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PHYSIOLOGY DATA ACQUISITION SYSTEM DESCRIPTION

MARK L. LOTZ

Technical Report

October 1990

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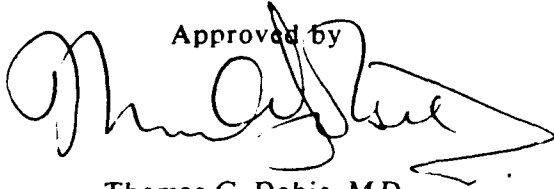
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13. ABSTRACT (Maximum 200 words) This technical report describes the Physiology Data Acquisition System used at NAVBIODYNLAB to acquire, record, and reproduce physiologic responses from human research volunteers subjected to short duration accelerations. The system is used to acquire data such as electrocardiograms, electromyograms, and somatosensory evoked responses. The impact accelerations are provided by horizontal and vertical accelerators. This report describes the systems used for physiology data acquisition during experiments performed on the horizontal and vertical accelerators. The equipment used and the interconnection of the equipment are discussed in detail.				
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PHYSIOLOGY DATA ACQUISITION SYSTEM DESCRIPTION

1. INTRODUCTION

The Naval Biodynamics Laboratory (NAVBIODYNLAB), located in New Orleans, LA, is the principal Naval facility conducting biomedical research on the effects of motion and impact encountered in ships and aircraft by Navy personnel. A continuing research program is underway to establish human tolerance limits for these mechanical forces and to develop methods and techniques to protect personnel from the damaging effects of such forces.

The NAVBIODYNLAB horizontal and vertical accelerators provide the accelerations required in these research programs. Each device is driven by a piston powered by gaseous nitrogen. Using these devices, human research volunteers (HRVs) are subjected to short-duration accelerations simulating crash situations. Their responses are monitored by three data acquisition systems:

- a. Inertial.
- b. Optical.
- c. Physiological.

The Inertial Data Acquisition System collects data from sled and subject mounted accelerometers. This system provides data on device acceleration as well as head and neck acceleration of the subject. The Optical System uses high speed cameras to film the physical movement of the HRV's body in response to the acceleration. The Physiological Data Acquisition System records the subject's physiological responses to the acceleration.

This report describes the Physiology Data Acquisition System used in both the horizontal and vertical accelerators. It discusses in detail the equipment used and the way that equipment is interconnected.

The NAVBIODYNLAB Physiology Data Acquisition System is designed to acquire, record, and reproduce physiologic data such as electrocardiograms (ECGs), electroencephalograms (EEGs), electromyograms (EMGs), somatosensory evoked potential responses (SEPs), and temperature measurements, should they be required, during experiments on the NAVBIODYNLAB horizontal or vertical accelerators. The system consists of a sled- or carriage-mounted card cage with associated electronics, a power source, and a voltage controlled oscillator (VCO)/transmitter package. Amplified physiology signals are sent to the VCOs which multiplex and transmit them to the control room for processing. The signals are demultiplexed and routed through a patch panel to chart recorders, tape recorders, and other recording/processing equipment. A block diagram of the system is provided in Figure 1.

This system makes extensive use of data multiplexing, which allows several channels of data to be recorded on a single recording channel. The NAVBIODYNLAB Physiology Data Acquisition System multiplexes eight data signals on a single data channel. With four multiplexed channels, thirty-two data signals can be recorded on four tracks of magnetic tape.

2. HORIZONTAL ACCELERATOR PACKAGE

The sled-mounted portion of the Physiology Data Acquisition System consists of:

- a. Circuit card cage.
- b. Battery pack.
- c. VCO/transmitter package.
- d. Constant current stimulator.

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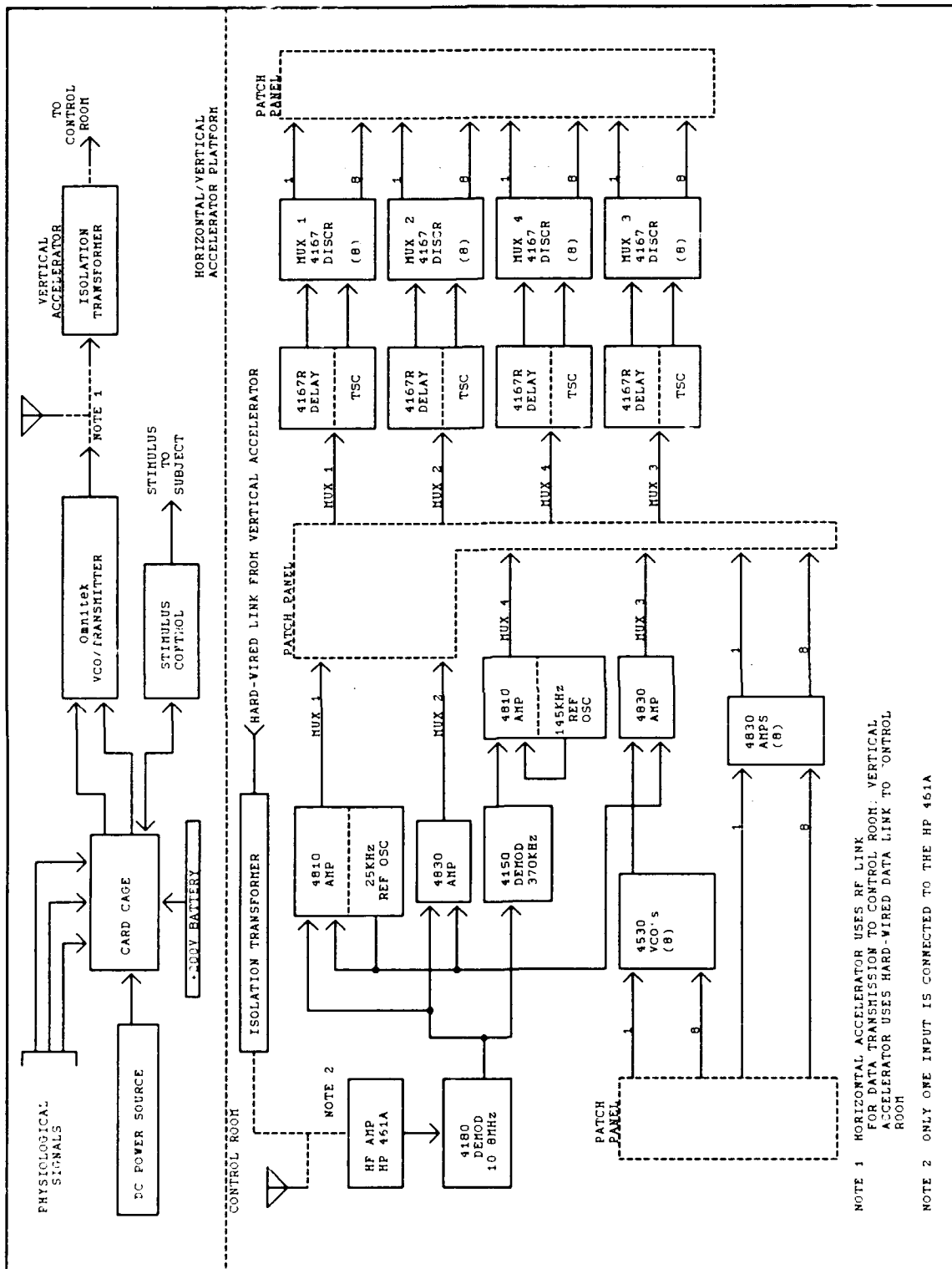


Figure 1. Physiology Data Acquisition System Block Diagram.

2.1 CIRCUIT CARD CAGE

The circuit card cage was fabricated in the NAVBIODYNLAB machine shop. It has slots and circuit card connectors for 18 4.0 x 4.5 in (10.1 cm x 11.4 cm) circuit cards (see Figure 2). The extreme left-hand position in the card cage is occupied by a fiberglass box that contains three 67.5 V batteries connected in series. These batteries supply approximately 200 V direct current (DC), which is required by the constant current stimulator.

Circuit card assignments for slots 1 through 18 are as follows:

SLOT NUMBER	CARD TYPE	SLOT NUMBER	CARD TYPE
1	Stimulus timing	10	EEG input program
2	Stimulus isolation	11	Not used
3	Stimulus voltage/ current monitor	12	EEG amplifiers
4	Shield	13	Spare amplifier
5	ECG input program	14	EEG output program
6	Signal test	15	Output program
7	Spare amplifier	16	EMG/temperature amplifier
8	ECG amplifiers	17	Spare amplifier
9	ECG output program	18	Input program

A schematic diagram of the card cage wiring is provided in Appendix A.

2.1.1 Amplifier Cards

The EEG and ECG amplifier circuit cards are identical except for the operational amplifiers used for the first stage of amplification. Card edge connector pin-outs are the same. The amplifiers use a differential input stage with programmable gain, a fixed gain (x2.5) second stage, and a programmable gain output stage. Programmable high-pass and low-pass filters are part of the circuitry. Gains and filter parameters are programmed using plug-in resistors and capacitors of selected values. These cards require ± 5 V power. Two other amplifier cards are available: One amplifies EMG signals obtained from the musculature of the neck during human subject experiments; the second amplifies the output of a temperature transducer, if required.

Schematic diagrams of these circuit cards may be found in Appendix A.

2.1.2 Input/Output Connectors

Several circular connectors are mounted to a panel attached to the top of the card cage. From left to right, the connectors are:

- ± 5 V power input.
- Stimulator control input/output.
- Stimulator +5 V power input.
- ECG input.
- ECG output.
- EEG input.
- EEG output.
- Four amplifier inputs.
- An auxiliary input.

Figure 3 provides a diagram of typical card cage signal interconnections.

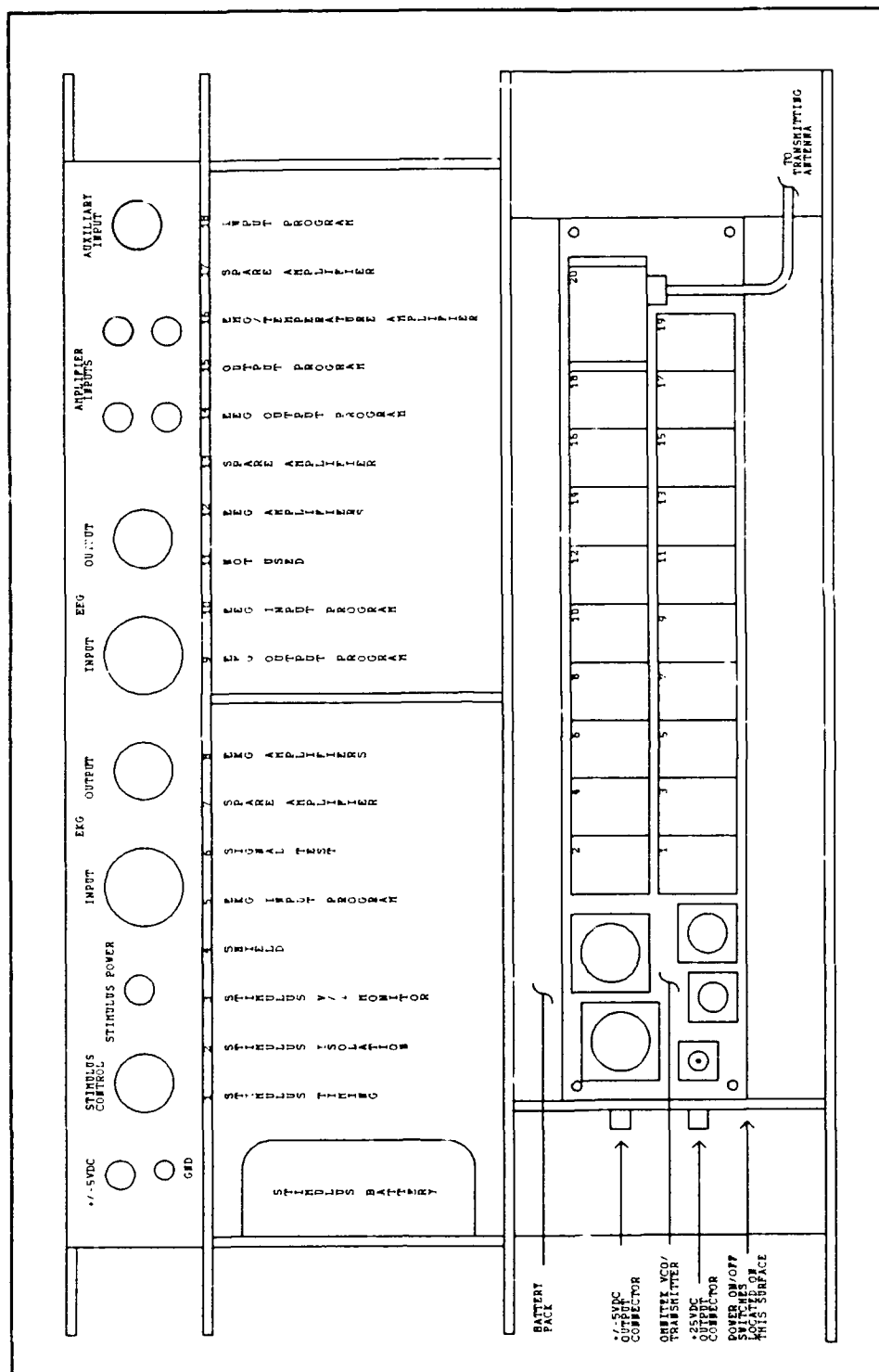


Figure 2. Physiology Card Cage — Horizontal Accelerator.

Physiology Data Acquisition System Description

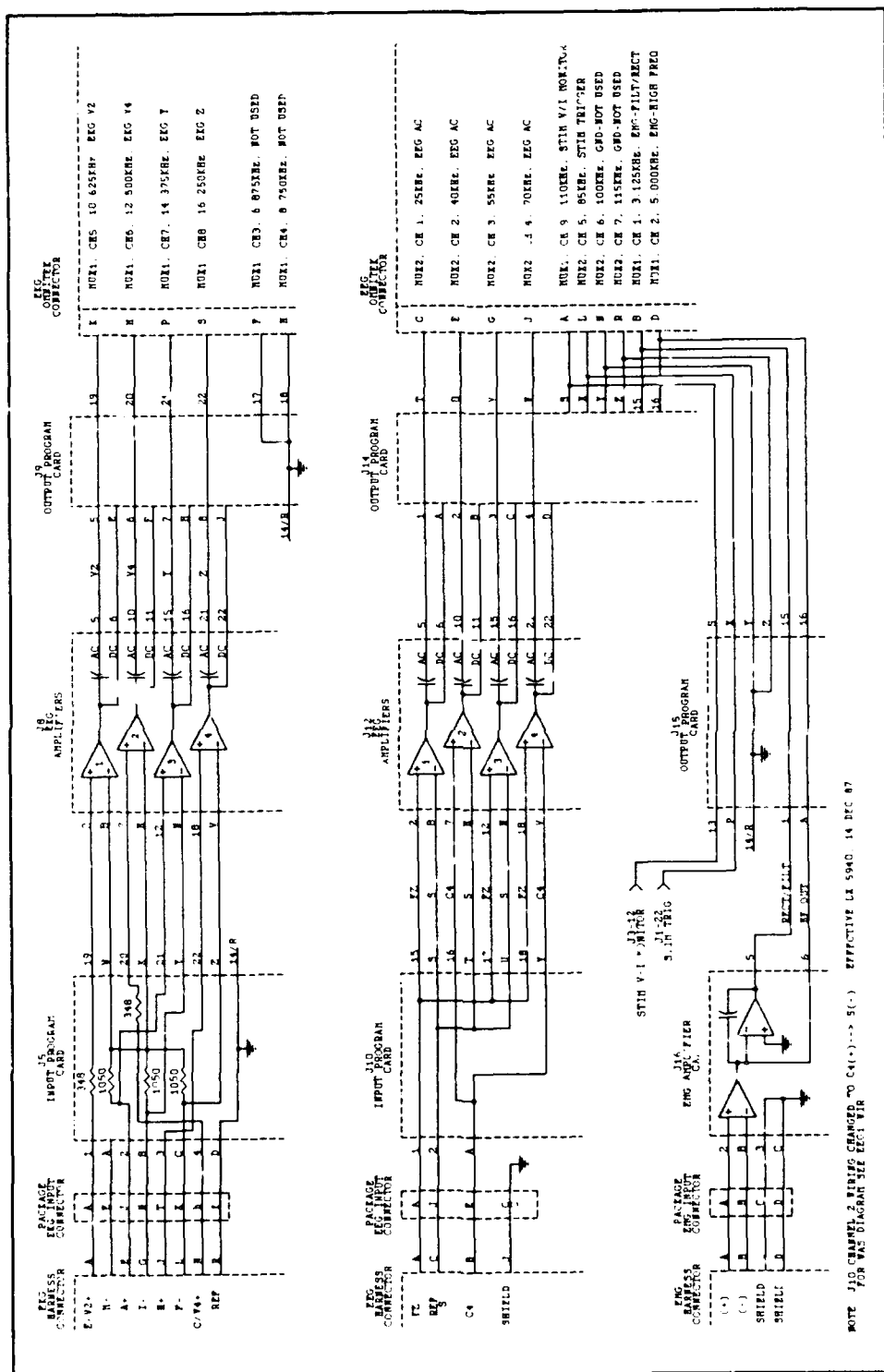


Figure 3. Typical Card Cage Signal Interconnection.

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2.1.3 Input Program Cards

These cards are used to route signals from input connectors on the card cage, via wire jumpers on the card edge contact, to the appropriate amplifier.

2.1.4 Output Program Cards

By using these cards, output signals from the various circuit cards may be routed to the output connectors on the card cage assembly. These signals are generally routed to the VCO/transmitter for multiplexing and transmission to the control room.

2.2 BATTERY PACKS

The card cage battery pack consists of nickel-cadmium rechargeable cells configured to provide ± 5 V to the amplifier cards and +25 V to the VCO/Transmitter package. The power output connectors, charging connectors, power on/off switches, and battery voltage test points for both ± 5 V and +25 V are located on the left side of the battery pack. (Refer to Figure 2.)

A second, separate rechargeable battery pack supplies +5 V to the stimulus control cards located in slots 1, 2, and 3 of the card cage. This pack has a power output connector, charging connector, power on/off switch, and voltage test points.

2.2.1 Battery Charger

The battery packs are recharged using two Heathkit™ power supplies located in the control room (Figure 4). The output of the Model IP-2701 power supply is set to 20.5 V at 300 milliamps (mA) and used to charge the 25 V battery pack. The output of the Model IP-2711 power supply is set to 12.6 V at 300 mA and used to charge the ± 5 V and the secondary +5 V battery packs. The outputs of the power supplies are connected through patch cords to the appropriate binding posts, which are located on a panel directly above the power supplies. The binding posts are connected to a charging cable that runs to the horizontal accelerator Make Ready Console. The charging cable terminates with connectors that mate with those on the battery packs.

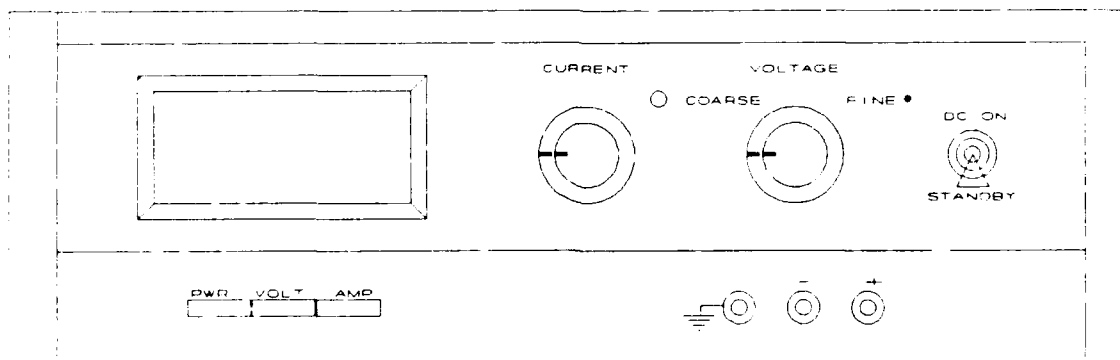


Figure 4. Battery Charging Power Supply.

2.3 VCO/TRANSMITTER

The VCO/transmitter package was manufactured by Omnitek, Inc. (part number DM90-20-1). The package contains 17 high level VCO's, a calibrator, a mixer amplifier, and a 10.8 MHz FM transmitter (Figure 5). There are two input connectors wired in parallel, a power connector, an auto-calibrate command connector, and a radio frequency (RF) output connector, as well as a manual-calibrate push button switch. The VCO outputs are grouped and resistively mixed to provide two multiplexed outputs:

MULTIPLEXER 1		MULTIPLEXER 2	
POSITION	FREQUENCY (kHz) CENTER/DEVIATION	POSITION	FREQUENCY (kHz) CENTER/DEVIATION
1	110.0 $\pm$ 36.0	3	25.0 $\pm$ 4.0
2	3.125 $\pm$ 0.5	5	40.0 $\pm$ 4.0
4	5.000 $\pm$ 0.5	7	55.0 $\pm$ 4.0
6	6.875 $\pm$ 0.5	9	70.0 $\pm$ 4.0
8	8.750 $\pm$ 0.5	11	85.0 $\pm$ 4.0
10	10.625 $\pm$ 0.5	13	100.0 $\pm$ 4.0
12	12.500 $\pm$ 0.5	15	115.0 $\pm$ 4.0
14	14.375 $\pm$ 0.5		
16	16.250 $\pm$ 0.5		

The multiplexer (MUX) 1 output is connected to a mixer amplifier located in position 19; the output of MUX 2 is routed to a NAVBIODYNLAB-designed buffer that has been installed in the package (refer to Figure 6). From the buffer output, the signal is sent to a 370.0 $\pm$ 90.0 kHz VCO (position 17). The MUX 2 signal is connected to the same mixer amplifier as the MUX 1 output. The output of the mixer amplifier is connected to the transmitter input. The transmitter frequency modulates this signal about a center frequency of 10.8 MHz.

2.4 ANTENNA

2.4.1 Transmitting Antenna

The RF output of the transmitter is connected to a 4 ft (1.2 m) length of Andrew RADIAX™ slotted coaxial cable type RX4-1 that constitutes the transmitter antenna. All cabling from the transmitter output to the antenna is Andrew Superflexible HELIAX™ cable type FSJ1-50. The transmitter antenna is attached to the undercarriage of the sled with wooden supports and is aligned parallel to the side wall of the track.

2.4.2 Receiving Antenna

The receiving antenna runs horizontally the length of the acceleration track and consists of Andrew RADIAX™ slotted coaxial cable type RX4-1. It is attached to hardwood blocks mounted along the side wall of the track and positioned so that it will be parallel and adjacent to the transmitting antenna as the sled travels down the track. The end of the antenna closest to the control room is connected by Andrew Superflexible HELIAX™ cable to a wideband amplifier located in the control room (see Section 4). The other end of the antenna terminates in a BNC connector.

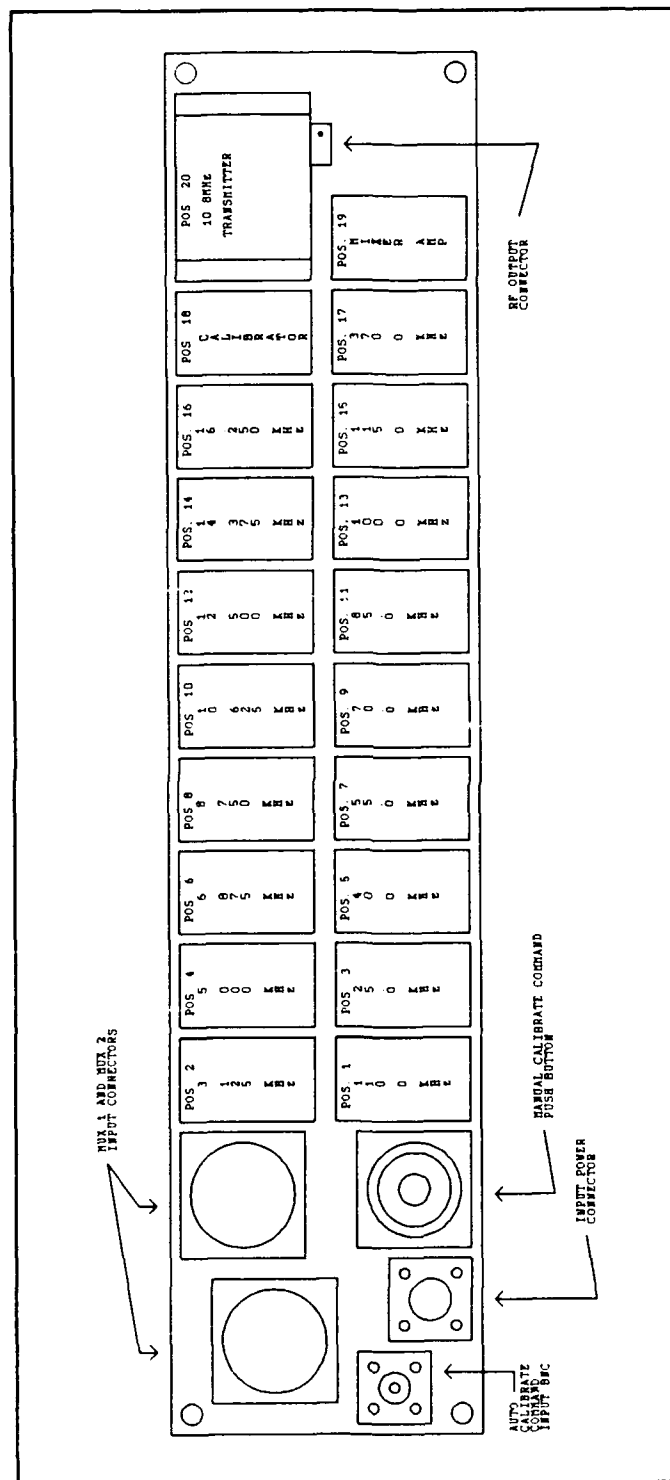


Figure 5. VCO/Transmitter Package.

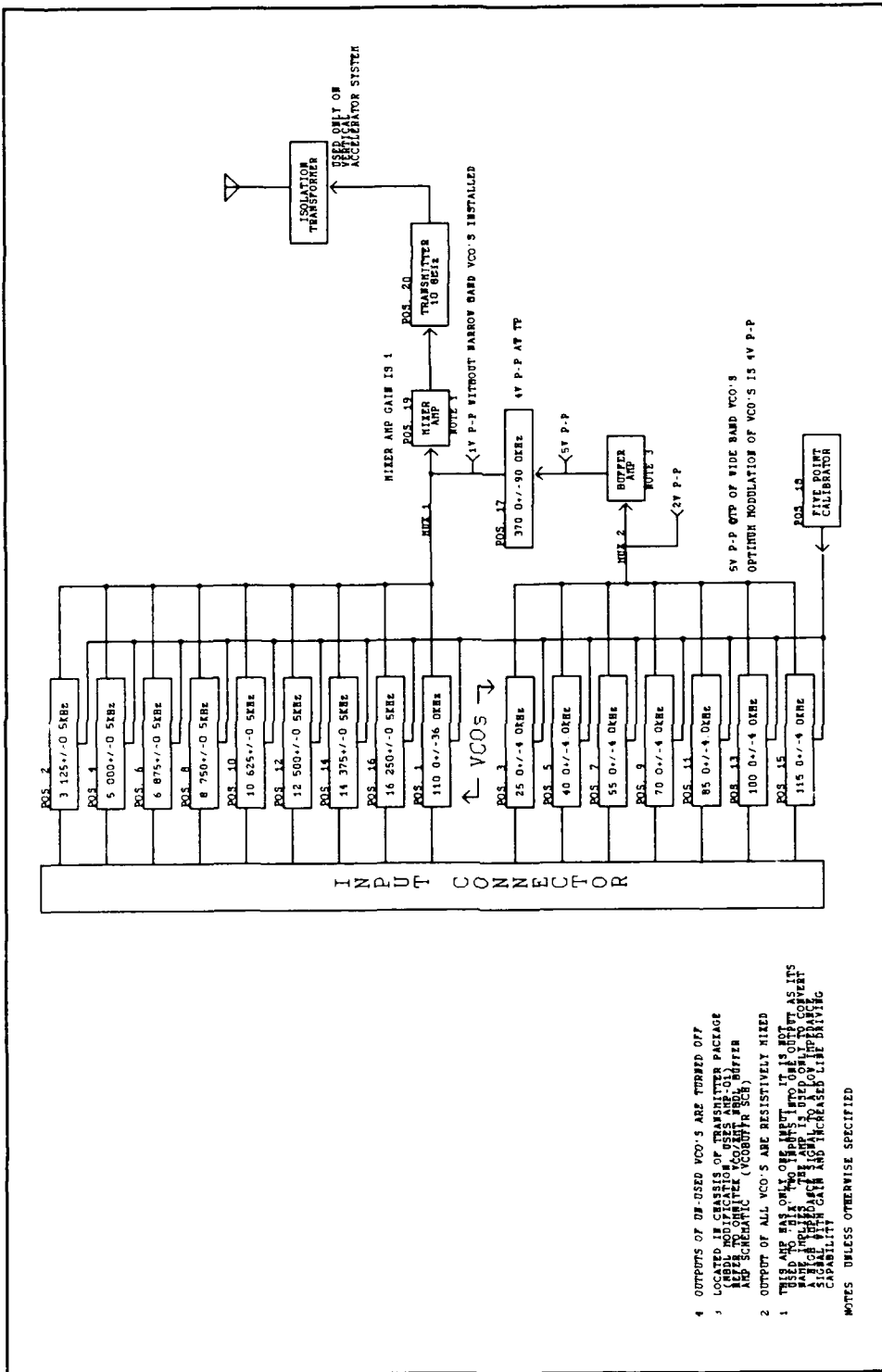


Figure 6. VCO/Transmitter Block Diagram.

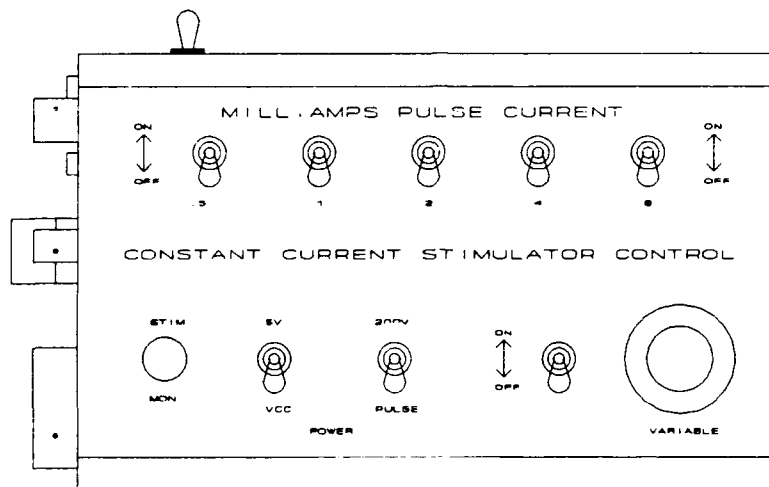


Figure 7. Stimulus Control Unit.

2.5 CONSTANT CURRENT STIMULATOR

The constant current stimulator is used in somatosensory evoked potential response studies. The stimulator system provides a constant current stimulus of a known intensity to the subject, a trigger time-locked to the stimulus, and a stimulus voltage/current monitor signal. The stimulus duration and repetition rate are adjustable. Maximum output is 26.5 mA.

The stimulator is composed of a DC power source, three circuit cards, and a control unit. It is powered by a rechargeable nickel-cadmium battery pack that has been configured to provide +5 V to the circuit cards. This power source was described in paragraph 2.2. An additional set of batteries, located in the left-hand side of the card cage, supplies the 200 V DC needed for the stimulus current.

Located in slots 1, 2, and 3 of the card cage are the stimulus timing, stimulus isolation, and stimulus voltage/current monitor circuit cards. The stimulus timing card contains an oscillator and a counter that generates a square wave at selected output frequencies. Available output frequencies are 20, 10, 5, 2.5, 2, 1.25, and 1 Hz. A square wave trigger signal with an adjustable output level is routed from the card edge to the VCO/Transmitter package. When somatosensory evoked potential response studies are being conducted, this demultiplexed signal in the control room is used to trigger a signal averager. This card also contains pulse shaping circuitry, which generates the stimulus pulse. The switches on the control panel that select the stimulus current level are connected to the timing card. Isolation of the stimulus pulse is accomplished on the stimulus isolation card using six specially wound transformers. The transformer outputs are summed to produce the pulsed current stimulus.

The stimulus voltage/current (V/I) monitor card samples the stimulus output. The monitor produces an output signal containing information on the current and voltage amplitudes of the stimulus.

The stimulus control unit contains a +5 V power on/off switch, a 200 V power on/off switch, and test points for the 200 V stimulus voltage. Also located on the unit are BNC connector test points for the stimulus and V/I monitor outputs, a connector for the cable from the stimulus cards in the card cage, and a second connector for the stimulus output to the experimental sub-

ject. There are five switches that select current values in steps of 0.5, 1, 2, 4, 8 mA. A ten-turn potentiometer provides continuously variable current from zero to 10 mA. A switch turns the variable current output on or off (Figure 7).

3. VERTICAL ACCELERATOR PACKAGE

The Physiological Data Acquisition System used on the NAVBIODYNLAB vertical accelerator differs slightly from that used on the horizontal accelerator (Figure 8). The differences are described in this section.

3.1 CIRCUIT CARD CAGE

A redesigned circuit card cage is used on the vertical accelerator. The card cage can hold up to 22 circuit cards and is mounted to the carriage of the vertical accelerator. Card assignments for slots 1 through 18 are as follows:

SLOT NUMBER	POSI- TION	CARD TYPE	SLOT NUMBER	POSI- TION	CARD TYPE
1	PS1	VCO/Transmitter power supply	12	9	ECG output program
2	1	Stimulus timing	13	10	EEG input program
3	2	Stimulus isolation	14	11	Spare program card
4	3	Stimulus voltage/ current monitor	15	12	EEG amplifiers
5	PS2	Stimulus +5 V power supply	16	13	Spare amplifier
6	4	Shield	17	14	EEG output program
7	PS3	Amplifier ± 5 V power supply	18	15	Output program
8	5	ECG input program	19	16	EMG/temperature amplifier
9	6	Signal test	20	17	Spare amplifier
10	7	Spare amplifier	21	18	Spare input program
11	8	ECG amplifiers	22	19	Spare

3.1.1 Amplifier Card

Amplifier cards used on the vertical accelerator to collect subject physiology data are identical with those used on horizontal accelerator Physiological Data Acquisition System.

3.1.2 Input/Output Program Cards

Input/output (I/O) program cards are used to route physiological input signals to the appropriate amplifier circuits. Amplified signals go to a specified VCO/Multiplexer channel. These I/O program cards are similar to those used on the horizontal accelerator system.

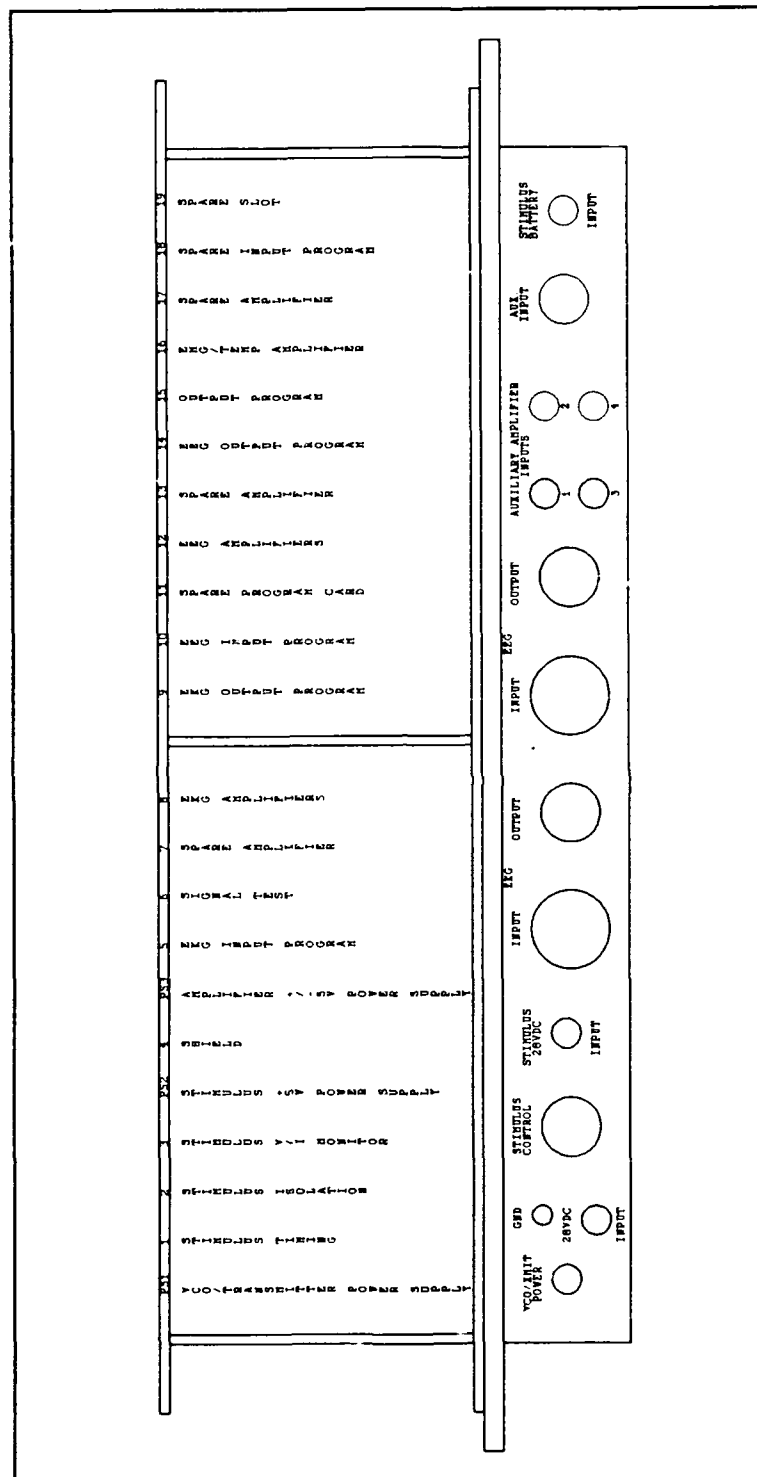


Figure 8. Physiology Card Cage — Vertical Accelerator.

3.1.3 Input/Output Connectors

Several circular connectors are mounted to a panel attached to the underside of the card cage. From left to right, the connectors are:

- a. VCO/transmitter power output.
- b. 28 V DC input.
- c. Stimulator control input/output.
- d. Stimulator 28 V DC input.
- e. ECG input.
- f. ECG output.
- g. EEG input.
- h. EEG output.
- i. Four auxiliary amplifier inputs.
- j. An auxiliary input.
- k. A stimulus battery input.

3.2 POWER SUPPLIES

Because of weight restrictions, batteries are not used on this package. Instead DC to DC converters, located in positions PS1, PS2, and PS3 of the card cage, are used. These are powered by separate 110 V AC to +28 V DC power supplies in the Physiology Instrumentation Console. The DC-DC converter power supplies provide the necessary isolation between the experimental subject and the AC power line.

3.2.1 Power Supply 1 (PS1)

This DC to DC converter supplies +30 V for the VCO/transmitter package.

3.2.2 Power Supply 2 (PS2)

This DC to DC converter provides +5 V to the stimulus circuit cards.

3.2.3 Power Supply 3 (PS3)

This converter supplies ± 5 V DC to the amplifier circuit cards.

3.2.4 28 V Power Supplies

Three modular 110 V AC to 28 V fused power supplies, controls, and indicators are mounted on a panel in the Physiology Instrumentation Console. Each supply has a fused AC input, a fused DC output, an on/off switch for the DC output, and a green indicator to show the DC output status. A single AC line switch is used to turn all power supplies on or off. An amber indicator shows the status of the AC line.

3.2.5 Stimulus Battery

The 200 V DC required by the constant current stimulator is provided by a single 225 V battery. This battery is housed in an enclosure that is mounted on the rear protective panel of the 28 V power supplies.

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3.3 VCO/TRANSMITTER PACKAGE

The Omnitek VCO/transmitter is identical with the one used on the horizontal accelerator system. This package is mounted to the carriage of the vertical accelerator, opposite the circuit card cage.

3.4 DATA TRANSMISSION LINK

The transmitter output is connected to a North Hills 1 kHz - 20 MHz wideband isolation transformer (#0005CC). This transformer output is connected to the control room using a combination of RG-59 coaxial cable and Andrew Superflexible HELIAX™ cable type FSJ1-50. At the control room, the HELIAX™ is connected to another North Hills isolation transformer. The transformer output is connected to the Hewlett Packard 461A wide band amplifier through a Tektronix 50 ohm 10x attenuator (#011-0059-02).

3.5 CONSTANT CURRENT STIMULATOR

The constant current stimulator is the same type as used on the horizontal accelerator. The control unit is mounted on the carriage.

4. CONTROL ROOM COMPONENTS

Equipment described in this section is common to both the horizontal accelerator and vertical accelerator systems. This equipment is located in the control room.

4.1 WIDE BAND AMPLIFIER

The wide band amplifier, a Hewlett Packard 461A, is used to amplify the 10.8 MHz RF data signal from the receiving antenna or hard-wire RF link. A front panel switch allows a gain selection of 20 or 40 dB. Additional information may be found in the HP 461A Operating and Service Manual. The output of the 461A is then routed to the discriminators. These were manufactured by EMR, Inc., and are used by the NAVBIODYNLAB Data Acquisition System to demodulate telemetry data.

4.2 EMR DISCRIMINATORS

Two channels of multiplexed physiological data are recovered from the telemetered data by two discriminators. These two channels of multiplexed data are processed to recover the original 16 data channels. The same equipment is also used to recover the original data channels from multiplexed signals recorded on magnetic tape.

A general functional description of the EMR equipment and how it is interconnected is presented here. For a more comprehensive description of the equipment, refer to the appropriate instruction manual.

The amplified RF signal from the HP 461A is routed to an EMR 4180 high frequency discriminator. The 4180 is used to detect information contained in the 10.8 MHz FM channel (Figure 9). The output of the 4180, which consists of MUX 1 and 370 kHz modulated MUX 2

Physiology Data Acquisition System Description

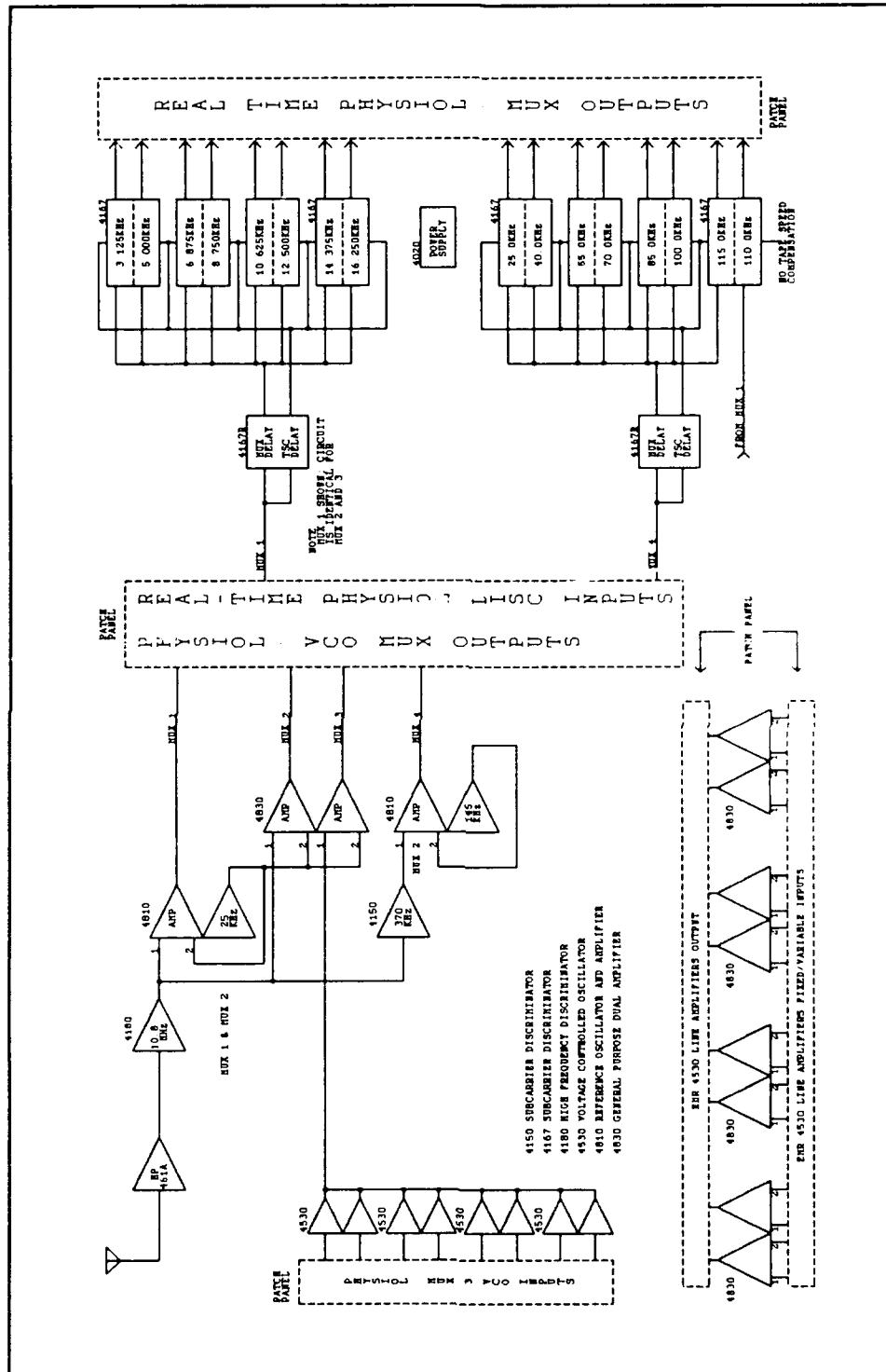


Figure 9. EMR Equipment Interconnect Block Diagram.

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data, is connected to the input of an EMR 4810 reference oscillator and amplifier.

The reference oscillator frequency is 25 kHz and is used for tape speed compensation (TSC). The crystal-controlled reference signal is mixed with the subcarrier multiplex signal during the data recording process. Frequency errors introduced into the data by tape-speed variations result in frequency variations in the reference signal that are directly proportional to tape-speed variations. During playback, the reference signal is separated from the multiplex channel and demodulated. The error signal is then applied to the bias circuit of the discriminator, which corrects for tape speed variations.

The amplifier portion of the 4810 mixes the reference signal with the MUX 1 input and drives the MUX 1 output signal. Amplifier gain is set to the X5 switch position. The MUX 1 signal is connected to the patch panel.

The output of the 4180 high frequency discriminator is also connected to the adjustable input of amplifier A of an EMR 4830 General Purpose Dual Amplifier Unit. This input contains the MUX 1 and 370 kHz modulated MUX 2 data. Each amplifier consists of two identical but functionally independent amplifier circuits; each amplifier has provisions for an adjustable and a fixed input. The fixed input on each amplifier is connected to the 25 kHz oscillator for TSC purposes. The output signal from amplifier A is now renamed and referred to as MUX 2. This is not the same MUX 2 signal that comes from the Omnitek VCO/transmitter package, but a redundant MUX 1 signal path (see Figure 9). The second amplifier's input/output is used for the MUX 3 signal (discussed below). The gain control switches on both amplifiers are set in the X5 position. MUX 2 and MUX 3 outputs are routed to the patch panel.

The 4180 high frequency discriminator output signal is routed to an EMR 4150 subcarrier discriminator. Here the 370 kHz modulated MUX 2 data from the Omnitek VCO/transmitter package are demodulated and separated from MUX 1 data. This output from the discriminator is connected to the adjustable amplifier input of an EMR 4810 reference oscillator and amplifier. The reference oscillator section provides a 145 kHz output, which is used for TSC on the wide-band multiplexer channel. The output is routed to the fixed input on the amplifier section (gain switch setting: X1). The output of the EMR 4810 is now referenced as MUX 4 and is routed to the patch panel.

The system has the capacity for eight additional input signals. These signals are multiplexed through EMR 4530 VCO's, mixed with the 25 kHz TSC signal, amplified, and sent to the patch panel as MUX 3 signals. The VCO inputs are labeled PHYSIOL. MUX. 3 VCO INPUTS and are located at Rows (R):23&24, Columns (C):A-H. The VCO frequencies and deviations are the same as those for sled MUX 1.

The outputs of the four multiplexers on the patch panel are labeled PHYSIOL. VCO MUX OUTPUTS and are located at R:5&6, C:A, C, E, G.

Eight undedicated EMR 4830 dual amplifier units are provided for general signal amplification and mixing. Their inputs and outputs are located on the patch panel and are labeled EMR 4530 LINE AMPLIFIERS, (R:25-28, C:(A)-(H)).

Individual channels contained in the multiplexed data are recovered using EMR 4167R and EMR 4167 subcarrier discriminators. The EMR 4167R also extracts the reference frequency from the recorded multiplex channels and detects any modulation of the reference frequency due to tape speed variations. The output of the 4167R is the tape speed error signal and is wired to all EMR 4167 discriminators for the particular multiplexed channel. Since there is a signal delay in the reference discriminator, a multiplex delay line is included. This line delays the FM multiplex to equal the delay of the reference discriminator. Therefore the TSC error and the FM multiplex applied to the data discriminators are time-coincident.

Inputs for four sets of discriminators are available on the patch panel. They are located under the label REAL-TIME PHYSIOL. DISC INPUTS at R:5, C:H, K, M, P. Outputs of the dis-

Physiology Data Acquisition System Description

criminator are located under the label REAL-TIME PHYSIOL. MUX.# DISC. OUTPUTS. The number sign (#) refers to MUX numbers 1, 2, 3, or 4. Outputs for MUX 1 through 4 discriminators are on the patch panel at R:17&18, C:A-(H).

The EMR 4080 five-point frequency calibrator provides five calibration frequencies to the EMR 4167 discriminators. Refer to the EMR 4080 instruction manual for additional information.

4.3 PATCH PANEL

An AMP 960 shielded patch bay is used to configure the system inputs and outputs. Connection points for the MUX and discriminator inputs and outputs have been identified throughout the functional descriptions (section 4.2). Three removable patch panels are used: one for human experiments, a second for tape playback of data, and a third for special configurations. The layout of the patch bay is shown in Appendix C.

4.4 CHART RECORDERS

Two chart recorders are used for recording data. One is an eight-channel Beckman™ S-2 and the other a twelve-channel Beckman™ Type R. The eight-channel recorder is primarily used as follows:

CHANNEL	SIGNAL
1	ECG-V2
2	ECG-V4
3	ECG-Y
4	ECG-Z
5	Heart Rate BPM
6	Neck Movement EMG
7	Device Acceleration
8	Time Marker

Controls are generally set to the positions indicated:

TYPE 9806A AC COUPLER
TIME CONSTANT DC
HIGH FREQUENCY 1

TYPE 486A PREAMP
Amplitude 1 V/cm (depends on input signal level)

TYPE 486A DYNOGRAPH™ AMPLIFIER	
Amplitude	x1 PREAMP
HF switch	IN
HF RESPONSE switch	CONT.
± switch	depends on input signal (used to change ZERO SET polarity)
ZERO SET	offset adjustment for input signal

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Gain controls may be set to accommodate the signal levels being recorded. Note that the gain for the ECG channels 1-4 should be the same: approximately 2 V/cm. Occasionally it will be necessary to change the gain level settings of these channels to accommodate the ECG signal levels.

A toggle switch on the front panel allows the selection of one of two groups of eight inputs from the patch panel. The up position of the switch, (labeled 1 TO 8) selects the eight signals labeled CHANNEL RELAY N/C INPUTS on the patch panel (R:29, C:(A)→(H)). The down position of the switch (labeled 9 TO 16) selects the eight signals labeled CHANNEL RELAY N/O INPUTS on the patch panel (R:30, C:(A)→(H)). The area labeled CHANNEL RELAY SWINGER on the patch panel (R:29, C:S→Z) is connected to the chart recorder inputs.

The twelve-channel recorder is generally configured as follows:

CHANNEL	SIGNAL
1	EEG — Channel 1: $F_z - C_z$
2	EEG — Channel 2: $C_z - REF$
3	EEG — Channel 3: $F_z - REF$
4	EEG — Channel 4: $F_z - C_z$
5	Stimulus monitor
6	Stimulus trigger
7	EMG — filtered signal
8	EMG — raw signal
9	ECG — V2
10	ECG — V4
11	ECG — Y
12	ECG — Z

Controls are generally set to the positions shown:

TYPE 9806A AC COUPLER
TIME CONSTANT DC
HIGH FREQUENCY 1

TYPE 486A PREAMP
Amplitude 1 V/cm — depends on input signal level.

TYPE 482AM8 DYNOGRAPH™AMPLIFIER	
Amplitude	x1 PREAMP
AUX switch	AUX OUT
± switch	depends on input signal — used to change ZERO SETTING polarity
ZERO SETTING	offset adjustment for input signal.
CAL/HF Response	1

Gain levels are set to accommodate the signals being recorded. The input connections to the chart recorder are made via the area labeled BECKMAN TYPE R DIFF. PREAMP INPUTS on the patch panel (R:25→27, C:A→M). These are differential inputs. The negative inputs are connected to the common on the patch panel and the positive preamplifier inputs are used.

4.5 TAPE RECORDERS

There are three instrumentation recorders located in the control room. Two are Ampex™ FR-2000 units; the third is an Ampex™ FR-2000A. The two FR-2000s are capable of recording and reproducing seven channels of data on 1/2-in (1.27 cm) wide magnetic tape. The FR-2000A can do the same, as well as record/reproduce 14 channels on 1-in (2.54 cm) wide magnetic tape. Their record/reproduce characteristics are configured to Inter-Range Instrumentation Group (IRIG) standard formats. Complete information is contained in the Ampex™ FR-2000 and FR-2000A system operation manuals.

One FR-2000 is used to record seven channels of physiological data and is centrally located in the physiological equipment racks in the control room. The second FR-2000 records seven channels of inertial instrumentation data and is located on the right side of the equipment rack. The FR-2000A is located on the left end of the equipment rack and is configured to record 14 channels of physiological data. This recorder has generally not been used when the FR-2000 can accommodate the physiological data recording requirements for a particular series of experiments. When recordings are required by facilities that do not have demultiplexing capability, it provides parallel recording of physiological data in IRIG proportional format.

Channel assignments for physiological data are as shown on the NBDL Magnetic Tape Data Log (Figure 10). Tape speed is 30 in (762 mm) per second when recording wide bandwidth MUX 4 data; otherwise, 7-1/2 in (190.5 mm) per second is used to conserve tape. Record inputs to the FR-2000 are provided at patch panel locations R:7&8, C:A→G and are labeled NO. 1 FR. 2000 RECORD INPUT. Reproduce outputs are labeled NO. 1 FR. 2000 REPRODUCE OUTPUTS and are located at R:7&8, C:H→P.

Inputs and outputs for the FR-2000 used to record inertial data are also on the patch panel and are labeled NO. 2 FR. 2000 RECORD INPUTS and NO. 2 FR. 2000 REPRODUCE OUTPUTS. They are located to the right of the inputs and outputs for the Number 1 FR-2000. Channel assignments for recording inertial data are as shown on the NBDL Magnetic Tape Data Log (Figure 11). Tape speed is 30 in (762 mm) per second when recording inertial data.

The areas on the patch panel labeled FR. 2000A RECORD INPUTS and NO. 2 FR. 2000A REPRODUCE OUTPUTS are for the Ampex™ FR-2000A.

4.6 AUDIO SYSTEMS

Voice communication is required during horizontal and vertical accelerator experimental runs. Personnel in the control room, test cell sled area, and vertical accelerator area must be able to communicate with one another. The equipment used to accomplish this is explained here.

4.6.1 Horizontal Accelerator

There are two audio systems used in the NAVBIODYNLAB control room (Figure 12). One system amplifies test cell/sled area voice information and uses an Altec™ M-20 microphone system wired to an Altec™ 438A microphone preamplifier, which in turn is connected to an Altec™ 1611A mixer/power amplifier. Amplified test cell voice information is output through two speakers located in the ceiling of the control room.

The Altec™ 1611A is located below the patch panel. The MIX 1 knob controls the level of the test cell microphone. The MIX 2 knob controls the level of the Fire Control Console (FCC) microphone. The MIX 3 knob controls the level of an input from the patch panel (ALTEC 1611 AUDIO IN NO.3, R:5, C:(G)). This input can be used to monitor voice annotations during playback.

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NAVAL BIODYNAMICS LAB ANALOG DATA ACQUISITION SYSTEM MAGNETIC TAPE DATA LOG

TAPE NUMBER: _____

BEGIN RUN NUMBER: _____

DATE: _____

END RUN NUMBER: _____

DATE: _____

RECORDER: FR-2000 (Physio.)

TAPE WIDTH: 1/2"

IPS: 30

TAPE CHANNEL	SIGNAL IDENTIFICATION	RECORD MODE	ATTENUATION RATIO*
1	<u>MUX. 1; Narrow Bandwidth</u>	<u>Direct</u>	<u>1</u>
2	<u>Test Cell Mic.</u>	<u>Direct</u>	<u>1</u>
3	<u>MUX. 2; Narrow Bandwidth</u>	<u>Direct</u>	<u>1</u>
4	<u>IRIG B Modulated Time Code</u>	<u>FM</u>	<u>1</u>
5	<u>MUX. 3; Narrow Bandwidth</u>	<u>Direct</u>	<u>1</u>
6	<u>P.A. Bridge Mic.</u>	<u>Direct</u>	<u>1</u>
7	<u>MUX. 4; Wide Bandwidth</u>	<u>Direct</u>	<u>1</u>
8	_____	_____	_____
9	_____	_____	_____
10	_____	_____	_____
11	_____	_____	_____
12	_____	_____	_____
13	_____	_____	_____
14	_____	_____	_____

* Conversion from 10 V p.p. t. 1 V RMS.

Figure 10. Magnetic Tape Log — Physiology Data

Physiology Data Acquisition System Description

NAVAL BIODYNAMICS LAB
ANALOG DATA ACQUISITION SYSTEM
MAGNETIC TAPE DATA LOG

TAPE NUMBER: _____

BEGIN RUN NUMBER: _____

DATE: _____

END RUN NUMBER : _____

DATE: _____

RECORDER: FR-2000 (Inertial)

TAPE WIDTH: 1/2"

IPS: 30

TAPE CHANNEL	SIGNAL IDENTIFICATION	RECORD MODE	ATTENUATION RATIO*
1	<u>Inertial MUX. 1 / Cell Mic.</u>	<u>Direct</u>	<u>1</u>
2	<u>Physiology MUX. 1</u>	<u>Direct</u>	<u>1</u>
3	<u>Inertial MUX. 2/P.A. Bridge Mic.</u>	<u>Direct</u>	<u>1</u>
4	<u>IRIG B Modulated Time Code</u>	<u>FM</u>	<u>1</u>
5	<u>Inertial MUX. 3</u>	<u>Direct</u>	<u>1</u>
6	<u>Physiology MUX. 4</u>	<u>Direct</u>	<u>1</u>
7	<u>Inertial MUX. 4</u>	<u>Direct</u>	<u>1</u>
8	_____	_____	_____
9	_____	_____	_____
10	_____	_____	_____
11	_____	_____	_____
12	_____	_____	_____
13	_____	_____	_____
14	_____	_____	_____

* Conversion from 10 V p.p. to 1 V RMS.

Figure 11. Magnetic Tape Log — Inertial Data

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The Altec™ 438A is located to the right of the Altec™ 1611A. The knob labeled VOLUME controls the output level. A second input to the 438A is provided on the patch panel (ALTEC 438A LINE IN, R:5, C:(H)). An output labeled CELL MIKE OUT (R:5, C:(E)) is also provided.

The second audio system provides audio from the control room to the test cell/sled area. Two Altec™ 626A Electret condenser microphones are connected to an Altec™ 1530A amplifier. This amplifier is located on the lower left side of the FCC. One microphone is on the Fire Control Console. The second microphone is located near the Beckman™ 12 channel chart recorder amplifier cabinet. Output of the amplifier is connected to two speakers located outside the control room. One is directly in front of the control room and the other is located 220 ft (67 m) down the track. The output of the Altec™ 1530A also drives a third speaker on the ceiling of the control room, above the FCC.

The MIX 1 knob on the 1530A amplifier controls the level of the FCC microphone; MIX 2 controls the level of the second microphone. The MIX 3 knob controls the level of the FM receiver located directly below the amplifier. (This FM receiver is no longer used during sled runs.) The MIX 4 knob controls the level of the microphone located in the NAVBIODYNLAB vertical accelerator FCC. (This provides audio information to the personnel manning the photography control console and the control room during vertical accelerator runs.) The knob labeled MASTER is used to adjust all signal levels simultaneously. A tap from the output of the audio amp is wired to the patch panel at R:5, C:(F) and is labeled P.A. BRIDGE OUT. This signal can be patched in to the tape recorder(s) to provide voice annotation on the data tapes.

4.6.2 Vertical Accelerator

Communication from the vertical accelerator area to the control room is done via a Telex™ IC-3M amplifier and microphone system mounted in the FCC. The output of this amplifier is connected to a speaker mounted to the wall. A second output from this Telex™ amplifier is routed to the horizontal accelerator control room. This signal level is adjusted with the MIX 4 control on the Altec™ 1530A amplifier. This communication link provides audio information to personnel manning the photography control console and the control room during vertical accelerator runs.

A Shure™ 587SB microphone wired in parallel with a Telex™ microphone provides communication from the control room to the vertical accelerator FCC area. The Shure™ microphone is used by personnel monitoring physiology data; the Telex™ microphone is used by the computer operator. Output of these microphones are routed to a Realistic™ MPA-20 amplifier located in the vertical accelerator Electrical General Purpose Console. This amplifier drives a speaker located on top of this console.

Connecting the P.A. BRIDGE OUT signal to the ALTEC 1611 AUDIO IN NO. 3 input on the patch panel allows the vertical accelerator FCC microphone signal to be output through the speakers located in the ceiling of the control room. The level of this signal is controlled by the Altec™ 1611 MIX 3 control.

5. AUXILIARY MONITORING EQUIPMENT

5.1 MONITOR OSCILLOSCOPES

There are five oscilloscopes used for signal/data monitoring during a run. An ECG monitor is located in the horizontal accelerator Make Ready Console (MRC) and displays four channels of ECG data (V2, V4, X, Y) for use by the NAVBIODYNLAB medical staff. A similar monitor is located in the vertical accelerator Physiology Instrumentation Console and is used to monitor

Physiology Data Acquisition System Description

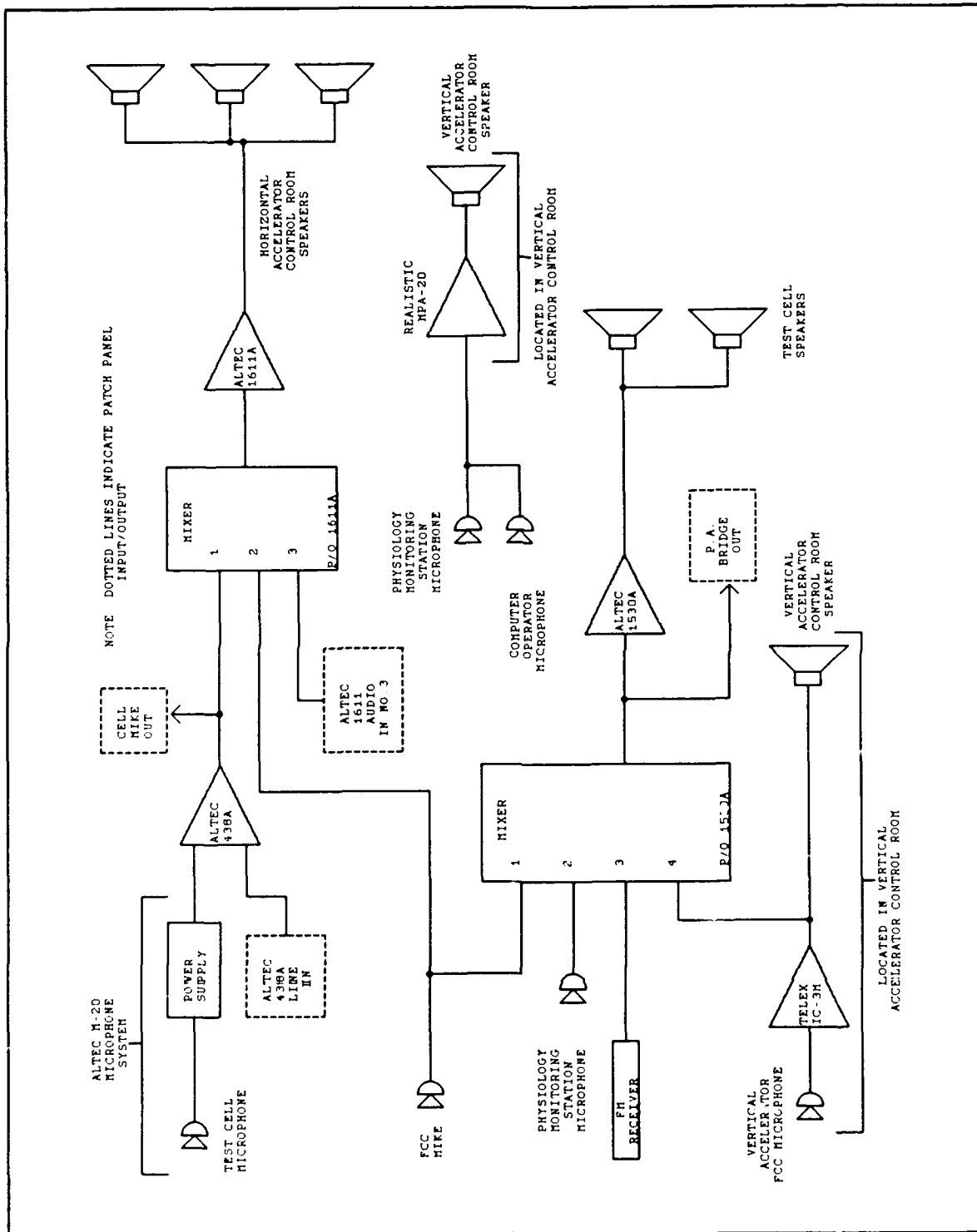


Figure 12. Audio System Block Diagram.

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four channels of ECG data during vertical accelerator experiments. Inputs to both oscilloscopes are on the patch panel in the area labeled ECG TO TRACK (R:23&24, C:J→M).

Another oscilloscope is located above the patch panel. This oscilloscope is used for general monitoring of signals of the patch panel and EMR equipment. Inputs are connected directly to the oscilloscope's vertical amplifiers and not through the patch panel.

The remaining three oscilloscopes are grouped together in the equipment rack located between the Ampex™ FR-2000A and FR-2000 Number 1. The uppermost oscilloscope is designated Number 1 and is used for general physiological signal monitoring. For example, in one series of experimental runs it was used to monitor the stimulus voltage/current level, stimulus trigger, EMG raw and filtered signals. Inputs to this oscilloscope are made via the patch panel and are labeled NO. 1 SCOPE PRE AMP (R:23&24, C:S→V). The next oscilloscope in this rack is used to monitor four channels of ECG (V2, V4, X, Y). Inputs are accessible through the patch panel and are labeled NO. 2 SCOPE PRE AMP (R:23&24, C:W→Z). Oscilloscope 3 is used to monitor four channels of EEG data. The patch panel inputs are labeled NO. 3 SCOPE PRE AMP (R:23&42, C:(A)→(D)). They also provide external trigger inputs to oscilloscopes 1, 2, and 3. These are labeled EXTERNAL TRIGGERS IN (R:21&22, C:W→Z). Inputs on the patch panel for oscilloscope 4 are not used.

5.2 HEART RATE MONITOR

A Hewlett Packard 5326B Timer-Counter-DVM located on top of the Consolidated Electrodynamics Corporation (CEC) recording oscillograph equipment rack is used to monitor the heart rate derived from an ECG signal. The output of the Beckman™ Cardiotach module is used as an input signal to a low-pass filter circuit. This filtered beats-per-minute signal is wired to the digital voltmeter input on the HP 5326B. The heart rate is read directly from the digital display.

5.3 RESPIRATION MONITOR

A Hewlett-Packard 78354A patient monitor is used during vertical accelerator runs to monitor the respiration rate of the subject. The monitor is located below the vertical accelerator ECG monitor oscilloscope.

APPENDIX A

SCHEMATIC DIAGRAMS

CONTENTS

ECG Amplifier	A-1
EEG Amplifier	A-2
FMG Amplifier	A-3
Temperature Probe Amplifier	A-4
Constant Current Stimulator — Control Unit	A-5
Constant Current Stimulator — Digital Section	A-6
Constant Current Stimulator — Isolation Section	A-7
Constant Current Stimulator — Voltage/Current Monitor	A-8
NAVBIODYNLAB VCO/Transmitter Buffer Amplifier	A-9

Physiology Data Acquisition System Description

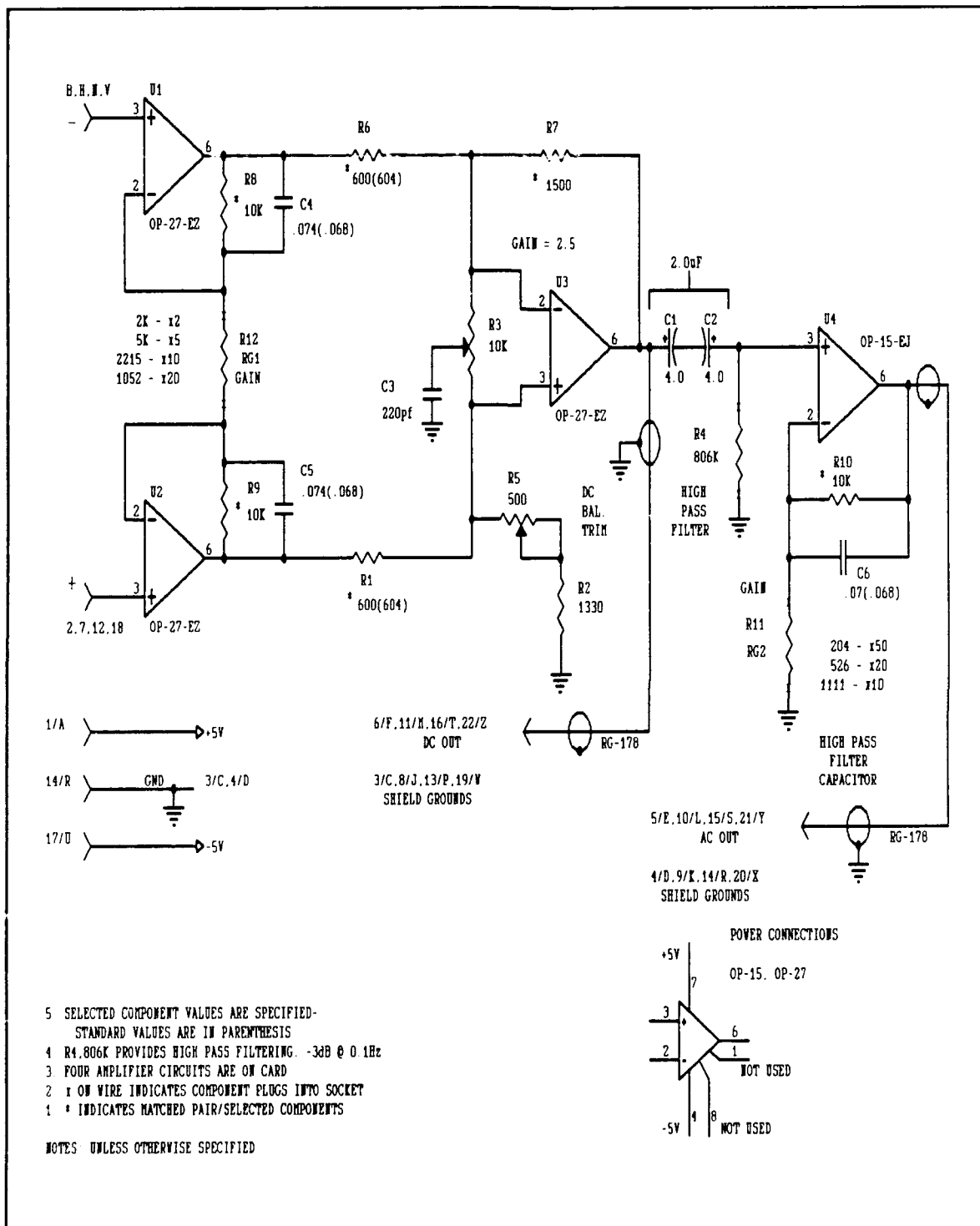


Figure A-1. ECG Amplifier.

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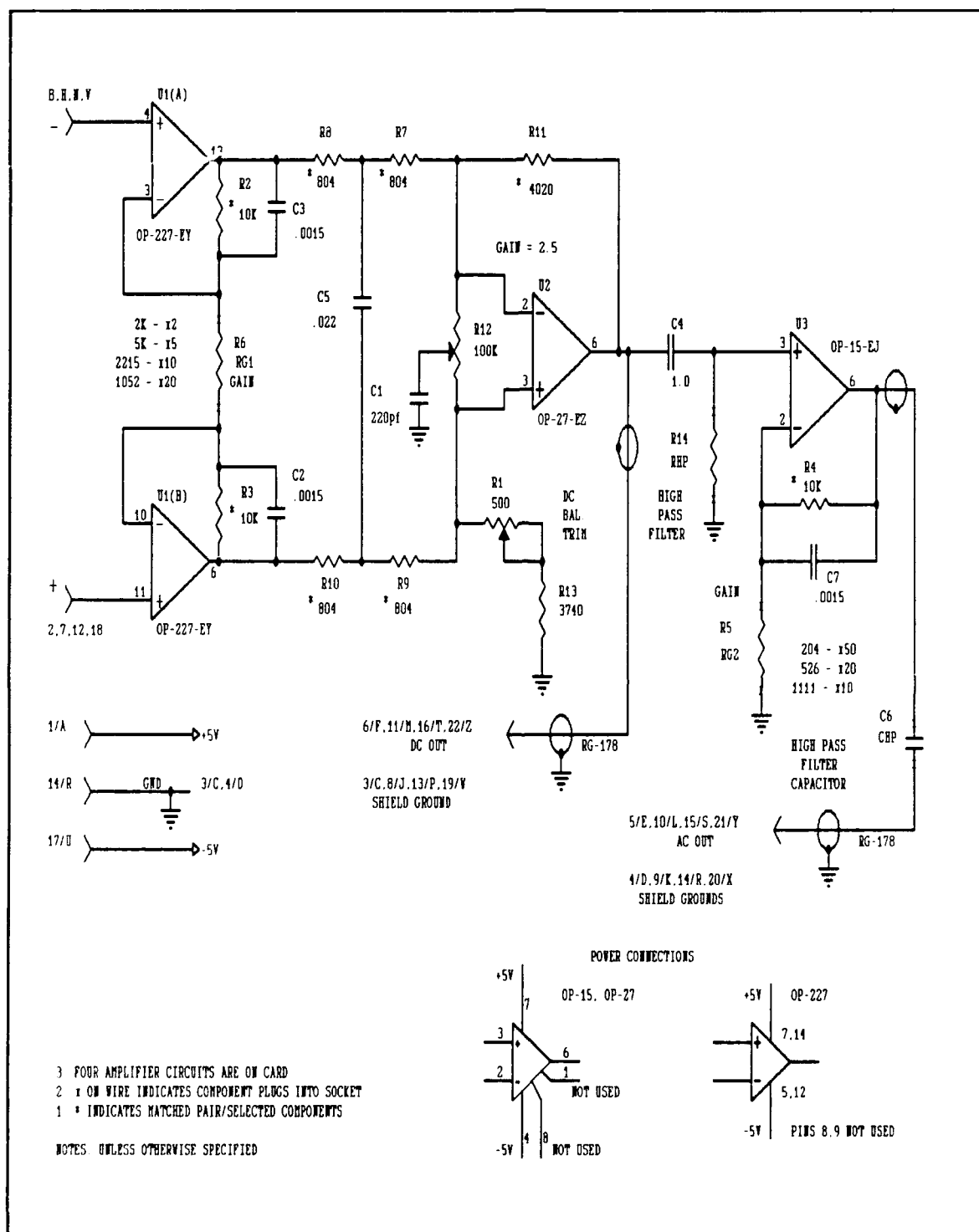


Figure A-2. EEG Amplifier.

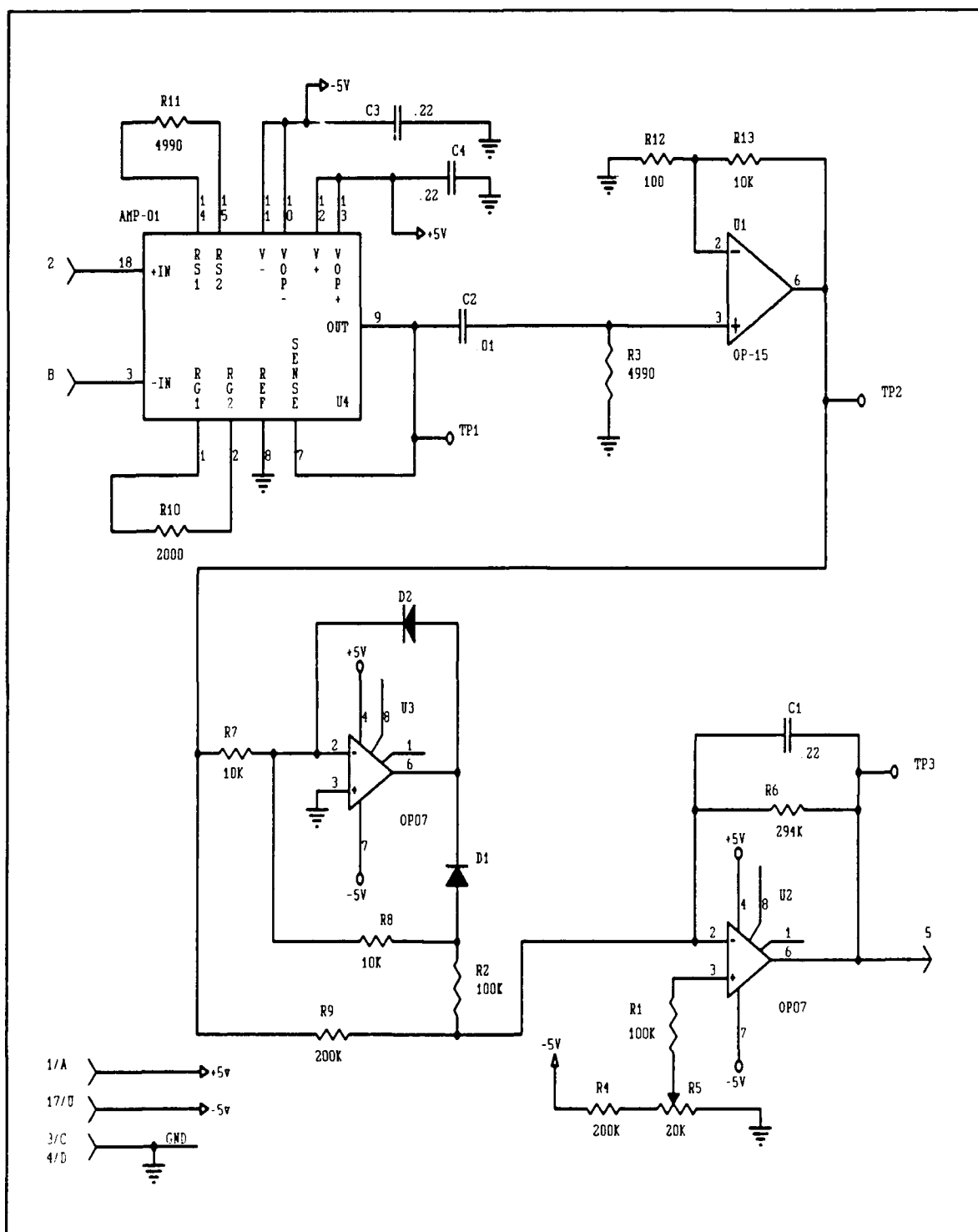


Figure A-3. EMG Amplifier.

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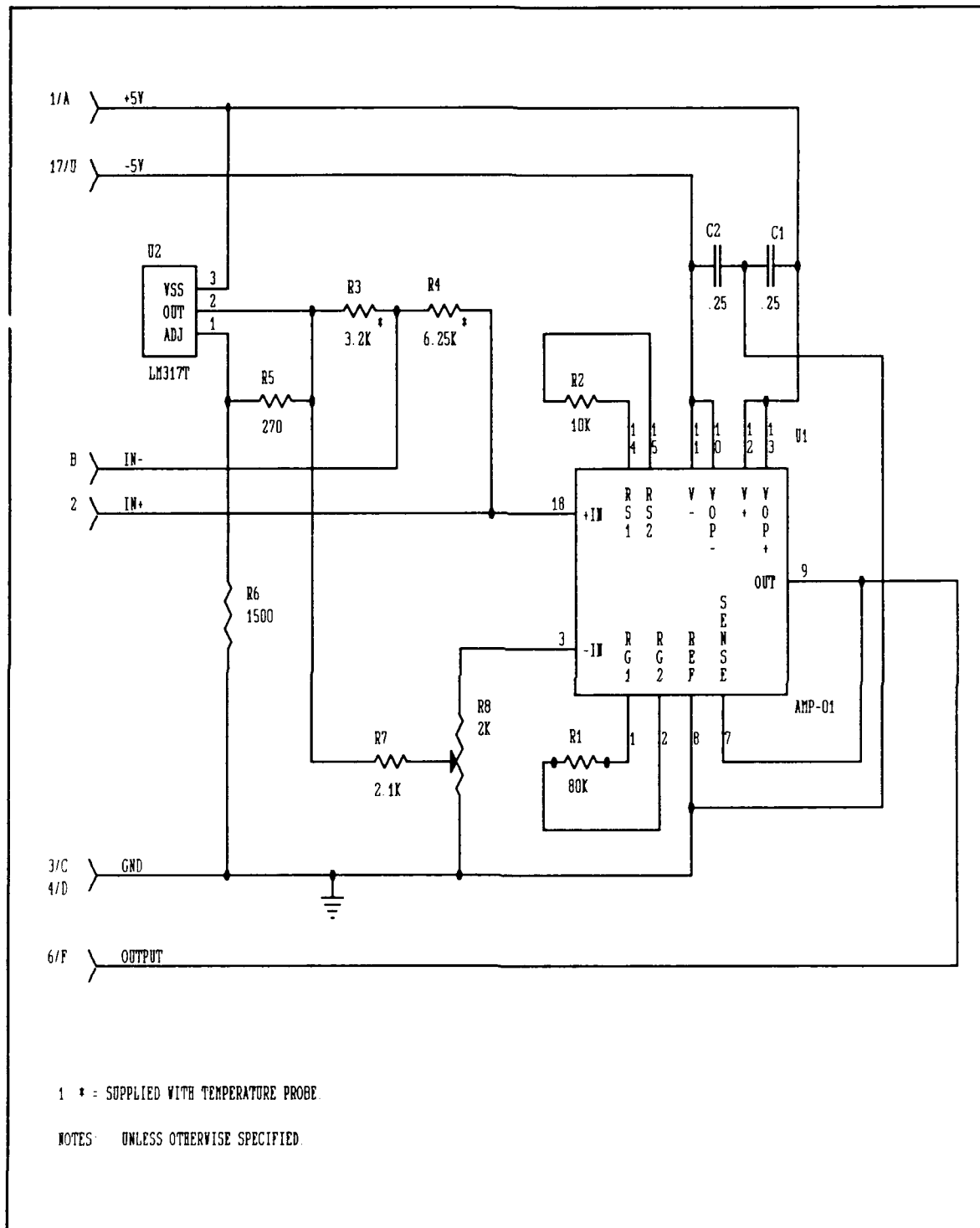


Figure A-4. Temperature Probe Amplifier.

Physiology Data Acquisition System Description

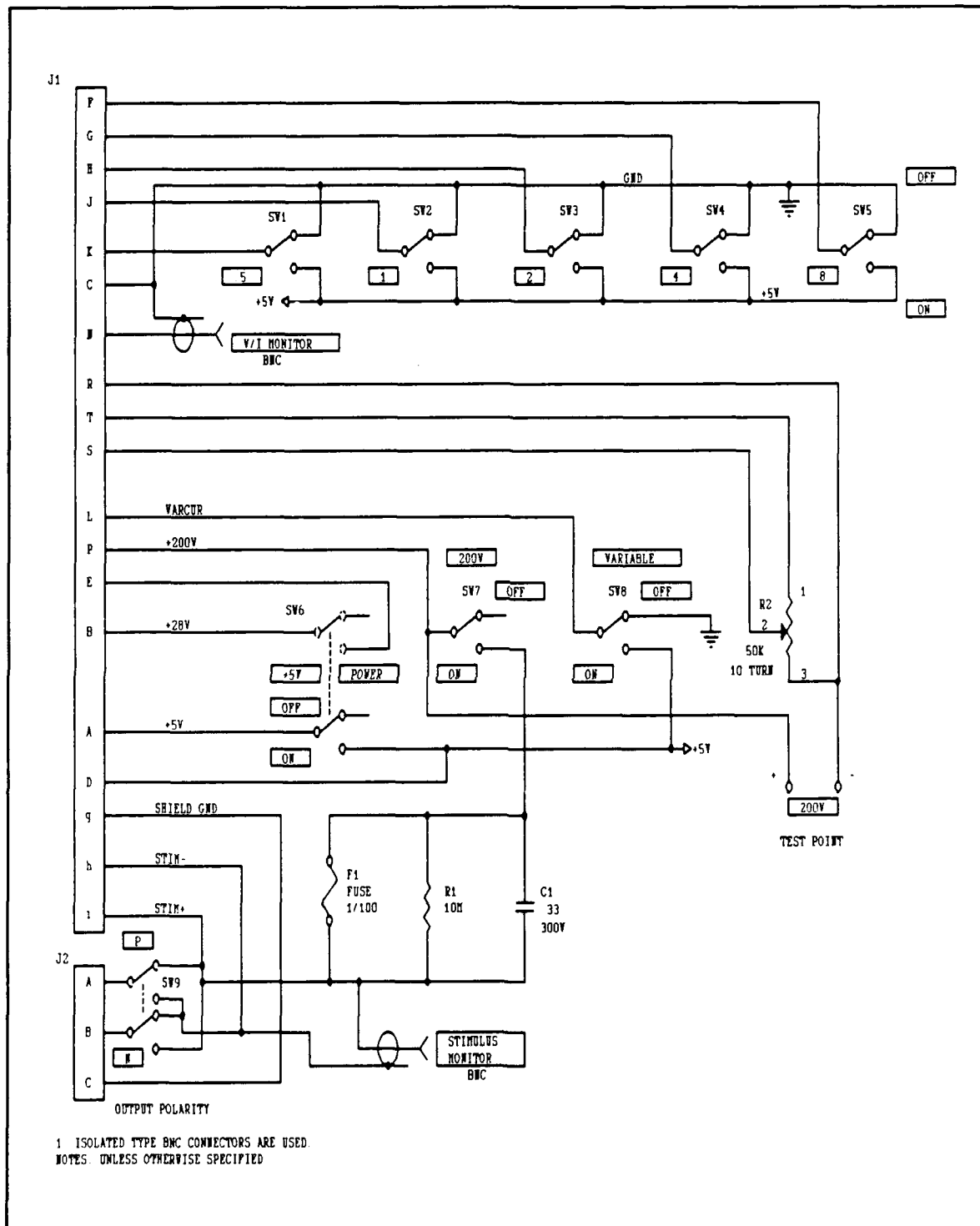


Figure A-5. Constant Current Stimulator — Control Unit.

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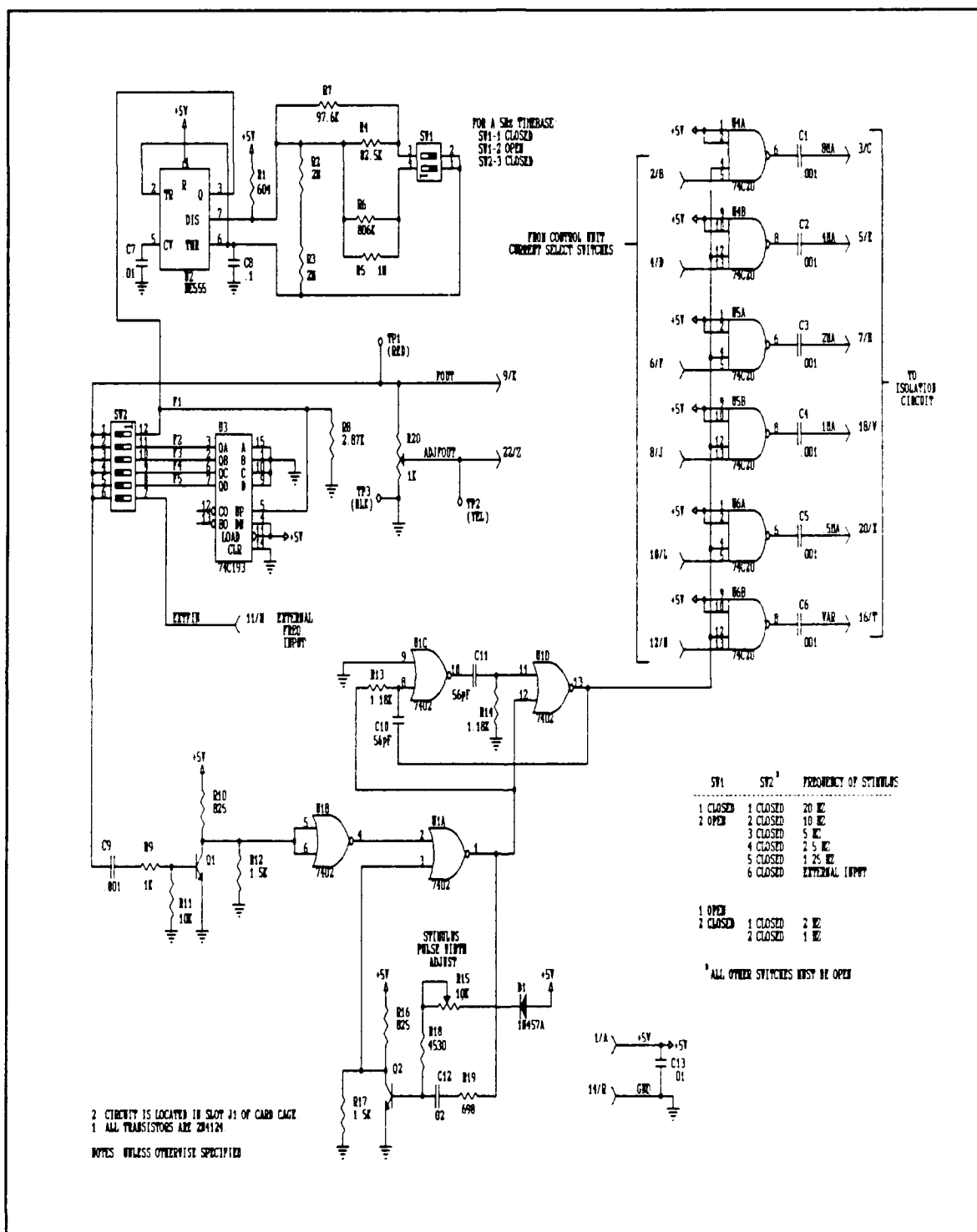


Figure A-6. Constant Current Stimulator — Digital Section.

Physiology Data Acquisition System Description

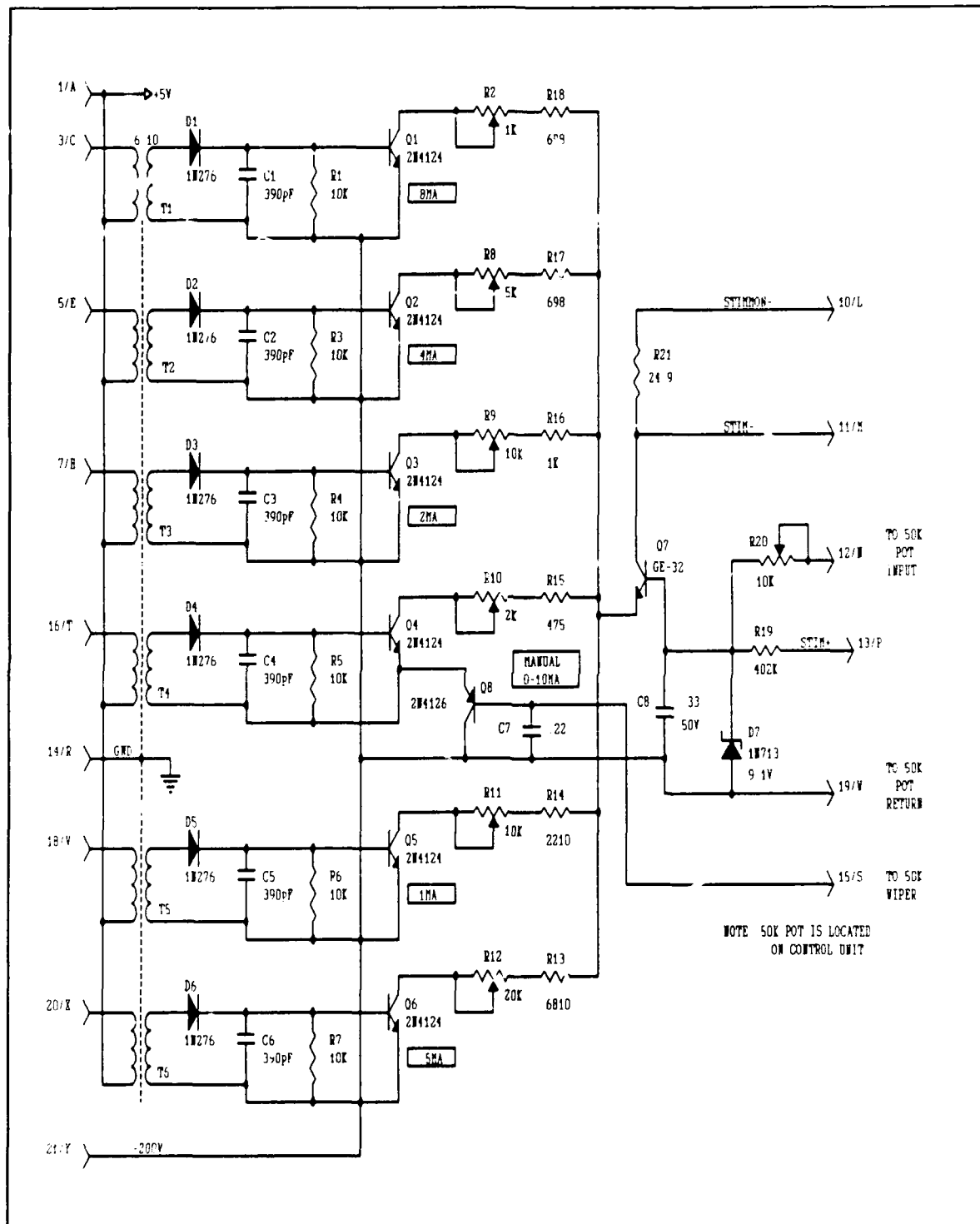


Figure A-7. Constant Current Stimulator — Isolation Section

NAVAL BIODYNAMICS LABORATORY TECHNICAL REPORT

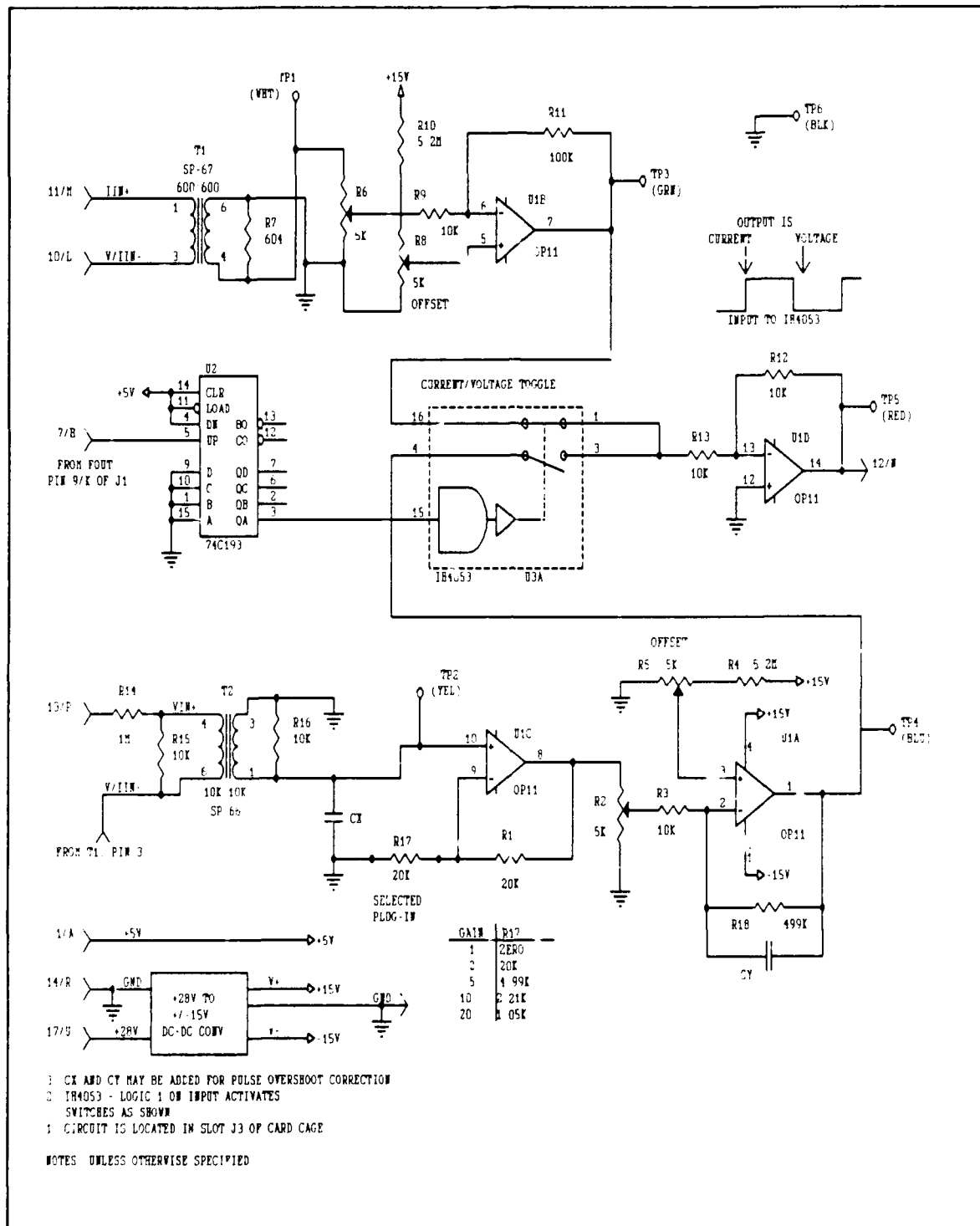


Figure A-8. Constant Current Stimulator - Voltage/Current Monitor.

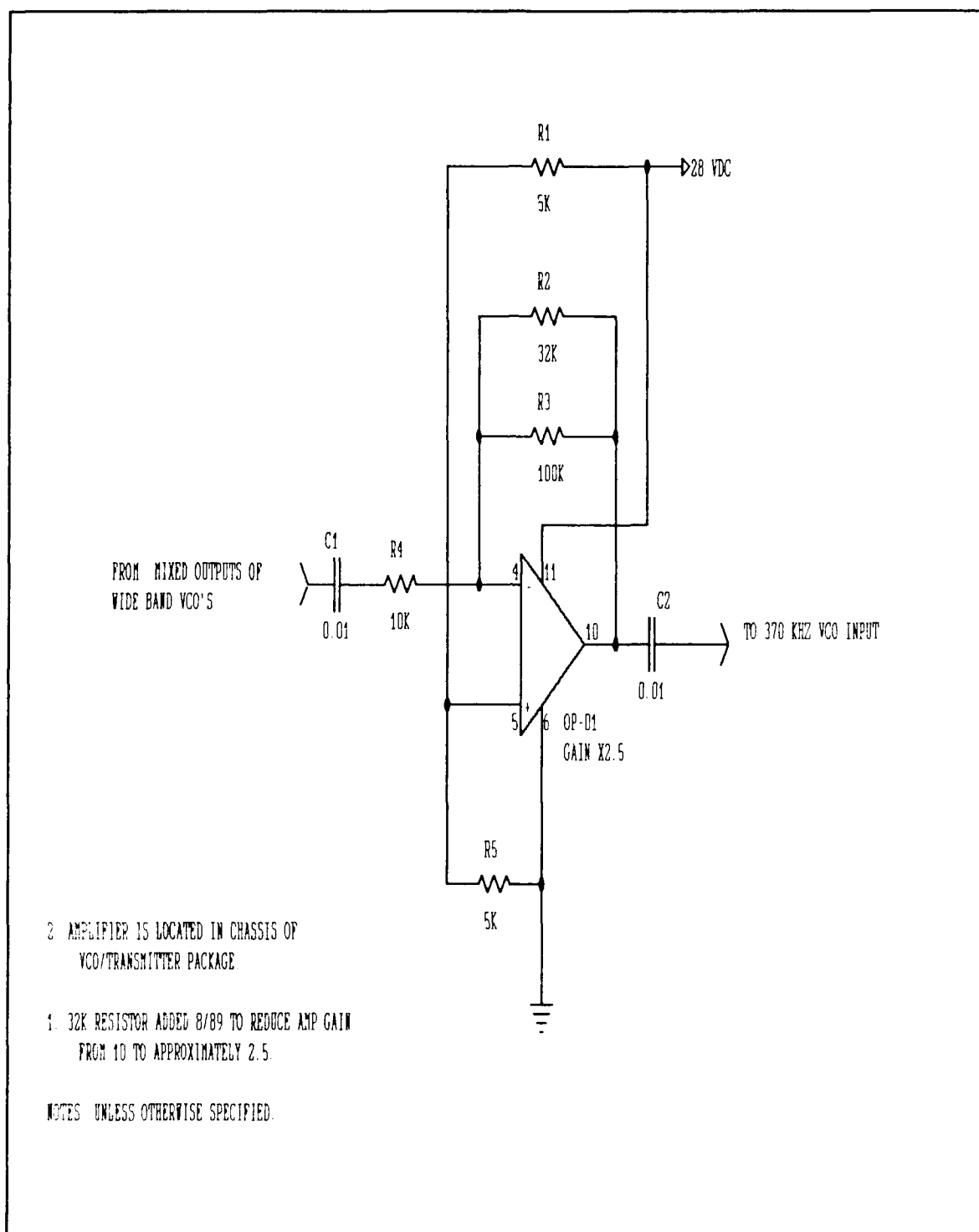


Figure A-9. NAVBIODYNLAB VCO/Transmitter Buffer Amplifier.

APPENDIX B

GAIN SELECTION CHART FOR THE ECG AND EEG AMPLIFIER CIRCUIT CARDS

Physiology Data Acquisition System Description

GAIN SELECTION CHART FOR THE ECG AND EEG AMPLIFIER CIRCUIT CARDS								
INPUT AMP GAIN/R _f		FIXED GAIN	DC GAIN	DC SYSTEM	AC GAIN AMP/R _f		TOTAL AMP GAIN	TOTAL SYSTEM GAIN
x20	1052	x2.5	50	200	x10	1111	500	2,000
					x20	526	1,000	4,000
					x50	204	2,500	10,000
					x100	101	5,000	20,000
					x200	50.3	10,000	40,000
					x500	20.4	25,000	100,000
x50	408	x2.5	125	500	x10	1111	1,250	5,000
					x20	526	2,500	10,000
					x50	204	6,250	25,000
					x100	101	12,500	50,000
					x200	50.3	25,000	100,000
					x500	20.4	62,500	250,000
x100	202	x2.5	250	1000	x10	1111	2,500	10,000
					x20	526	5,000	20,000
					x50	204	12,500	50,000
					x100	101	25,000	100,000
					x200	50.3	50,000	200,000
					x500	20.4	125,000	500,000
x200	100.5	x2.5	500	2000	x10	1111	5,000	20,000
					x20	526	10,000	40,000
					x50	204	25,000	100,000
					x100	101	50,000	200,000
					x200	50.3	100,000	400,000
					x500	20.4	250,000	1,000,000

NOTES: R_f = Feedback Resistor. Resistor values are in ohms. System has a gain of four.

APPENDIX C

CARD CAGE WIRING AND PATCH PANEL DIAGRAMS

CONTENTS

Horizontal Accelerator Physiology Card Cage Wiring	C-1
Vertical Accelerator Physiology Card Cage Wiring	C-2
Patch Panel	C-3

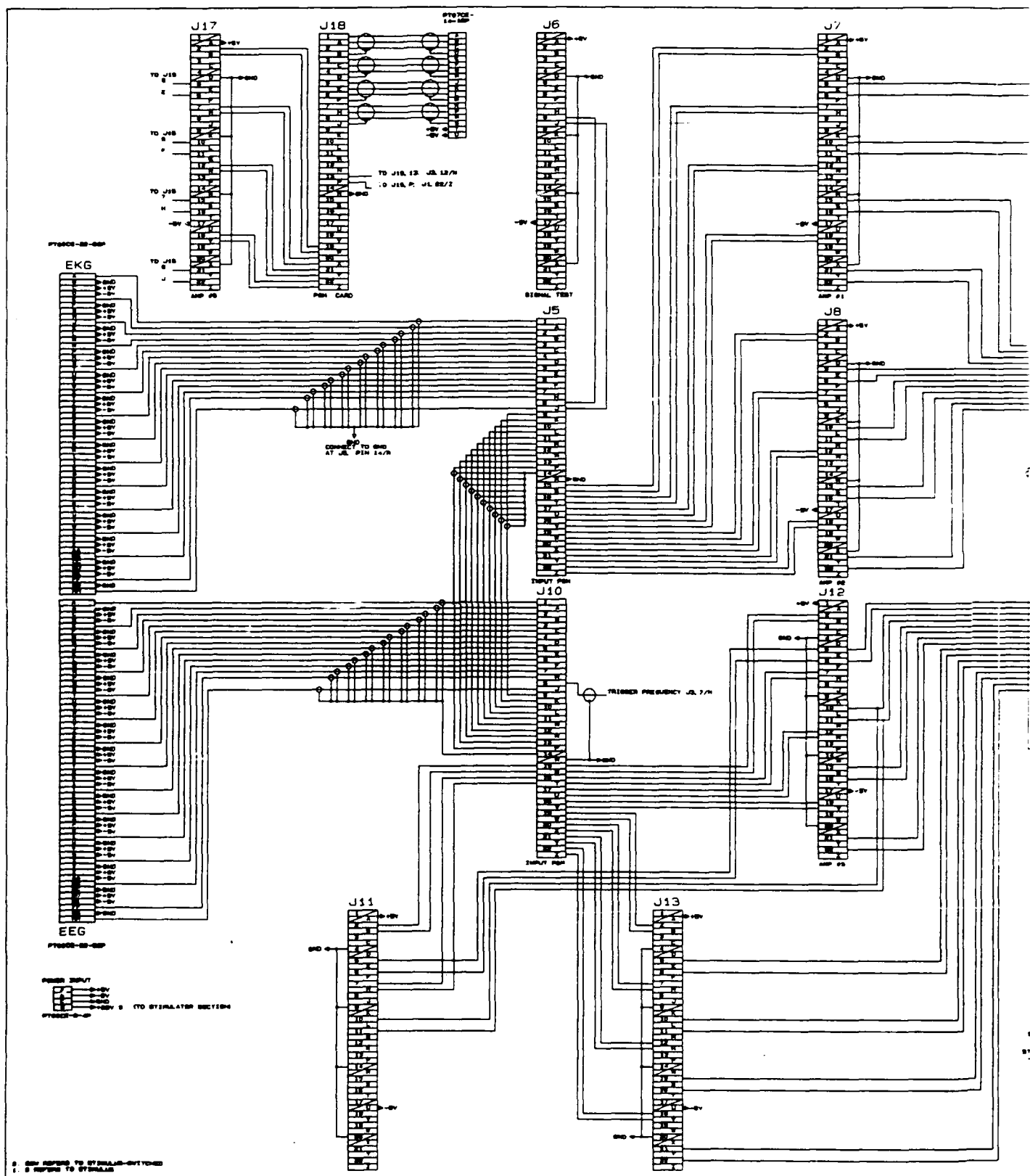
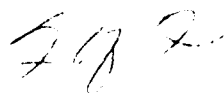
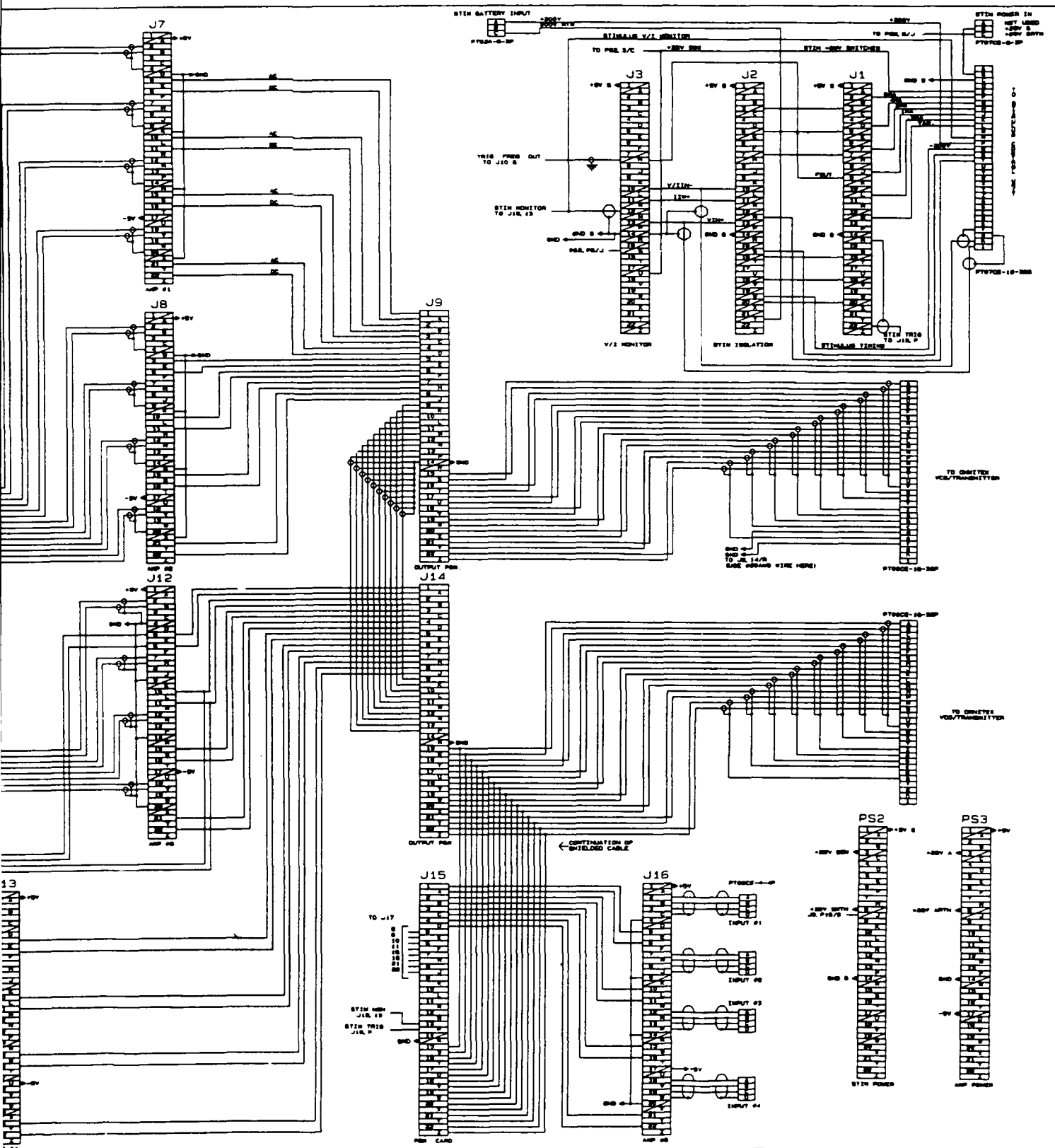


Figure C-1. Horizontal Accelerator Physiology Card Cage Wiring.





	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T	U	V	W	X					
1	60	61	62	63	64	65	66	67	68	69	70	71	72	73	TRUNK LINES TO PACER				74	75	76	77	78	79	80	81	
2																											
3	INERTIAL V.C.O.'s MUX. 1 INPUTS								1	INERTIAL V.C.O.'s MUX. 2 INPUTS								1	INERTIAL V.C.O.'s MUX. 3 INPUTS								
4	2	3	4	5	6	7	8			2	3	4	5	6	7	8			2	3	4	5	6				
5	PHYSIOL. VCO. MUX. OUTPUTS				P. MUX. 2	P. MUX. 3	P. MUX. 4	P. MUX. 1	REAL-TIME PHYSIOL. DISC INPUTS				P. MUX. 2	P. MUX. 3	P. MUX. 4	I. MUX. 1	I. MUX. 2	I. MUX. 3	I. MUX. 4	I. MUX. 5	I. MUX. 6						
6									P. MUX. 1	SPEED-UP PHYSIOL. DISC INPUTS				P. MUX. 2	P. MUX. 3	P. MUX. 4											
7	NO. 1 FR. 2000 RECORD INPUTS								1	NO. 1 FR. 2000 REPRODUCE OUTPUTS								1	NO. 2 FR. 2000 RECORD INPUTS								
8	2	3	4	5	6	7	8			2	3	4	5	6	7				2	3	4	5	6	7	8		
9	C.T. SERVO SIGNAL SOURCE	C.T. REPRO SIGNAL	RECORD AMP C.T. SIGNAL IN	TEST SEL SWITCH OUT	LINE IN	VOICE LOG LINE IN	VOICE LOG AUX OUT			PARALLEL BUS								C.T. SERVO SIGNAL SOURCE	C.T. REPRO SIGNAL	RECORD AMP C.T. SIGNAL IN	TEST SEL SWITCH OUT	LINE IN	VOICE LOG LINE IN	VOICE LOG AUX OUT			
10	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8					
11																											
12	1-7 AUX. 1 OUT	1-7 AUX. 2 OUT	RECORD AMP C.T. 1-7 SIG IN	8-14 AUX. 1 OUT	8-14 AUX. 2 OUT	RECORD AMP C.T. 1-7 SIG IN	LINE IN	VOICE LOG LINE OUT	VOICE LOG AUX OUT	EXT. SWKR	EXT. FREQ STAND IN	C.T. REPRO SIGNAL SOURCE IN	C.T. SERVO SIGNAL SOURCE	TEST SEL SWITCH OUT				PARALLEL BUS							NO. 1		
13	INERTIAL DISC. MUX. 1 OUTPUTS								1	INERTIAL DISC. MUX. 2 OUTPUTS								1	INERTIAL DISC. MUX. 3 OUTPUTS								
14	2	3	4	5	6	7	8			2	3	4	5	6	7	8			2	3	4	5	6				
15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20							
16																											
17	REAL-TIME PHYSIOL. MUX. 1 DISC. OUTPUTS								1	REAL-TIME PHYSIOL. MUX. 2 DISC. OUTPUTS								1	REAL-TIME PHYSIOL. MUX. 3 DISC. OUTPUTS								
18	2	3	4	5	6	7	8			2	3	4	5	6	7	8			2	3	4	5	6				
19	SPEED-UP PHYSIOL. MUX. 1 DISC. OUTPUTS								1	SPEED-UP PHYSIOL. MUX. 2 DISC. OUTPUTS								1	SPEED-UP PHYSIOL. MUX. 3 DISC. OUTPUTS								
20	2	3	4	5	6	7	8			2	3	4	5	6	7	8			2	3	4	5	6				
21	C.B.W. DISC.	7 30 P.B.W.	1	2	3	4	5	6	IRIG C.B.W. DISC. OUT				7	8	9	10	11	12	13	14	15	16	#2 PREAMPS OUT	EXTERNAL			
22	MUX. INPUT	DISC. OUT																									
23	1	2	3	4	5	6	7	8	EKG TO V2 TRACK	EKG TO V4 TRACK	EKG TO Y TRACK	EKG TO Z TRACK	PARALLEL BUS				1510 SPECT	NO. 1 SCOPE PRE AMP				1	2	3	4	NO. 2 SCOPE	
24																											
25	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12							+1	+2	+3	+4	+5	+6			
26	COM.	COM.	COM.	COM.	COM.	COM.	COM.	COM.	COM.	COM.	COM.	COM.							COM.	COM.	COM.	COM.	COM.	COM.	COM.	COM.	
27	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	SPARE						-1	-2	-3	-4	-5	-6			
28	1	2	3	4	5	6	7	8	9	10	11	12							1	2	3	4	5	6			
29	1	2	3	4	5	6	7	8	9	10	11	12							1	2	3	4	5	6			
30	BOARD AND BUS								PARALLEL BUS										RIGHT WARMER TYPE Q	LEFT WARMER TYPE S-2							
	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T	U	V	W	X					

Figure C-3. Patch Panel.

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