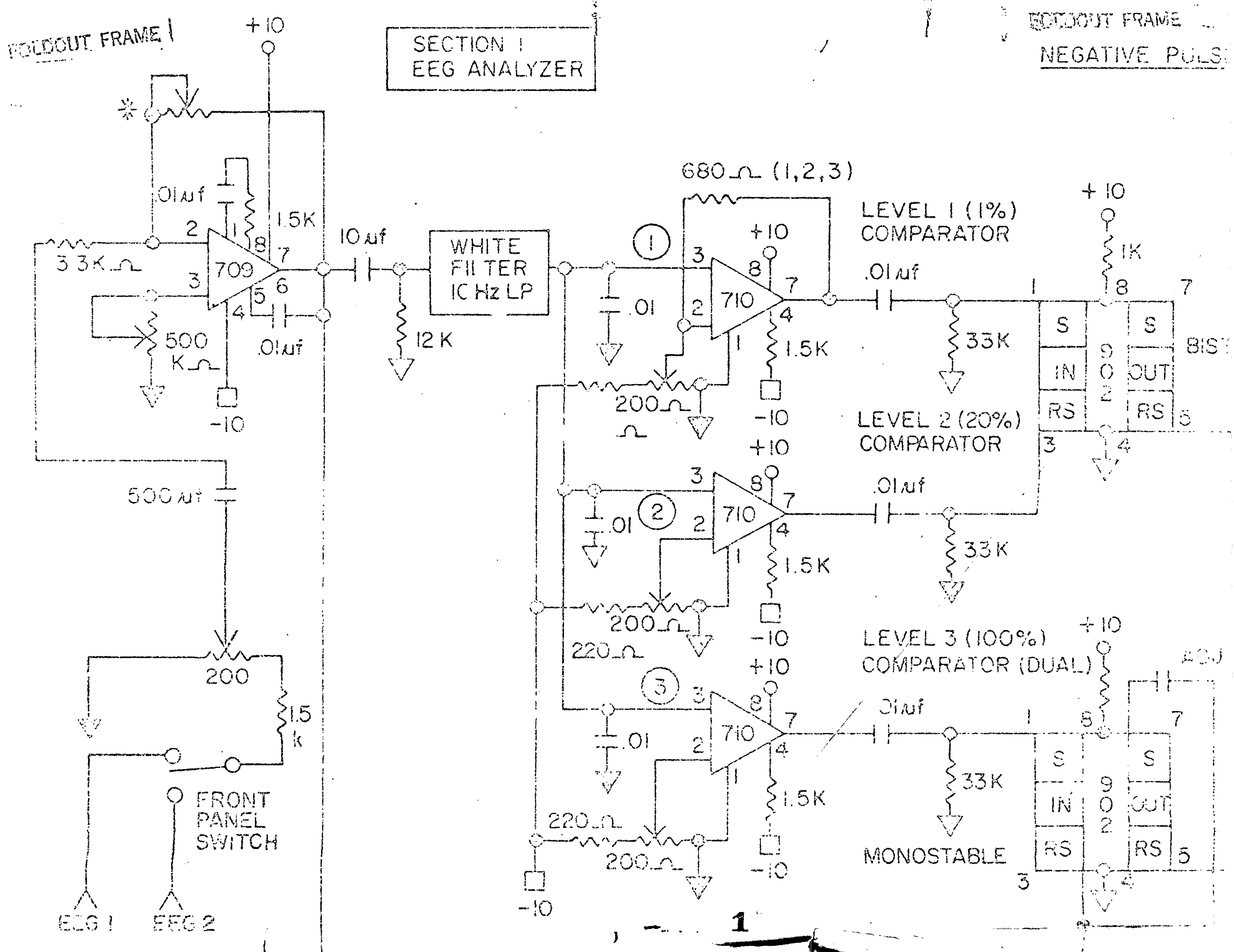
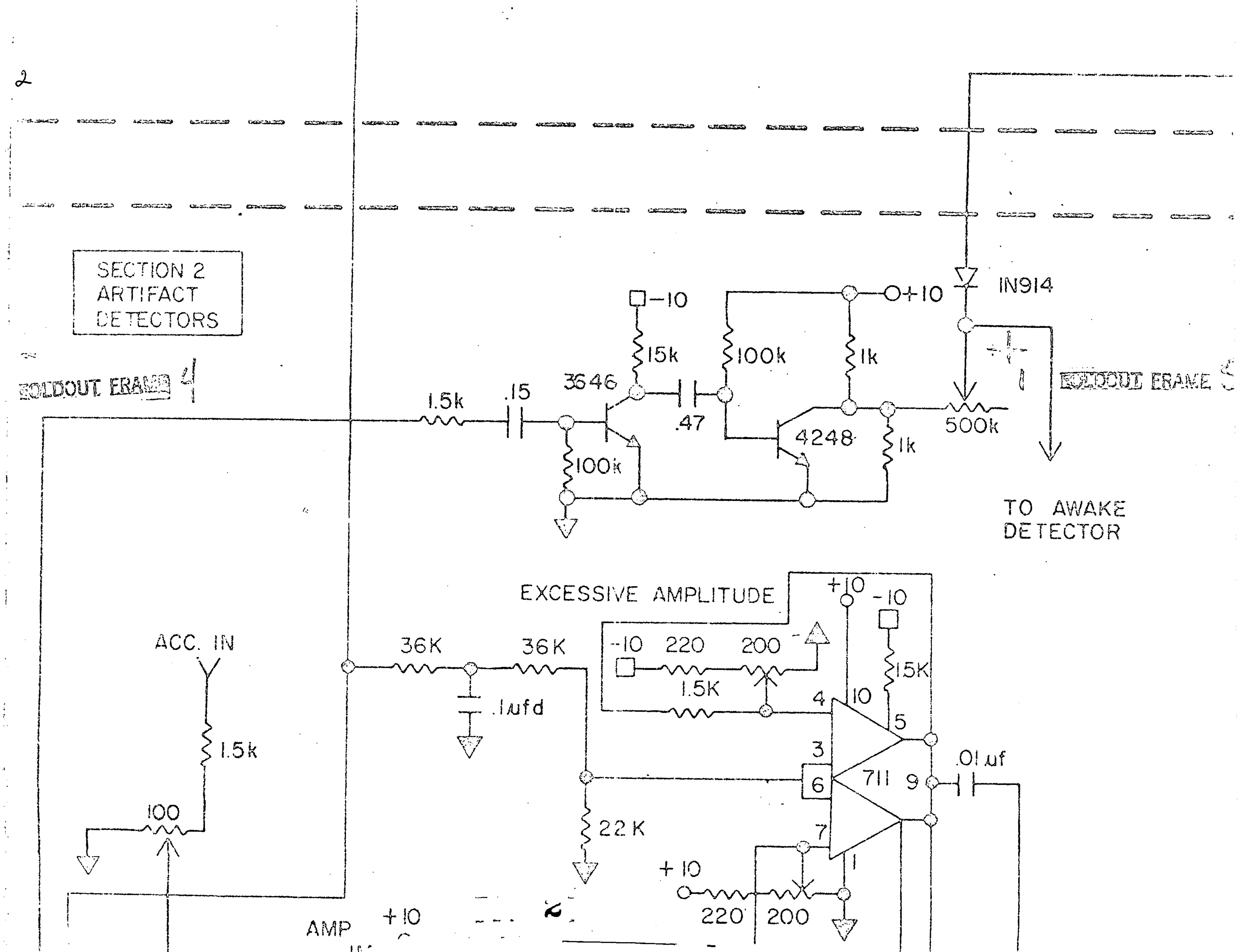


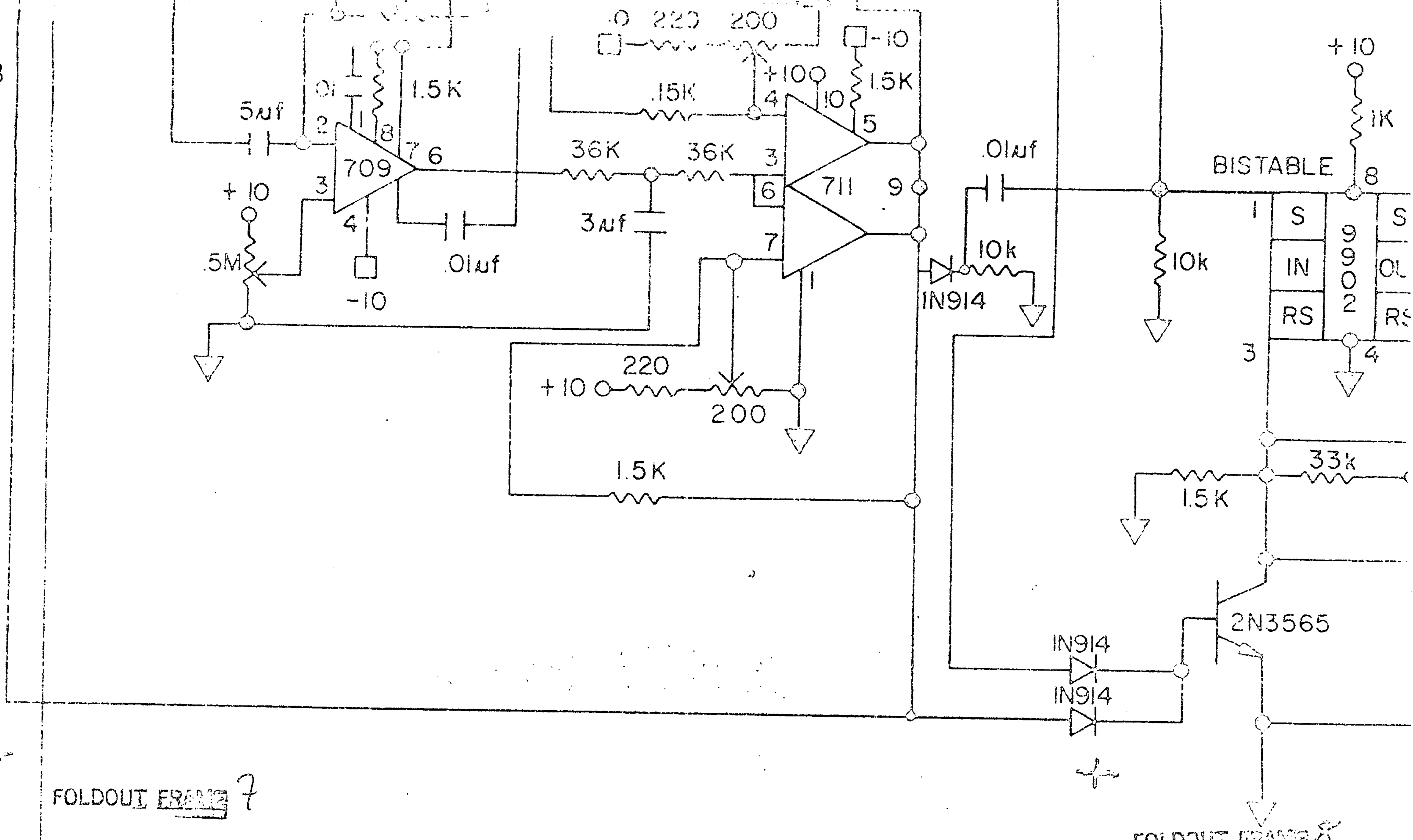
FOLDOUT FRAME
SECTION I
EEG ANALYZER
NEGATIVE PULS
+10
.01uf
1.5K
3.3K
709
500 K
-10
10uf
WHITE FILTER 1C Hz LP
12 K
680 (1,2,3)
LEVEL 1 (1%) COMPARATOR
LEVEL 2 (20%) COMPARATOR
LEVEL 3 (100%) COMPARATOR (DUAL)
710
.01
200
220
1K
33K
S
IN
RS
OUT
902
BIST
MONOSTABLE
500uf
1.5 k
FRONT PANEL SWITCH
EEG 1
EEG 2

1



SECTION 2
ARTIFACT
DETECTORS
FOLDOUT FRAME 4
1.5k
.15
3646
100k
15k
-10
.47
100k
1k
4248
1k
+10
IN914
500k
FOLDOUT FRAME 5
TO AWAKE DETECTOR
EXCESSIVE AMPLITUDE
ACC. IN
1.5k
100
36K
36K
.1ufd
22 K
-10
220
200
1.5K
+10
-10
15K
4
10
5
3
6
711
9
7
1
.01 uf
+ 10
220
200
AMP
+10

3



FOLDOUT FRAME 7

FOLDOUT FRAME 8

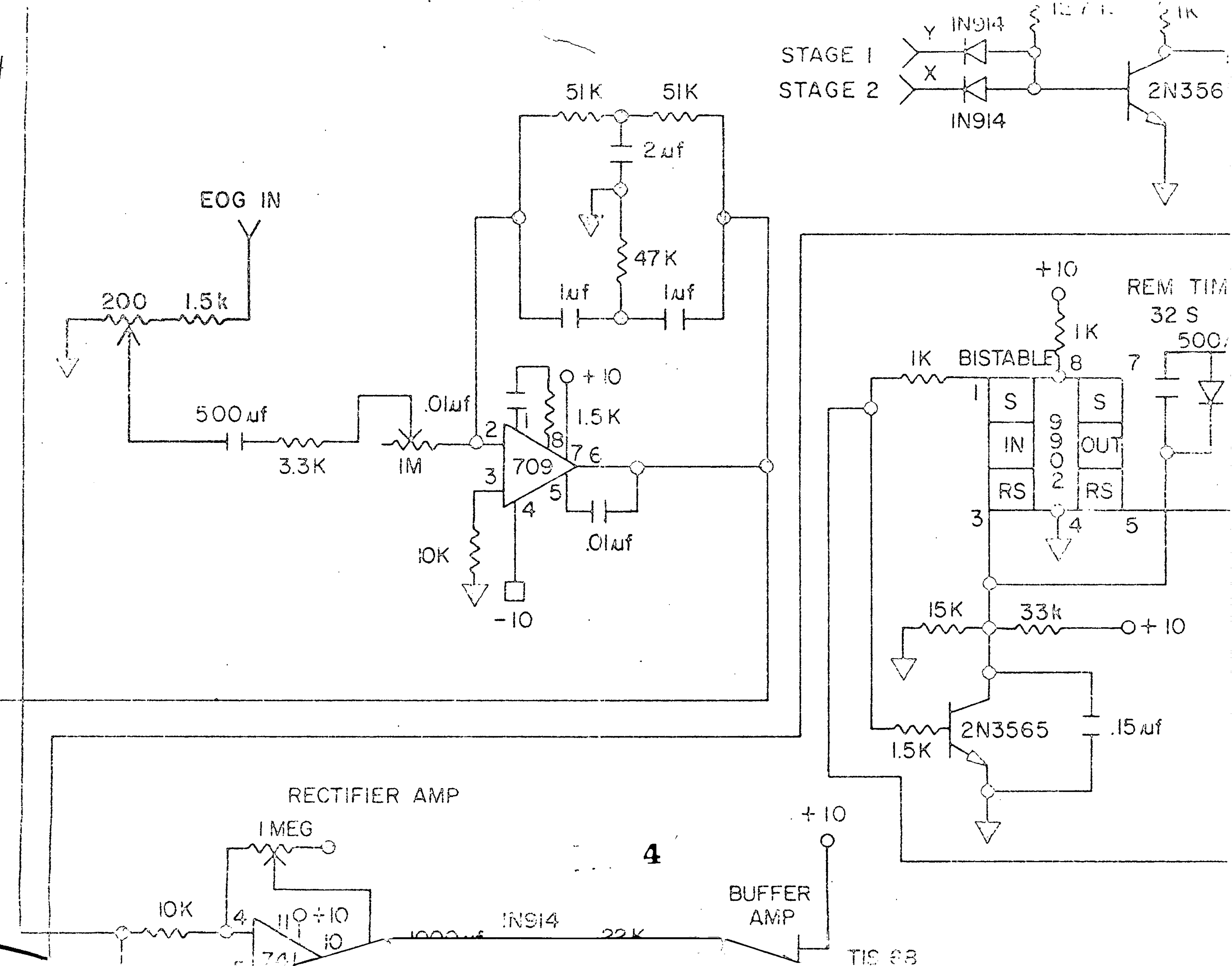
SECTION 3
REM DETECTION

3

EOG AMP-FILTER

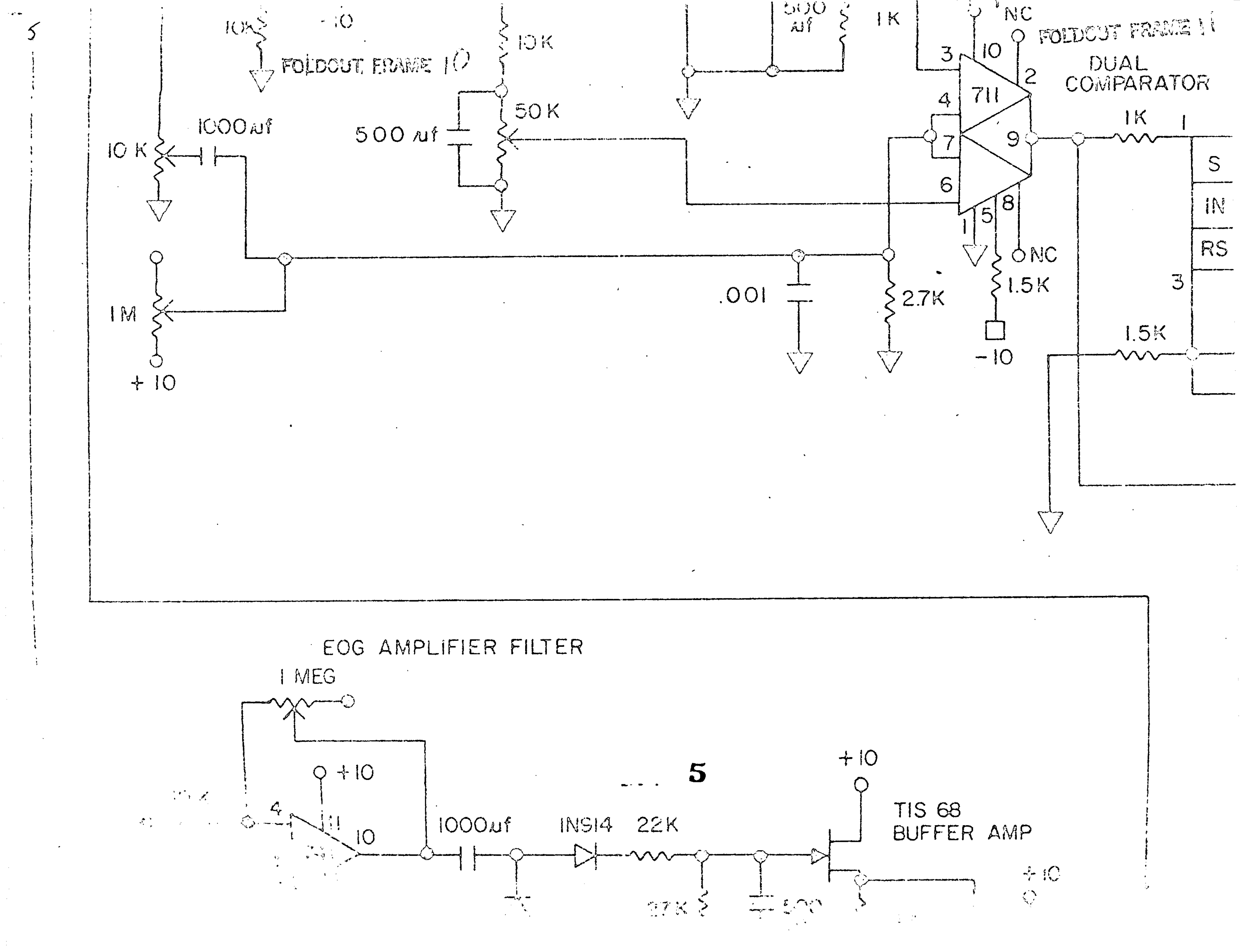
LEVEL LOGIC REM

+10

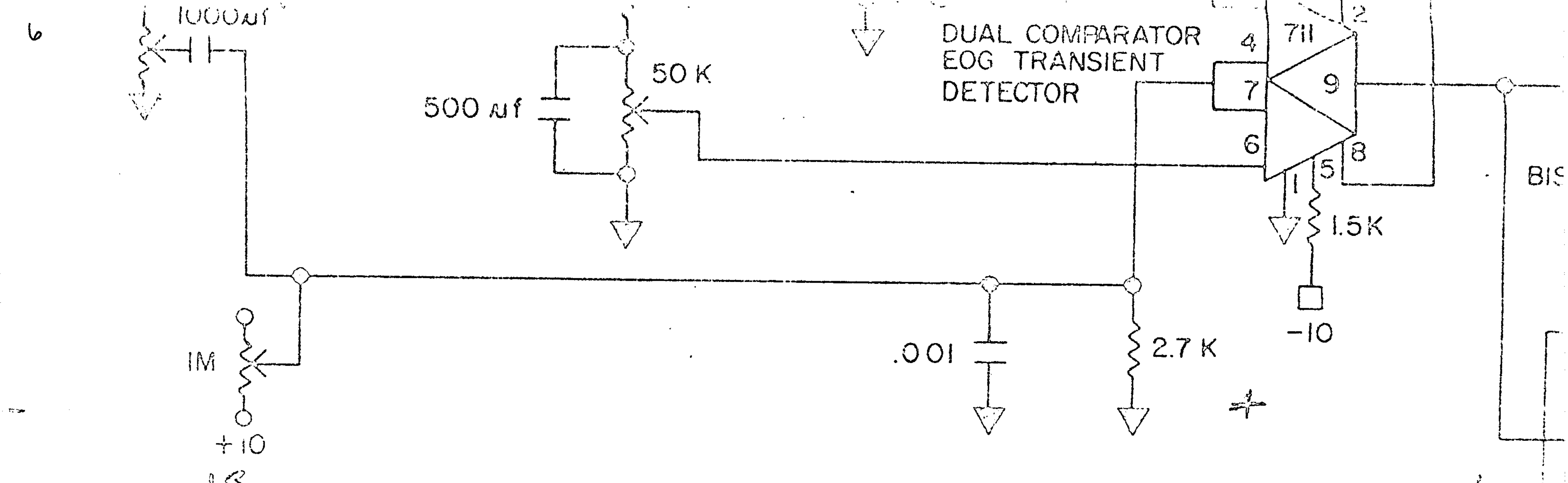


EOG IN
200
1.5k
500uf
3.3K
1M
.01uf
51K
51K
2uf
47K
1uf
1uf
709
+10
1.5K
.01uf
10K
-10
STAGE 1
STAGE 2
Y
X
IN914
IN914
2N356
REM TIM
32 S
1K
BISTABLE
+10
1K
S
IN
RS
9902
S
OUT
RS
15K
33k
+10
2N3565
1.5K
.15uf
RECTIFIER AMP
1 MEG
10K
+10
IN914
BUFFER AMP
+10

4


10K
-10
FOLDOUT FRAME 10
10K
1000 uf
10 K
50K
500 uf
500 uf
1K
NC
FOLDOUT FRAME 11
DUAL COMPARATOR
711
1K
S
IN
RS
.001
2.7K
1.5K
NC
-10
1.5K
1M
+10
EOG AMPLIFIER FILTER
1 MEG
+10
1000uf
IN914
22K
27K
+10
TIS 68
BUFFER AMP
+10

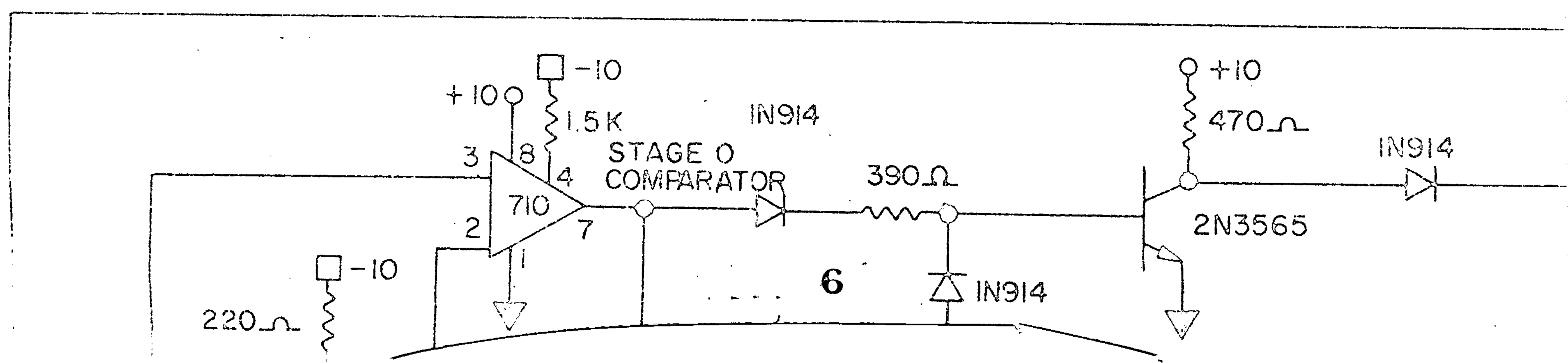
6

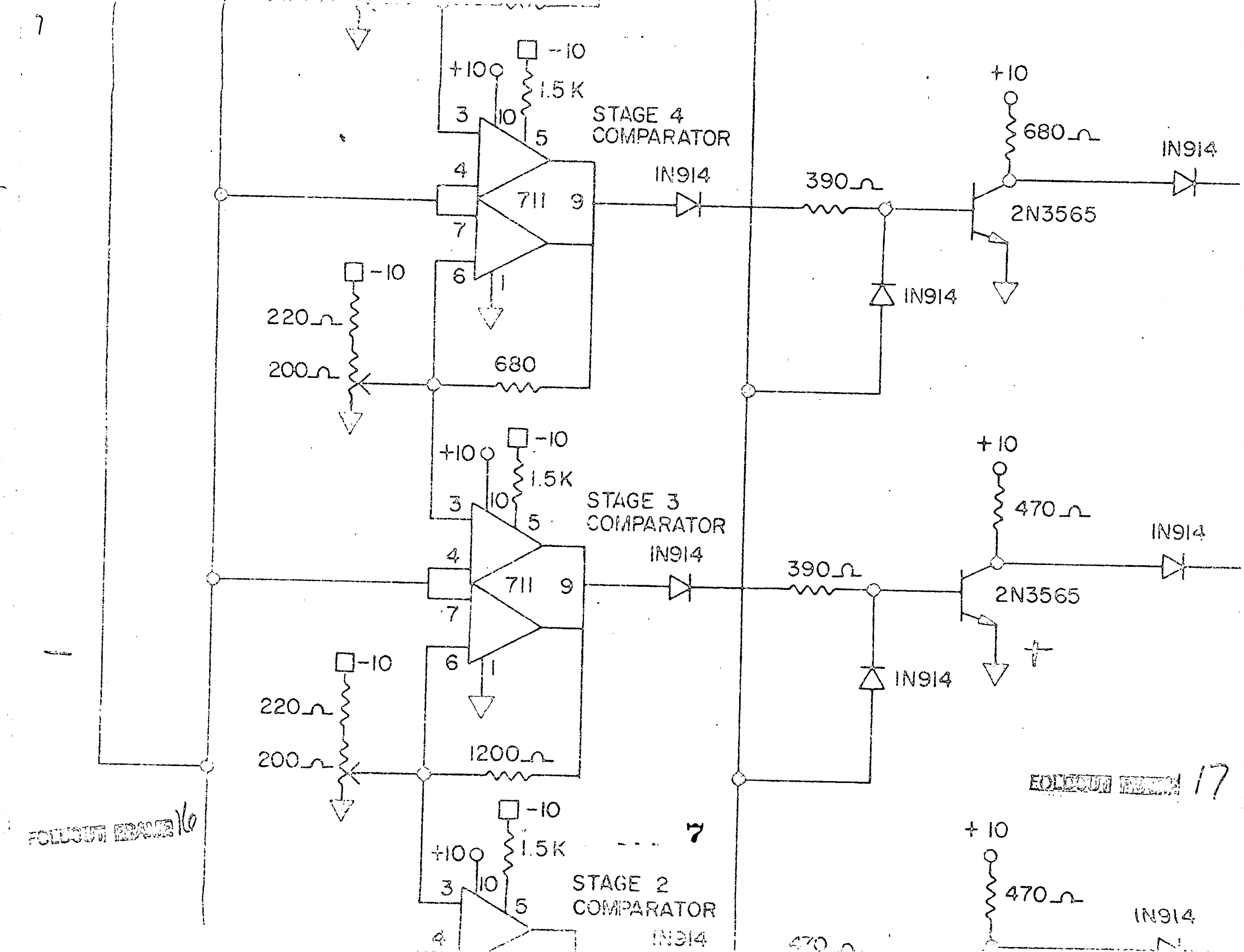


FOLDOUT FRAME 13

FOLDOUT FRAME 14

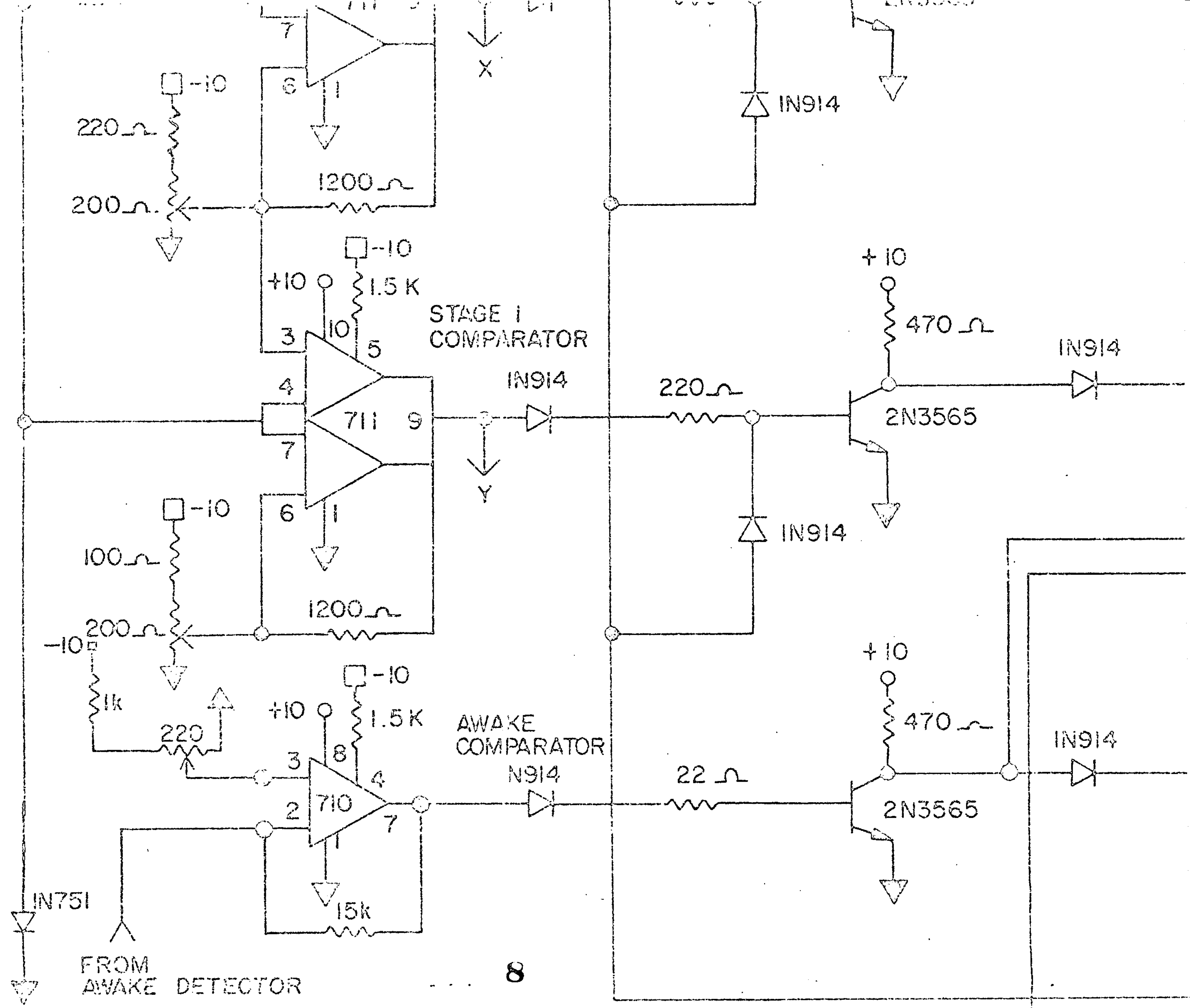
SECTION 4
SLEEP STAGE OUTPUT



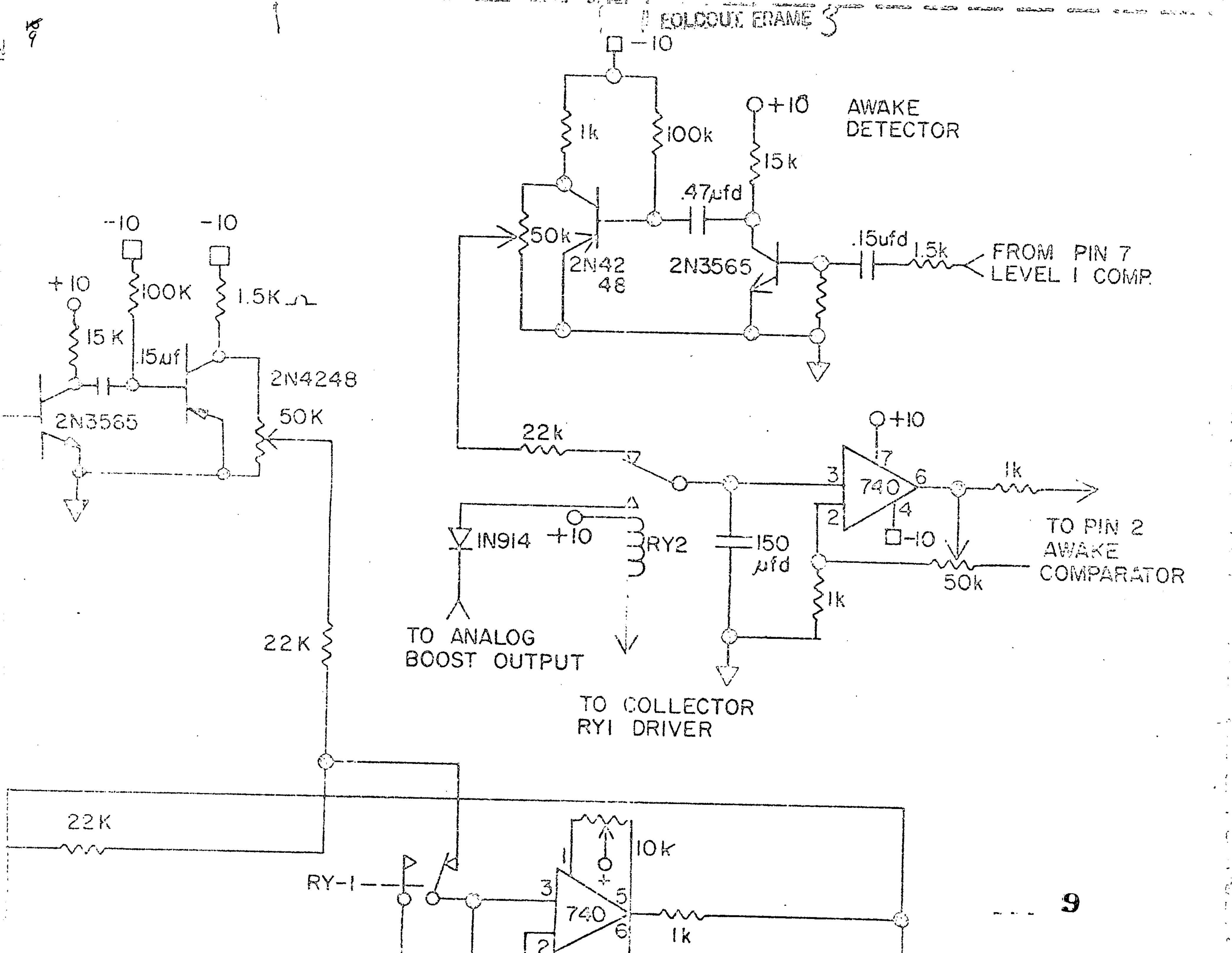


FOLDOUT FRAME 16

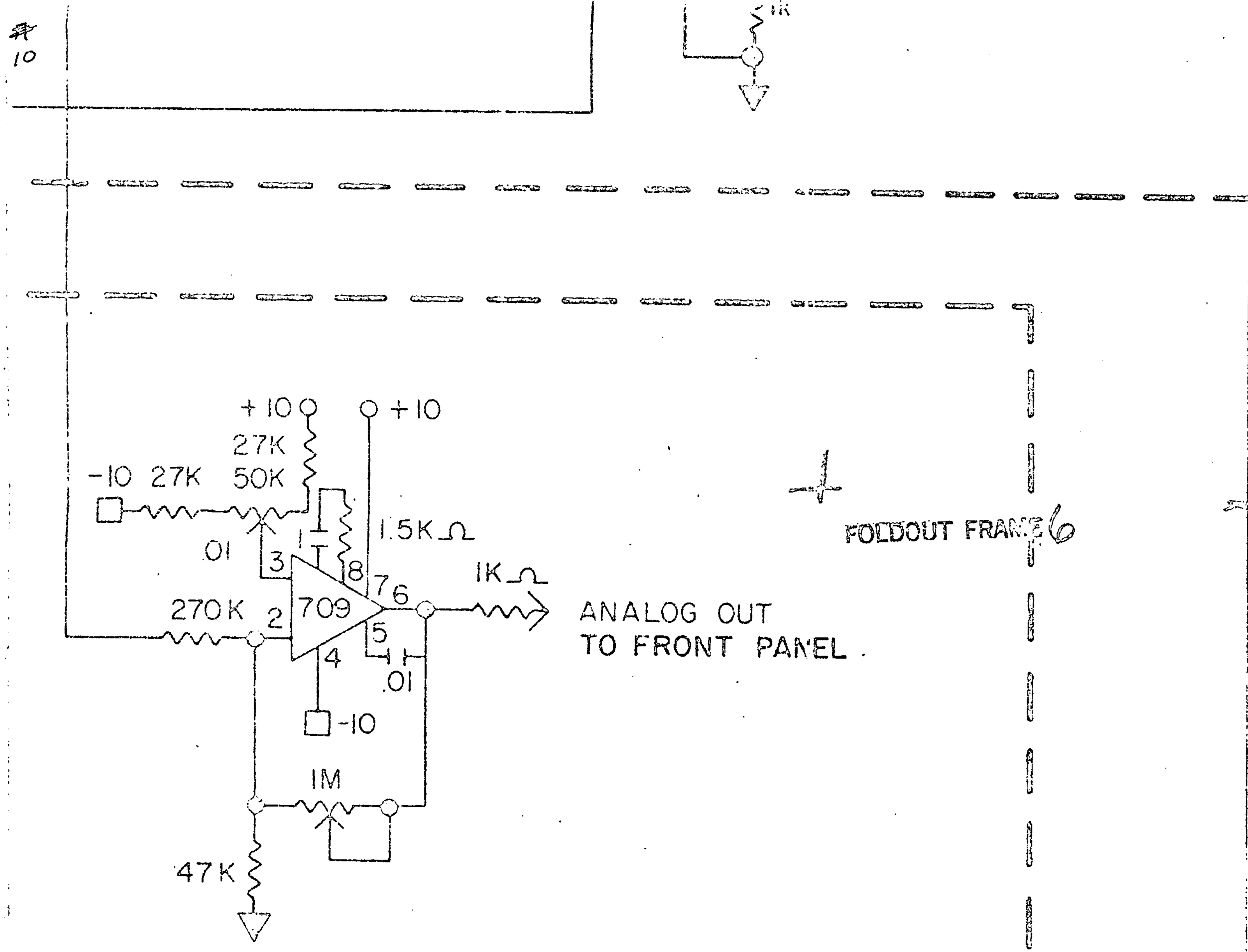
FOLDOUT FRAME 17



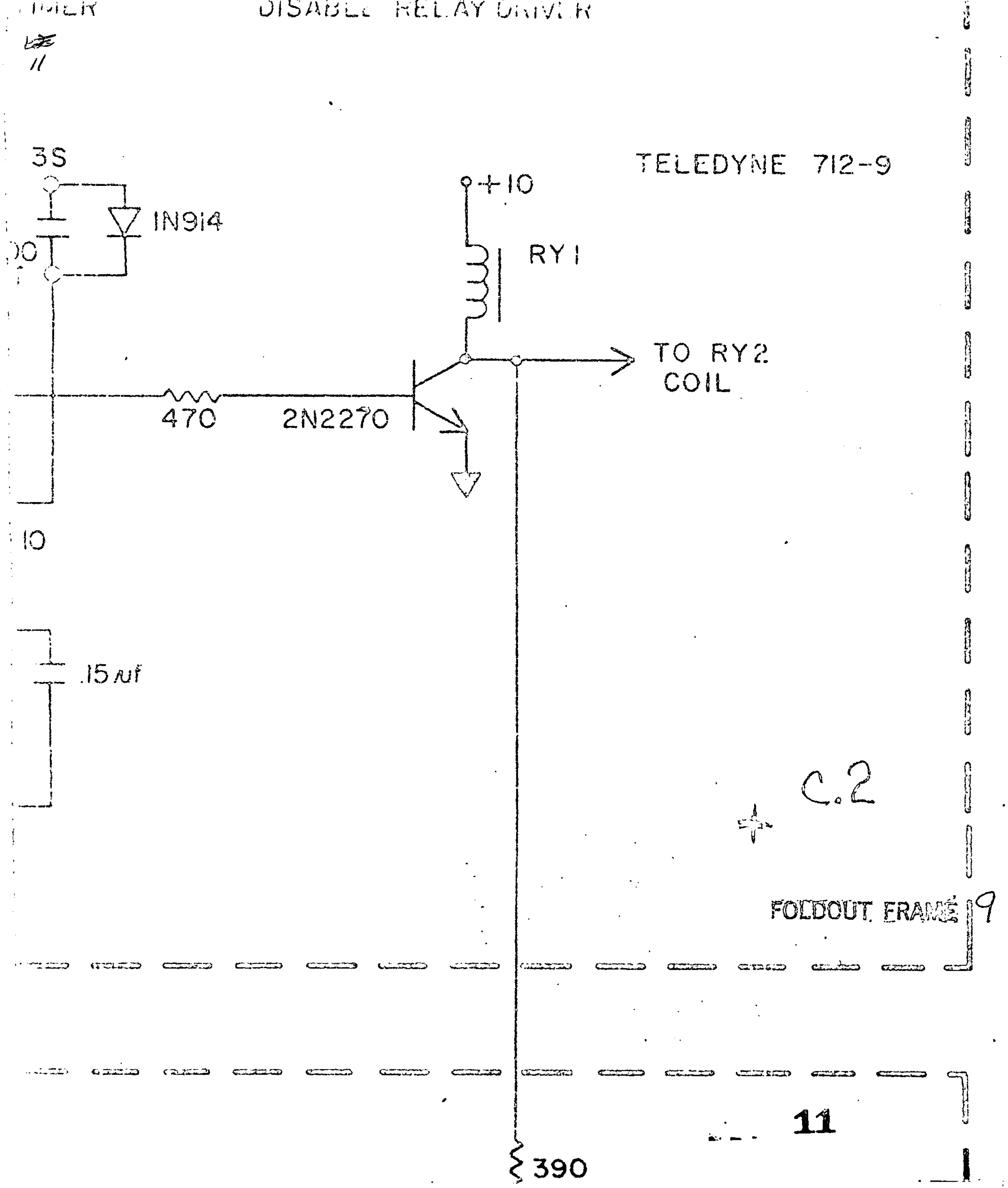
-10
220 Ω
200 Ω
1200 Ω
7
6
1
X
IN914
+10
1.5 K
STAGE I
COMPARATOR
3
10
5
4
711
9
Y
220 Ω
2N3565
+ 10
470 Ω
100 Ω
-10
200 Ω
1k
220
+10
8
4
AWAKE
COMPARATOR
N914
22 Ω
2
710
15k
IN751
FROM
AWAKE DETECTOR

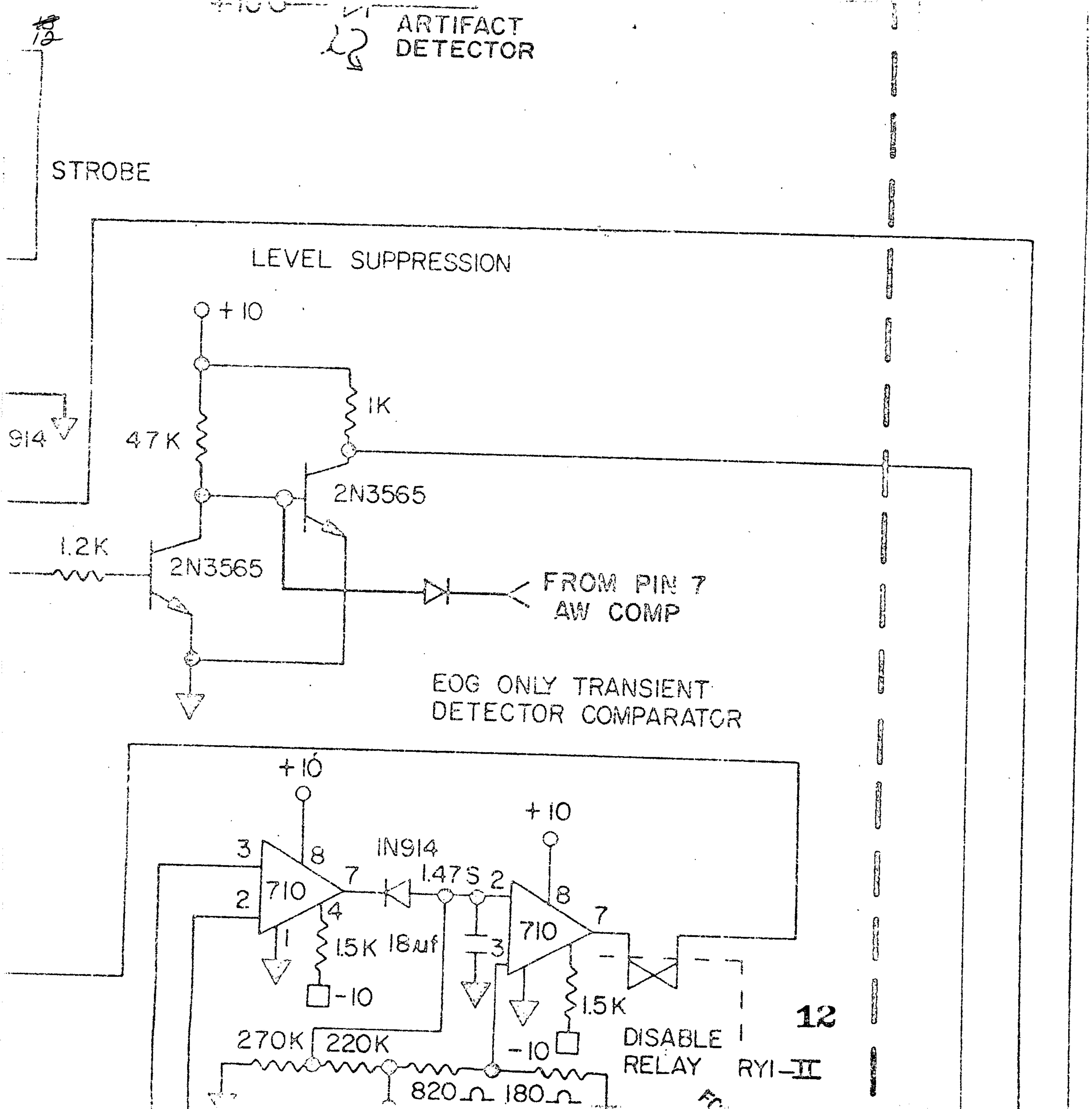

FOLDOUT FRAME 3
AWAKE DETECTOR
-10
+10
1k
100k
15k
.47µfd
50k
2N42 48
2N3565
.15ufd
1.5k
FROM PIN 7 LEVEL 1 COMP.
-10
-10
+10
100K
1.5K
15 K
.15µf
2N4248
2N3565
50K
22k
+10
3
740
6
7
4
2
1k
TO PIN 2 AWAKE COMPARATOR
1N914
+10
RY2
150 µfd
50k
1k
TO ANALOG BOOST OUTPUT
TO COLLECTOR RY1 DRIVER
22K
22K
RY-1
10k
1
3
740
5
6
2
1k

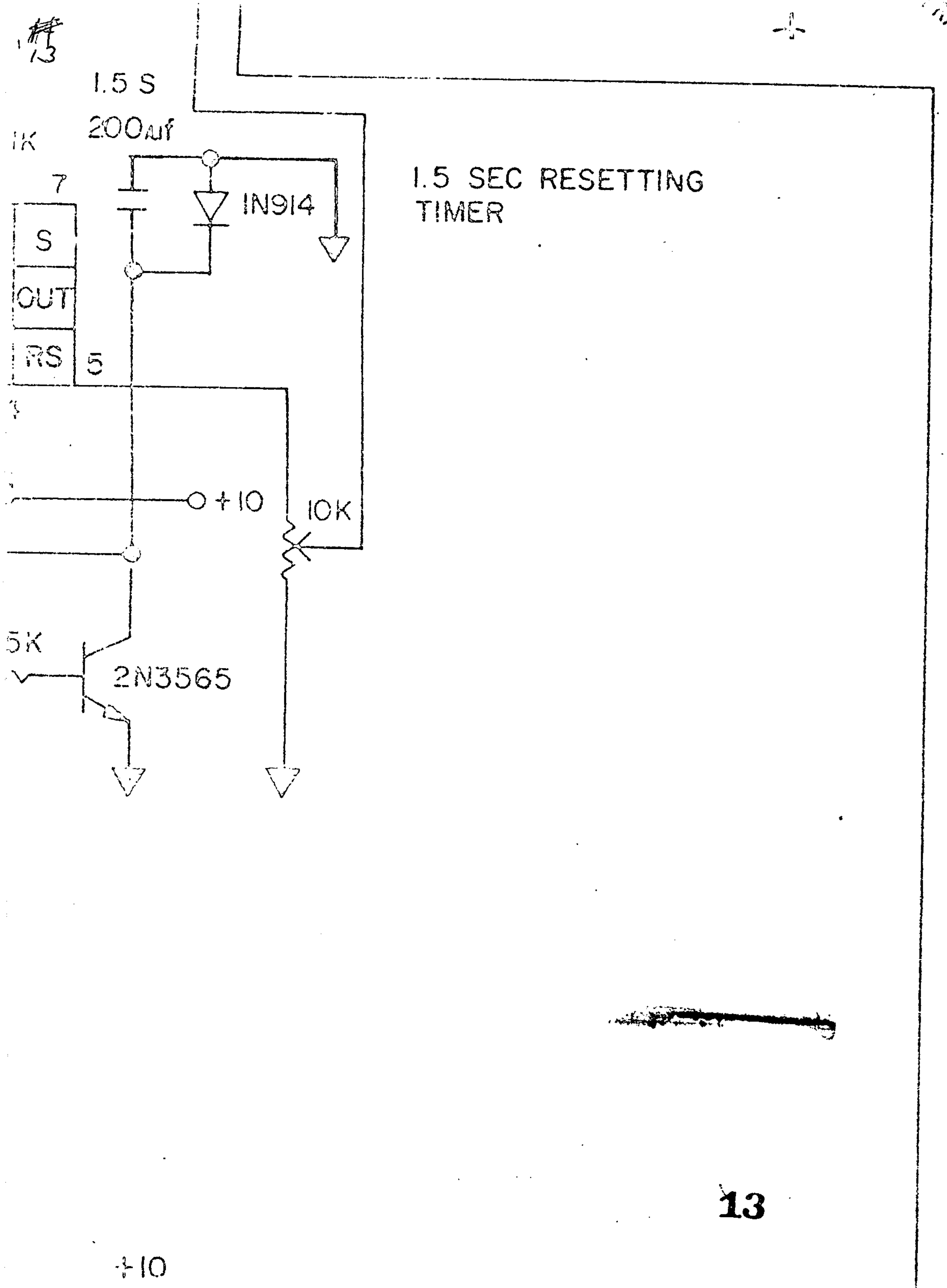
#10



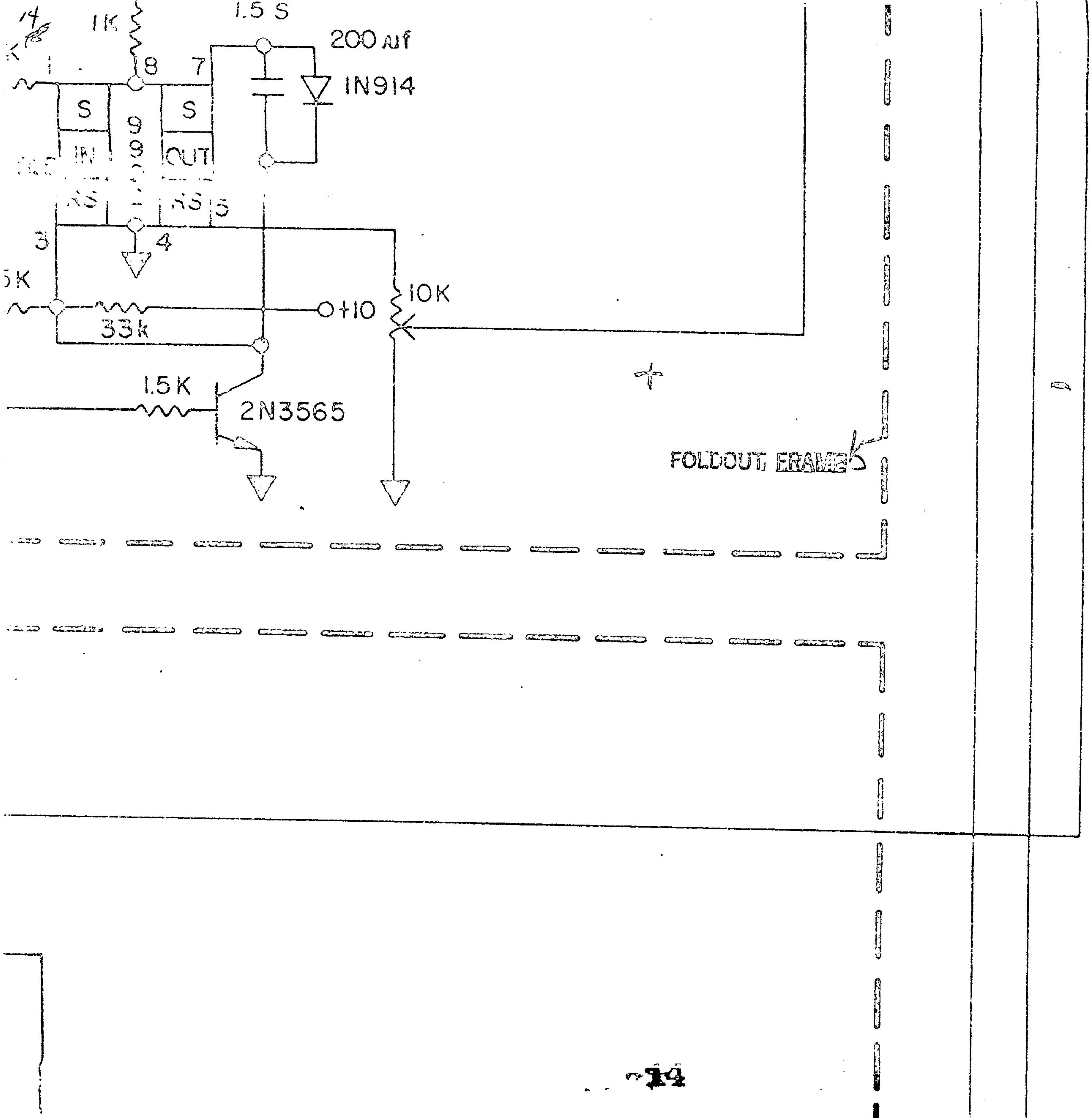
FOLDOUT FRAME 6


DISABLE RELAY DRIVER
3S
IN914
10
.15 µf
470
2N2270
+10
RY1
TELEDYNE 712-9
TO RY2 COIL
390
C.2
FOLDOUT FRAME 9

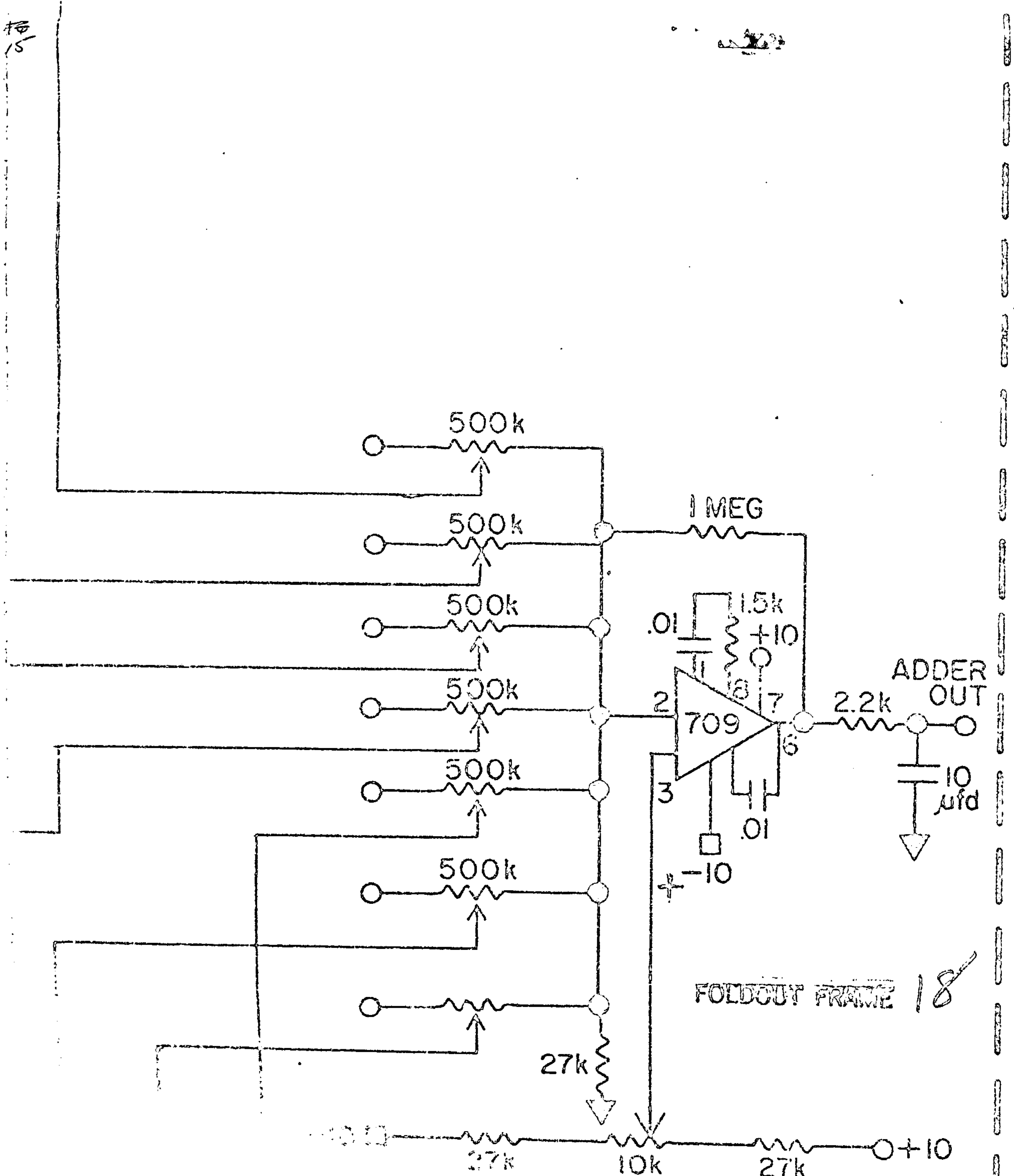

ARTIFACT
DETECTOR
STROBE
LEVEL SUPPRESSION
+10
1K
47K
914
2N3565
1.2K
2N3565
FROM PIN 7
AW COMP
EOG ONLY TRANSIENT
DETECTOR COMPARATOR
+10
+10
3
8
IN914
1.47S
2
710
7
2
4
710
8
7
1
1.5K
18uf
3
-10
1.5K
-10
270K
220K
DISABLE
RELAY
RYI-II
820Ω
180Ω
12



1.5 SEC RESETTING
TIMER

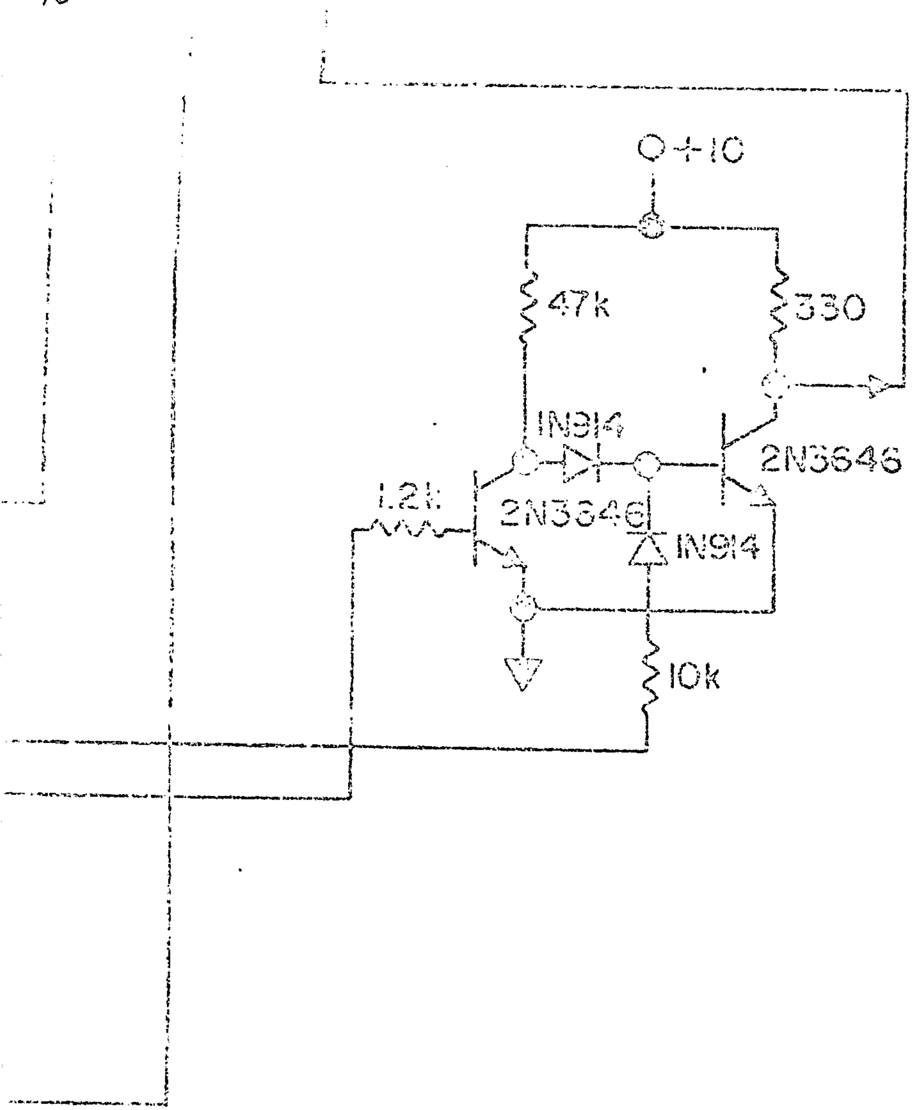


1K
1.5 S
200 µf
IN914
8
7
S
S
9
9
IN
OUT
RS
RS
5
3
4
10K
+10
33k
1.5 K
2N3565
FOLDOUT FRAME



FOLDOUT FRAME 18

17
16



OUTPUTS TO ASSEMBLY
6 (TELEMETRY CODER)

CR-115745

FINAL REPORT

Contract NAS 9-11855

Research Program for Experiment M133

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(NASA-CR-115745) RESEARCH PROGRAM FOR EXPERIMENT M133 Final Report J.D. Frost, Jr. (Baylor Univ.) 31 May 1972 56 p CSCL 06B

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G3/05 Unclas 37450

May 31, 1972

CONTENTS

ABSTRACT

Development of the automatic data-acquisition and sleep-analysis system, supported over the past four years by NASA contracts and grants (NGR-44-003-025, NAS 9-7237, NAS 9-9418, NAS 9-10747), continued under the current contract. The purpose was consultation and evaluation in the transition of the Skylab M133 Sleep-Monitoring Experiment equipment from prototype to flight status; review of problems associated with acquisition and on-line display of data in near-real time via spacecraft telemetry; and development of laboratory facilities and design of equipment to assure reliable playback and analysis of analog data.

The Principal Investigator conferred with Dr. DeLucchi and other NASA scientists on numerous occasions concerning the continuing development of the automatic sleep-analysis system for use on Skylab missions and the problems associated with data processing during the flights. The existing prototype system has been modified, and the changes improve the performance of the analysis circuitry and increase its reliability. These modifications are useful for pre- and postflight analysis, but are not now proposed for the inflight system. There have also been improvements in the EEG recording cap, some of which will be incorporated into the flight hardware.

The M133 hardware was scheduled for acceptance testing early in March of this year at the McDonnell Douglas Astronautics Co. in Huntington Beach, Calif. The Principal Investigator suggested several changes in test protocol and attended the acceptance testing held in late March, 1972.

I. M133 SLEEP-MONITORING SYSTEM EXPERIMENT HARDWARE DESIGN VERIFICATION TEST UNIT (DVTU)

The first design verification test unit (DVTU) was delivered by SCI Electronics on April 15, 1971, for testing purposes. A thorough examination and test was made of all essential circuits, including the tape-recorder interfaces (using NASA-supplied recorders [Cook Electric Co.]). Two all-night runs enabled us to further evaluate the system, which in general was highly satisfactory. A few problem areas were identified, and these are described later.

There were several meetings between Dr. DeLucchi and the Principal Investigator during and subsequent to the preliminary testing which took place from April 15 through May 11, 1971.

Problem Areas Encountered in Testing

In general, it was concluded that the DVTU system would meet the requirements of the Skylab mission if the discrepancies outlined below were rectified. Difficulties with the DVTU #1 encountered in testing covered the following areas.

Electrode-Check Mode

Both preamplifiers were tested for threshold value (which should be 100 k).

Threshold values for preamplifier Unit 1 were: O_2, 60 k; C_4, 58 k; EOG_2, 43 k; EOG_1, 37 k; O_1, 6 k; C_3, 3 k.

Threshold values for preamplifier Unit 2 (with Martin hybrid circuits) were: All 75 k except EOG_1, which was 73 k. EOG_1 (L EOG) was considerably dimmer than other LEDs when illuminated.

(Unit 3, which also contained Martin hybrid circuits, was tested briefly and gave results identical to Unit 2.)

Conclusions: The DVTU should be reset to trigger at 100 k using the Martin hybrid preamps, and this was subsequently done.

Note: The lateral EOG electrode activates the center EOG control panel LED; the center EOG electrode activates the lateral EOG control panel LED.

Preamplifier-Unit Cable

The cable was too stiff over its entire length, but especially at the junction with the preamp. The potting boot at the junction of preamp and cable contacted the bed when in use and occasionally caused one or both central electrodes to lift off the scalp.

Difficulty was experienced with the durability of the cables. Broken wires were found initially in both Units 1 and 2.

Conclusions: The cable must be made more flexible to eliminate interference with sleep. The potting boot must be eliminated or greatly modified so that mechanical forces are not transmitted directly to the preamplifier.

On February 14, 1972, a new, more flexible and durable preamplifier unit was received from SCI. This unit has performed well in preliminary testing, and more extensive trials are now underway.

Accelerometers

This unit responded in the vertical (up-down) and front-back axes instead of the vertical (up-down) and lateral (right-left) axes as originally specified. The responses of the Baylor prototype unit and the SCI DVTU are compared in Fig. 1 during side-by-side tests. The then existing configuration was considered unsatisfactory, since it did not permit detection of side-to-side head motion. Fig. 2 shows a comparison of the two units on a subject lying in bed when both were mounted side-by-side on the same cap. Fig. 3 shows a similar inability of the new unit to detect left-right rotations of the head while the subject is sitting up.

A third unit supplied by SCI was tested briefly, and it was noted that the gain of the preamplifier was approximately two times that of Unit 2. (Both units were of the new Martin hybrid configuration.)

Conclusions: 1) Lateral and vertical axes must be used. 2) A problem may exist in the gain factors of different units.

On February 14, 1972, a new preamplifier unit which contained an accelerometer with the recommended lateral and vertical axes was received. It did not function properly at that time and was returned to SCI, where the problem was determined to be a manufacturing defect in the accelerometer itself. Subsequently, another unit was received in this laboratory, and preliminary tests show it to be acceptable.

Cross Talk

EEG channels to accelerometer channel —

Cross talk was observed from both EEG channels into the accelerometer channel. Although the magnitude was only about 10% of the EEG signal, when high-amplitude artifactual signals occurred in the EEG they could trigger the accelerometer circuit.

10-Hz tone signal into EEG channels —

This was observed during playback of the analog tapes but not observed at the tape inputs.

Conclusions: 1) EEG-to-accelerometer cross talk must be eliminated. 2) 10-Hz tone signal should be reduced in amplitude at tape input to approximately 5 mV p-p (now about 20 mV p-p).

Settings

The following settings were initially incorrect, but they have been modified in the DVTU:

1. Excessive amplitude was approximately 400%; now it is set to 600%.
2. The disable timer was 3.75 sec; now it is set to 4 sec.
3. The REM timer was 35 sec; now it is set to 30 sec.

Calibration Criteria

The following criteria were established for calibration of future units:

Sleep-stage comparators

Transition		Frequency of signal crossing levels 1 and 2 but not 3
From	To	
Awake	1	5.0 Hz
1	2	3.8 Hz
2	3	2.3 Hz
3	4	1.8 Hz
4	0	0.61 Hz
0	4	0.74 Hz
4	3	2.1 Hz
3	2	2.6 Hz
2	1	4.1 Hz
1	Awake	5.3 Hz

EEG-transient detector

1. The frequency of the test signal must be equal to the peak response of the EOG filter (≈ 3.0 Hz).

2. The threshold level should be set to 350% of the average peak EEG input level.

EOG-transient detector

1. The frequency of the test signal must be equal to the peak response of the EOG filter (≈ 3.0 Hz).

2. The threshold level should be set to 250% of the average peak EEG input level.

Interconnection of Tape Recorders to System

Each channel of each recorder had to be adjusted (with the entire system working and with zero input signal to preamplifier) to zero output level. The adjustment of one recorder sometimes interacted with the corresponding channel of the other recorder (inputs are in parallel). Disconnection of one recorder could cause an offset in some channels of the other recorder.

Gain of L and R EEG Channels

Testing of the unit revealed a small difference in gains as measured at the tape-recorder outputs (e.g., R side $\approx 10\%$ higher).

Disable Circuit

When in the disable mode, the analog of sleep signal drifted (discharged) at approximately 0.76 V/30 min. This was an excessive amount and was considerably higher than the drift rate of the prototype. Modifications of the DVTU by SCI personnel corrected this problem.

Electrode Caps

1. No snaps were included on caps or preamp cables, but this omission has been remedied by a more recent design of the flight caps which includes a pouch to retain the preamplifier assembly.

2. The electrodes were too dry in all cases except recently manufactured caps (see below).

EEG Recording-Cap Improvement

Cap Durability

The Principal Investigator attended a demonstration of two flight-type cap assemblies at the MSC Bioinstrumentation Laboratory on January 14, 1972. At that time, the general feeling was that several problem areas remained regarding construction of the caps; the hope was that relatively simple changes in procedure would improve the situation.

Both caps (approximately 7 months old) evaluated during the test appeared very crushed, shriveled, and wrinkled when removed from their vacuum-sealed bags, although immediate weighing revealed no significant loss of weight of the entire assembly. The fabric felt slightly damp. At least one electrode exhibited small cracks in the vinyl coating at the point where the sealing tab had been bent over by the compressional forces. All electrodes appeared moist, but not normally filled, when the sealing tabs were cut off. Some electrolyte could be expressed by moderate squeezing of the sponge, but no spontaneous oozing of electrolyte (as seen with freshly filled units) was observed.

The caps were donned by a test subject, and resistance readings were obtained with a 10-Hz impedance meter. Readings ranged around 1 MΩ to 100 kΩ after considerable manipulation of the electrodes against the scalp. Although successful recordings would probably have been possible with these caps for the first hour or so, it is doubtful that all-night recording would have been successful due to the low volume of electrolyte within the electrodes.

One cap was grossly dissected immediately after use. Visual inspection revealed no component failure. The silver disc appeared intact, and the chloride coating was continuous. There was no sign of corrosion at the soldered junction of the silver disc and the insulated wire. The sponge material was moist with electrolyte but not saturated and appeared to be approximately one-half filled by volume. Inspection of the vinyl coating revealed that the interior surface of the portion contacting the cap material (i. e., the portion glued onto the cap) was ridged with the fabric pattern of the Lycra material, although no fabric appeared to be actually penetrating through into the interior of the electrode. When the vinyl was stripped off of the fabric, pinhole-like openings were evident over this portion, scattered over the vinyl when it was observed against a lighted background.

The Principal Investigator returned cap S/N 102 (the second one tested) to his laboratory and studied the vinyl coating-to-cap fabric interface under a 10-30 power dissection microscope. The holes evident visually on the first cap were also clearly seen on all electrodes of this cap except the L central.

In summary:

L occipital	several small holes
R occipital	several small holes
R central	several large holes, one open
L central	good; no holes evident
Ground	several small holes
L EOG	impression of 0.5-cm circle with several small holes around it
Central EOG	linear row of holes across electrode

There was a good possibility that electrolyte fluid was being lost through the cap-electrode interface into the fabric, which might itself act as a wick. The proximity of the cap-material fibers to the interior of the electrode via the holes and ridging in the vinyl may have made this possible. Although most holes were covered by a thin membrane, its thickness was only a small fraction of the intended thickness of the vinyl coating over the base. In addition, a passageway for electrolyte migration to this interface existed between the silicone-rubber base and the vinyl coating over the base, since these two compounds did not adhere to one another. In fact, the interior surface of the base and the vinyl coat were covered by a thin layer of electrolyte, both visible under the microscope and apparent to touch (sticky feeling).

The basic problem seemingly involved the method for attaching the electrodes to the cap. They had been glued on with a vinyl material identical to that used in the coating process, and consequently the glue application softened the coating over the base, permitting the fabric to indent it severely when the electrode was pressed into place. Bubbles may also have formed during the gluing process and led to formation of the holes.

There was also the possibility that fluid loss occurred more uniformly over the entire vinyl surface due to permeability and subsequent evaporation. If this were the case, an alternate coating material had to be considered.

Two possible solutions to these problems were investigated in this laboratory and at SCI Electronics.

1) Fluid loss through base. An attempt to alleviate this problem was studied. A circular disc of thick (50-100 mils) vinyl was glued to the electrode base; then this thick portion was attached to the cap. This provided a buffer zone of vinyl between the fibers of the cap and the interior of the electrode, thereby eliminating the possibility of fluid loss through this mechanism.

2) Permeability of vinyl. A number of electrodes were taken to Union Carbide Corporation where they were coated with a thin ($\gtrsim$0.5 mil) layer of Parylene® plastic. This material has an extremely low moisture-vapor transmission property and completely bridges pinhole openings which may be present in the vinyl. These treated electrodes are now being tested at SCI under typical packaging conditions.

The test period will last three months, having begun in March, 1972, and the final data will not be available until after submission of this report. These caps were stored for life testing: caps of the original configuration; nonParylene coated, vinyl backed; and Parylene coated, vinyl backed.

After approximately a month, caps of the original configuration lost 51% of their beginning electrolyte weight, the nonParylene-coated, vinyl-backed caps conserved the electrolyte only somewhat better, but the Parylene-coated, vinyl-backed caps lost only 2.5% of their original weight. It appears at this stage that the Parylene-coating method is superior and is conducive to a cap shelf life sufficient for the purposes of the M133 experiment.

Modification in Recording-Cap Design

While this item remains essentially the same as described in the Final Report, Contract NAS 9-10747, several changes in the pattern were incorporated during the contract period which result in a better fit and consequently more reliable electrode-scalp contact. Figs. 4, 5, and 6 show cap patterns for sizes small, medium, and large, while Fig. 7 indicates the placement of Velcro strips used to attach the chin strap and preamplifier (at the top of the cap).

—— Required Information for Ground-Based Data Analysis During Skylab ——

With each pass over a ground receiving station, telemetered information will update a comprehensive display terminal at Mission Control.

Background

During each sleep-monitoring period throughout a flight, the telemetered sleep-stage information will be relayed from the various ground tracking stations to Mission Control. True real-time data will be available only for a few minutes during each pass over a ground station. In the frequent periods when the spacecraft will be out of communication range, data will be accumulated onboard by the spacecraft telemetry recorders and transmitted to ground at a high rate during the passes over tracking stations. The information recorded in the control center during a sleep period will consequently be somewhat sporadic, ranging from real time to delays of up to approximately two hours. Data-processing equipment in the control center will collate the incoming data and preserve the time relationships such that a complete profile of sleep stage versus elapsed time eventually will evolve.

Video consoles in the control center will display the data graphically, permitting an estimate of sleep quantity and quality on a near real-time basis. The data processors will provide also cumulative statistical information as each sleep period progresses, such as the amount and percentage of time occupied by each of the sleep stages. At the conclusion of a sleep period, hard copies of the complete sleep-stage profile will be available, as well as complete statistical evaluation of various sleep parameters (e.g., total sleep time, time to fall asleep, number of arousals, percent stage time, number of sleep cycles, etc.).

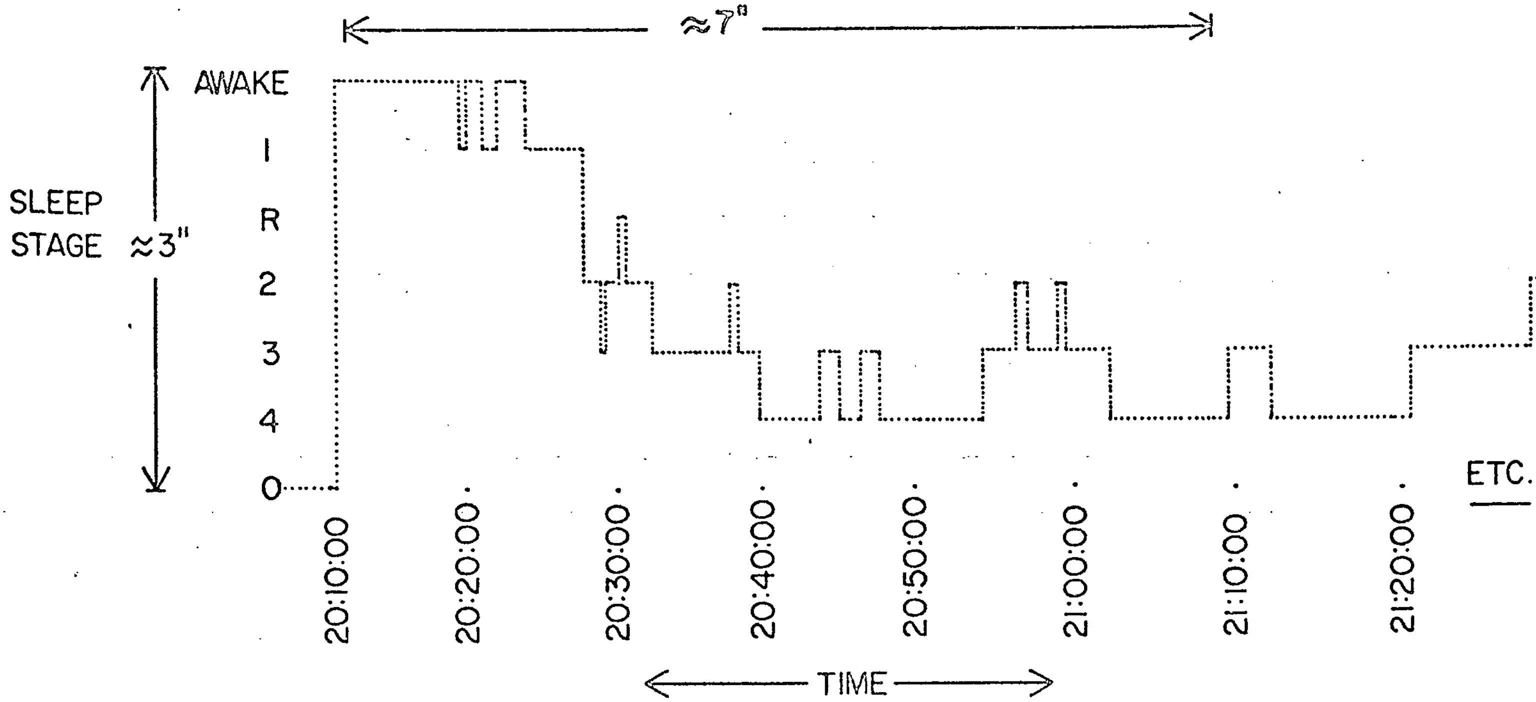
Data-display requirements for the M133 experiment were discussed at the June 4, 1971, meeting, and the requirements are outlined below. The telemetry rate will be 1.25 samples/sec (or 0.8 sec/sample). The telemetry format for sleep stages (in V dc) will be:

Awake	0.929
Stage 1	1.561
Stage REM	2.194
Stage 2	2.826
Stage 3	3.459
Stage 4	4.091
Stage 0	4.723

Information Which Must Be Displayed During Mission Sleep Periods

1. Graphic Plots

A graph showing sleep stage versus real time was required, and the following general configuration served as an example:



In order to make the data suitable for human analysis, the strip chart was made to represent about 1 hr in a 7-in. horizontal span, with the vertical span limited to 3 in.

The resolution of points along the time axis will be at least one data point for each 10-sec epoch of real time. Since 10 sec of real time consists of 12.5 telemetered values (at the rate of 1.25 samples/sec), it was acceptable to plot only the predominant value for the 10-sec epoch (e.g., A, A, A, 1, 1, A, A, 1, A, 1, A, 1 would be plotted as a single A point).

It was recommended that provision be made to produce a hard copy of the scope display at any time desired.

Graphic display of these entities is needed:

Real time as is available and practical,

Cumulative plots showing all the data recorded up to the moment for the current sleep period (night) and at the end of the period,

Complete plots encompassing the entire rest period.

2. Statistical Data Required at the End of Each Sleep Period

Total Rest-Period Time — the time from the beginning of the sleep period as indicated by the first activation of the M133 hardware until the deactivation of the hardware at the end of the sleep period.

Total Sleep Time — the hours actually occupied by Stages 1-4 and REM during the total rest-period time.

Total Sleep Percentage — total sleep time divided by rest-period time multiplied by 100. Under this category, the total Stage 0 time is considered important and should be provided.

Sleep Latency — the time from the first activation of the M133 hardware at the beginning of the rest period until the first Stage 2 indication following the first Stage Awake indication.

Sleep-Stage Characteristics — a display indicating the total time spent in each sleep stage and also showing the percent of the total sleep time each sleep stage occupied. It should be set up in a fashion similar to this:

Total Time In	% Time in Stage
Stage 1 ________	________
Stage REM ________	________
Stage 2 ________	________
Stage 3 ________	________
Stage 4 ________	________

Percent of time was arrived at using this formula:

$$\% = \frac{\text{total time in stage}}{\text{total sleep time}} \times 100.$$

Postflight Data Analysis

At the conclusion of each mission, the analog tapes from the onboard recorders will be returned for more detailed analysis. The data will be re-evaluated by conventional, visual scoring means after playback onto a graphic recorder and by various computer techniques that will permit a quantitative assessment of any EEG frequency and amplitude changes occurring throughout the mission periods.

The Principal Investigator has received a Geotech graphic recorder from NASA and has used it for playback from the Cook recorders, using tapes from the DVTU and the flight hardware (during tests at McDonnell Douglas). It has also been used in baseline studies from the Apollo 16 flight and will be used for the Skylab Medical Experiment Altitude Test (SMEAT).

This laboratory is continuing development of EEG analysis by computer, and these methods will be suitable for postflight analysis of flight tapes. The basic technique developed here (Carrie, 1969; Frost, 1969; Carrie and Frost, 1971) involves use of a small, general-purpose computer (such as the LINC-8 or PDP-12).

The 'period-amplitude' data-acquisition technique of Legewie and Probst (1969) most closely resembles ours, although our data-acquisition system differs from theirs in the following respects: 1) Baseline crossings exceeding a predetermined amplitude are identified by the software program in our system instead of by a manually adjusted peripheral device. 2) In the alpha range, our system collects a fixed number of waves instead of collecting all the waves occurring in a specified time. (The latter procedure is used for analysis of theta activity in our method.) 3) Our system sorts the waves into smaller wavelength categories, providing a higher degree of temporal resolution. 4) Our system includes computer programs for printing out a graphic display of quantitative information about the EEG waveform and for computing and printing statistical measurements derived from this information.

A high degree of correlation is found between the EEG analysis of the prototype system and that of an electroencephalographer. A similar but more extensive study is currently underway, using the more detailed information about the quantitative characteristics of the EEG waveform that is provided by the newer system. This investigation will have two purposes. Firstly, the results of this study on the prototype system will be extended. Secondly, an attempt will be made to develop an automatic EEG description system that will not only provide a printout of the quantitative characteristics of the EEG waveform but will state the statistical probability that electroencephalographers of known reliability would ascribe particular characteristics to a particular EEG, e.g., with respect to symmetry/asymmetry or regularity/irregularity.

This EEG-analysis system (see Fig. 8) defines the characteristics of an EEG waveform in terms of several quantitative variables. A large computer will be used to carry out a multivariate discriminant analysis in order to determine which variables discriminate most effectively between experimental or clinical groups. The multivariate analysis will also provide discriminant function coefficients relating to groups which can be used to compute diagnostic probabilities on the basis of results from individual subjects. This latter computation can then be carried out on the LINC-8, using specially designed programs. The larger computer will be used only for the initial analysis and for subsequent updating of coefficients as more subjects are studied. In later phases of the study, the 'pre-processing' programs on the small computers will be expanded to compute additional variables.

The foregoing method and others investigated in this laboratory have been developed under grants and contracts other than the present one, but these methods are useful in the area of investigation which this contract encompassed.

Suggested Changes in the Integrated Systems Acceptance Test Protocol

This test was originally scheduled for March 10, 1972, at McDonnell Douglas Astronautics Co., Western Division, in Huntington Beach, Calif. The proposed outline for testing would have incompletely evaluated the hardware and could possibly have caused misinterpretation of some tests.

Accordingly, suggested changes in test protocol, which the Principal Investigator felt would be acceptable, were submitted to the Principal Coordinating Scientist, Experiment M133, on March 6, 1972. These suggestions were based on several trial runs performed two weeks previous to the submission of test-change suggestions, utilizing the DVTU Sleep Monitoring System No. 1 and Sleep Monitor System Test Set No. 2.

The Changes

Sequence 86:* Fasten the M133 preamplifier and accelerometer to the top surface of the M133 panel assembly, using adhesive tape.

Comment. As then written, Sequence 86 instructed the test conductor to attach the preamplifier to the Test Set Accelerometer Arm. During our tests, improper operation of the DVTU resulted when this procedure was followed. Mechanical vibrations resulting from activation of the Test Set Start Switch were sufficient to consistently activate the accelerometer artifact-detection circuits within the DVTU system. Several test sequences were invalidated by this effect, including all those pertaining to the artifact circuitry and all those associated with detection of the REM stage of sleep. Attaching the preamplifier to the DVTU panel-assembly case, as stated above, provides sufficient stability.

Sequence 87: Add: Connect a jumper wire between terminals on Test Set labeled "Test Set Case" and "SMS Case."

Comment. Erratic performance of the Test Set resulted when these points were not connected. Personnel at SCI Electronics (manufacturers of the Test Set) felt that the jumper might or might not be needed when the DVTU was operated on the workshop power. The proposed procedure, as well as the operation manual for the Test Set, did not discuss this point.

Sequence 105: Verify the M133 panel assembly. Electrode status indications are illuminated.

Comment. Sequence 105 stated, "Verify the M133 Panel Assy. Electrode status indications are extinguished." Proper operation, verified by SCI personnel and by testing on the DVTU, is for continued illumination when the electrode isolate switch is released.

Sequence 162: Add: Attach preamplifier and accelerometer to the Test Set Accelerometer Arm.

Comment. This addition was necessary because of the change suggested in Sequence 86, above.

Sequences 174-202:

Comment. These procedures duplicated those of Sequences 141-168, except that the source was Right EEG instead of Left EEG, and Tape Recorder #2 was used instead of #1. Since the purpose was to evaluate the performance of the analysis circuitry within the Sleep Monitoring System, and since the same circuitry was utilized in both left and right modes of operation with only the input source changed, the entire sequence was a needless waste of time. The following simple sequence verifies the operation of Right EEG adequately.

Test No.	SMS Timer		
	4 sec	30 sec/10	30 sec hi/60 sec
11	N.A.	N.A.	0
01	N.A.	N.A.	Awake

*Sequence numbers refer to Document 1B84566, Acceptance Test Procedure Experiment M133.

Further Comment. The time saved by eliminating Sequences 174-202 could be utilized to test aspects that are not checked by the procedure as now written; specifically:

	Gain Pot.	Test No.	SMS Timer		
			4 sec	30 sec/lo	30 sec hi/60 sec
Level 3 Test	0.96	12	N.A.	N.A.	Awake
	2.40	13	N.A.	N.A.	2 or 3
Excessive Amplitude Test	"	14	N.A.	N.A.	Awake
	"	15	Awake	2, 3, 4, or 0	0
REM Circuitry Test	0.96	16	N.A.	N.A.	Awake
	"	17	Awake	Awake	Awake
	"	18	N.A.	N.A.	1
	"	19	REM	REM	1
	"	20	N.A.	N.A.	2
	"	21	REM	REM	2
	"	22	N.A.	N.A.	3
	"	23	3	3	3
	"	24	N.A.	N.A.	1
	"	25	1 or 2	1	1

Sequences 223, 225, 229, 231: Add: With eyes closed (subject should remain as relaxed as possible).

Sequences 225, 227, 229, 231:

Comment. Each recording period in these sections was specified as 60 sec. Since some time (15-20 sec) is required for amplifier stabilization after switching, the actual time for data recording was possibly only 40-45 sec in each case. This was not enough time for proper evaluation of the EEG and EOG signals recorded on the tape. We suggested that the 60-sec time specified be changed to a minimum of 3 min in each case, and this was accepted.

II. M133 INTEGRATED SYSTEMS TEST

Background

On March 31 and April 3, 1972, acceptance-testing procedures involving the M133 Sleep-Monitoring Experiment flight hardware were carried out at McDonnell Douglas Astronautics Co., Western Division, Huntington Beach, Calif. Their purpose was to establish the satisfactory integration of the M133 experiment into the Skylab orbital workshop. During the procedures, all interfaces between the experimental hardware and the workshop hardware were evaluated, the system was operationally tested while running on the workshop power system, and the various storage operations were verified. Details of the acceptance-test procedure are outlined in document 1B84566, prepared by

McDonnell Douglas Astronautics Co.

The M133 Principal Investigator participated in these test procedures:

1. Preparation of Test Protocol

Numerous meetings were held with NASA personnel during the past year to establish acceptable limits and constraints for proper testing of the flight hardware. Specifications were provided for the development of a sleep monitoring system test set to be used during the integrated systems test.

2. Observation of Test Procedures

The Principal Investigator was present during the M133 integrated systems test and participated in discussions with testing personnel throughout the procedures.

3. Post-Test Analysis of Tape-Recorded Data

During the procedures, the test data were recorded on the M133 analog tape recorders, which preserve unprocessed EEG, EOG, and head-motion activity during the flight. Evaluation of data quality was carried out after playback on special equipment in this laboratory.

Test Protocol

The test protocol was designed to accomplish the major objectives described briefly here and in detail in the test document (1B84566, McDonnell Douglas).

1. Stowage Requirements and Mechanical Interfaces

As a part of the systems test procedure, all M133 hardware was first stowed in the orbital workshop in the proper prelaunch configuration. The equipment included: 43 recording-cap assemblies, 18 chin straps, 3 preamplifier-accelerometers, 3 panel assembly-to-SIA cables, 1 power cable, 2 tape-return canisters, 3 preamplifier-accelerometer protection bags, 1 M133 panel assembly with recorders and cables, and 1 storage rucksack for caps and preamplifiers. During the procedure, each item (or a representative sample) was removed from its stowed location and installed in its operating position prior to testing. Following the testing, the items were restowed to verify the deactivation process.

2. Electrical Interfaces and Operation of M133 Hardware

The electrical interfaces (power input and telemetry output) were tested for proper operation prior to and after operation of the hardware. The hardware (exclusive of the cap assembly) was tested while installed in its normal operating position and while connected to the workshop power system.

Proper operation of the M133 panel assembly was evaluated by use of the Sleep Monitor System Test Set (SCI P/N 600884-001), which tested the following circuitry:

a) electrode-test circuitry for each electrode,
b) electroshock-protection circuits, and
c) each major section of the sleep-analysis circuitry.

3. Operation of Cap Assembly

One of the cap assemblies was donned by a test subject in the sleep compartment, and experimental operation was evaluated for several minutes with the test subject in the Awake state. This test verified that the telemetry output correctly indicated Stage Awake. The analog tapes were later removed from the M133 panel-assembly recorders and returned to the Principal Investigator's laboratory for evaluating the quality of the recorded signals (see below).

Test Results

All objectives of the testing procedure were accomplished, and in general the hardware performed according to specifications. Only minor difficulties were encountered with respect to the stowage and mechanical interfaces, and these were either satisfactorily resolved during the test, or minor changes in the configuration were suggested for future consideration. The M133 flight hardware performed normally during the electrical tests, although at one point the Ground Support Test Set (Sleep Monitor System Test Set) performed erratically and required on-the-spot repair. Although this problem was resolved, this unit should be thoroughly evaluated prior to further test procedures.

Two reels of half-inch magnetic tape, representing data from each of the two M133 analog recorders (NASA Biomedical Recording System MSC-REC-SYS-GF-C1 developed by the Cook Electric Co.), were supplied to this laboratory for playback and data evaluation.

Description of Recorded Data (Played Back 5/2/72)

1. Tape Recorder #1 (S/N 014-105); Take-Up Reel S/N 0000004

Channel Designations	Signal
1	(Unused channel)
2	(Unused channel)
3	EEG (C_1O_1)
4	EEG (C_2O_2)
5	EOG
6	Accelerometer
7	10-Hz time code

Time (seconds)	Description	Comments
0	High-voltage transient, all channels	Beginning of recorded data
25	Transient, all channels	
25	10-Hz signal starts ch. 7, small amount of noise in other channels.	Beginning of electrode test mode (Sequence 12, p. 5.38*)
37	$\approx$12-Hz signal starts ch. 6	Probably electrode-test signal
131	Transient ch. 6, other signals continue as before.	Sequence 1, p. 5.40? Press electrode-isolate switch.
164	Transient ch. 6, other signals continue as before.	Sequence 3, p. 5.40? Release electrode-isolate switch.
184	Transient ch. 6, other signals continue as before.	Sequence 6, p. 5.41? Press electrode-isolate switch.
193	Transient ch. 6, other signals continue as before.	Sequence 8, p. 5.41? Release electrode-isolate switch.
225	Transients ch. 3-7; 12-Hz signal on ch. 6 ends. 10-Hz signal on ch. 7 continues.	Sequence 11, p. 5.42? Switch to L EEG positive.
244	Transients ch. 3-6; 10-Hz signal continues.	Sequence 13, p. 5.42? Turn electrode-select switch to C_4.
278	High-frequency, moderately high amplitude noise begins in ch. 3-5; ch. 6, only very low amplitude noise; 10 Hz continues on ch. 7.	Sequence 14, p. 5.42? Conduct electroshock test for C_4.

*Document IB84566

Time	Description	Comments
333	Noise on ch. 3-5 stops; 10 Hz on ch. 7 continues.	Sequence 17, p. 5.43. End electroshock test for $\underline{C_4}$.
341	Transients ch. 3-6; 10 Hz on ch. 7 continues.	Sequence 18, p. 5.43. Select electrode $\underline{O_2}$.
348	High-frequency, moderately high amplitude activity on ch. 3-4; very low voltage noise, ch. 5, 6; 10 Hz continues on ch. 7.	Sequence 19, p. 5.43? Conduct electroshock test for $\underline{O_2}$.
365	High-frequency activity, ch. 3, 4, ends; low-voltage, 10-Hz activity, ch. 3-6; 10-Hz activity on ch. 7 continues.	Sequence 22, p. 5.43? Electroshock test $\underline{O_2}$ ends.
370	Transient ch. 3-6; 10 Hz on ch. 7 continues.	Sequence 23, p. 5.44. Turn electrode select to $\underline{C_3}$.
375	Same as 348	Sequence 24, p. 5.44. Conduct electroshock test for $\underline{C_3}$.
390	Same as 365	Sequence 27, p. 5.44. Electroshock test $\underline{C_3}$ ends.
395	Same as 370	Sequence 28, p. 5.44. Select electrode $\underline{O_1}$.
400	Same as 348	Sequence 29, p. 5.44. Conduct electroshock test for $\underline{O_1}$.
408	Same as 365	Sequence 32, p. 5.45. Electroshock test for $\underline{O_1}$ ends.
419	Same as 370	Sequence 33, p. 5.45. Select electrode <u>LAT</u>.
427	High-frequency, high-voltage activity ch. 5; low-voltage, high-frequency activity in ch. 7; very low voltage noise ch. 3,4; 10 Hz on ch. 7 continues.	Sequence 34, p. 5.45. Conduct electroshock test for <u>LAT</u>.

Time	Description	Comments
440	High-frequency activity ends, only low-voltage noise ch. 3-6; 10 Hz on ch. 7 continues.	Sequence 37, p. 5.46. Electroshock test LAT ends.
444	Same as 370	Sequence 38, p. 5.46. Select electrode ABOVE.
449	Same as 427	Sequence 39, p. 5.46. Conduct electroshock test for ABOVE.
459	Same as 365	Sequence 42, p. 5.46. Electroshock test for ABOVE ends.
463	Same as 370	Sequence 43, p. 5.46. Select Frontal.
469	Same as 427	Sequence 44, p. 5.47. Conduct electroshock test for Ground.
480	High-frequency activity ends; very low voltage noise in all ch. 10 Hz continues on ch. 7.	Sequence 47, p. 5.47. Electroshock test for Ground ends.
486	High-voltage transients ch. 3-6; 10 Hz on ch. 7 continues.	Sequence 48, p. 5.47. TEST OFF
503	Moderate-amplitude 10-Hz signal ch. 3, 4; 10-Hz signal on ch. 7 as before; very low noise ch. 5, 6.	Sequence 50, p. 5.47. TEST SET started.
662	Ch. 3, 4 switched to $\approx$ 5.6-Hz signal; other ch. remain as before.	Sequence 7, p. 5.49. Start test 01. (50 μV p-p, 5.5 Hz) Noise level estimate (refer to input). Ch. 3 $\approx$ 10 μV Ch. 4 $\approx$ 15 μV Ch. 5 $\approx$ 10 μV Ch. 6 $\approx$ 10 μV
865	Ch. 3, 4 switched to 4.8 Hz; other ch. remain as before.	Sequence 18, p. 5.50. Start test 02.

Time	Description	Comments
1083	Ch. 3, 4 switch to 4.29 Hz; other ch. remain as before.	Sequence 29, p. 5.50. Start test 03.
1185	Ch. 3, 4 switch to 3.61 Hz; others are as before.	Sequence 40, p. 5.54. Start test 04.
1323	Ch. 3, 4 switch to 2.78 Hz; other ch. are the same.	Sequence 51, p. 5.56. Start test 05.
1428	Ch. 3, 4 switch to 2.23 Hz; others remain the same.	Sequence 62, p. 5.58. Start test 06.
1529	Ch. 3, 4 switch to 2.17 Hz; others remain the same.	Sequence 73, p. 5.60. Start test 07.
1635	Ch. 3, 4 switch to 1.62 Hz; others remain the same.	Sequence 84, p. 5.62. Start test 08.
1805	Ch. 3, 4 switch to 0.81 Hz; others remain the same.	Sequence 95, p. 5.63. Start test 09.
1910	Ch. 3, 4 switch to 0.54 Hz; others remain the same.	Sequence 106, p. 5.65. Start test 10.
2018	Ch. 3, 4 switch to no signal; others remain the same.	Sequence 115, p. 5.67. Start test 11.
2114	Ch. 3, 4 switch to 10 Hz; others remain the same.	Sequence 128, p. 5.69. Start test 12.
2220	Ch. 3, 4 switch to 3.19 Hz; others remain the same.	Sequence 139, p. 5.71. Start test 20.
2430	5 cycles of $\approx$2.5 Hz on ch. 5; others remain the same.	Sequence 150, p. 5.73. Start test 21.
2651	Irregular, low- to high-voltage activity begins in ch. 6; occasional transients in other channels; 3.19 Hz continues in ch. 3, 4; 10 Hz on ch. 7.	Probably Sequence 157-159, p. 5.74-5.75. Rearranging accelerometer.
2666	Same as 2651, plus $\sim$6 cycles of 2.5 (9.5?) Hz on ch. 5 (appears like test 21).	?

Time	Description	Comments
2676	Same as 2666	?
2671	Similar to 2666	?
2695	Similar to 2666	?
2701	Similar to 2666	?
2722	Similar to 2666	?
2781	Similar to 2666	?
2826	Ch. 3, 4 switch to 10 Hz; very low voltage noise and/or 10 Hz on ch. 5, 6; 10 Hz continues on ch. 7.	Sequence 161, p. 5.76. Start test 26.
2925	Same as 2826, except occasional small transients begin to be seen in ch. 6.	Probably movement of pre-amp associated with test personnel activity.
2933	Ch. 3, 4 switch to 6.5 Hz; others remain the same.	Sequence 172, p. 5.77. Start test 27.
3090	Ch. 3, 4 switch to no signal (except for low-voltage noise); ch. 6 begins to show periodic high-voltage transients at a rate of $\frac{1}{2}$ sec; others remain as before.	Sequence 181, p. 5.79. Start test 28.
3120	High-voltage transient on ch. 6 stops, ch. 6 now as in 2925; other ch. are as before.	Sequence 183, p. 5.79. End of accelerometer motion, test 28.
3239	Ch. 3, 4 switch to 10 Hz; others remain the same.	Sequence 188, p. 5.80. Start test 12.
3354	High-frequency ($>$ 50 Hz), moderately high voltage noise begins on ch. 3, 4, 5, 6; ch. 7 continues with 10-Hz. signal.	Sequence 10, p. 5.85. Spares interface test starts (Ground problem with test set).

Time	Description	Comments
3711	High-voltage noise stops ch. 3-6; ch. 7, 10 Hz.	Working on Ground problems
3723	High-voltage transient ch. 3-7; then continues as before.	Working on Ground problems
3763	Occasional high-voltage transient begins on ch. 3-6; otherwise, continues as before.	Working on Ground problems
3931	Ch. 3, 4 switch to 10 Hz; others remain the same.	Sequence 10, p. 5.85
4081	Same as 3354	Sequence 10, p. 5.85
4748	Same as 3931	Sequence 10, p. 5.85
5089	Ch. 3-6, no signal except for very low voltage noise; ch. 7, 10 Hz.	Sequence 39, p. 5.91
5171	Same as 3931	Sequence 41, p. 5.91
5421	High-voltage transient ch. 3-6, followed by same as 3931.	Sequence 55, p. 5.93
5492	Same as 5421	Sequence 72, p. 5.96
5566	Ch. 6 switches to $\approx$ 12 Hz, high-voltage signal; ch. 3-5, low-voltage 12 Hz plus noise; ch. 7, 10 Hz.	Sequence 19, p. 5.122. Electrode check, Kerwin wearing cap.
5756	Ch. 3, 4 switch to EEG signal, ch. 5 switch to EOG signal, ch. 6 switch to accelerometer signal, ch. 7, 10 Hz.	Sequence 22, p. 5.123. Start Kerwin EEG test.
5904	High-voltage transients ch. 3-7; followed by same as 5756.	Sequence 28, p. 5.124. Continue Kerwin EEG test.
6044	No signal, all channels	Tape Recorder #1 test ends.

2. Tape Recorder #2 (S/N 021-101); Take-Up Reel S/N 0000003

Channel Designations	Signal
1	(Unused channel)
2	(Unused channel)
3	EEG (C_1O_1)
4	EEG (C_2O_2)
5	EOG
6	Accelerometer
7	10-Hz time code

Time	Description	Comments
0	Transients ch. 3-7, followed by 10-Hz signal on ch. 3, 4; ch. 5, no signal except for low-voltage noise; ch. 6, occasional sporadic transients.	Sequence 5, p. 5.100. Start Recorder #2 test.
33	Ch. 3, 4 switch to no signal, except low-voltage noise; others are the same.	Sequence 9, p. 5.101. Start test 11.
639	Ch. 3, 4 switch to 5.5 Hz, others remain the same.	Sequence 20, p. 5.103. Start test 01.
761	Ch. 3, 4 switch to EEG signal, ch. 5 switch to EOG signal, ch. 6 switch to accelerometer signal, ch. 7, 10 Hz.	Sequence 33, p. 5.125. Start Recorder #2 portion of Kerwin EEG test.
1064	Transient ch. 3-7, followed by same as 761.	Sequence 43, p. 5.126. Continuation of Kerwin EEG.
1236	Transient ch. 3-7, followed by $\approx$12-Hz, high-voltage signal in ch. 6; ch. 3-5, low-voltage 12 Hz and noise; ch. 7, 10 Hz.	Sequence 1, p. 5.128. Electrode test.
1270	No signal, all channels	End of Tape Recorder #2 test.

General Comments on Recorded Data

Examples of recorded Test Set signals are shown in Figs. 9, 10, and 11 for Recorder #1 and Fig. 12 for Recorder #2. (Time and sequence numbers are indicated on the figures.) It is obvious from inspection of the records that the noise level is somewhat above the 3 μV p-p output level specified for the M133 flight hardware and confirmed during its acceptance tests. For example, the noise seen in the EEG channels in Fig. 12 appears to be equivalent to approximately 10-15 μV. This increased noise level apparently represents the noise levels and cross talk inherent in the Cook recorders utilized in the M133 panel assembly and in the Geotech recorders used for playback.

Further investigation of this problem in this laboratory has indicated that improvement could be achieved by changing the gain factors of the signals supplied to the Cook recorder inputs. The recorders have a dynamic range of from 0 to +20 mV. The output signals of the M133 system are biased at +10 mV, thereby providing the capability for a maximum signal range of +10 to -10 mV. The gain factors of the M133 hardware are now set as follows:

EEG channels . . . . . $\pm$300 μV equivalent to $\pm$10 mV at tape input

EOG channel . . . . . . $\pm$600 μV equivalent to $\pm$10 mV at tape input

Past experience in this laboratory indicates that the highest amplitude EEG signals (of interest in the study of sleep) are no greater than 300 μV p-p and EOG signals no greater than 600 μV p-p. Consequently, an improvement in the signal-to-noise situation could be made by changing the M133 hardware gain factors as follows:

EEG channels . . . . . $\pm$150 μV equivalent to $\pm$10 mV at tape input

EOG channel . . . . . . $\pm$300 μV equivalent to $\pm$10 mV at tape input

Incorporation of this change could decrease the apparent noise seen on playback to 5-7 μV p-p, which is a more acceptable value.

In spite of the relatively high noise levels, the recorded EEG and EOG tracings are of acceptable quality. Fig. 13 shows a section during the test run on Recorder #1 (Sequence 28, p. 5.124), while the subject was standing quietly with his eyes closed. Fig. 14 illustrates the eyes-open and eyes-closed conditions during the test of Recorder #2 (Sequence 33, p. 5.125), while Fig. 15 demonstrates the effects of head motion (Sequence 43, p. 5.123).

III. IMPROVEMENTS IN SLEEP-ANALYSIS CIRCUITRY

The analysis circuitry has previously been described at length (Final Report, Contract NAS 9-10747, May, 1971). The relevant portions involved can be seen and compared in the logic diagrams (Figs. 16 and 17) accompanying this report. Fig. 16 depicts the unmodified analysis circuitry, and Fig. 17

shows the recently made changes. A complete schematic diagram of the sleep-analyzer portion of the prototype system is included as Fig. 18. This diagram includes the circuits described below.

Modification I

This modification eliminates the necessity to adjust the EEG gain factor for each subject. The unmodified version (Fig. 16, section 1) operates in this fashion: The signal enters three level detectors, each set to indicate a different EEG amplitude. Level 3 is greatest, arbitrarily called 100%. Level 2 is at 20% of the distance from the baseline to level 3, and level 1 is at 1%, just above the noise level of the system. The gain of the preamplifier is adjusted once for each subject so that only the greatest amplitude, negative-going waves in his eyes-closed waking EEG exceed level 3, with the average peak amplitude falling mid-way between levels 2 and 3 (i.e., approximately 60%). Thus, the higher voltage activity during sleep will frequently cross the 3rd level, whereas the low-voltage activity during Stage 1 will exceed only levels 1 and 2.

Although there can be considerable variation in the waking EEG amplitude from person to person, there is little variance in sleep amplitudes, and this is the principle underlying the modification. The former version of the analyzer determined Stages Awake, 1, 2, 3, 4, and 0 (abnormal), all based on one gain setting. The new scheme employs a fixed gain setting which is 19.0 μV peak equivalent to level 3, or 100%.

The analyzer is essentially the same for Stages 1, 2, 3, 4, and 0 (fixed gain), but for the Awake stage (see Fig. 17) we have added a negative-pulse generator, disable relay 3, an integrator, and integrator output driver 1 (Fig. 17, section 1), all solely concerned with Awake status.

The Awake state is now determined differently, solely on the basis of dominant frequency. The level 1 comparator changes its output state each time the EEG crosses the 1% baseline level. The positive-going deflections drive the negative-pulse generator, which produces a constant amplitude and duration pulse each time the EEG crosses the baseline in a positive-going direction. The train of pulses from the negative-pulse generator is integrated with a 10-sec time constant. The output of this integrator (output driver 1 voltage level) is consequently proportional only to the dominant EEG frequency and is independent of amplitude.

Section 1 of the analyzer logic diagram now has two outputs.

Output 1 indicates the voltage level proportional to the dominant EEG frequency and is used to determine the presence of the Awake state only.

Output 2 (integrator output driver 2) uses the previous amplitude-weighted frequency-measurement scheme (see pp. 12-13, Final Report, Contract NAS 9-10747), and its voltage level is proportional to sleep Stages 1-Abnormal (Stage 0).

In the final determination of sleep stage (Fig. 17, section 4), a single comparator observing the output of integrator driver 1 determines the Awake state. Its threshold is set so that an input signal of 7.0 Hz or higher produces a true output. The comparator output is interconnected to the analyzer's telemetry output logic so that if the Awake state is present, all other outputs are suppressed.

Integrator output 2 (Fig. 17, section 1) leads into the sleep-stage output section as it did in Fig. 16, but it now connects only to the comparators for Stages 1, 2, 3, 4, and 0. These stages are determined as before, but they are all suppressed if the single Awake comparator is producing a true output.

REM determination enters the output section as it previously did, except it is also suppressed by the Awake comparator.

Modification II

The second modification improves the artifact-detection circuitry, whose purpose is to prevent signals having a high probability of artifactual contamination from influencing the sleep-stage determination systems. As originally described, this was accomplished by disabling the EEG and EOG analysis sections during and for 4 sec following either of these events — excessive EEG amplitude or head motion exceeding tolerable limits, determined from the accelerometer on the recording-cap preamplifier. More detailed description of this circuitry as originally designed can be found on pages 17-19, Final Report, Contract NAS 9-10747.

Experience has shown that in most cases in which a subject exhibits prolonged movement during sleep, the subject simultaneously shows EEG signs of arousal. Therefore, one has a better chance of correctly describing a moving subject's level of consciousness if one tends toward classifying his state as one of arousal rather than the state in which he was when the movement episode began.

The modification consists of adding disable relay 3, which serves the same purpose for the Awake state detector as disable relay 1 did for the original configuration for Awake and Stages 1, 2, 3, 4, and 0. Disable relay 1 will still function for Stages 1, 2, 3, 4, and 0. Consequently, if an artifact is detected, disable relays 1 and 3 will maintain the stage indicated at the time of artifact onset.

Also added is an analog booster (see Fig. 17, section 2). This is a negative-pulse generator which is triggered each time the accelerometer comparator is triggered. The output of the negative-pulse generator is led to the normally open contacts of disable relays 1 and 3, so if these relays become activated (by an artifact being detected), and head motion is perceived by the accelerometer comparator, negative pulses are added to the integrator circuits, with one pulse for each detected movement.

If the subject moves frequently, though the artifact circuit is activated (preventing true data analysis), the voltage on the integrators will therefore rise in proportion to the frequency of the motion. This causes a gradual upward progression of sleep-stage output, and prolonged series of movements eventually result in indication of Awake status regardless of which state the subject was in at the artifactual-period onset.

If the analyzer indicates Stage 0 (abnormal), and a continuous movement is detected at the rate of 1 Hz, the output will reach Awake status in 55 sec. This figure has been experimentally derived from observation of numcrous records. (Note: This criterion is only applicable when dealing with motion artifact. Excessive EEG amplitude alone will not produce this result, since, for example, excessive EEG amplitude can be artifact due to a faulty electrode and may be unrelated to subject activity.)

Although these modifications to the analysis circuitry cannot be included in the Skylab Sleep-Monitoring Experiment flight hardware, they will be useful in preflight testing procedures which utilize the prototype hardware and will be of value during the postflight analysis of the recorded flight data.

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Carrie, J. R. G. The modal alpha wavelength. Electroenceph. Clin. Neurophysiol., 1969, 27: 703.

Carrie, J. R. G. and Frost, J. D., Jr. A small computer system for EEG wavelength-amplitude profile analysis. Bio-Med. Comput., 1971, 2: 251-263.

Frost, J. D., Jr. Wavelength analysis of the EEG — the alpha profile. Electroenceph. Clin. Neurophysiol., 1969, 27: 702-703.

Legewie, H. and Probst, W. On-line analysis of EEG with a small computer (period-amplitude analysis). Electroenceph. Clin. Neurophysiol., 1969, 27: 533-535.

FIGURES

46

FIG. I

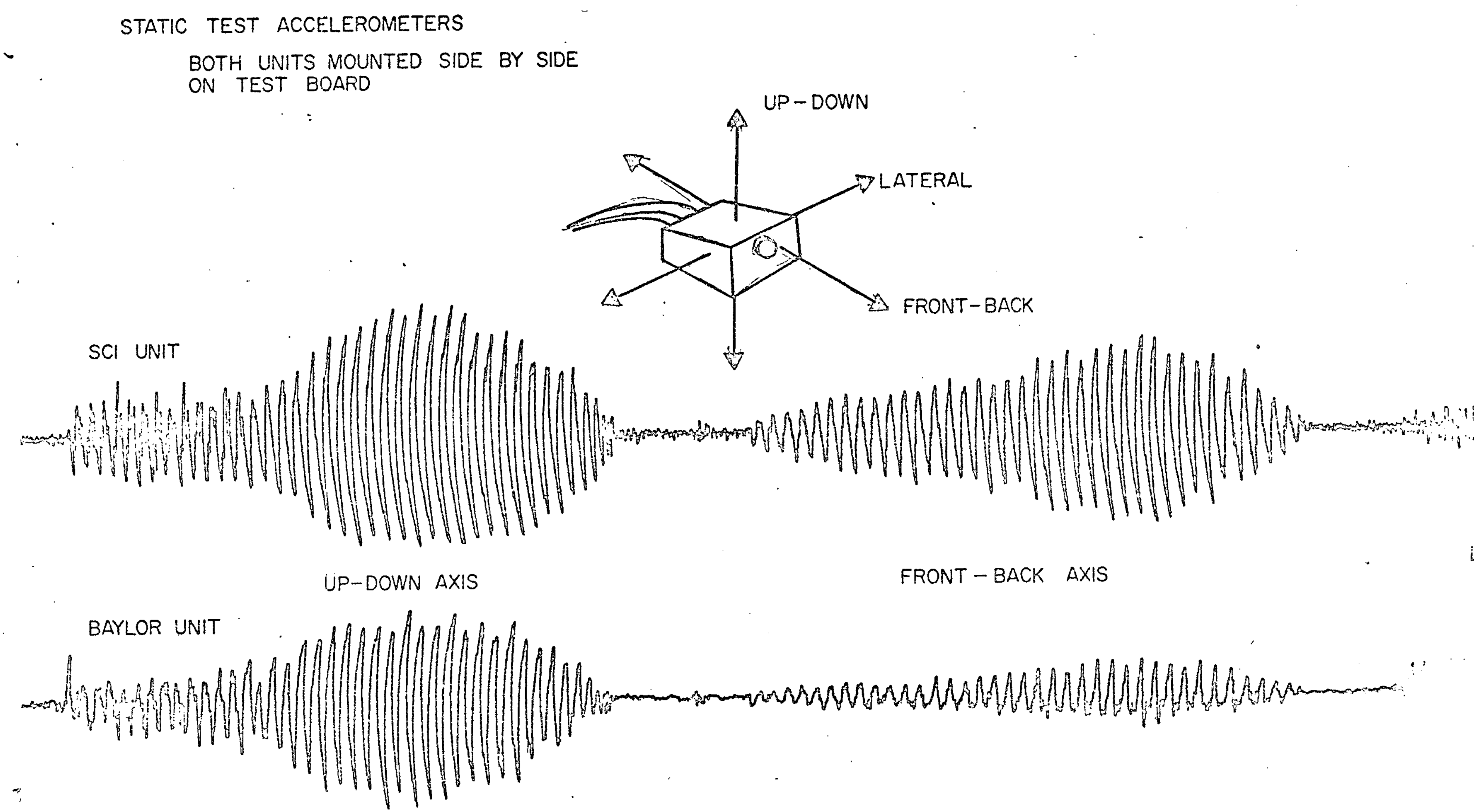

STATIC TEST ACCELEROMETERS
BOTH UNITS MOUNTED SIDE BY SIDE
ON TEST BOARD
UP-DOWN
LATERAL
FRONT-BACK
SCI UNIT
UP-DOWN AXIS
FRONT-BACK AXIS
BAYLOR UNIT

FIG. I

CCELEROMETERS

S MOUNTED SIDE BY SIDE
BOARD

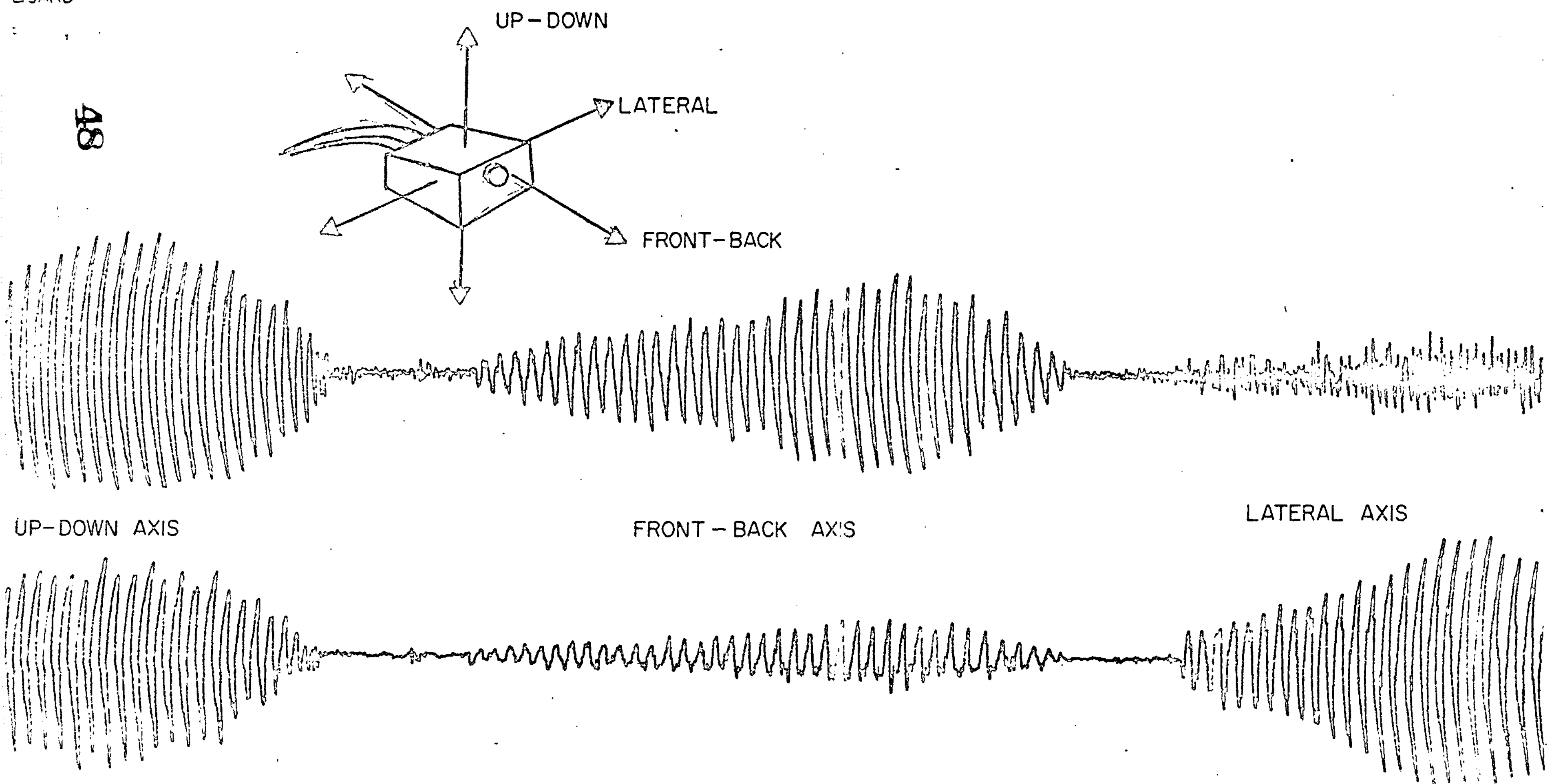


FIG. 2

5/11/71

ACCELEROMETER BED TEST

— BOTH UNITS MOUNTED ON SAME CAP, SIDE BY SIDE

— GAINS SAME AS FIG. I

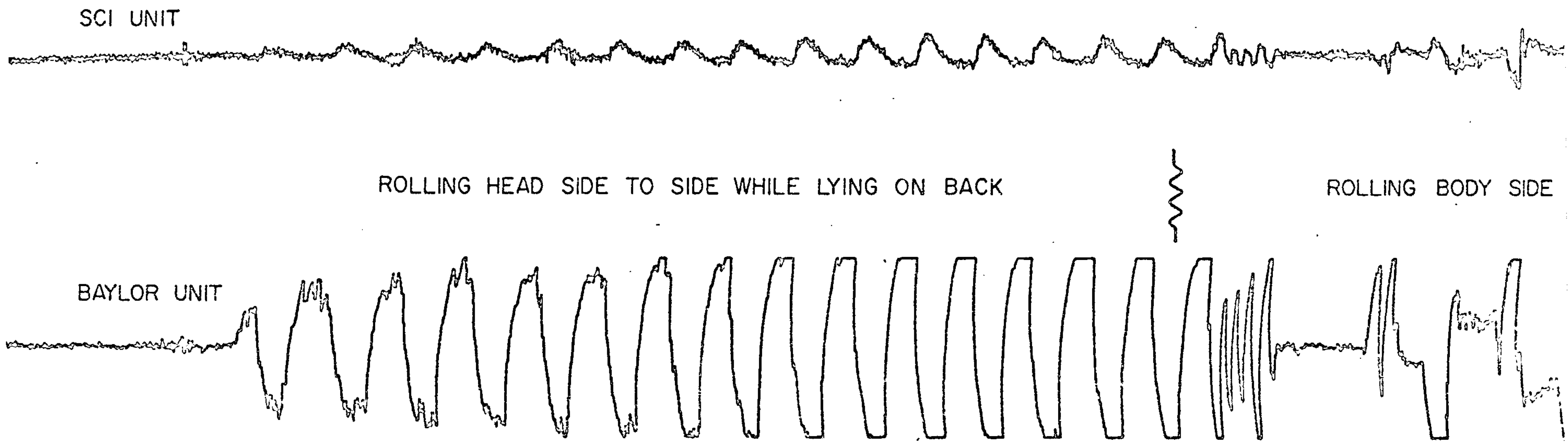
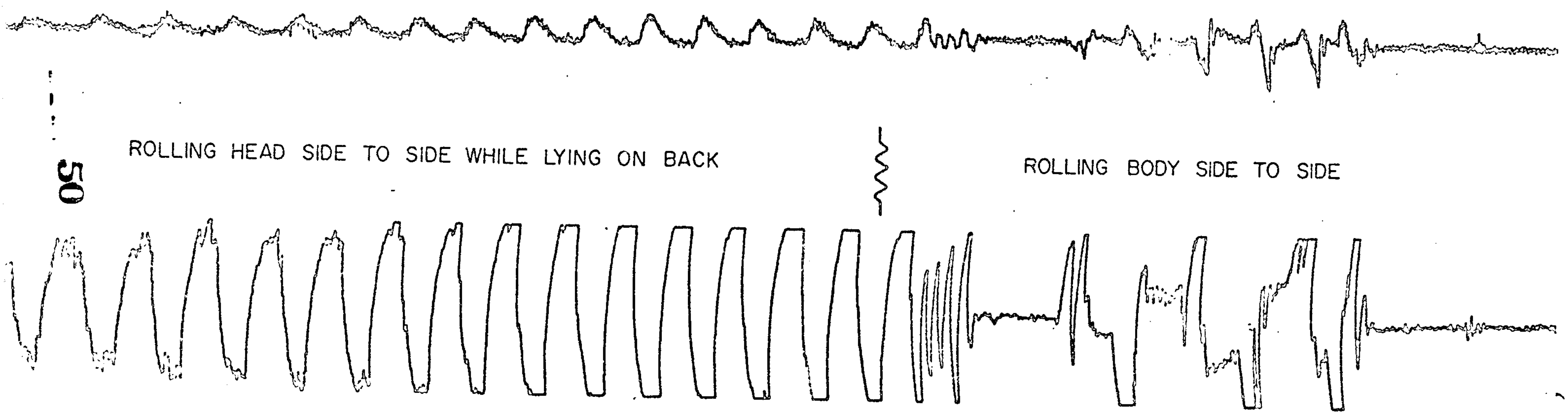


FIG. 2.

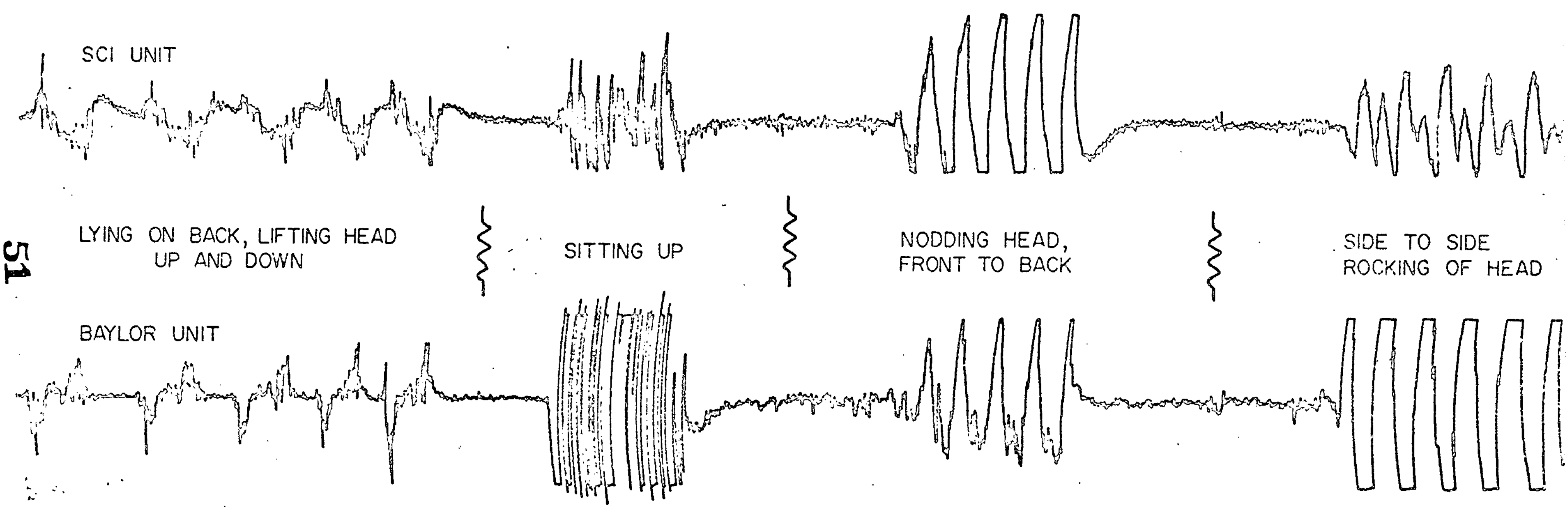
ETER BED TEST
NITS MOUNTED ON SAME CAP, SIDE BY SIDE
SAME AS FIG. I



FOLDOUT FRAME 2

FIG. 3

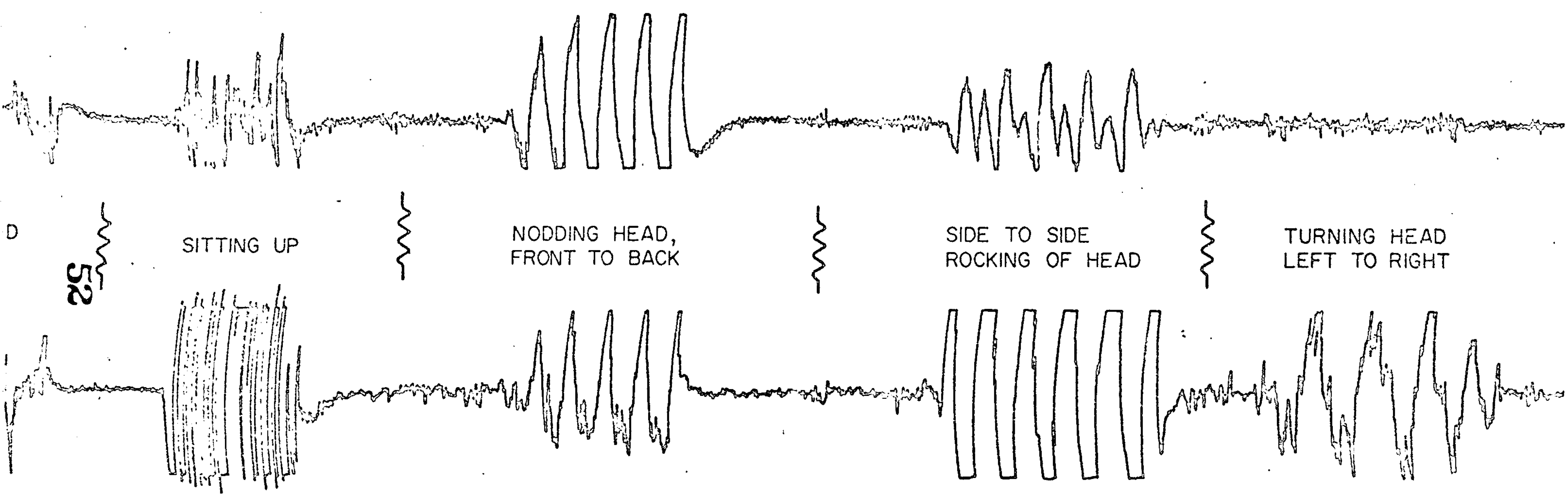
5/11/71
ACCELEROMETER BED TEST (CONT'D)



FOLDOUT FRAME 1

FIG. 3

T (CONT'D)



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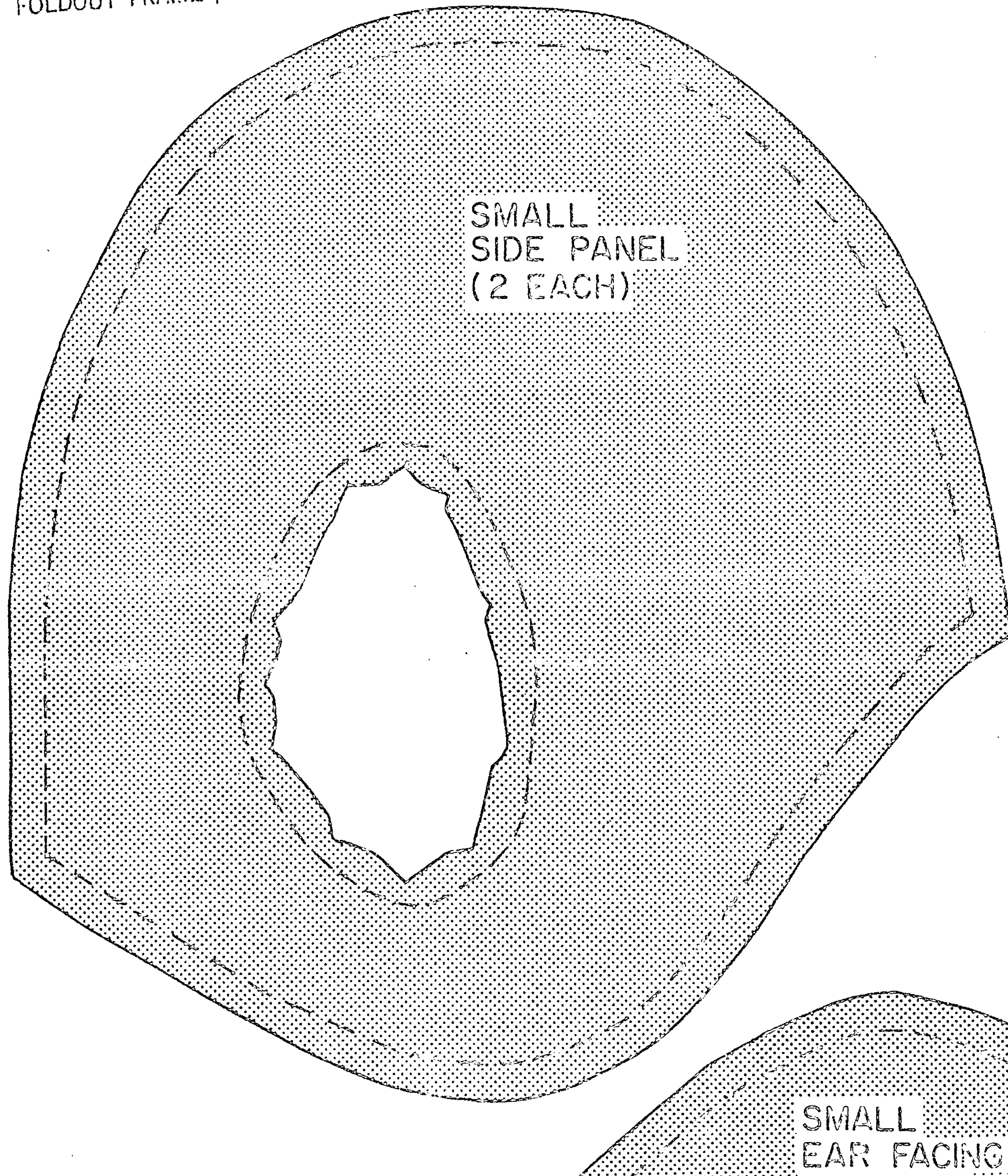
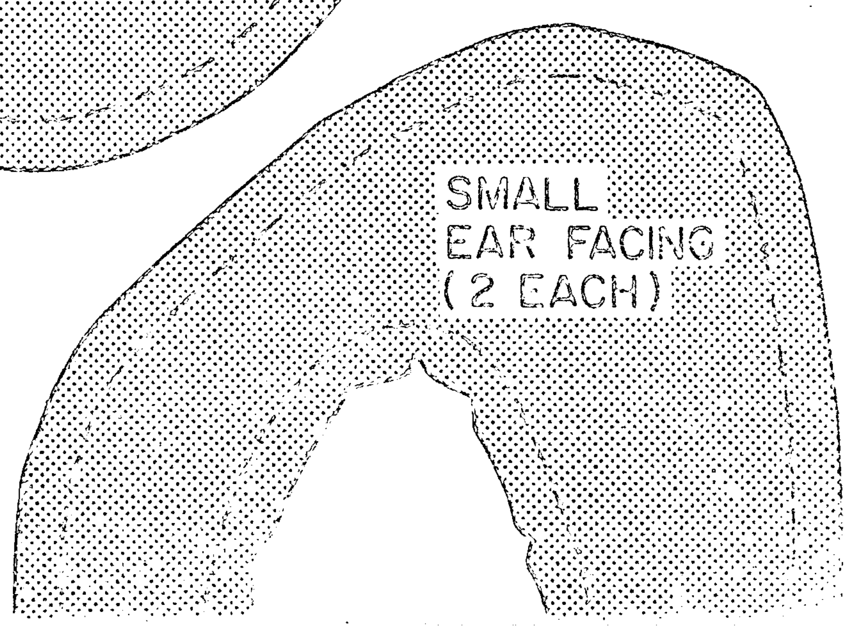
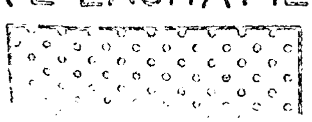
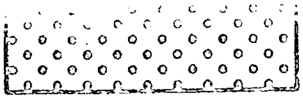


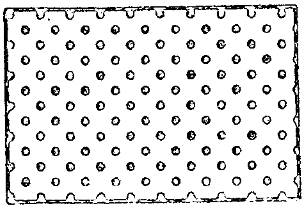


CHIN STRAP - CAP
CONNECTORS
(2 EACH)(PILE)

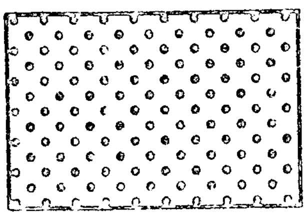


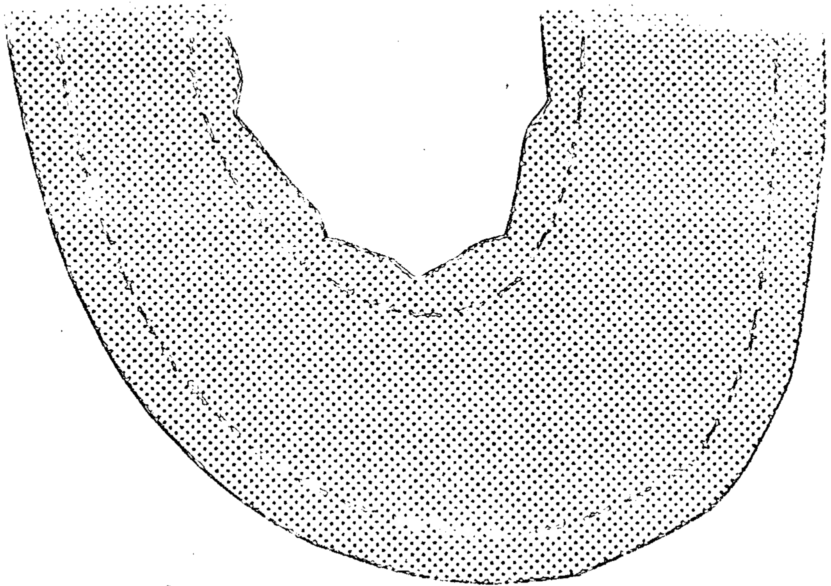


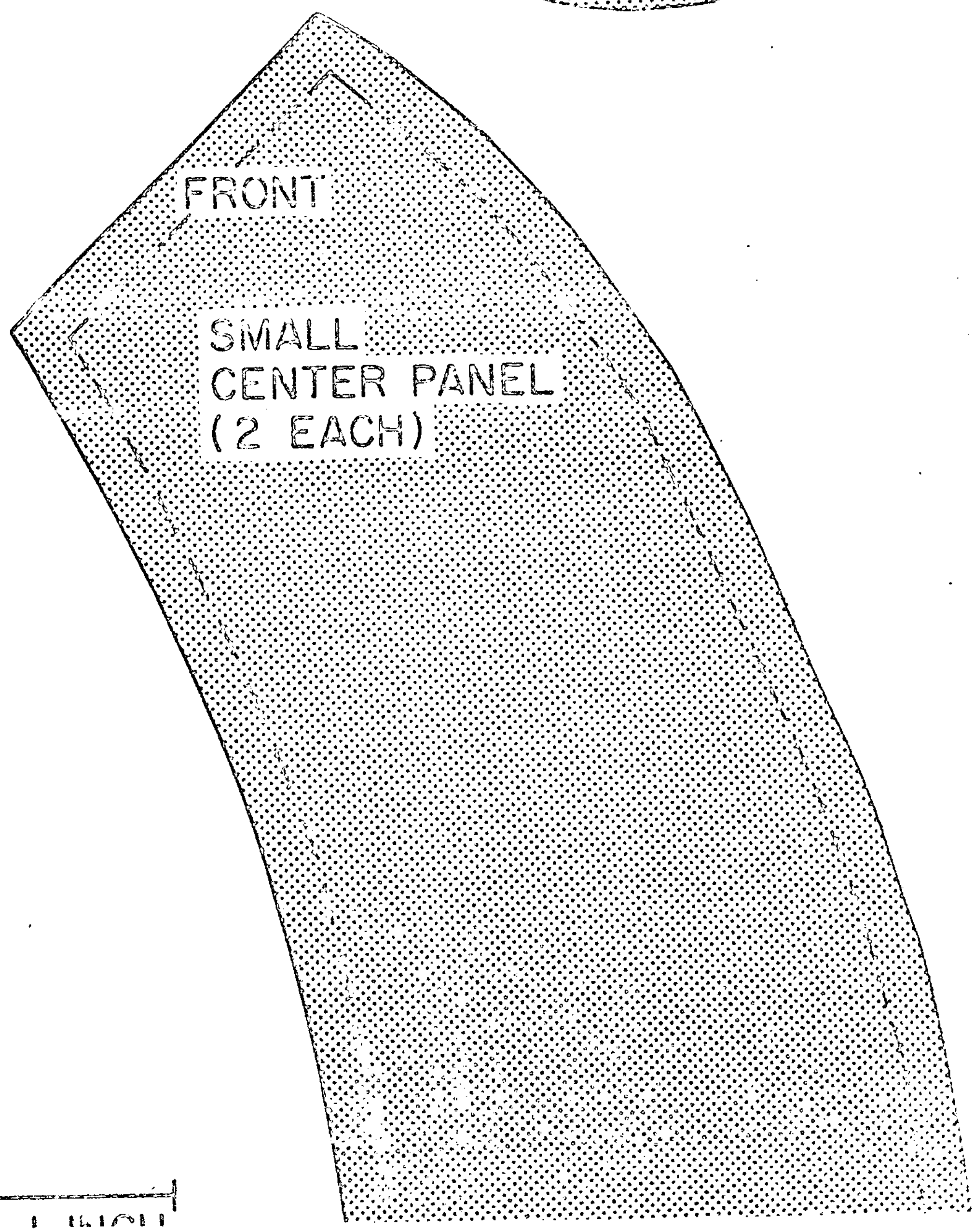
CAP-CHIN STRAP
CONNECTORS
(2 EACH)(HOOK)

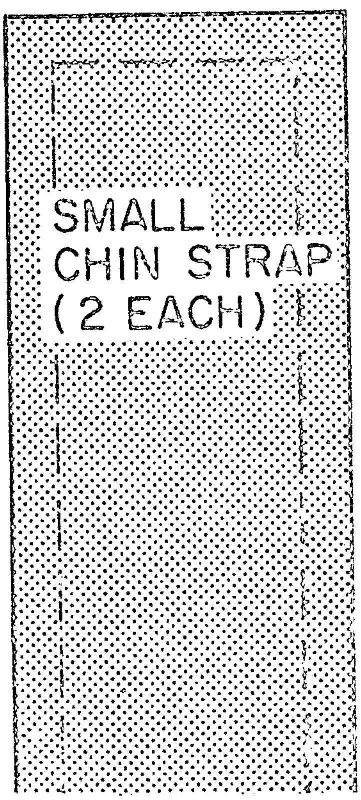


AMPLIFIER
CONNECTOR
(1 EACH)(PILE)









FOLDOUT FRAME 1

FOLDOUT FRAME 3

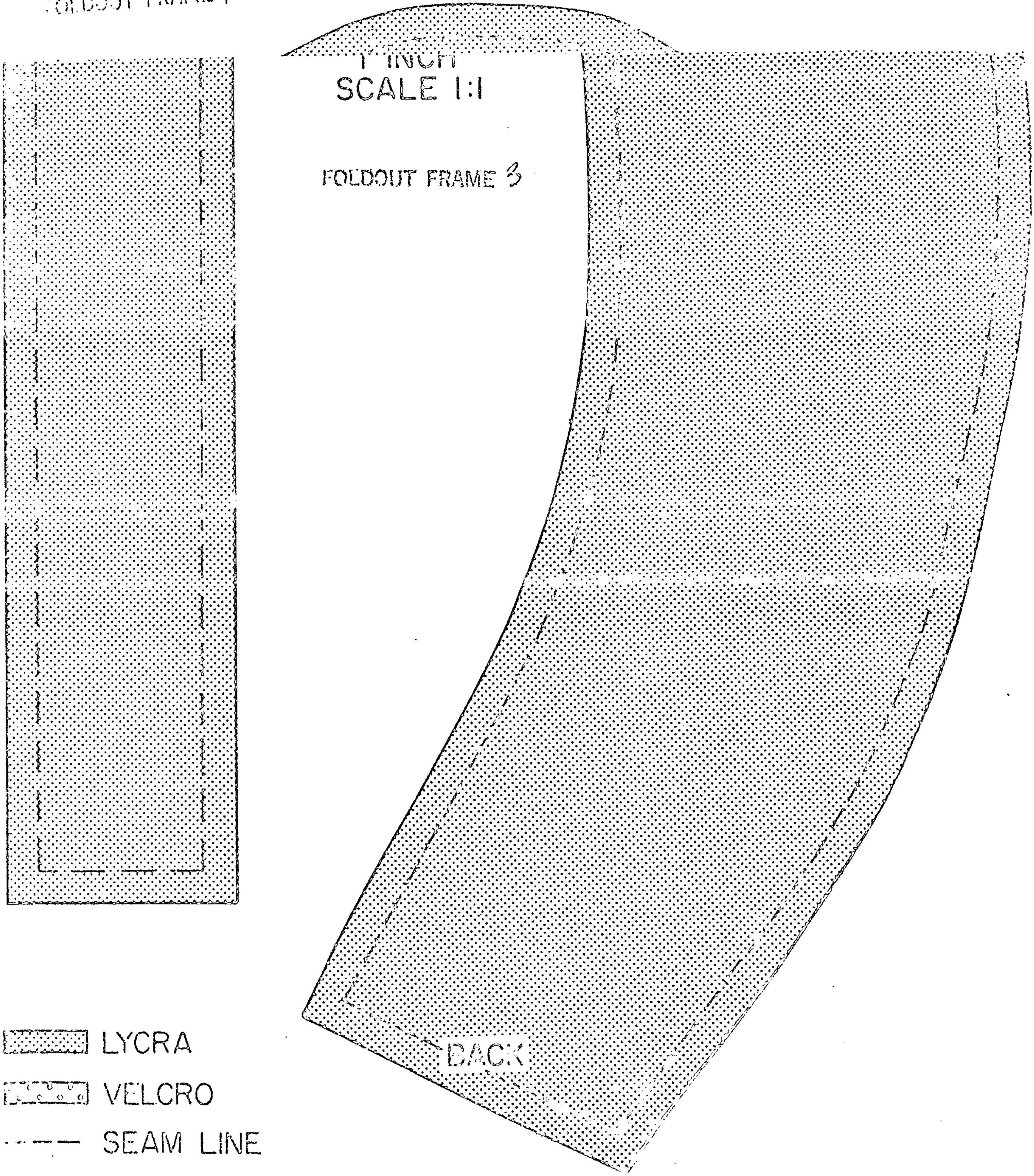
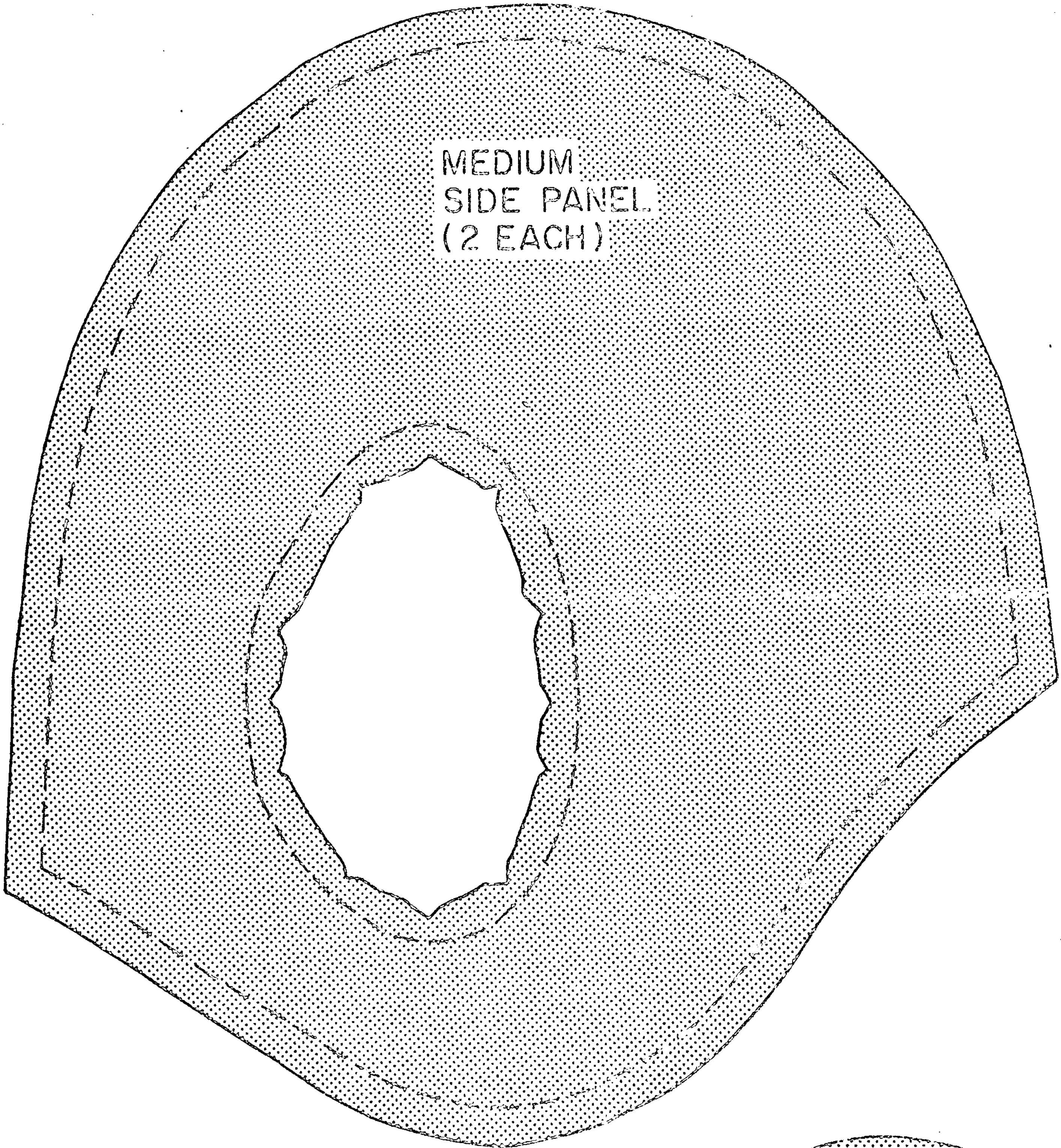
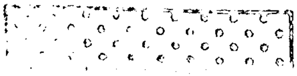


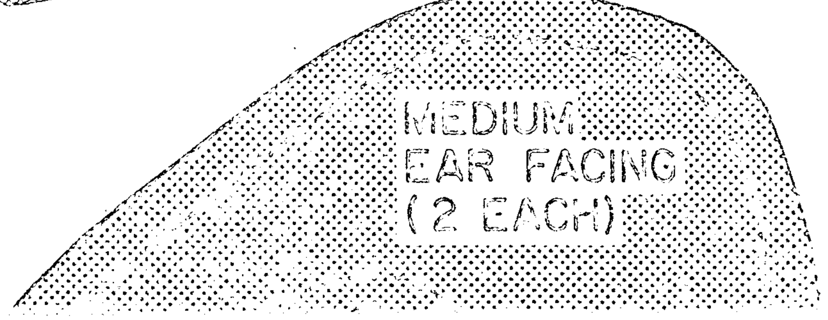
Fig. 4

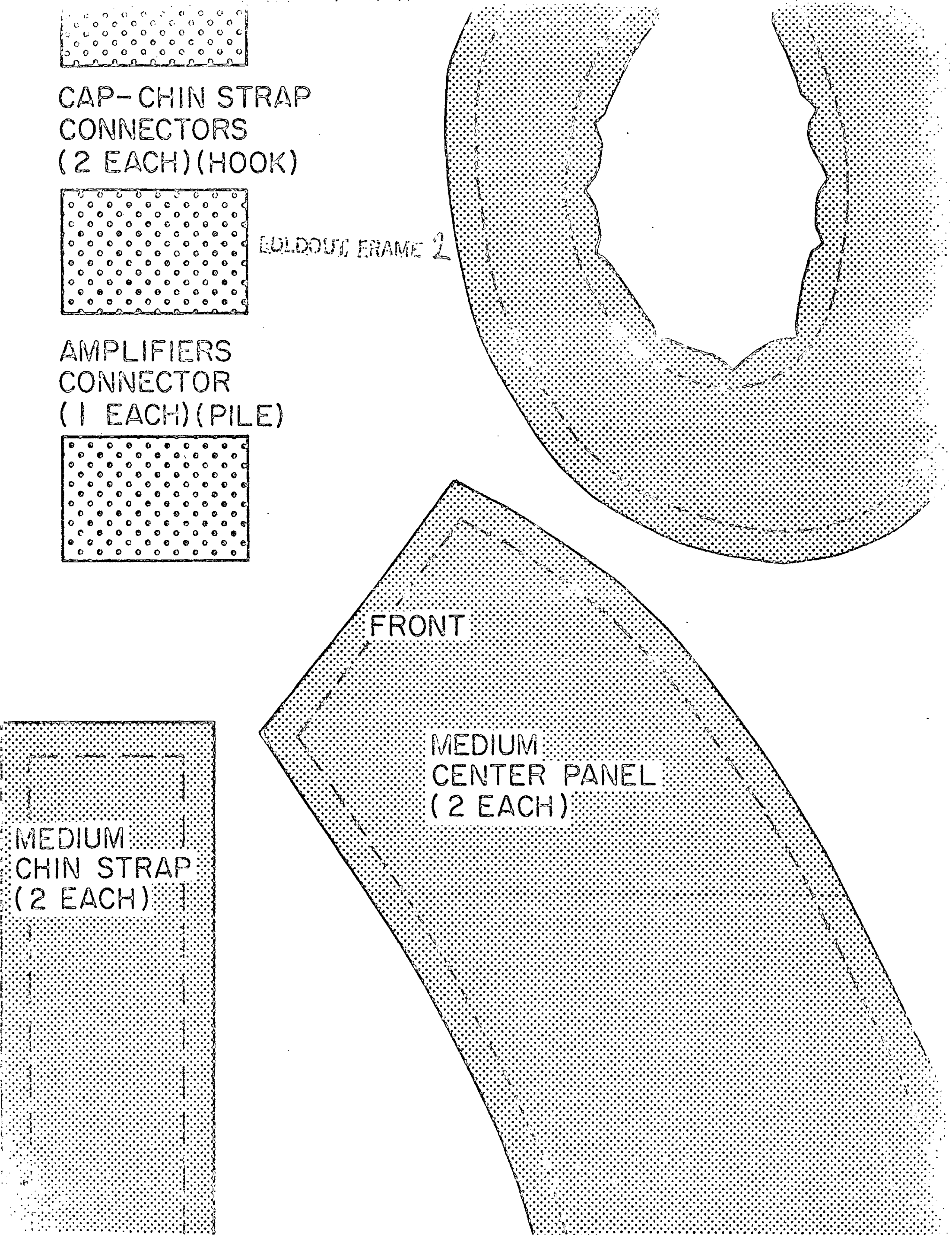
FOLDOUT FRAME 1



CHIN STRAP-CAP
CONNECTORS
(2 EACH) (PILE)






CAP-CHIN STRAP
CONNECTORS
(2 EACH)(HOOK)
FOLDOUT FRAME 2
AMPLIFIERS
CONNECTOR
(1 EACH)(PILE)
FRONT
MEDIUM
CENTER PANEL
(2 EACH)
MEDIUM
CHIN STRAP
(2 EACH)

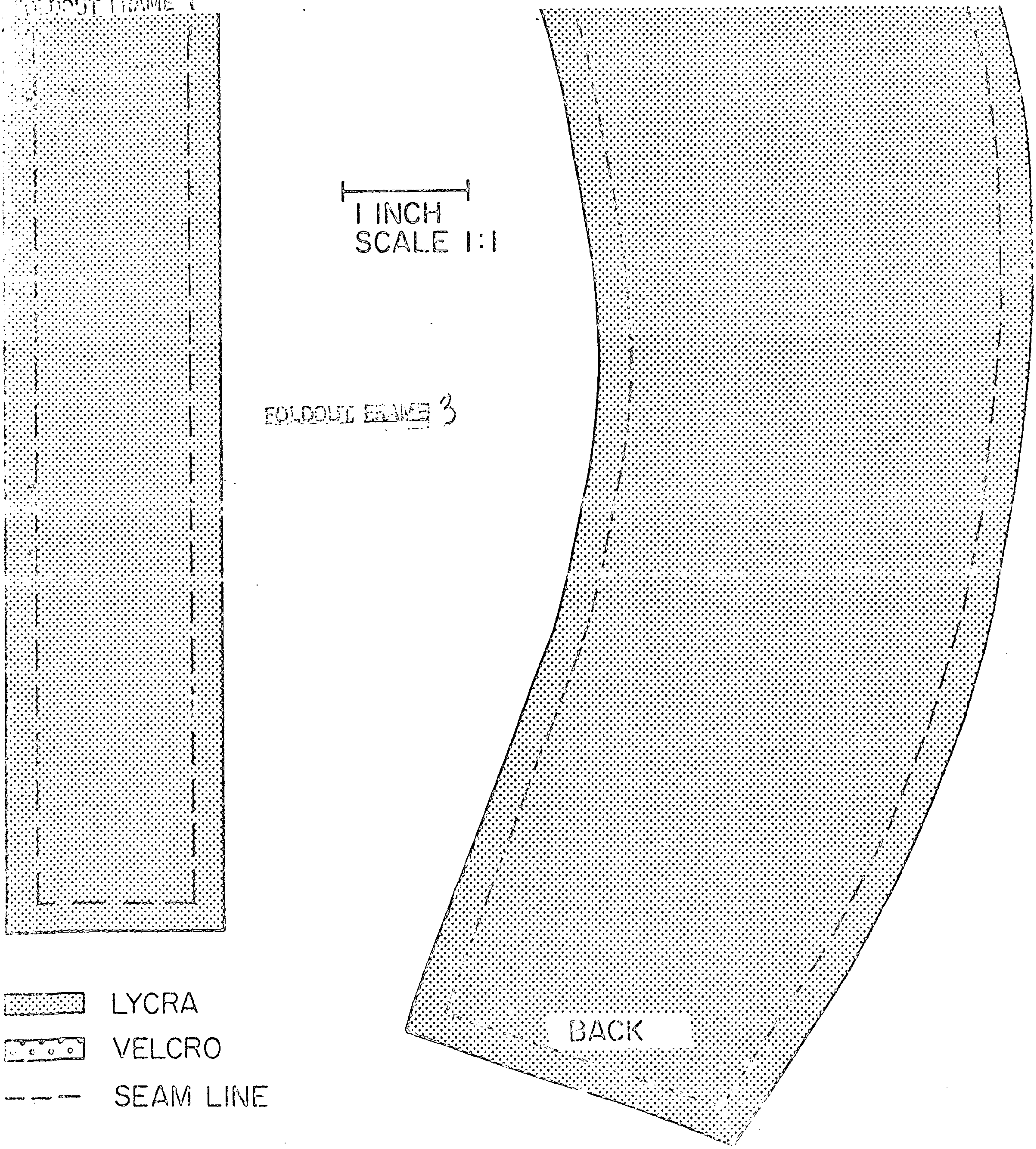
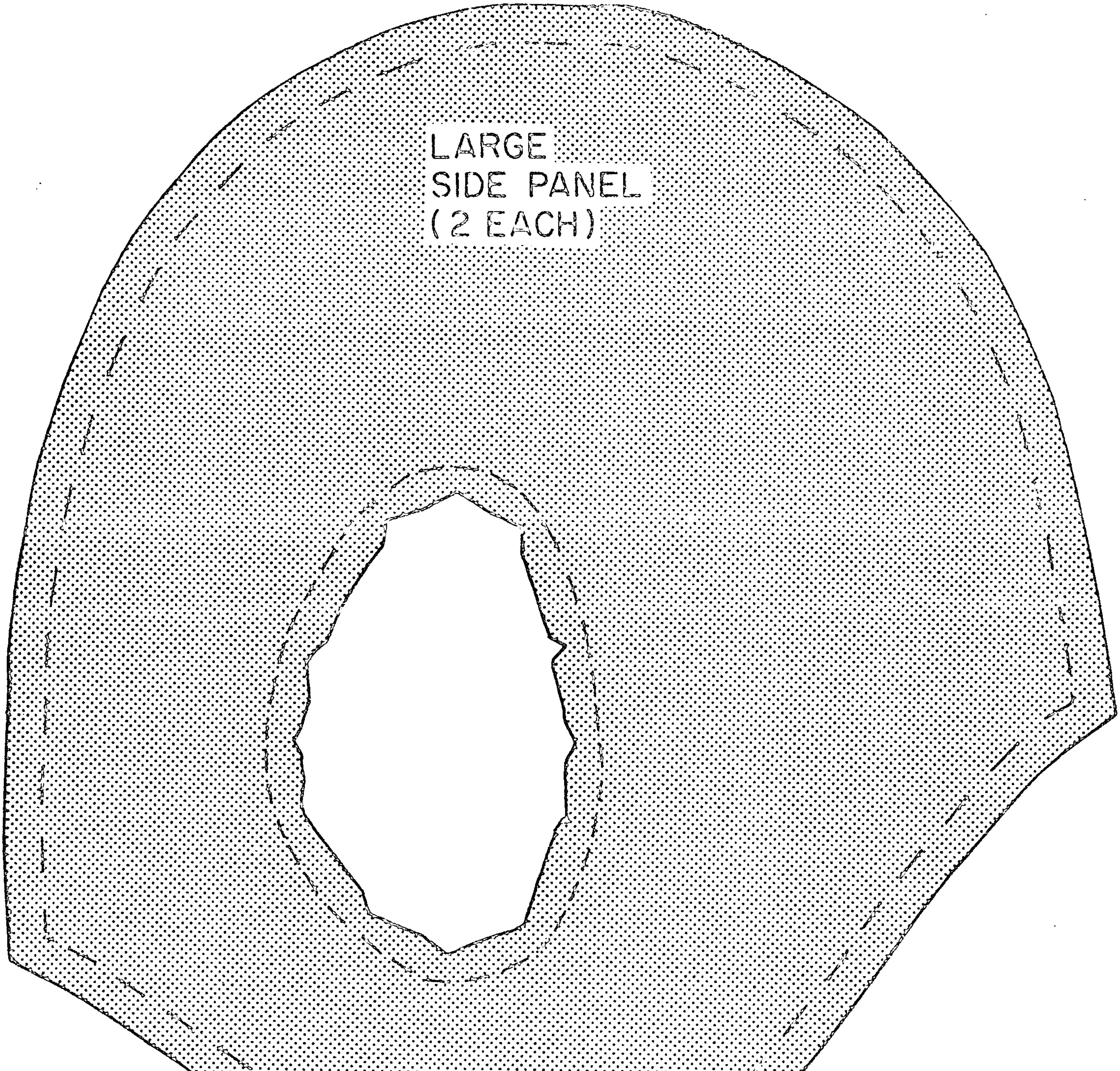
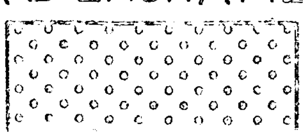


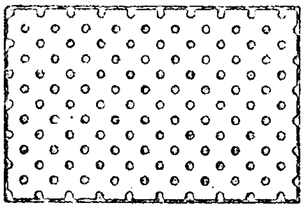
Fig. 5



CHIN STRAP-CAP
CONNECTORS
(2 EACH) (PILE)

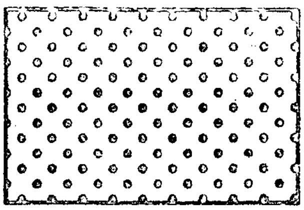


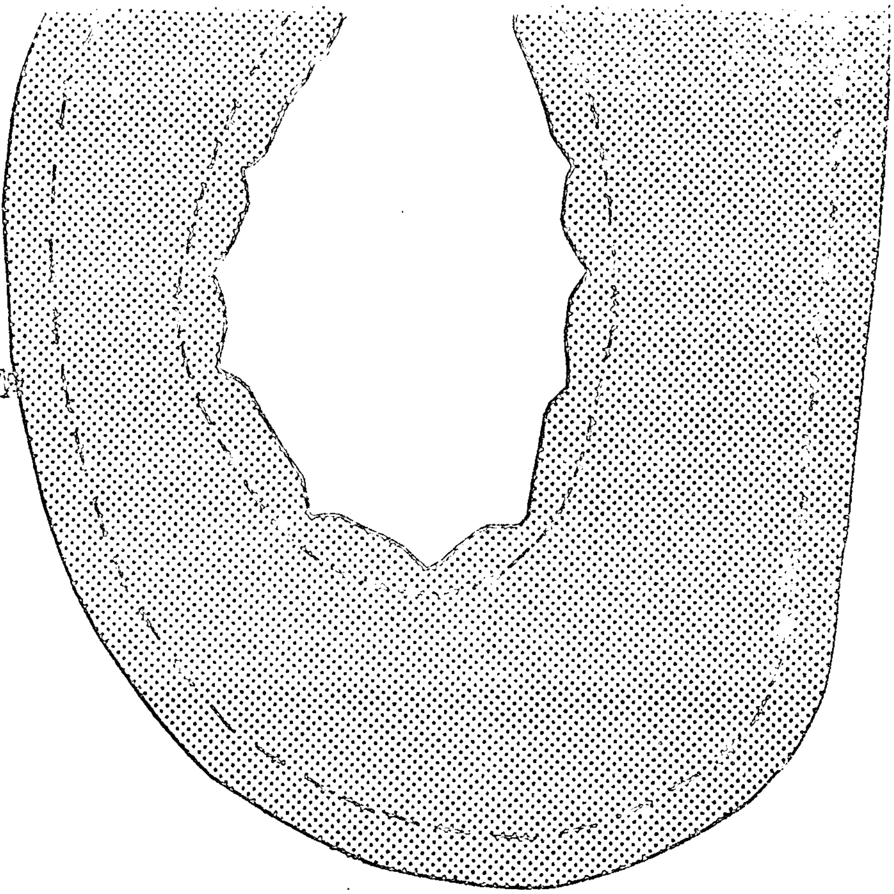
CAP-CHIN STRAP
CONNECTORS
(2 EACH)(HOOK)

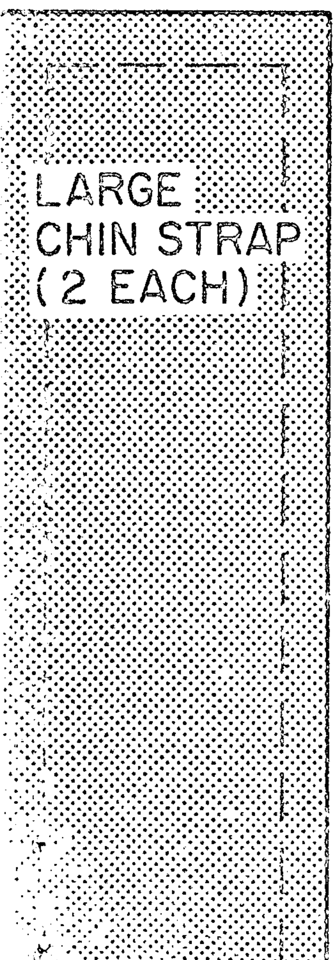


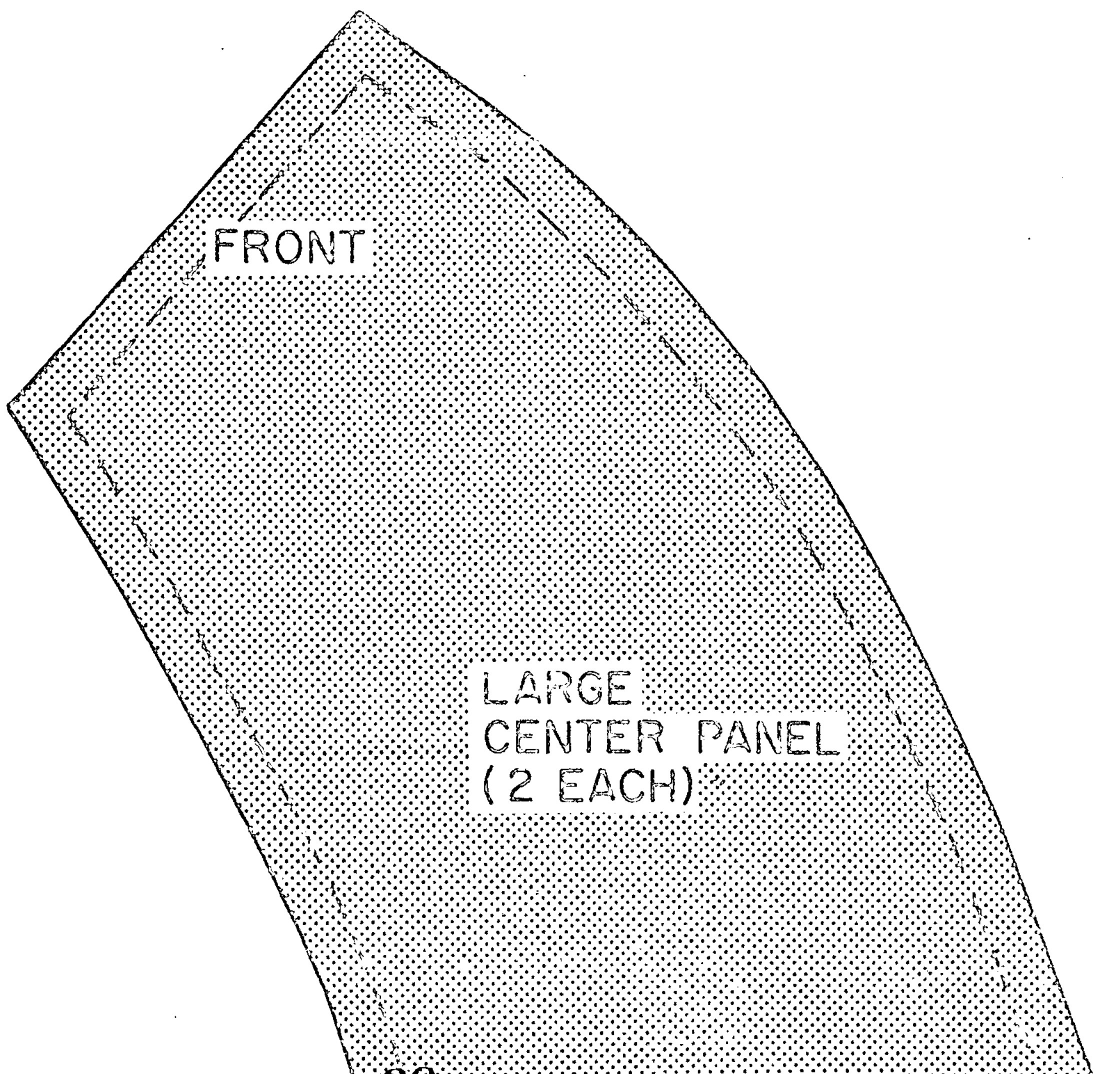
FOLDOUT FRAME 2

AMPLIFIERS
CONNECTOR
(1 EACH)(PILE)









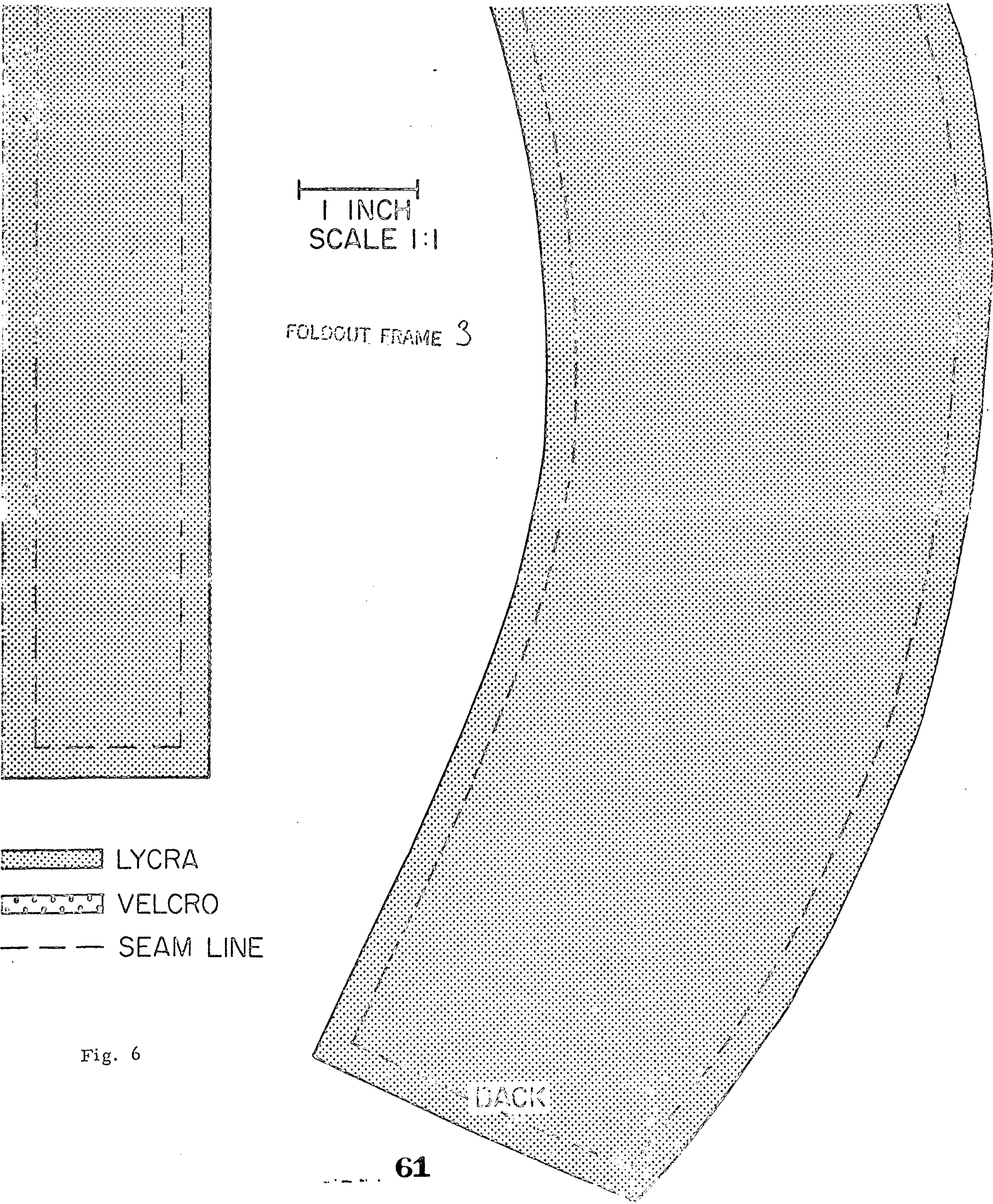


Fig. 6

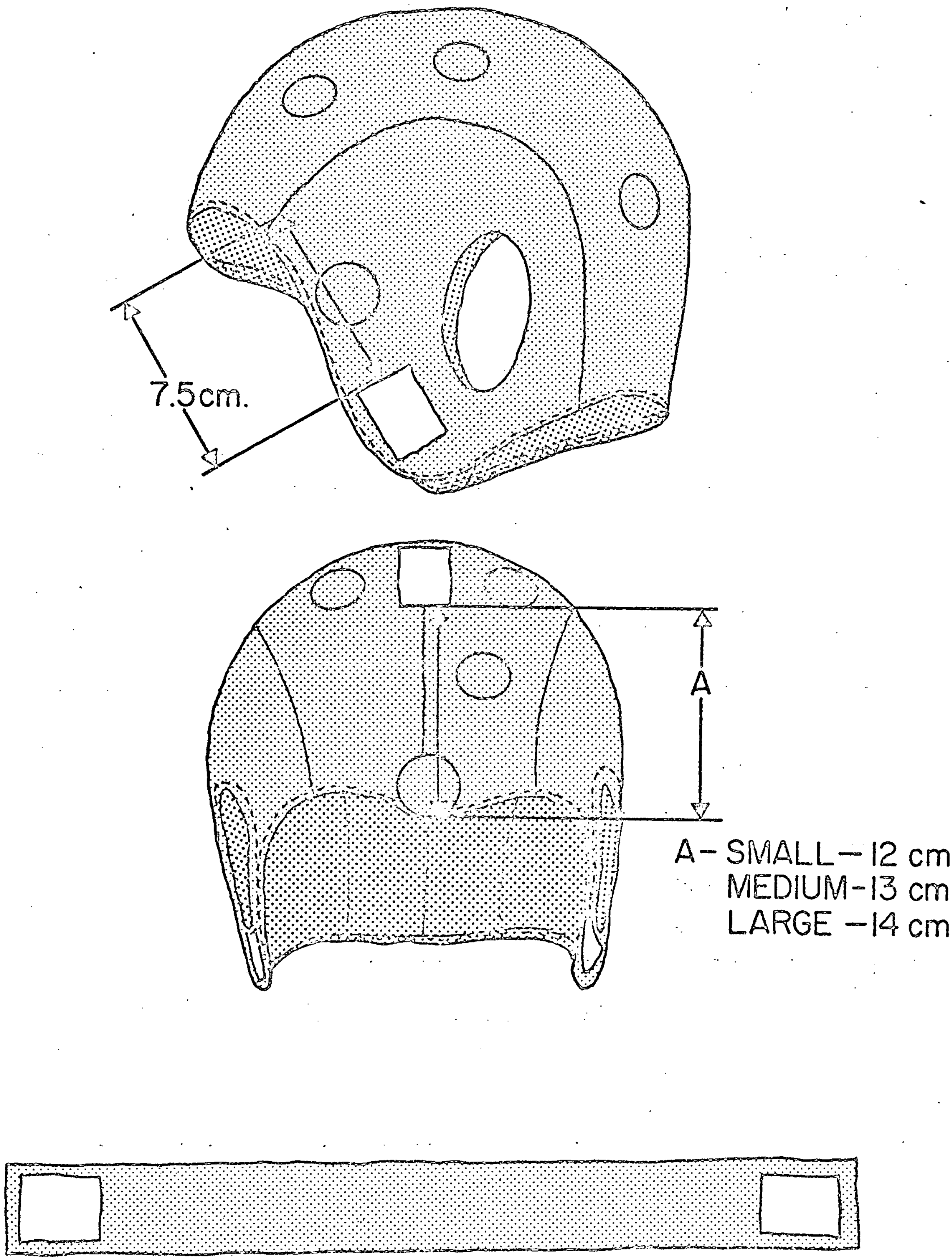


FIG. 7

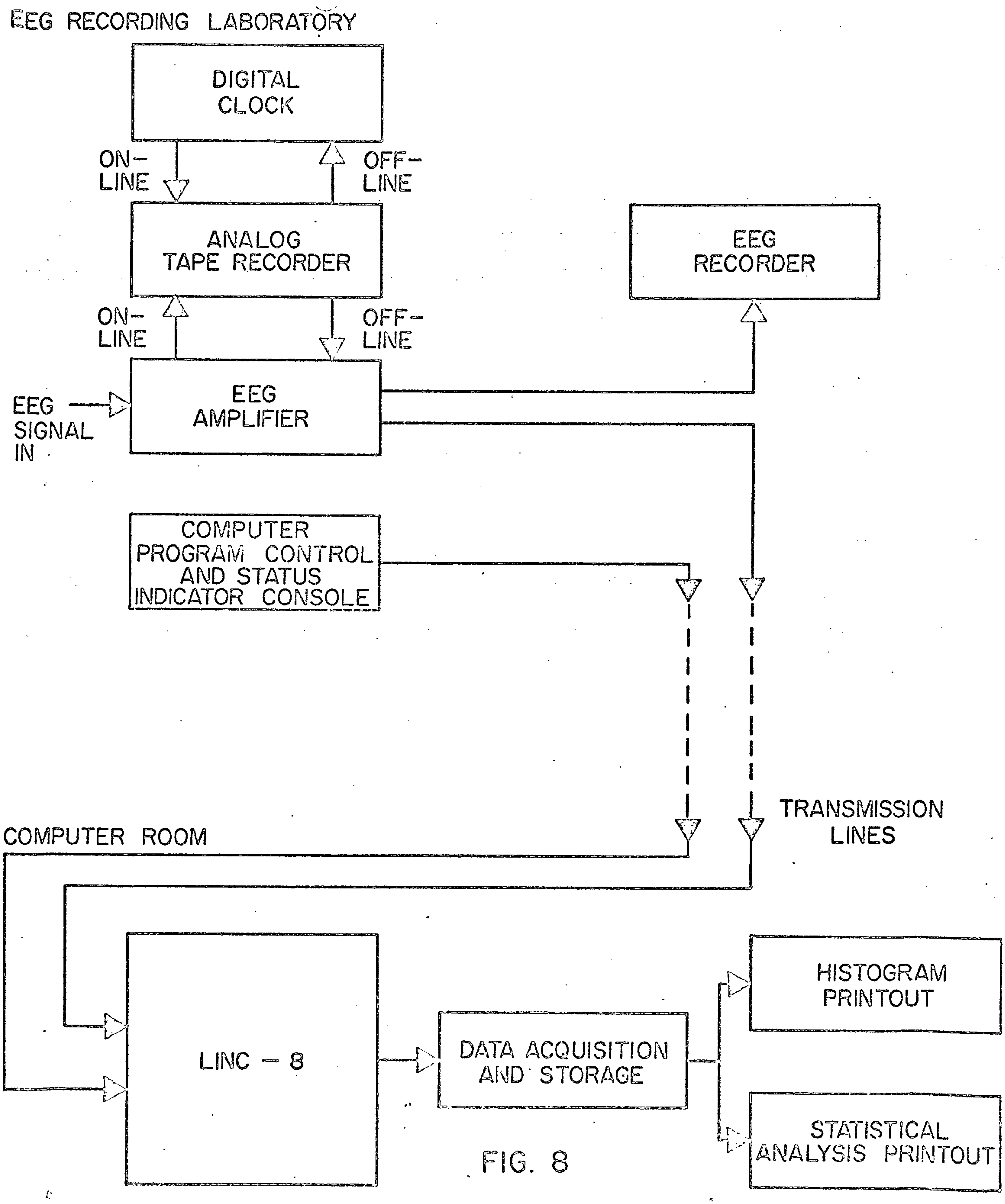

EEG RECORDING LABORATORY
DIGITAL CLOCK
ON-LINE
OFF-LINE
ANALOG TAPE RECORDER
ON-LINE
OFF-LINE
EEG RECORDER
EEG SIGNAL IN
EEG AMPLIFIER
COMPUTER PROGRAM CONTROL AND STATUS INDICATOR CONSOLE
TRANSMISSION LINES
COMPUTER ROOM
LINC — 8
DATA ACQUISITION AND STORAGE
HISTOGRAM PRINTOUT
STATISTICAL ANALYSIS PRINTOUT

FIG. 8

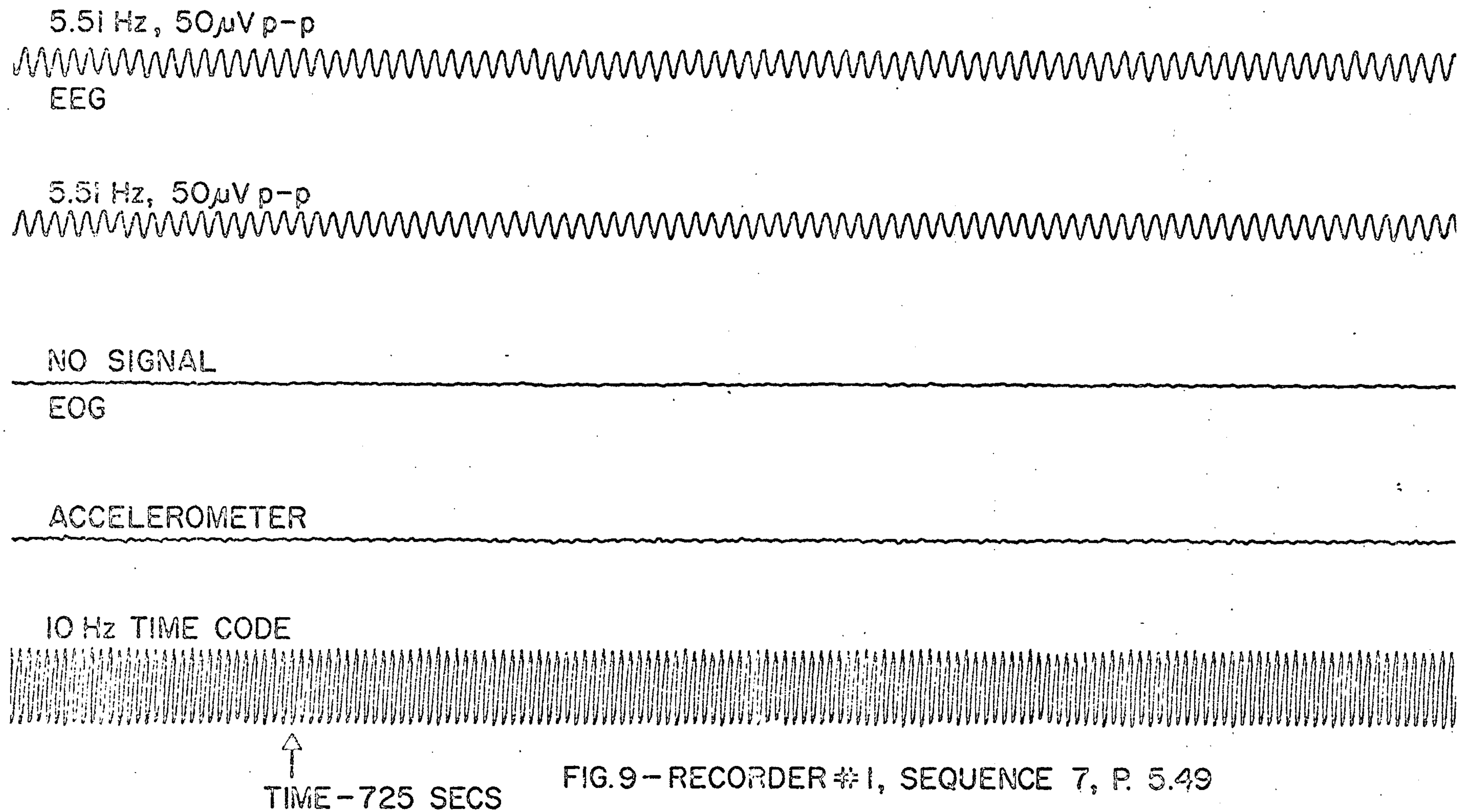


FIG. 9 — RECORDER #1, SEQUENCE 7, P. 5.49

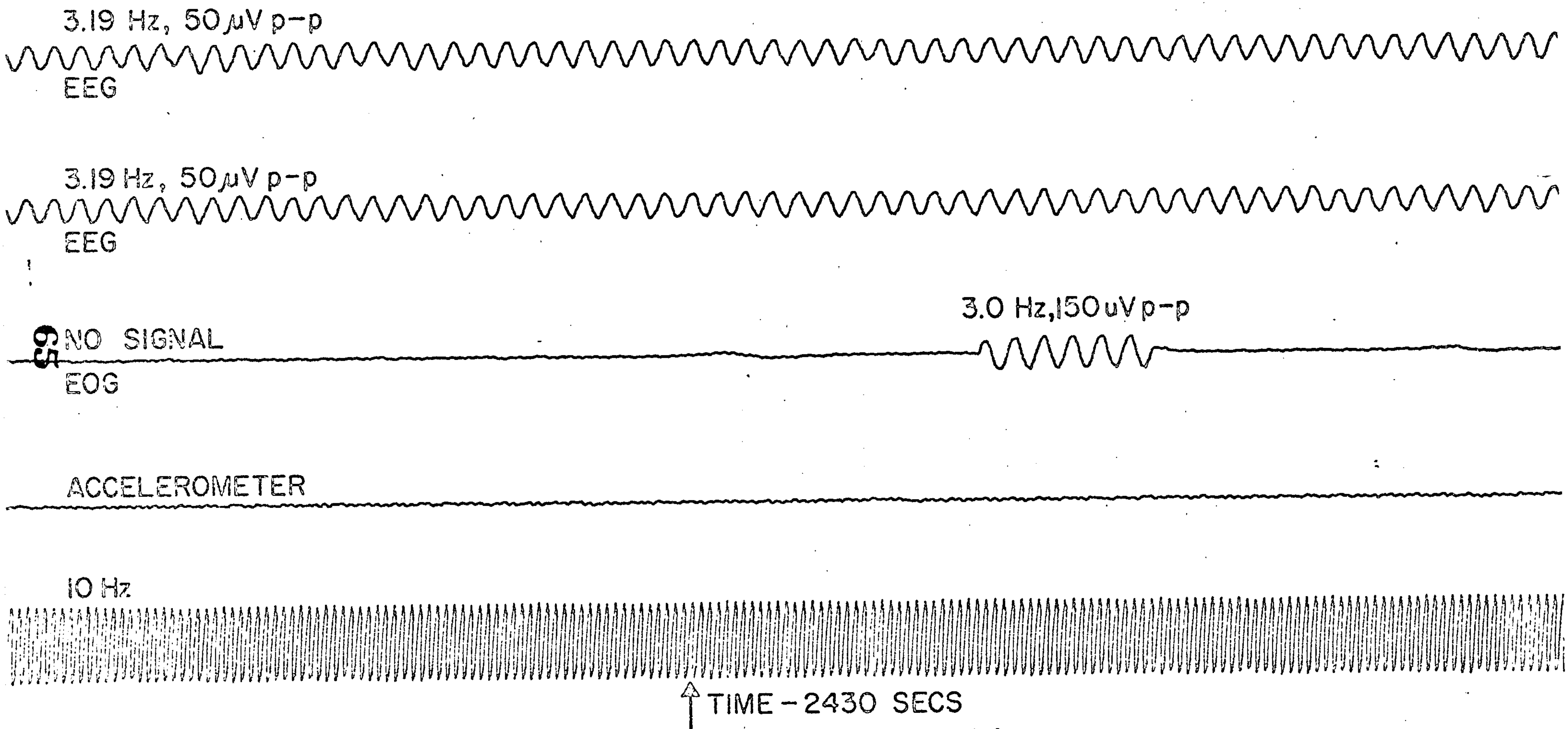


FIG.10, RECORDER #1, SEQUENCE 150, P. 5.73, (REM TEST)

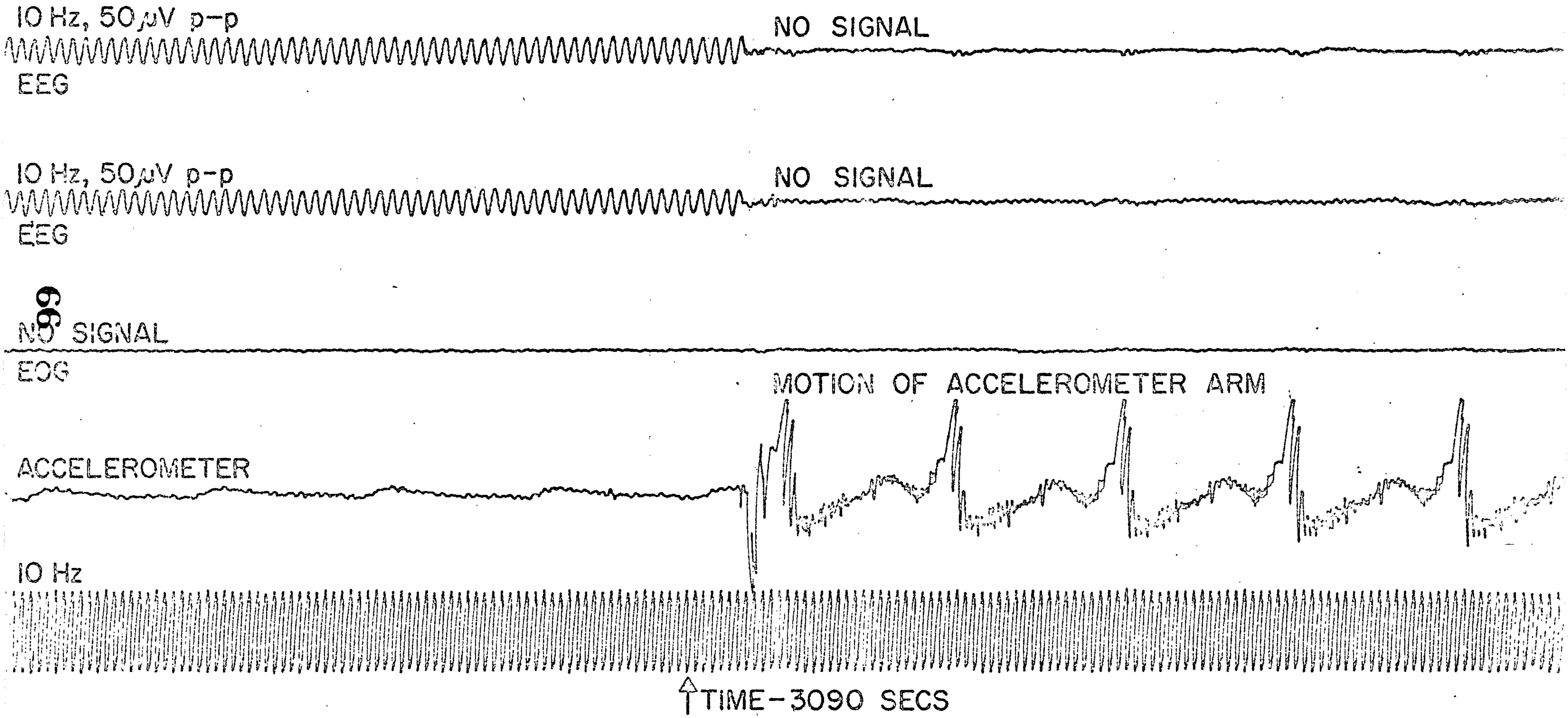


FIG. 11 - RECORDER #1, SEQUENCE 181, P. 5.79, (ACCELEROMETER TEST)

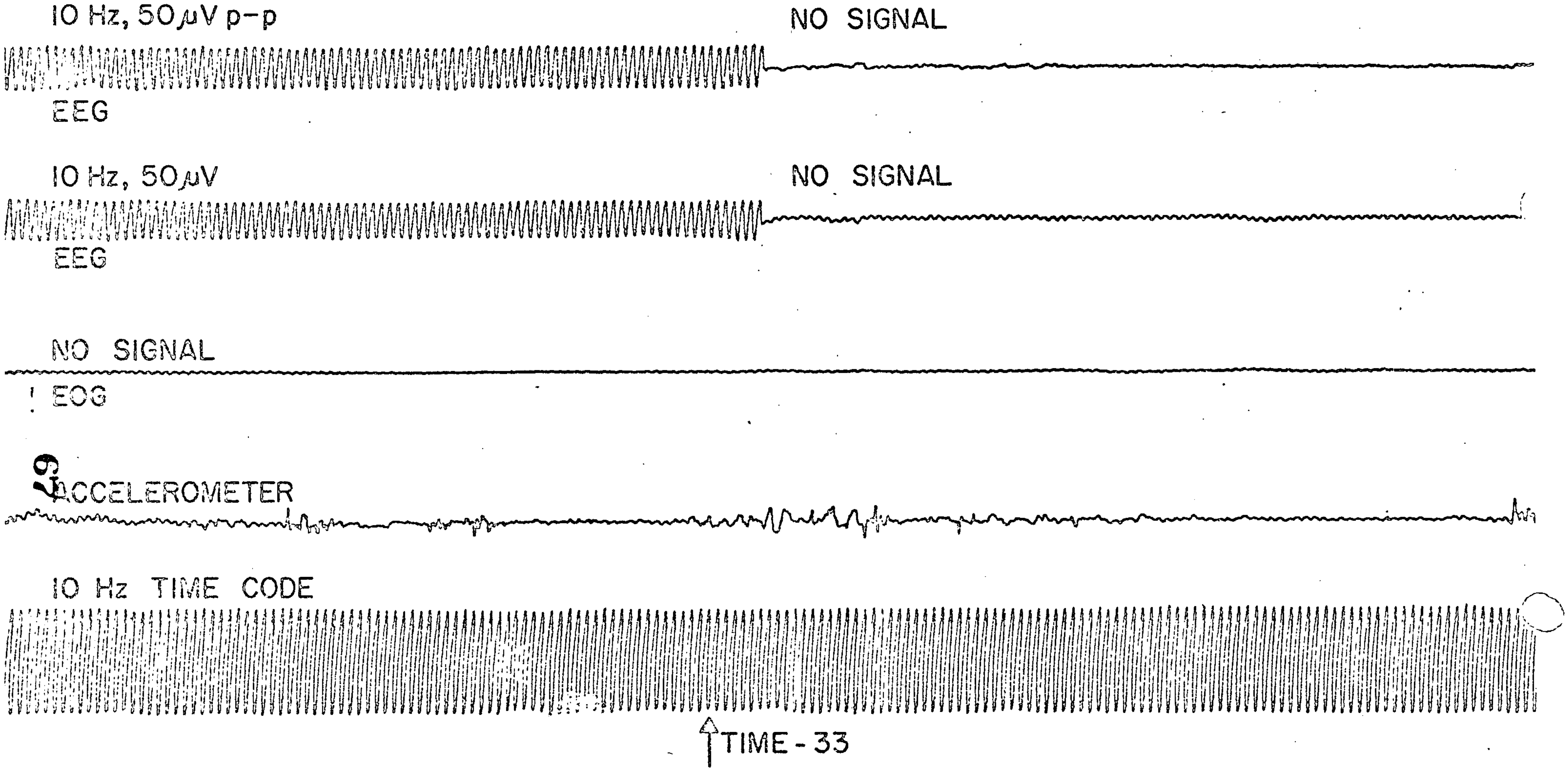


FIG. 12 — RECORDER #2, SEQUENCE 5, P 5.100

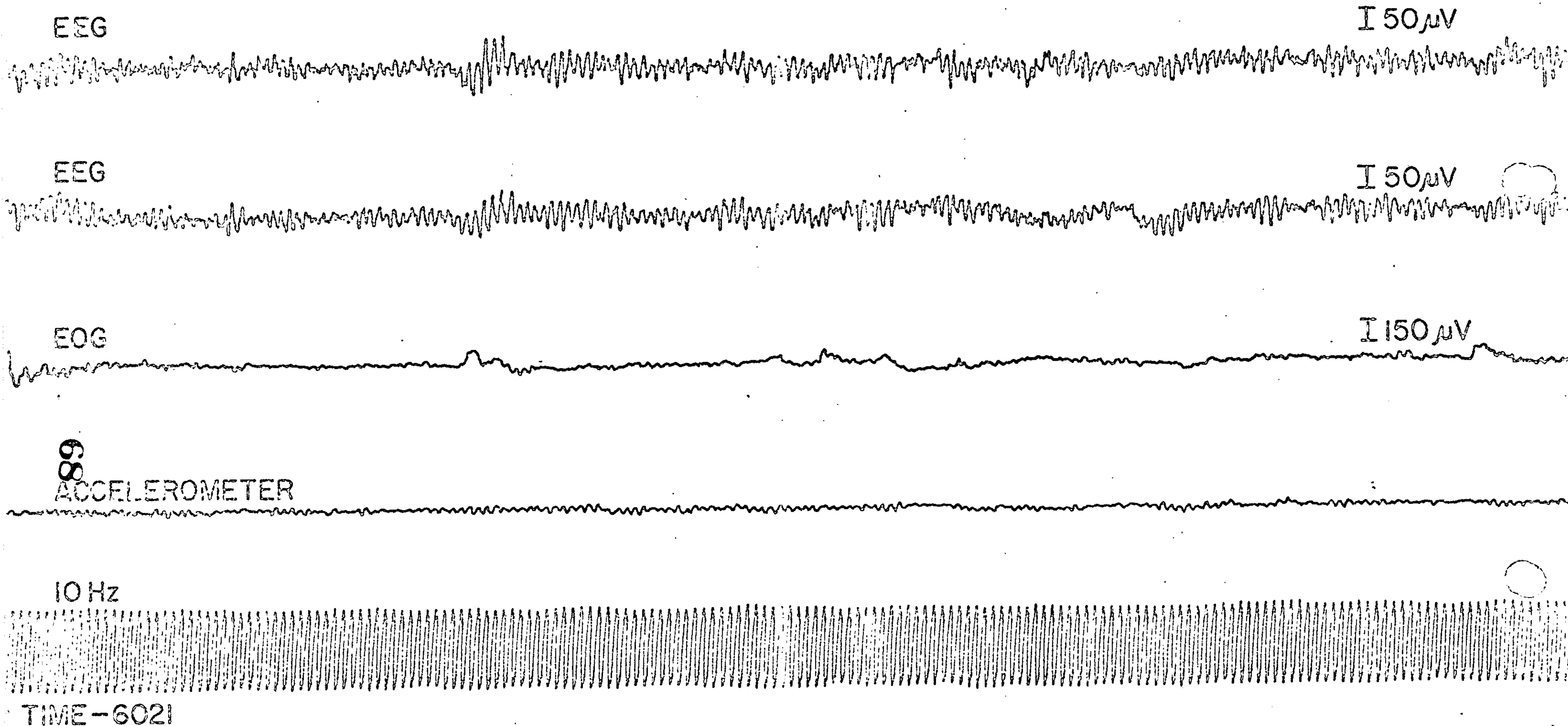


FIG. 13 - RECORDER #1, SEQUENCE 28, P. 5.124 (TEST SUBJECT RECORDING)

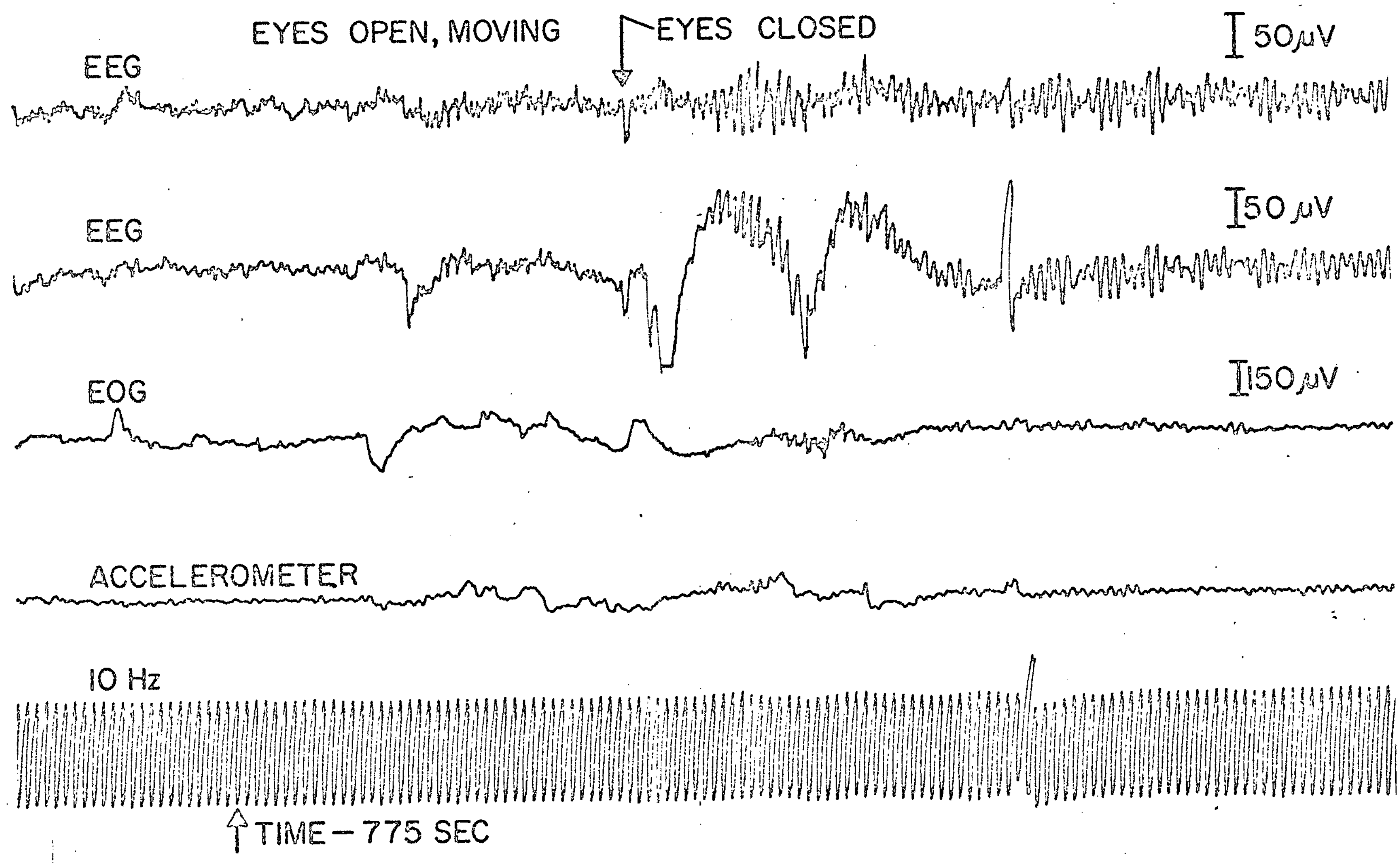


FIG. 14 — RECORDER #2, SEQUENCE 33, P. 5.125
(TEST SUBJECT RECORDING)

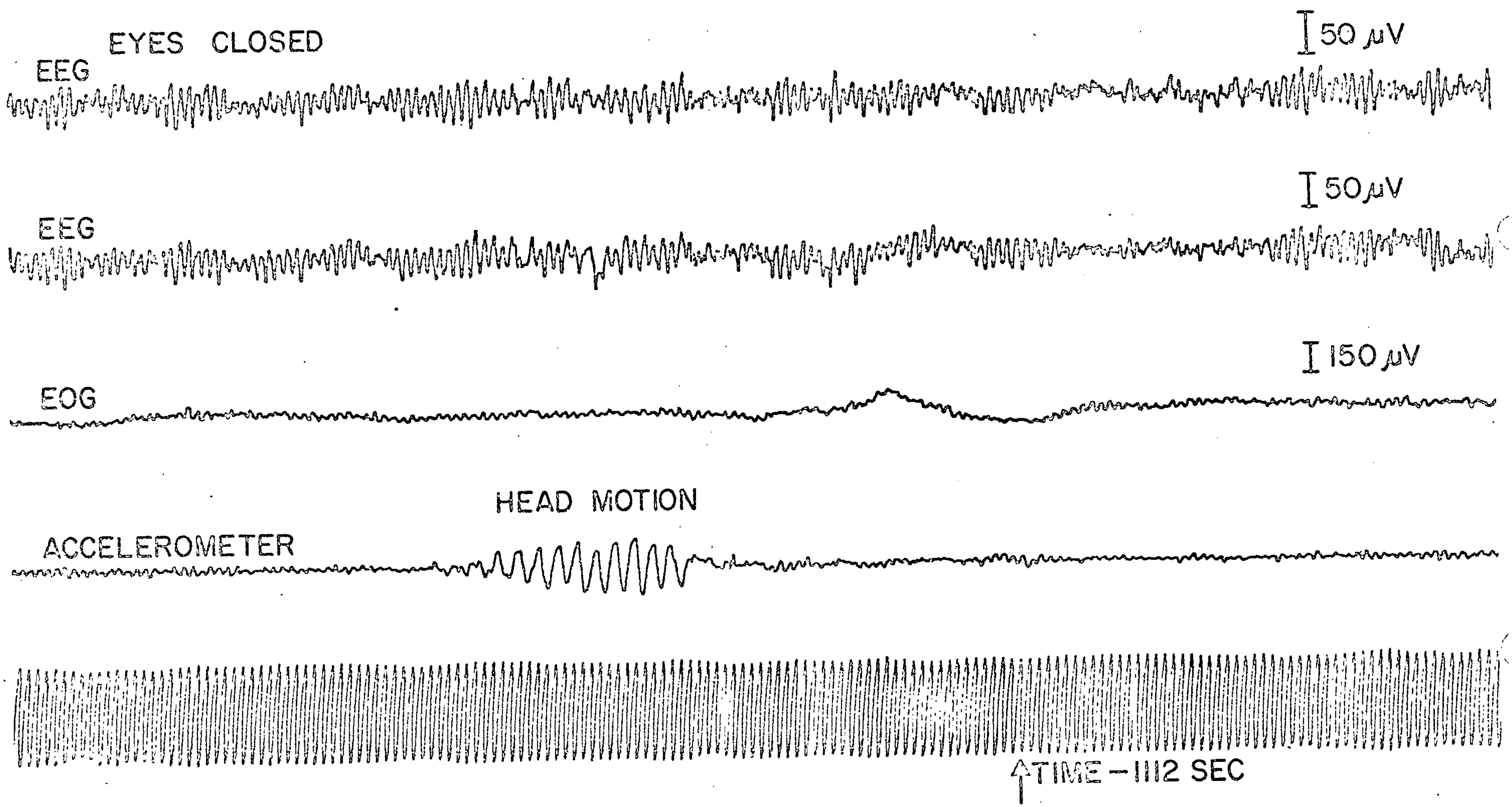


FIG. 15.– RECORDER #2, SEQUENCE 43, P. 5.123 (TEST SUBJECT RECORDING)

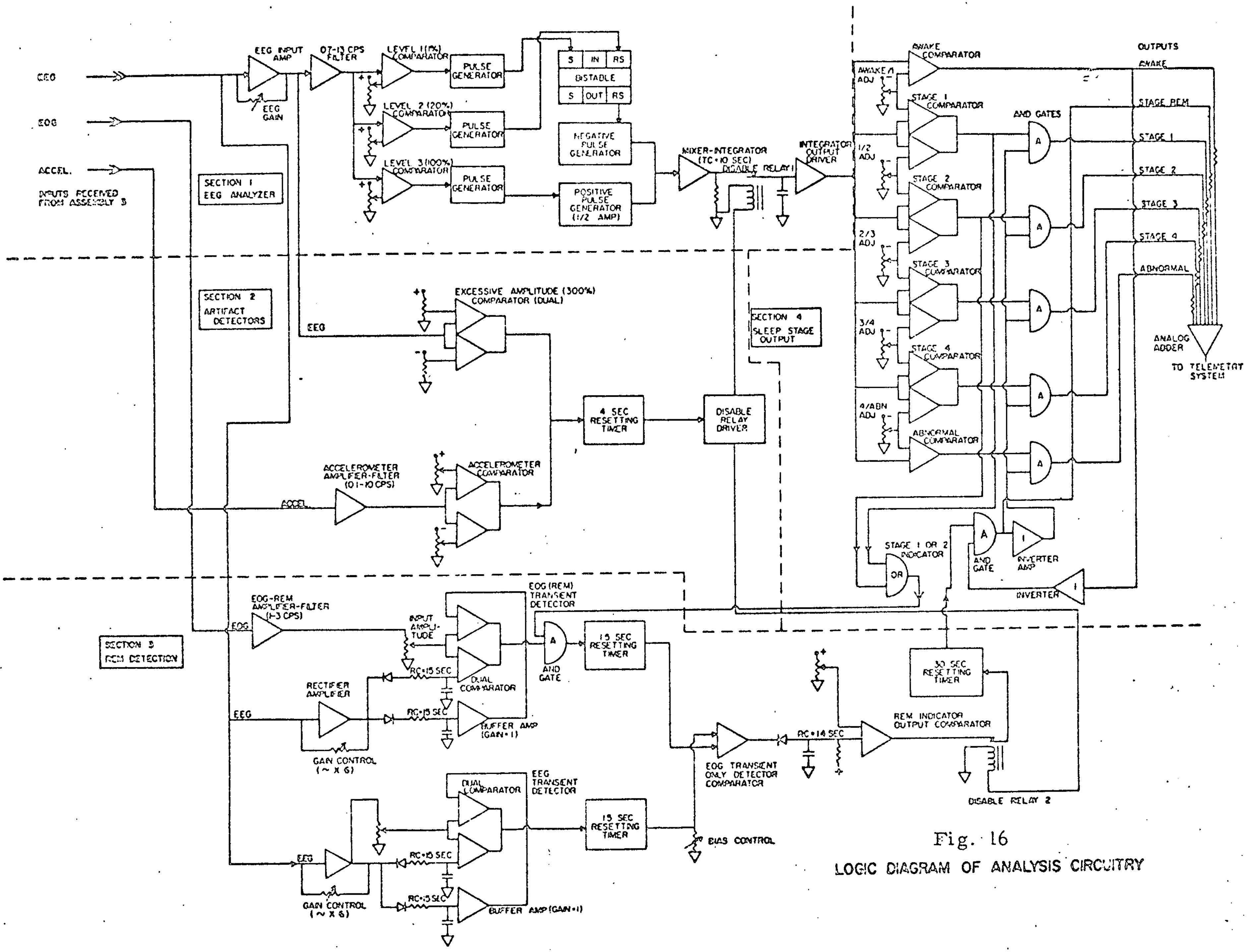


Fig. 16

LOGIC DIAGRAM OF ANALYSIS CIRCUITRY

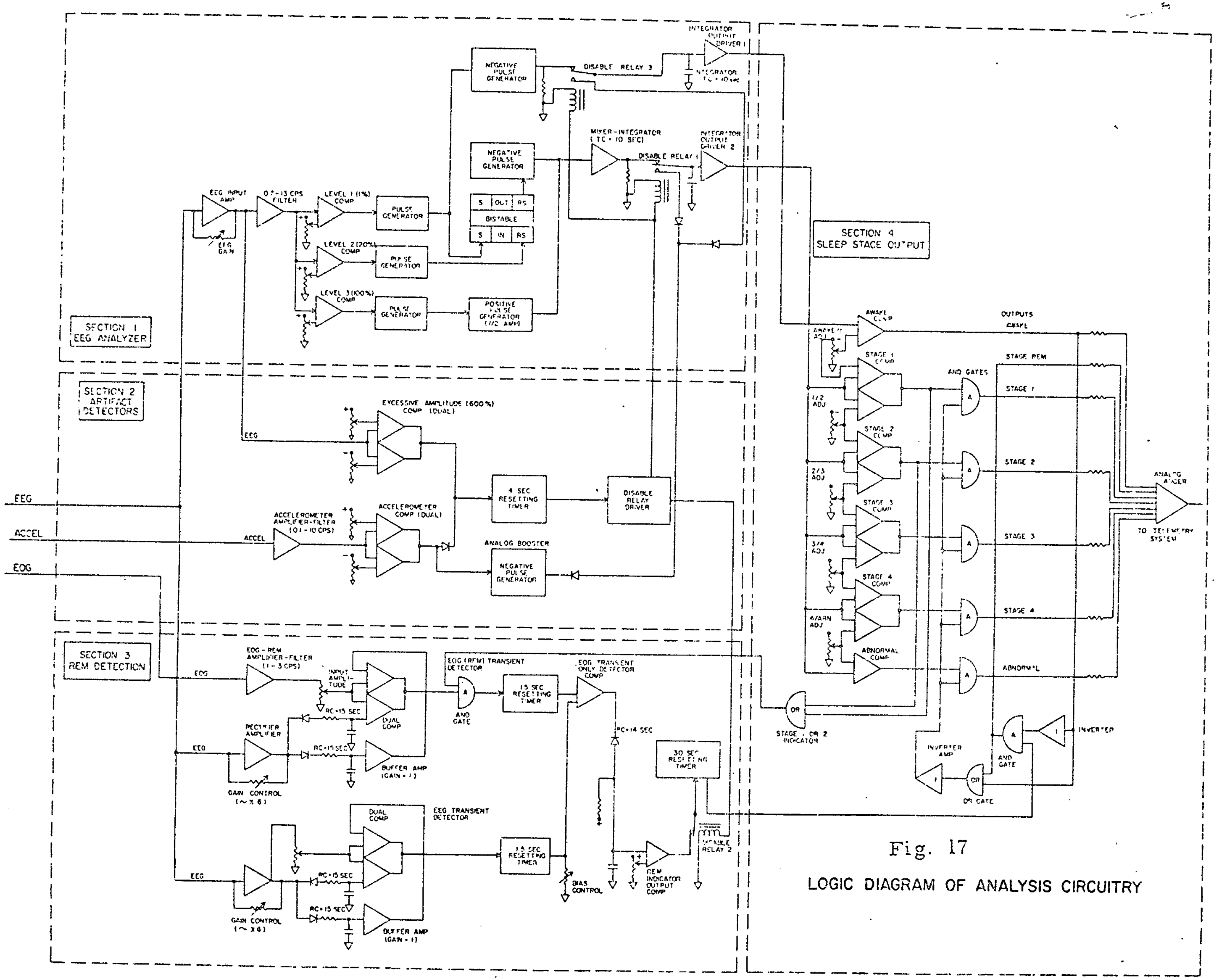


Fig. 17

LOGIC DIAGRAM OF ANALYSIS CIRCUITRY