.5.3 Nameplates and Marking

3.5.3.1 Identification - Components, assemblies, and parts shall be marked for identification in accordance with Standard MIL STD-130 as a guide.

3.5.4 Interchangeability - All parts having the same manufacturer's part number shall be interchangeable with each other with respect to performance.

3.5.5 Design - The simulators shall be designed to be compatible with all applicable documents defined in Section 2.

3.6 Performance - Performance requirements for the simulators are as follows:

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968.

3.6.1 Active Simulators - The active simulator shall provide the capability to calibrate all the electrical data lines of the types indicated in Figure 1 which interface with the primate.

3.6.1.1 The outputs shown in Figure 1 shall be provided in the following combinations:

All simulator output channels of the same type shall be switched concurrently at the 3 voltage levels and the 3 frequencies shown in Figure 1. This applies to EEG, EMG, EOG, and EKG. (See GTS-9008 attached.) The two temperature channels and the 6 Blood Pressure channels will be individually adjustable.

3.6.1.2 Output impedances of the simulator channels shall be as defined in Figure 1. The signal conditioner impedances into which the simulator operates are to be considered 1 megohm or greater for EEG, EOG, EMG. The EKG signal conditioner impedance is 260K ± 1%.

3.6.1.3 Maximum allowable noise levels of each simulator channel output shall be as shown in Figure 1.

3.6.1.4 The active simulator shall provide its own power source capable of at least 24 hours of continuous operation without degradation of the amplitude or frequency of the simulator output signals. The power source shall be easily replaced when expended or shall be recharged. The use of batteries, internal to the simulator, as the power source is recommended.

3.6.1.5 The active simulator shall be capable of connecting to the prime signal conditioner harnesses with the minimum simulator lead length. It shall be a design goal to package the active simulator so that it can be located within the defined envelope of the primate within the capsule. (Interface Drawing A 12789). The envelope of the simulator shall be 16 inches x 7 inches x 4 inches.

3.6.1.6 The simulator, its power supply, and all wires emanating from the simulator shall be electrically shielded to insure low noise operation under a normal laboratory environment. This shield system shall be floating and shall be capable of being connected to an external ground.

3.6.1.7 The simulator itself shall be capable of at least 24 hours of continuous operation.

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968

3.6.1.8 Indicator lamps drawing no more than 8 m.a. for Power-On and Charge Cycle indications will be provided.

3.6.1.9 The Power-On switch and the Charge Cycle switch will be interlocked so that the power to the simulator will be automatically interrupted during the charging process.

3.6.1.10 All coaxial cable will be Microdot 250-3804 (Simulator #1), and Microdot 250-3823 (Simulator #2).

3.6.1.11 A battery test switch and battery meter will be provided.

3.6.1.12 An interchangeable plug-in battery pack will be provided.

3.6.1.13 A transparent see-through door with an electrostatic shielding efficiency of at least 65% of that of aluminum will be provided so that, once the controls are set, accidental changes to the controls will be eliminated. The shielded transparent door will also provide additional shielding for the switches and controls mounted on the front panel.

3.6.1.14 A Voltage Regulator test connector, a battery cell test connector, and a battery test connector will be provided so that measurements can be made using the AGE equipment.

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968

3.7 Service Conditions - Operating - The simulators shall perform in accordance with paragraph 3.6 while subjected to the following conditions:

a. Temperature - +60°F to +90°F

b. Humidity - 5% to 95% RH

c. Pressure - 13.2 psia to 16.2 psia.

3.8 Service Conditions - Non-Operating - The simulators shall operate satisfactorily in accordance with paragraph 3.6 after being subjected to the following conditions for a period of up to two years:

a. Temperature - -25°F to +125°F

b. Humidity - 5% to 100% RH (with condensation in the form of water or frost when suitably protected by shipping container.

c. Pressure - 4.37 psia to 16.2 psia

d. Vibration (transportation): Specification is as follows:

Frequency (cps)	Double Amplitude
5-27	±1.3 g rms
27-52	0.036 inch
52-500	±5 g rms

(as modified by shipping container)

e. Shock (transportation): Specifications are as follows:

(1) Packaged

Truck - 8 g's, 5 to 40 milliseconds

Air - Vertical: 5.5 g's, 10 to 30 milliseconds
- Lateral: 1.5 g's, 10 to 30 milliseconds
- Longitudinal: 0.8 g's, 10 to 30 milliseconds

Handling - Shocks resulting from free fall drops of from 16 to 30 inches depending on size: Edgewise and corner rotational drops of 12 to 36 in inches, depending on size (as modified by shipping container).

(2) Unpackaged

Free fall drop of 1 inch and rotational drops of 6 inches.

f. Acceleration (transportation)- As required to meet transportability requirements, 3 g's in any direction acting independently.

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968

3.9 Life

3.9.1 Operating - The simulators shall have a minimum anticipated life (excluding power source for active simulator) of 2000 hours with reasonable servicing and replacement of parts, and an overall possible life time goal of five (5) years.

3.9.2 Storage - The simulators shall be capable of operation per paragraph 3.6 after two (2) years in a sheltered environment as defined in section 3.8. Batteries must be stored dry to satisfy this specification.

3.9.3 Weight - The weight of the active simulator shall not exceed 30 pounds.

3.10 AGE shall be provided to perform all necessary check-out and calibration of the simulators defined in this specification. The AGE shall be capable of connecting to all electrical simulator outputs and shall provide the necessary circuitry to make the desired parameters available to standard readout equipment such as oscilloscopes, meters, etc.

4.0 Quality Assurance Provisions

4.1 Classification of Tests - Each simulator shall be subjected to acceptance tests, to assure compliance to this specification and the drawing.

4.1.1 Acceptance Tests - The following tests shall constitute the acceptance tests. (See 4.4)

4.1.1.1 Visual Examination - Examination of the product to ensure conformance with the drawing. (See 4.4.1)

4.1.1.2 Functional Tests - Tests to ensure performance of the product in conformance with this specification. (See 4.4.2)

4.2 Rejection and Retest - Any simulator which does not meet the requirements of the acceptance tests in this specification shall be considered failed and shall be rejected. Upon correction of a failure the simulator shall be retested per section 4.4 unless requirements are specifically waived by NASA.

4.3 Test Conditions - All tests shall be performed under the following ambient conditions:

a. Temperature - $77^{\circ}F \pm 10^{\circ}F$

b. Relative Humidity - 90% maximum

c. Barometric Pressure - 29 to 32 inches Hg

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968

4.3.1 Test Equipment - Laboratory apparatus calibrated at intervals properly spaced to assure accuracy, shall be used to test the product for specification compliance. Accuracy of test equipment shall exceed ten times the accuracy requirement of the parameter being measured where possible.

4.4 Acceptance Tests

4.4.1 Visual Examination - Each simulator shall be visually inspected for conformance of manufacture, fabrication, and markings with this specification, the referenced drawings, and all working drawings.

4.4.2 Functional Tests

4.4.2.1 Power - Self-contained rechargeable batteries will be used.

4.4.2.2 Continuity Test - Continuity tests shall be performed with simulator power off to ensure that all portions of a simulator are connected in accordance with the schematic and wiring diagrams.

4.4.2.3 Electrical Test - The active simulator shall be energized and performance measured to ensure that all functions are in accordance with the requirements of paragraphs 3.6 through 3.10. The inability of the simulator to perform within the allowable tolerances shown within or referenced in section 3.6 shall be cause for rejection per section 4.2.

4.4.2.4 EMI Tests.

4.4.2.4.1 Environment

The simulator may be exposed to normal 60 cycle radiation and to broad band ambient radiation in the 15 KHz to 400 MHz range with a field intensity of 1 volt/meter maximum.

4.4.2.4.2 Susceptibility.

Any type of shielding or filtering technique may be used to minimize the susceptibility of the simulator to EMI.

4.4.2.4.3 Suppression.

Filtering, arc suppression and other appropriate techniques may be used to minimize emission of EMI from the simulator.

5.0 Preparation for Delivery

5.1 Packing - The simulators shall be overpacked in shipping containers which shall adequately protect each package during ordinary handling and shipping and shall meet the minimum requirements of the carrier handling and shipping for safe transportation at the lowest rate to the point of delivery.

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968

5.2 Marking - Shipping containers shall be marked with the name and address of both consignee and consignor, contract or purchase order number, and the item part number. All markings shall be legible and waterproof.

6.0 Operation and Maintenance Manual - Two manuals shall be provided for each simulator. The manuals shall contain at least the following information:

6.1 Operating Instructions

6.2 Basic Maintenance and Trouble-Shooting Instructions
(Including AGE operation)

6.3 Electrical Schematics

6.4 Parts List

6.5 Calibration Instructions - Manuals
(Including AGE operation)

7.0 Additional Information

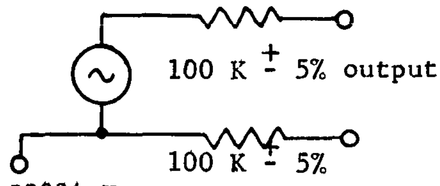
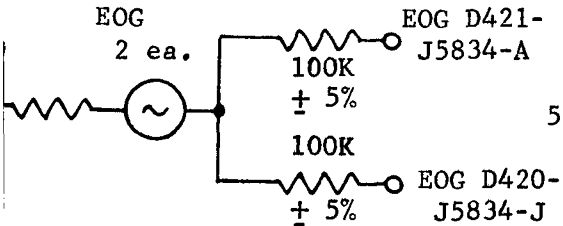
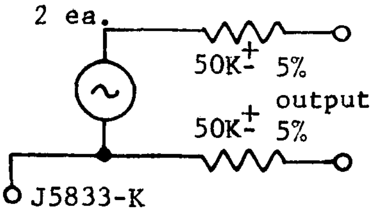
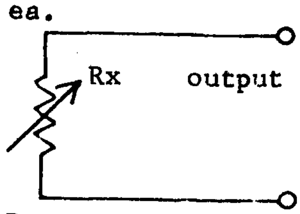
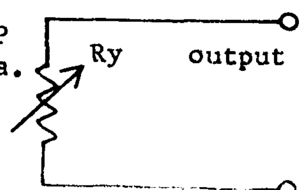
Figure 2 contains the details of the Primate Head Connector Configuration.

Figure 3 is a wiring connection table which gives the details of the head cable connections and the body cable connections.

Figure 4 provides additional details of the Body Leads Cable.

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968

FIGURE 1: ACTIVE SIMULATOR ELECTRICAL REQUIREMENTS

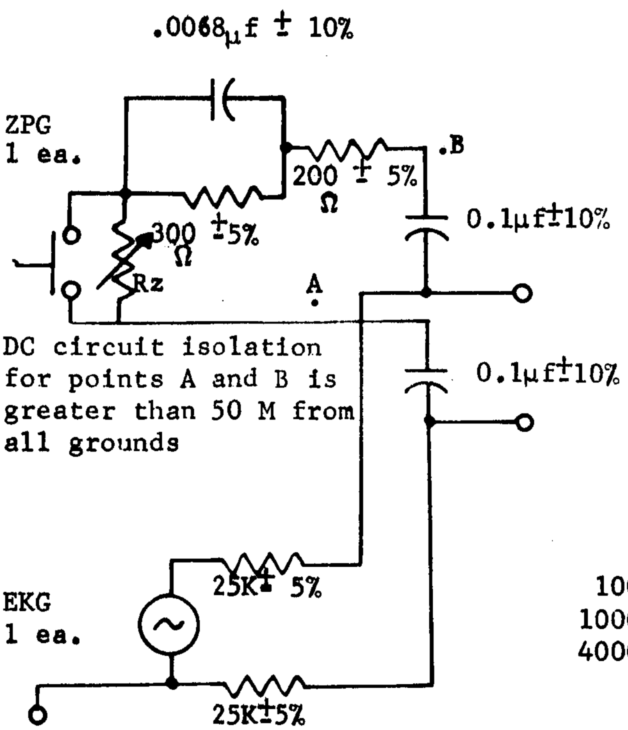
SIGNAL TYPE & QUANTITY	PRIMATE EQUIVALENT CIRCUIT	P-P OUTPUT AMPLITUDES	FREQUENCIES IN HZ (±10%)	WAVEFORM (±10% distortion)	MAX. NOISE (P-P) (±5%)
EEG 10 ea.		10 ± 1μV 80 ± 5μV 500 ± 25μV	0.5 3.0 35.0	SINE	2.5μV 4 μV 25 μV
EOG 2 ea.		100 ± 10μV 500 ± 50μV 5000 ± 250μV	0.5 3.0 35.0	SINE	30 μV 30 μV 250 μV
EMG 2 ea.		100 ± 10μV 1000 ± 50μV 5000 ± 250μV	0.5 3.0 35.0	SINE	30 μV 50 μV 250 μV
GSR 1 ea.	 D.C. circuit isolation is greater than 50 M from all grounds.	Rx: 100 KΩ ± 1% 750 KΩ ± 1% 1.2 MΩ ± 1%	N/A	N/A	-
TEMP 2 ea.	 D.C. circuit isolation is greater than 50 M from all grounds.	Ry: 52 KΩ ± 1% 60 KΩ ± 1% 68 KΩ ± 1%	N/A	N/A	-

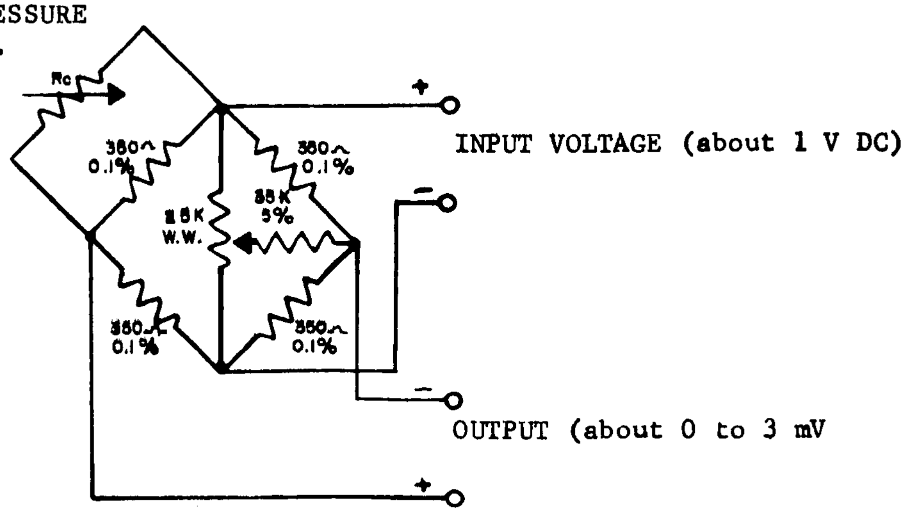
Note: Insulation resistance for all signal paths to case ground is 50 M when measured at 500 Volts.

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 2, May 3, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968

FIGURE 1 (Cont'd.): ACTIVE SIMULATOR ELECTRICAL REQUIREMENTS

SIGNAL TYPE & QUANTITY	PRIMATE EQUIVALENT CIRCUIT	P-P OUTPUT AMPLITUDES	FREQUENCIES IN HZ (+10%)	WAVEFORM (± 10% distortion)	ALLOWABLE MAX. NOISE (P-P) (+ 5%
ZPG 1 ea.		Rz: 0-10Ω ± 2% 0-20Ω ± 2%	N/A	N/A	
EKG 1 ea.		100µV ± 10µV 1000µV ± 50µV 4000µV ±200µV	0.5 3.0 35.0	SINE	50µV 50µV 200µV
BLOOD PRESSURE 6 ea.					





NOTE: Insulation resistance for all signal paths to case ground is 50M when measured at 500 Volts.

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968

FIGURE 1 (CONT'D): ACTIVE PRIMATE SIMULATOR REQUIREMENTS

	P-P OUTPUT AMPLITUDES	FREQUENCIES IN HZ (±10%)	WAVEFORM (±10% distortion)	ALLOWABLE MAX. NOISE (P-P) (±5%)
	Rc:			
	40K ± 1% 80K ± 1% ∞	D.C. only	D.C.	-

Note 1:

The ZPG, EKG, and Blood Pressure circuits shall be attached, via a three-foot shielded cable, to P5781 and P5782 per Drawing A-12766.

Note 2:

Allowable D.C. common mode or differential offset voltages for the voltage generating circuits shall be less than one volt. No common mode or differential offset voltages shall be present on the variable impedance circuits.

Note 3:

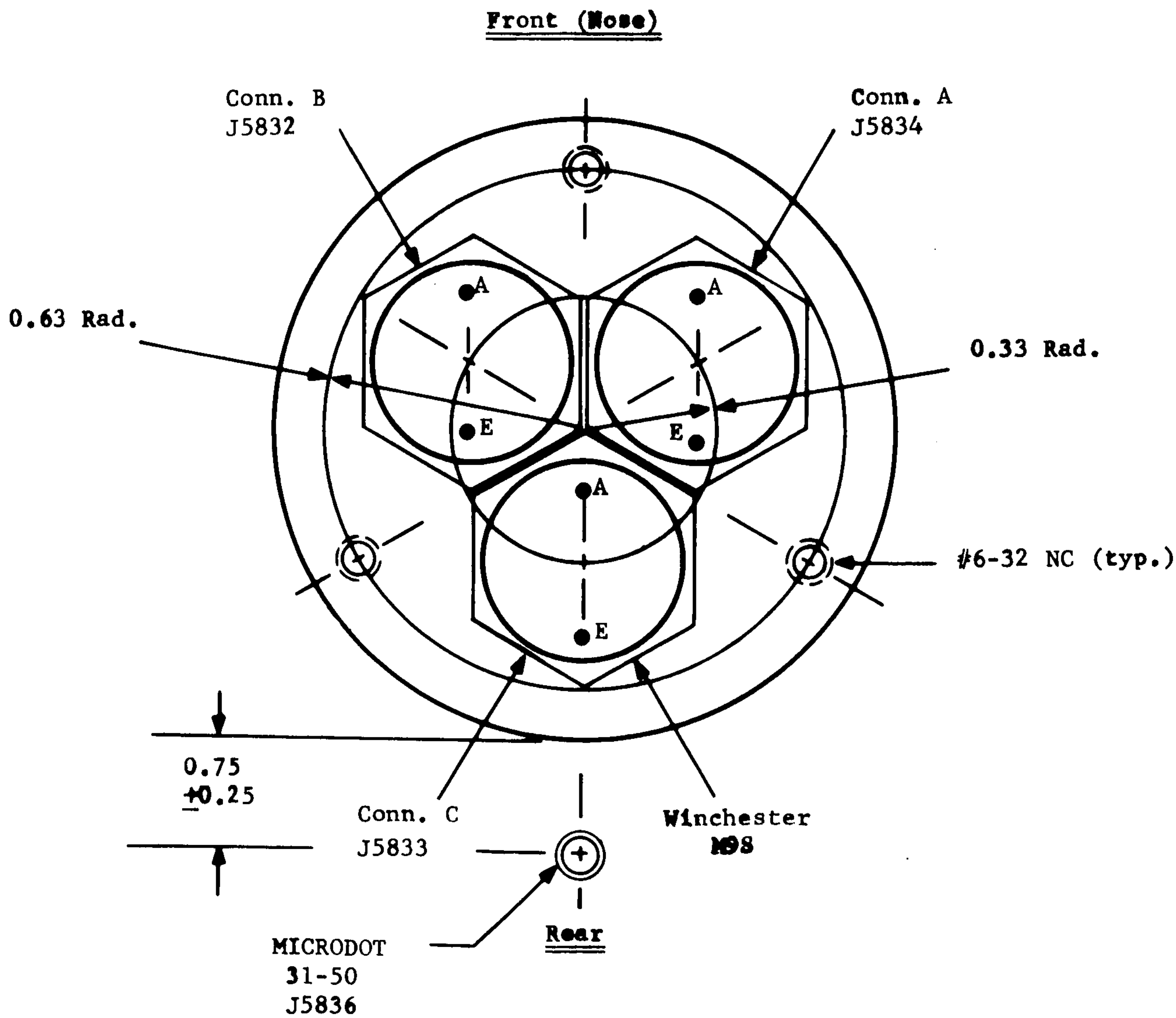
Insulation resistance between all conductors and the case will be 50 Megohms or greater, when measured at 500 Volts.

Note 4:

For blood pressure, supply voltage across the (+) and (-) terminals will be 11 V DC ± 10% with no greater than 0.6 Volts peak-to-peak noise. Input impedance of signal source will be 3.5K ohms ± 10%.

FIGURE 2

PRIMATE HEAD CONNECTOR CONFIGURATION



(For Information Only)

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968

FIGURE 3.

HEAD IMPLANT AND COUCH WIRE SIGNALS

Signal	Connector	Pin
EEG1 D410	J5834	B
	J5834	C
EEG3 D412	J5834	D
	J5834	E
EEG5 D414	J5834	F
	J5834	H
EEG2 D411	J5832	A
	J5832	J
EEG4 D413	J5832	B
	J5832	C
EEG6 D415	J5832	D
	J5832	E
EEG8 D417	J5833	E
	J5832	H
EEG7 D416	J5832	F
	J5833	F
EEG9 D418	J5833	A
	J5833	D
EEG10 D419	J5833	B
	J5833	C
Ground for all signals except EOG's	J5834	K
	J5833	K
EOG2 D421	J5834	A
EOG1 D420	J5834	J
Common for EOG's	J5832	K
Temp 1-D400	JJ4	A
	JJ4	B

(For Information Only)

(continued)

Signal	Connector	Pin
EMG1 D424	J5833	H
	J5833	J
EMG2 D426	5835(JJ5)	A
	5835(JJ5)	B
Temp.2 D401	5835(JJ5)	C
	5835(JJ5)	D
GSR-D428	5835(JJ5)	E
	5835(JJ5)	F
All Shields (A,B,E and F)	5835(JJ5)	H

-See Figure 1, Note 1

Signal	Connector	Pin
EKG D409	(PP8)	16
ZPG D423	(PP7)	16

Note 1:
The shields of coaxial cables numbered 5835(A,B,E and F) are tied together at 5835H. The shields can be either case grounded or externally grounded (through a wire coming out the side of the case along with the Blood Pressure cables. (See Drwg.GTS-9010)

Note 2:
The body lead cables 5835(A to F, incl.) will terminate in an Amphenol 165-12-TY AN connector mounted on the left side of the simulator. (See Drwg.GTS-9010)

Note 3:
The coaxial cables numbered 5835 (A,B,E, and F) will be 1-foot long and terminated at one end in Deutsch 1841-1 5620 connectors. 5835-C & D will also be 1-foot long and will be terminated in a Microdot 31-34 connector.

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968

FIGURE 3 (Cont'd): HEAD IMPLANT AND COUCH WIRE SIGNALS

Note 3 (Cont'd):
The shield 5835-D will be carried through the connector. The other end of cables 5835 will be terminated in an Amphenol 165-9-TY AN with corresponding pin letters. The shields of (A,B,E,F) will be tied to pin H of PP5, as per drawing GTS-9010. (See Fig. 4)

Note 4:
The 24 blood pressure transducer cables and the 2EKG/ZPG cables (5835 H and J) will be connected to Deutsch connectors through a 3-foot cable as illustrated in Drawing No. A12766-R-C, "USC Experiment Interconnect Diagram," and GTS-9010, Connector Diagram: Active Primate Simulator. These cables will be brought out through the left-hand surface of the active primate simulator case; and the cable exit holes will be located at the approximate center of this 4 inch x 16 inch surface.

FINAL SPECIFICATION FOR ACTIVE PRIMATE SIMULATOR
PROJECT BIOSATELLITE (REFER TO DOCUMENT #883-11-14, Rev. 1, March 27, 1967)
GENERAL TECHNICAL SERVICES, Rev. 3, February 1, 1968

GENERAL COMMENTS

a. Simple AGE equipment will be provided so that the active simulator can be quickly and easily checked out.

b. Indicator lamps drawing no more than 8 m.a. will be provided for power on and charge cycle indications.

c. The "Power On" switch and the "Charge Cycle" switch will be interlocked so that the power to the simulator will be automatically interrupted during the charging process.

d. All external cable will be Microdot 250-3804 coaxial cable.

e. A battery test switch and battery meter will be provided with the active simulator.

f. A plug-in battery charger will be provided with the AGE system.

g. A transparent see-through door with an electrostatic shielding efficiency of 65% of that of aluminum will be provided so that, once the controls are set, accidental changes to the controls will be eliminated. The shielded transparent door will also provide additional shielding for the switches and controls mounted on the front panel.

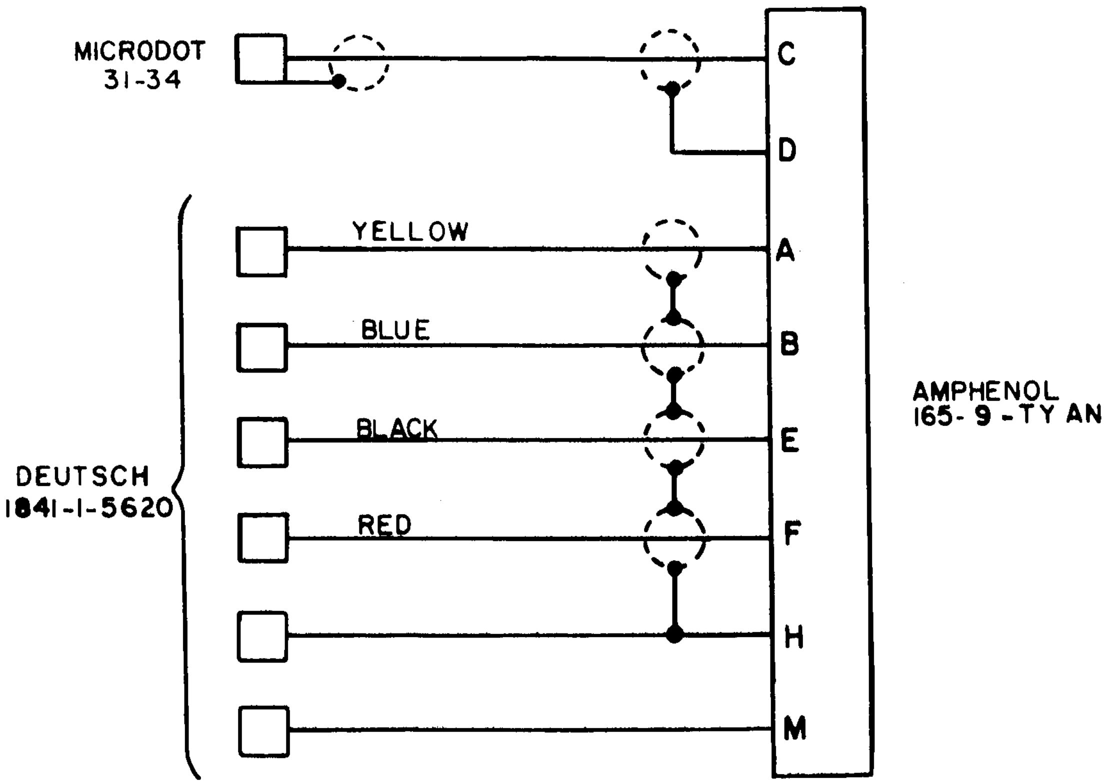
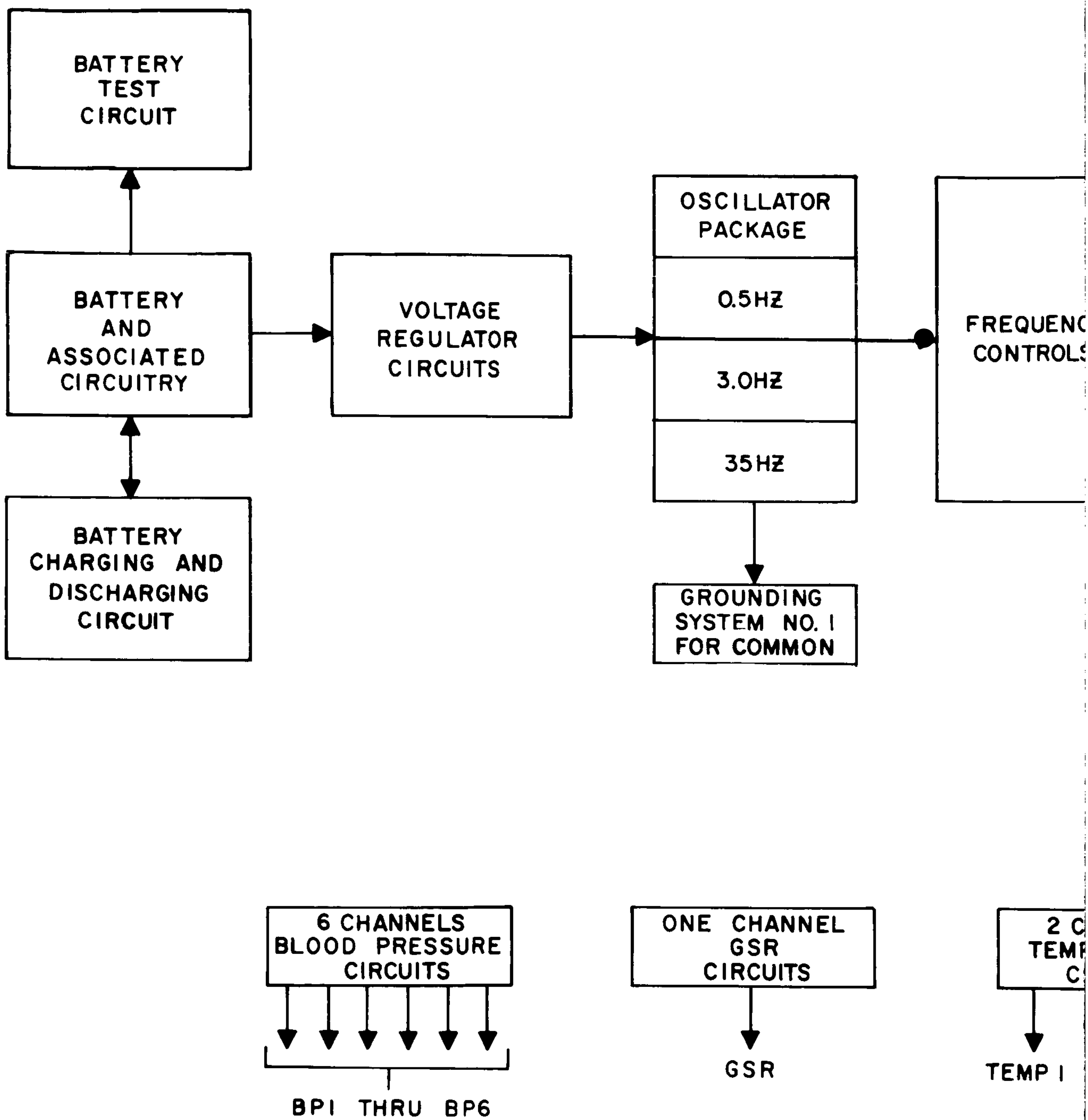
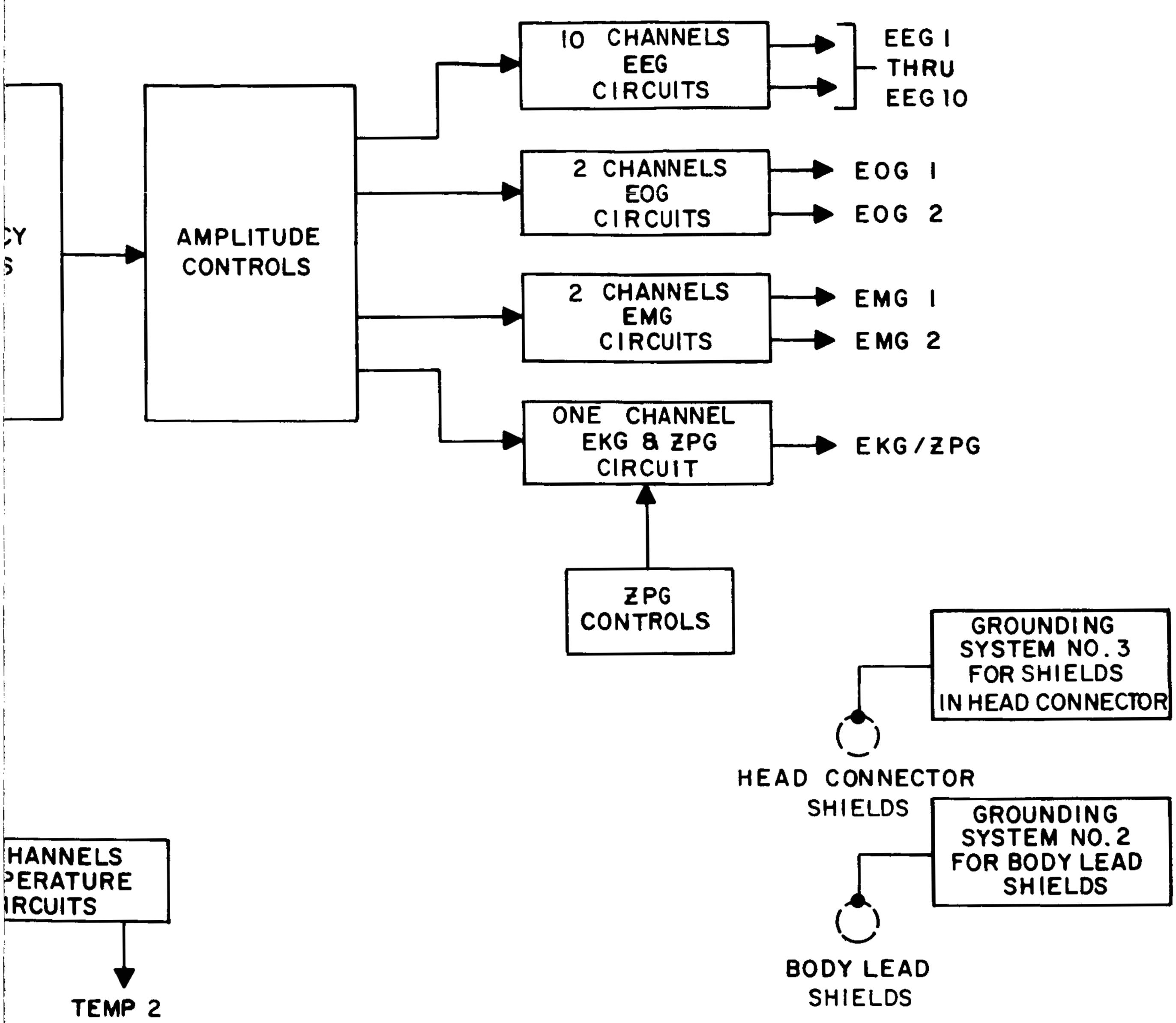


FIGURE 4 - BODY LEADS CABLE DETAILS


BATTERY
TEST
CIRCUIT
BATTERY
AND
ASSOCIATED
CIRCUITRY
VOLTAGE
REGULATOR
CIRCUITS
OSCILLATOR
PACKAGE
0.5HZ
3.0HZ
35HZ
FREQUENC
CONTROLS
BATTERY
CHARGING AND
DISCHARGING
CIRCUIT
GROUNDING
SYSTEM NO. 1
FOR COMMON
6 CHANNELS
BLOOD PRESSURE
CIRCUITS
BP1 THRU BP6
ONE CHANNEL
GSR
CIRCUITS
GSR
2 C
TEMP
C
TEMP 1

FOLDOUT FRAME 2



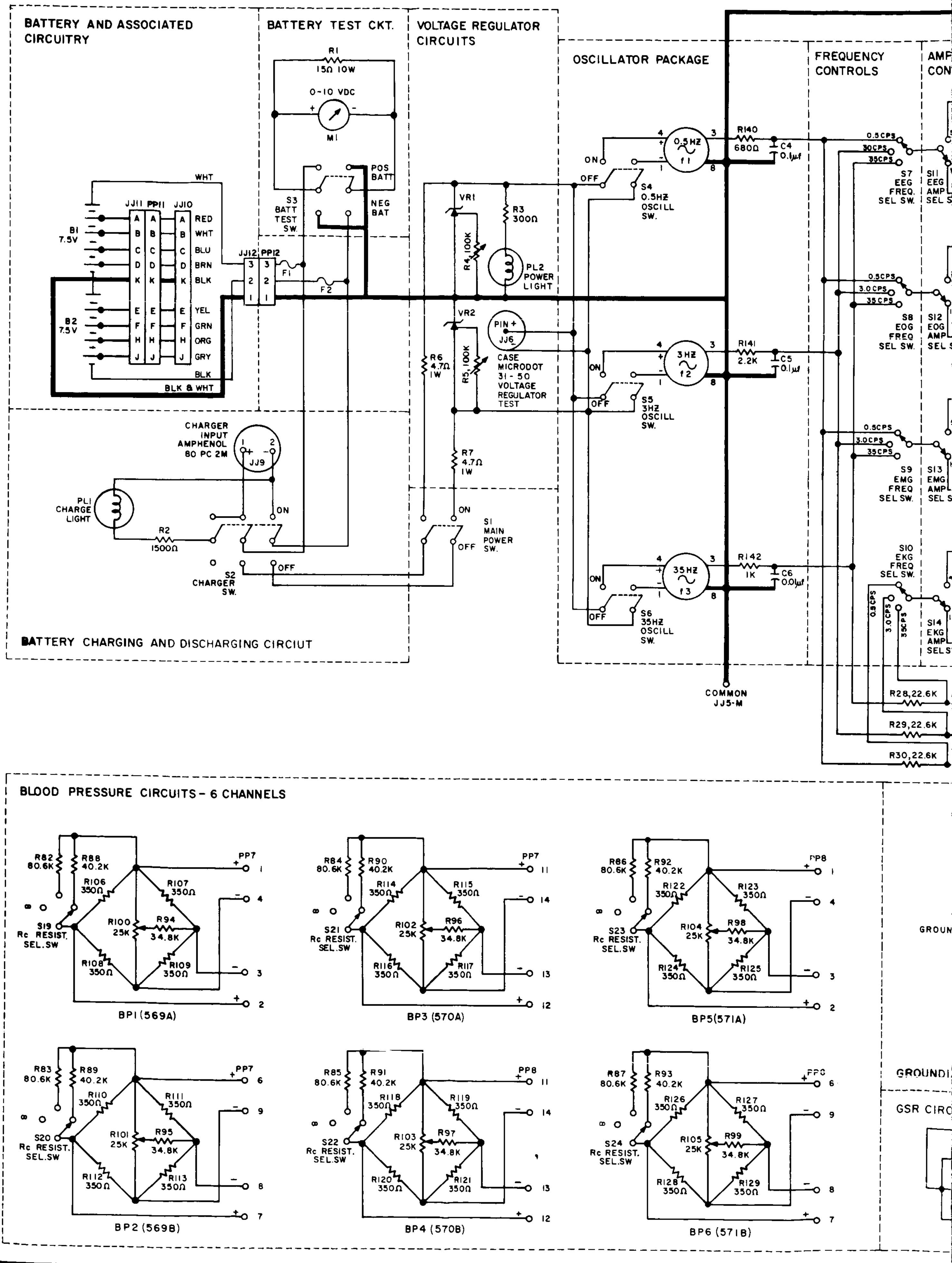
GENERAL TECHNICAL SERVICES, INC.
UPPER DARBY, PA. 19082

SCALE: NONE
DATE: 12 / 20 / 67
APPROVED BY: D. A. [signature]
DRAWN BY: A. M. REVELLI

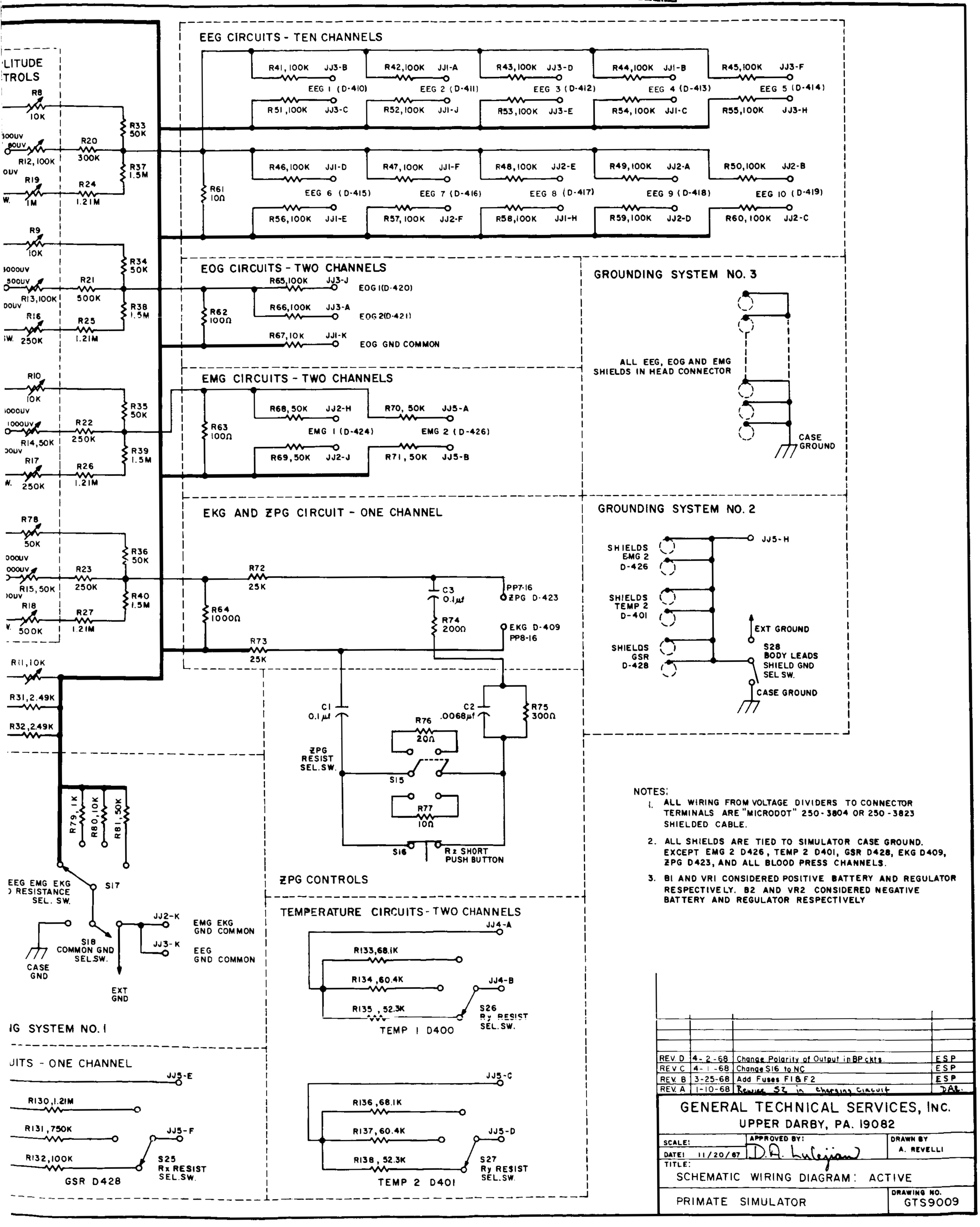
TITLE:
BLOCK DIAGRAM: ACTIVE PRIMATE SIMULATOR

DRAWING NUMBER
GTS9008

FOLDOUT FRAME



FOLDOUT FRAME



NOTES:

1. ALL WIRING FROM VOLTAGE DIVIDERS TO CONNECTOR TERMINALS ARE "MICRODOT" 250-3804 OR 250-3823 SHIELDED CABLE.
2. ALL SHIELDS ARE TIED TO SIMULATOR CASE GROUND. EXCEPT EMG 2 D426, TEMP 2 D401, GSR D428, EKG D409, ZPG D423, AND ALL BLOOD PRESS CHANNELS.
3. B1 AND VR1 CONSIDERED POSITIVE BATTERY AND REGULATOR RESPECTIVELY. B2 AND VR2 CONSIDERED NEGATIVE BATTERY AND REGULATOR RESPECTIVELY

REV. D	4-2-68	Change Polarity of Output in BP ckts	ESP
REV. C	4-1-68	Change S16 to NC	ESP
REV. B	3-25-68	Add Fuses F1 & F2	ESP
REV. A	1-10-68	Revise S2 in Charging Circuit	DAL

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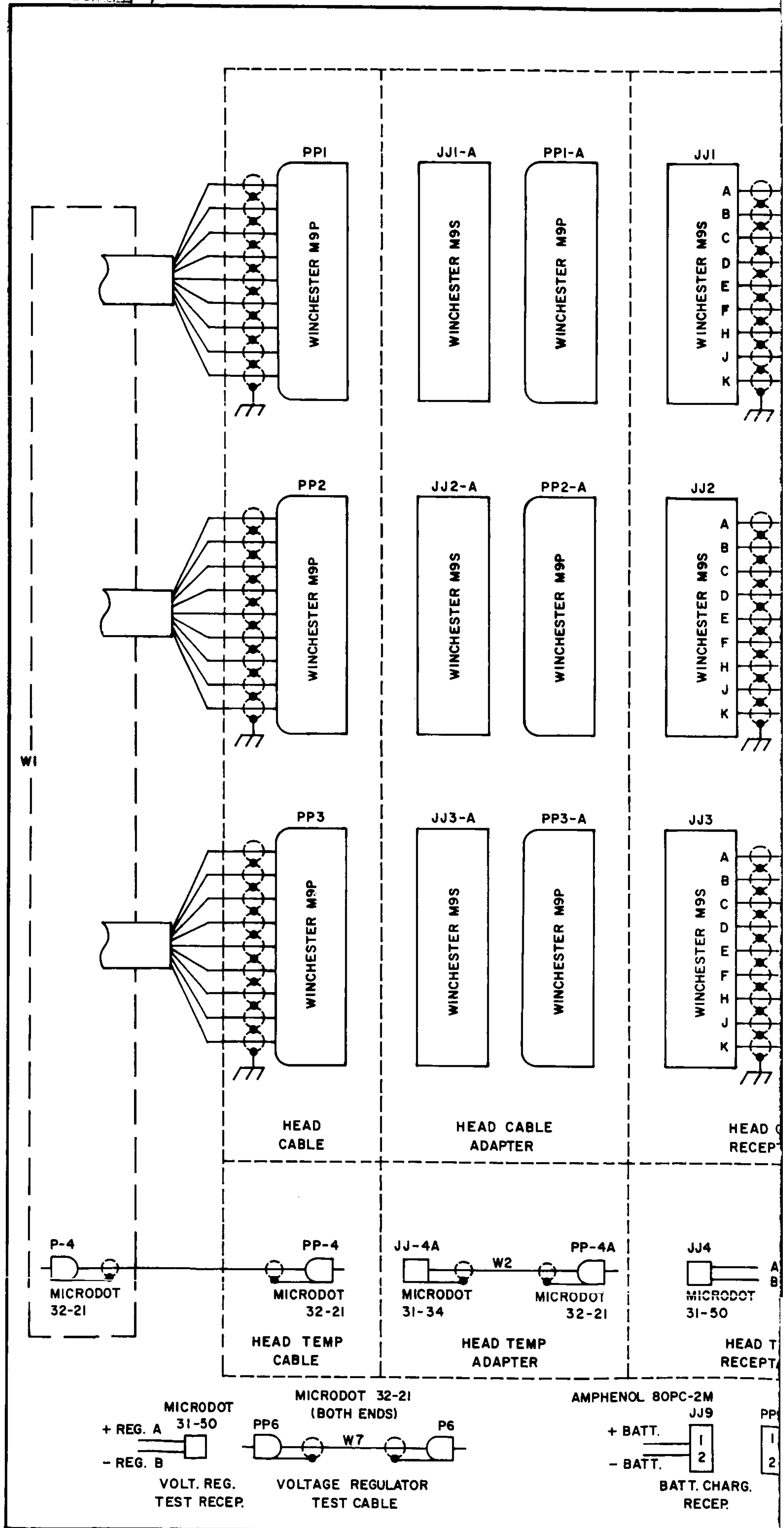
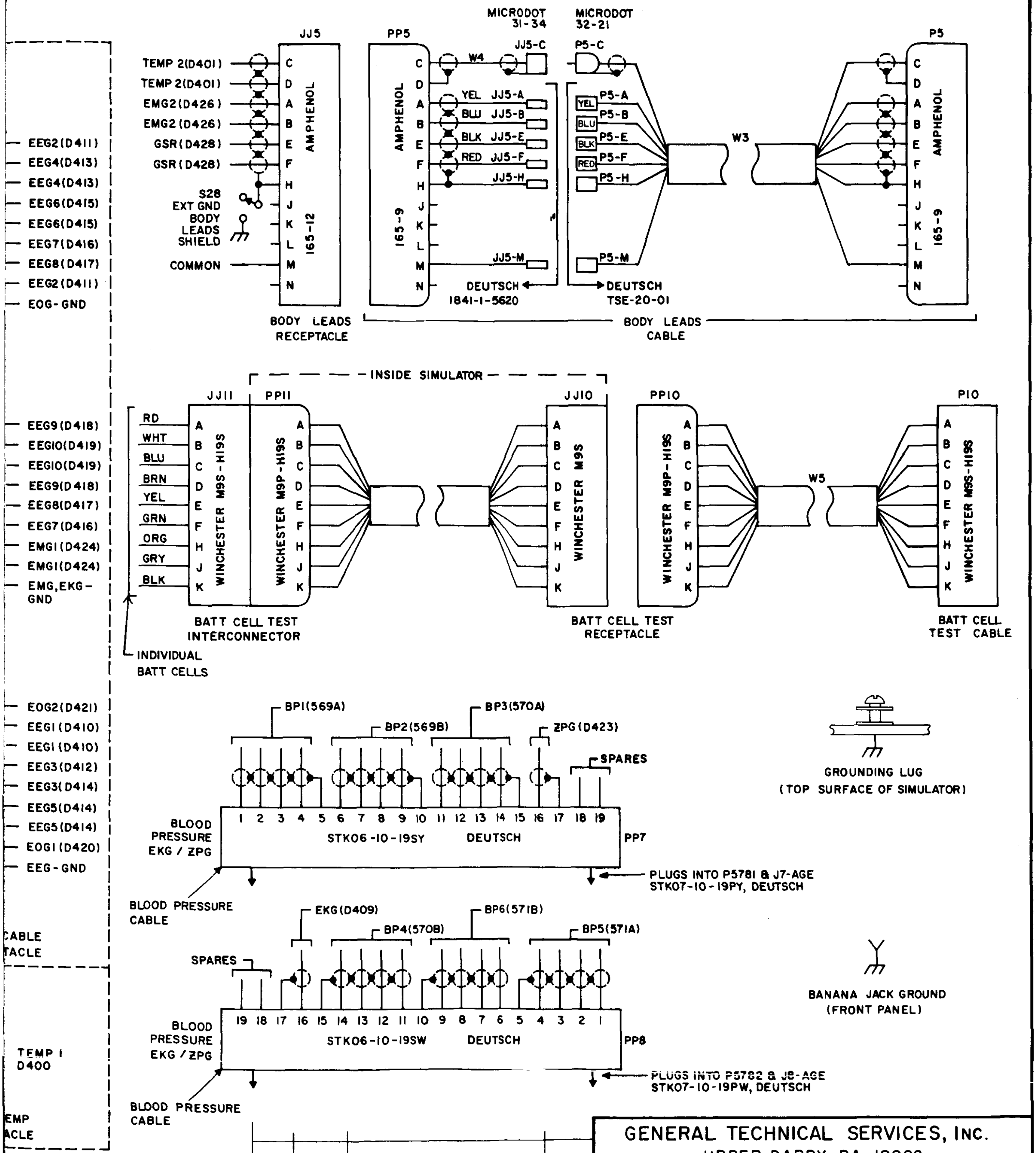
SCALE:
DATE: 11/20/67
APPROVED BY: D.A. Lulejian
DRAWN BY A. REVELLI
TITLE: SCHEMATIC WIRING DIAGRAM: ACTIVE PRIMATE SIMULATOR
DRAWING NO. GTS9009

I

FOLDOUT FRAME 1



FOLDOUT FRAME 2



REV A	2-2-68	ADDED CABLE & CONN. DESIG.

GENERAL TECHNICAL SERVICES, INC.
UPPER DARBY, PA. 19082

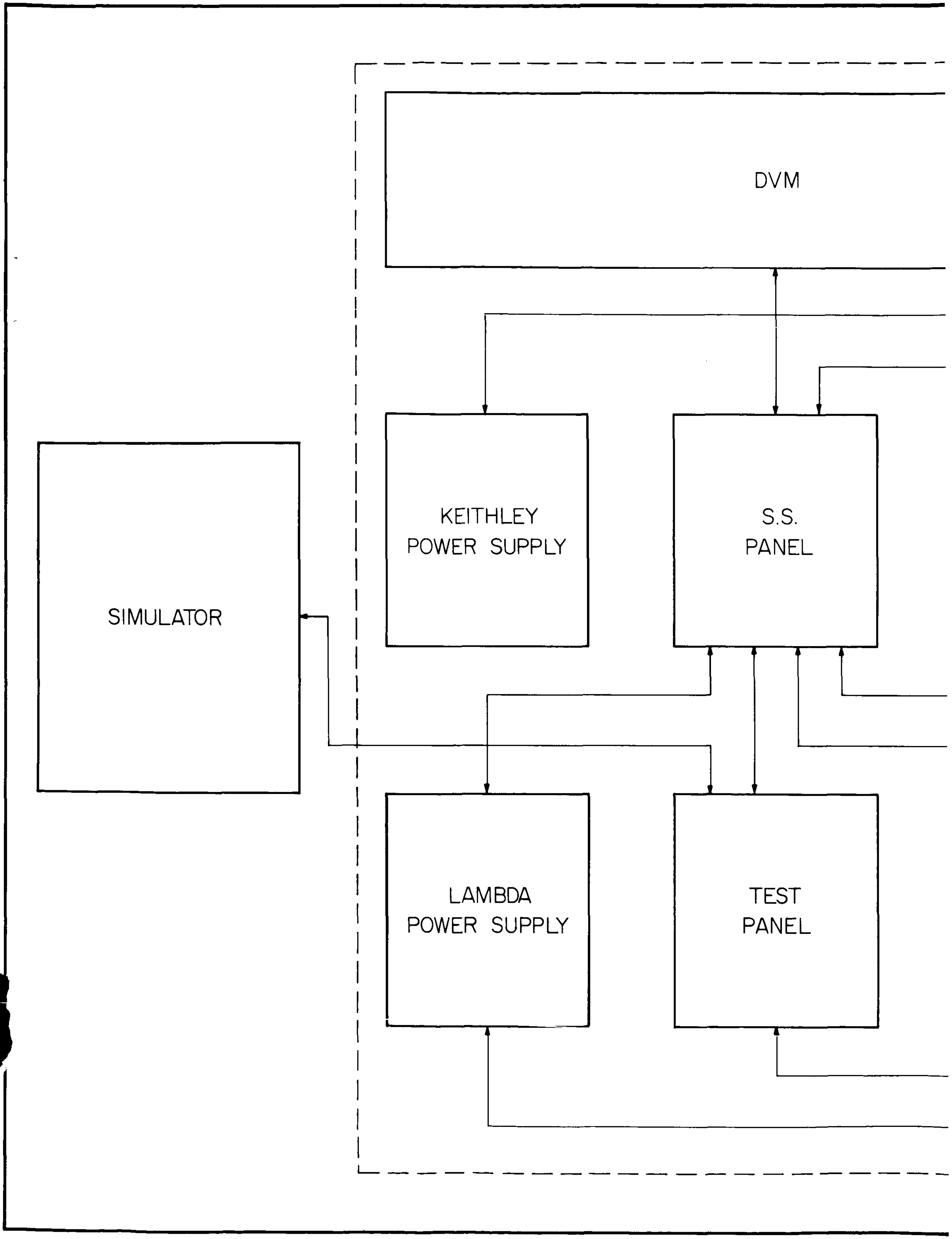
SCALE: NONE	APPROVED BY: D.A. [signature]	DRAWN BY: A.M. REVELLI
DATE: 1/8/68		

TITLE: CONNECTOR DIAGRAM

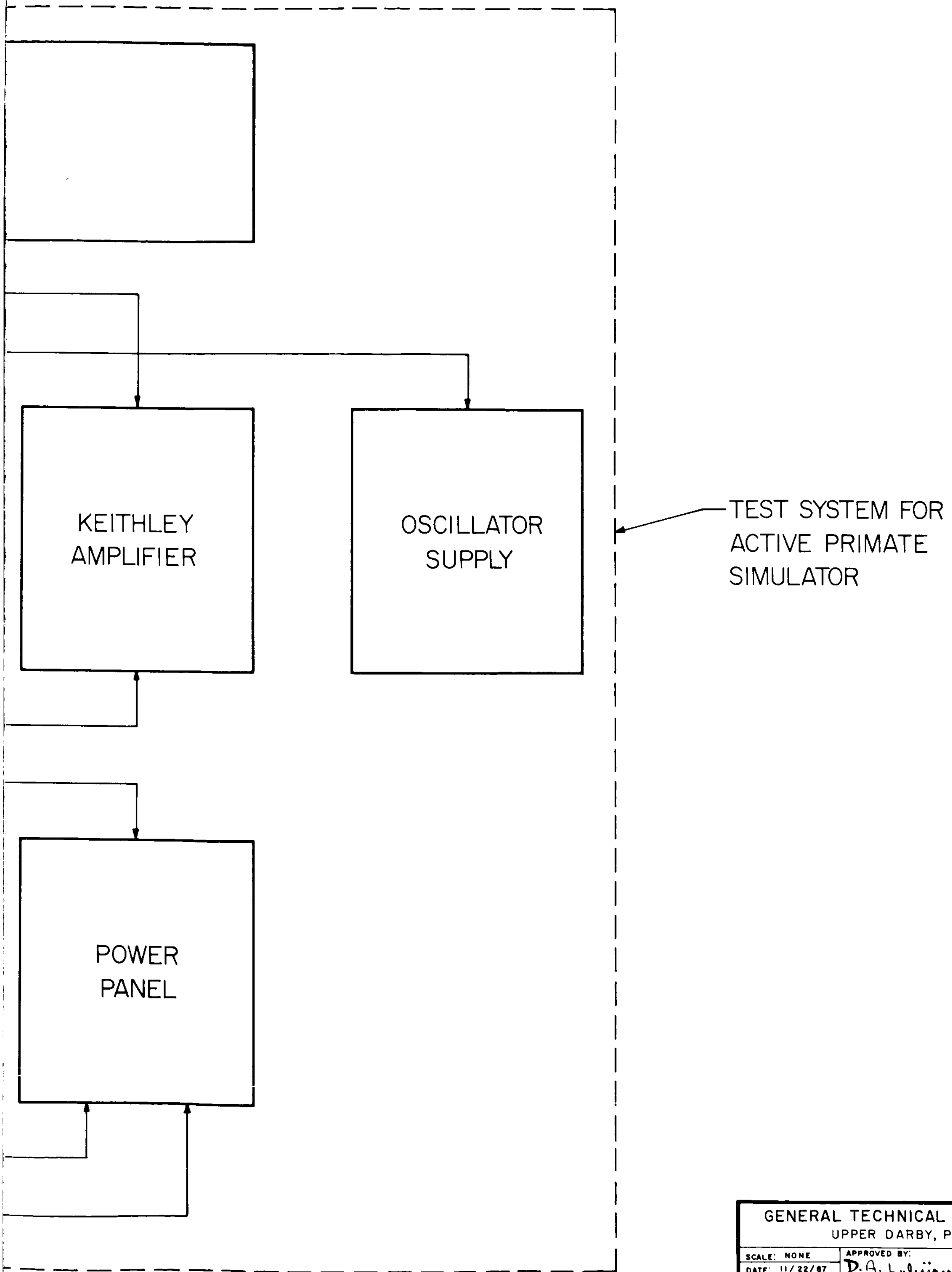
ACTIVE PRIMATE SIMULATOR

DRAWING NO. GTS-9010

FOLDOUT FRAME 1

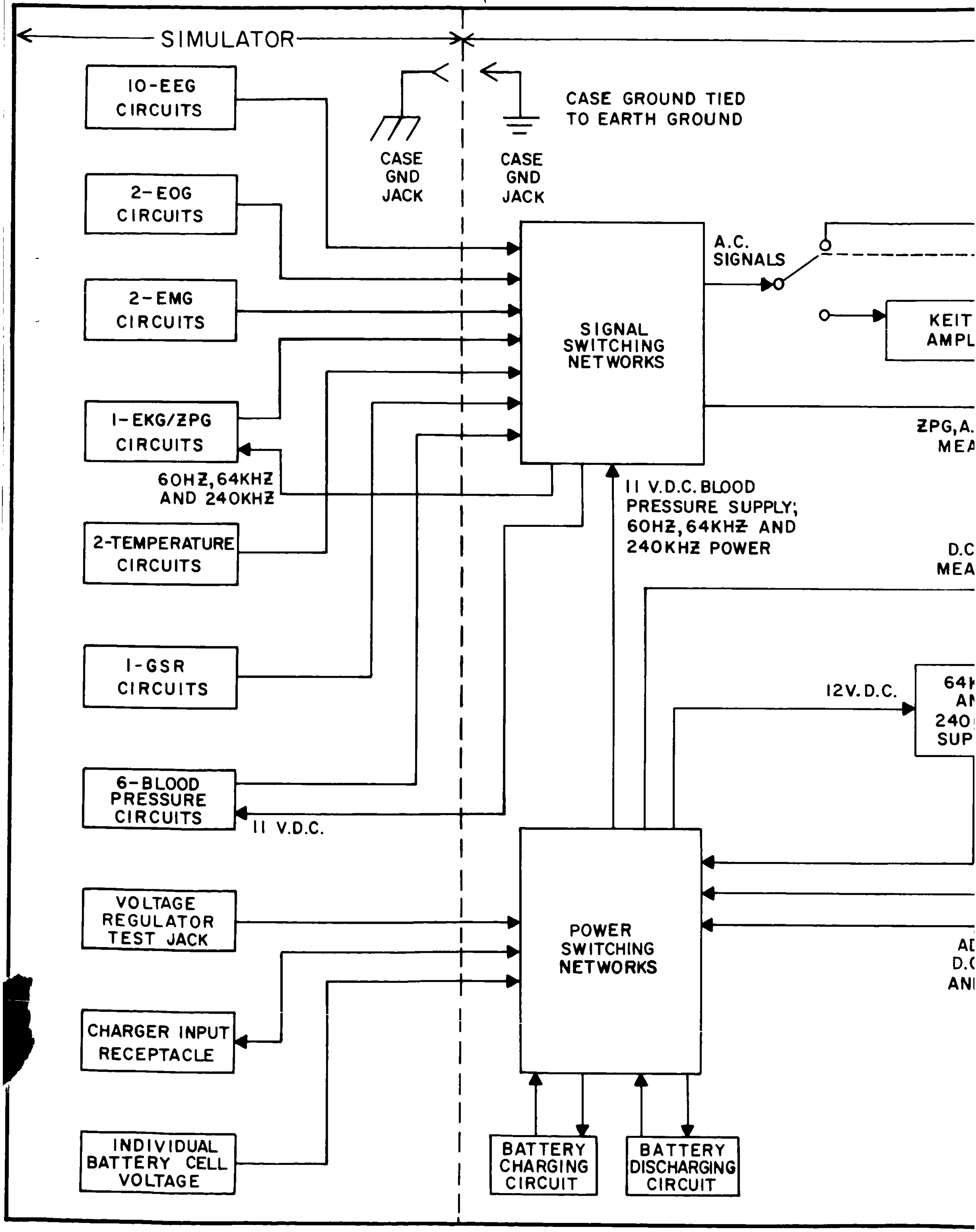


FOLDOUT FRAME 2

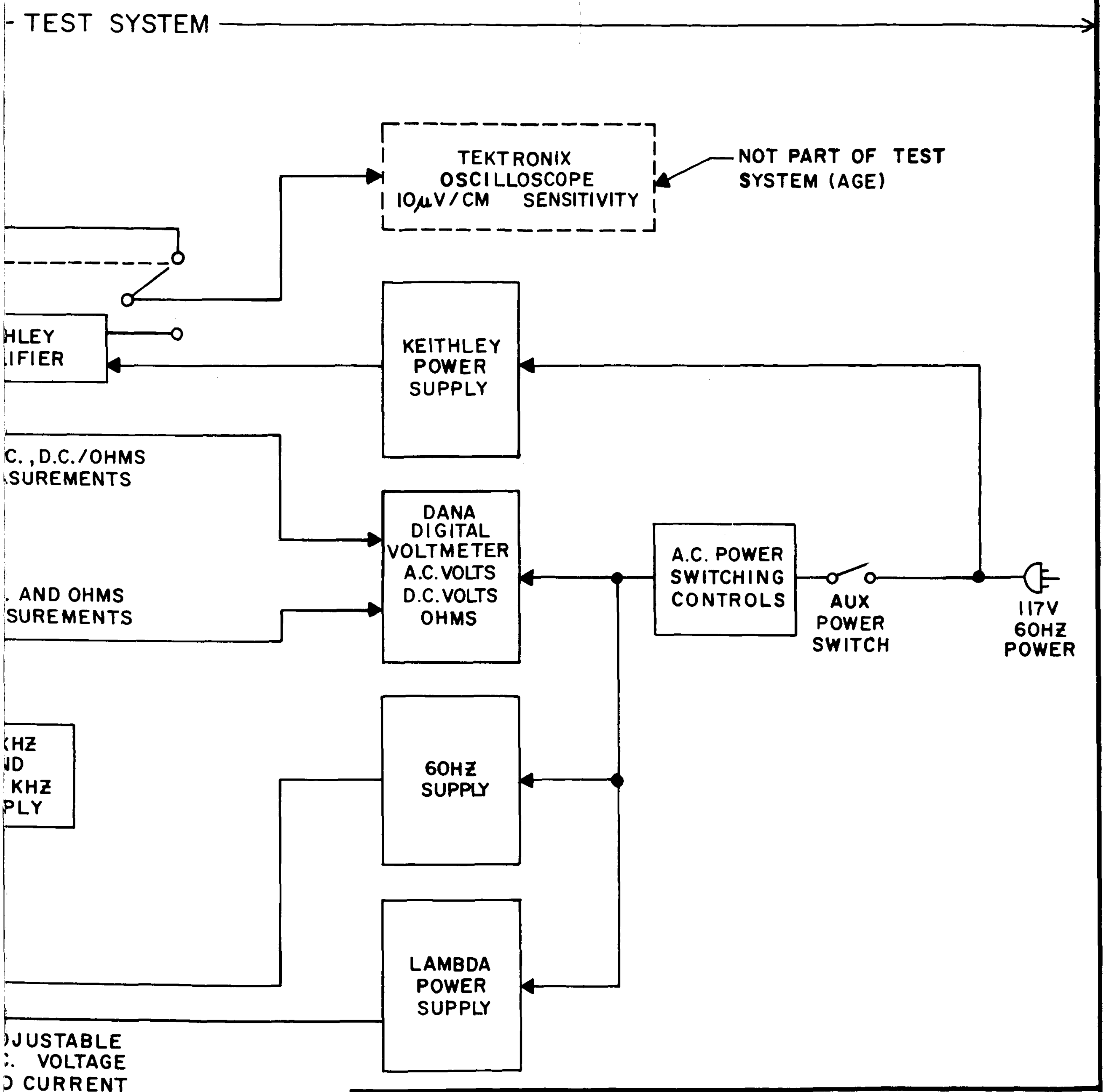


GENERAL TECHNICAL SERVICES, INC.
UPPER DARBY, PA. 19082

SCALE: NONE DATE: 11/22/67	APPROVED BY: D. A. Lulejian	DRAWN BY: A. REVELLI
TITLE: SIMPLIFIED BLOCK DIAGRAM OF TEST SYSTEM FOR ACTIVE PRIMATE SIMULATOR (AGE)		DRAWING NO. GTS-9011


SIMULATOR
10-EEG CIRCUITS
2-EOG CIRCUITS
2-EMG CIRCUITS
1-EKG/ZPG CIRCUITS
60HZ, 64KHZ AND 240KHZ
2-TEMPERATURE CIRCUITS
1-GSR CIRCUITS
6-BLOOD PRESSURE CIRCUITS
11 V.D.C.
VOLTAGE REGULATOR TEST JACK
CHARGER INPUT RECEPTACLE
INDIVIDUAL BATTERY CELL VOLTAGE
CASE GND JACK
CASE GND JACK
CASE GROUND TIED TO EARTH GROUND
SIGNAL SWITCHING NETWORKS
A.C. SIGNALS
KEIT
AMPL
ZPG, A.
MEA
11 V.D.C. BLOOD PRESSURE SUPPLY; 60HZ, 64KHZ AND 240KHZ POWER
D.C
MEA
12V. D.C.
64K
AN
240
SUP
POWER SWITCHING NETWORKS
AD
D.C
AN
BATTERY CHARGING CIRCUIT
BATTERY DISCHARGING CIRCUIT

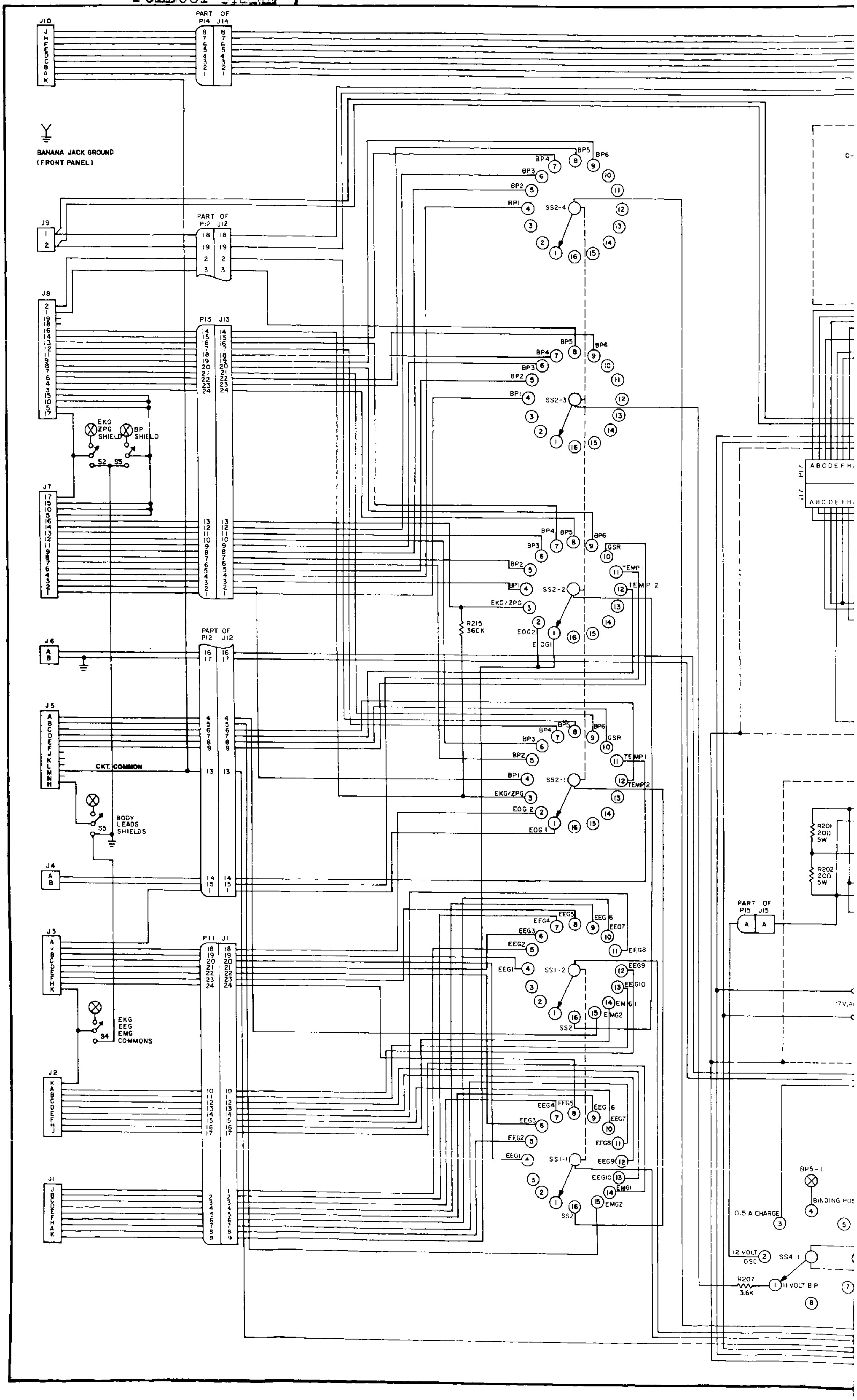
FOLDOUT FRAME 2



GENERAL TECHNICAL SERVICES, INC.
UPPER DARBY, PA. 19082

SCALE: NONE DATE: 11-14-67	APPROVED BY: D. A. Lukejian	DRAWN BY: A. REVELLI
TITLE: BLOCK DIAGRAM: TEST SYSTEM FOR ACTIVE PRIMATE SIMULATOR (AGE)		
		DRAWING NO. GTS9012

FOLDOUT FRAME 1

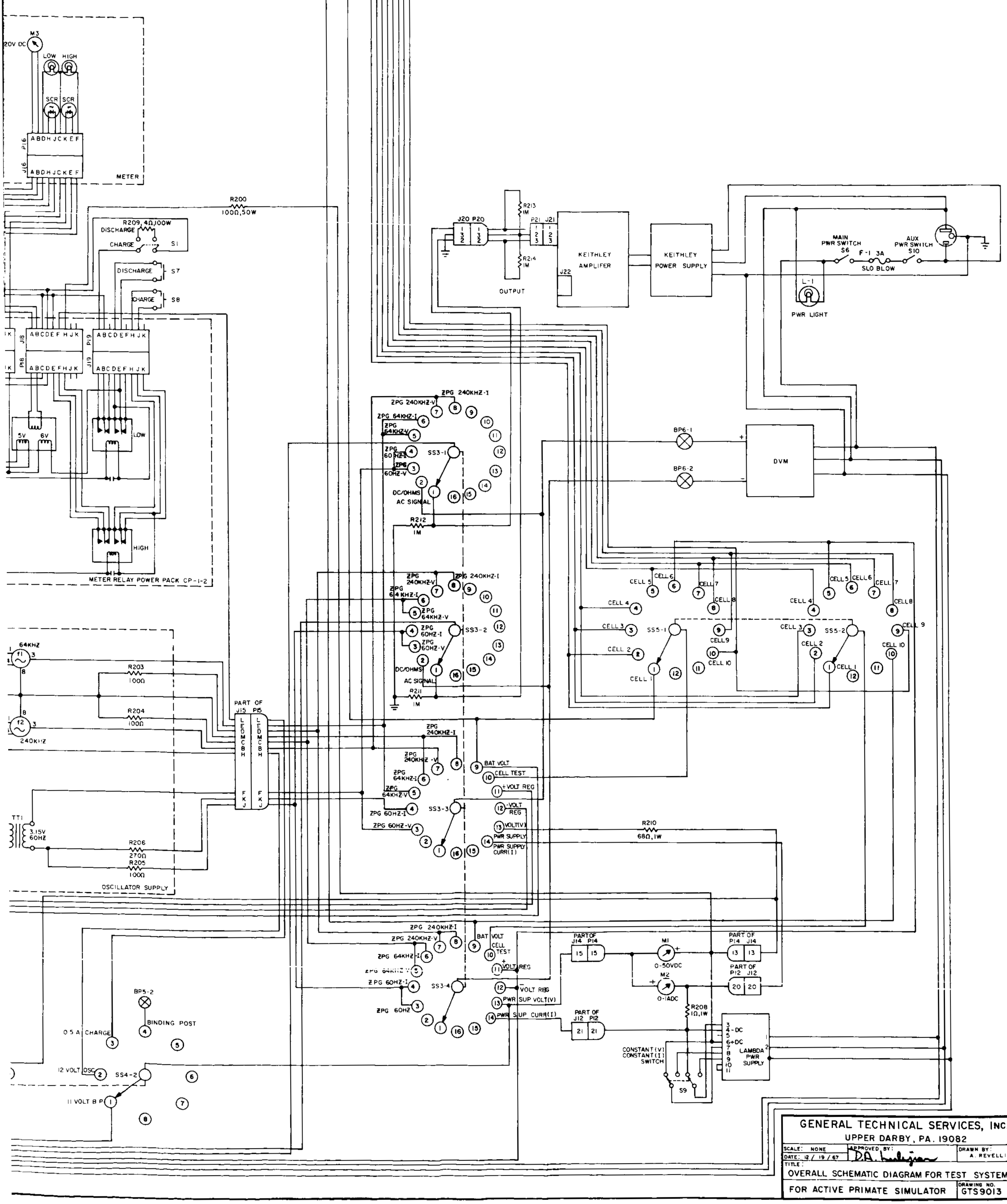


FOLDOUT FRAME 2

REV-A	2-27-68	ADDED GND TO J6-B, -CHG R207 FROM 3.5K TO 3.6K, - CHG CONN. J1 PINS A TO J & J TO A, - CHG. CONN. J3 PINS A TO J & J TO A.	A.M.R.
REV-B	3-29-68	ADDED DESIGNATIONS F-1 & L-1	F.P.

NOTE:

1. ALL CABLING FROM INPUT CONNECTORS ON TEST PANEL TO SWITCHES ON S.S. PANEL TO BE MICRODOT 250-3804 OR 250-3822 SHIELDED CABLE EXCEPT J6, J9 AND J10 WHICH ARE UNSHIELDED AND ANY GROUND WIRES.
2. TEST SYSTEM CHASSIS GROUND TIED TO EARTH GROUND.



GENERAL TECHNICAL SERVICES, INC. UPPER DARBY, PA. 19082		
SCALE: NONE DATE: 12 / 19 / 67	APPROVED BY: D.A. [signature]	DRAWN BY: A. REVELLI
TITLE: OVERALL SCHEMATIC DIAGRAM FOR TEST SYSTEM FOR ACTIVE PRIMATE SIMULATOR		DRAWING NO. GTS9013