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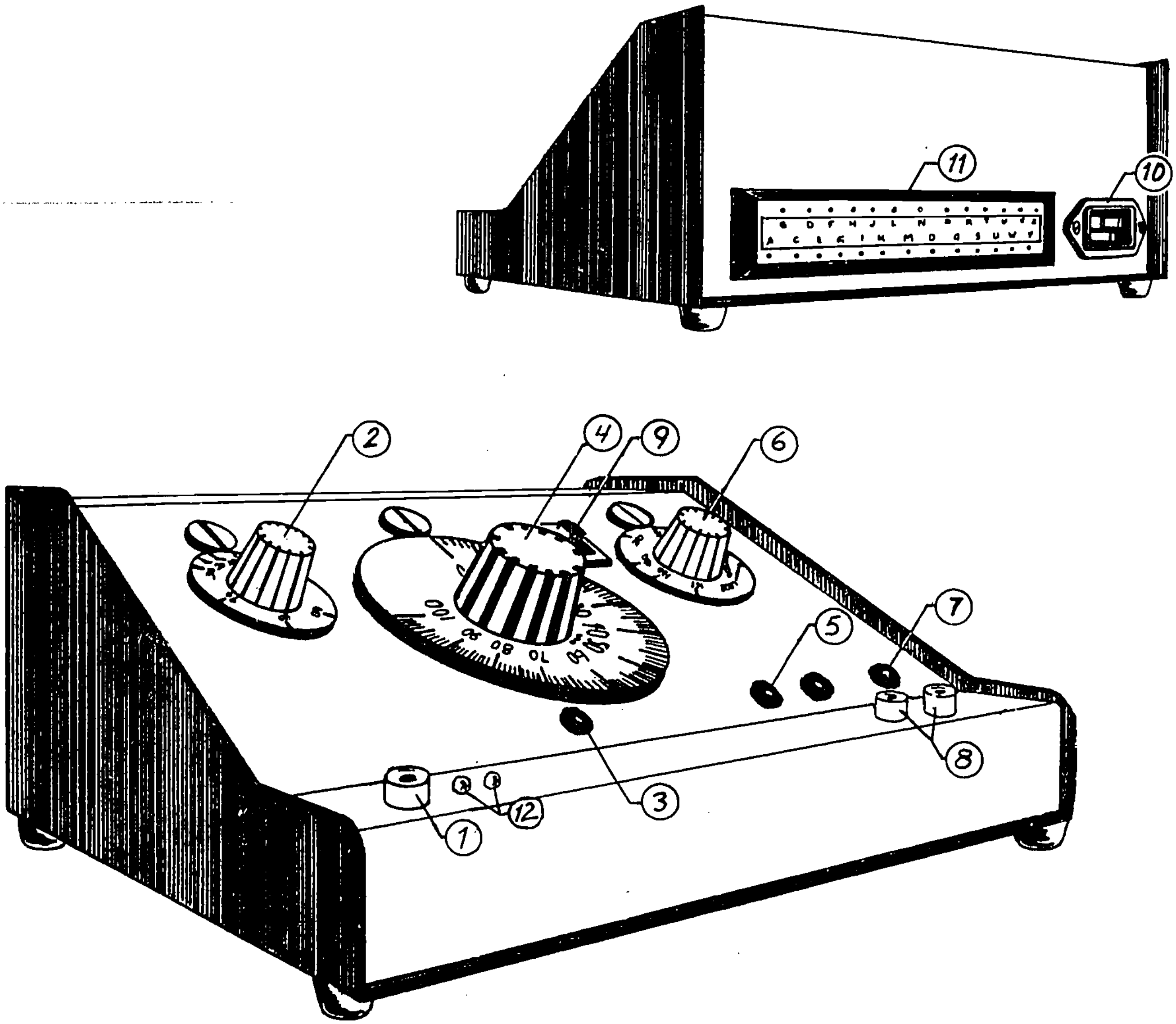
ABSTRACT

Described is the Biomedical Instrument Package (BIP) and its use. The BIP was developed for use in understanding colorimetry, sound, electricity, and bioelectric phenomena. It can also be used in a wide range of measurements such as current, voltage, resistance, temperature, and pH. Though it was developed primarily for use in biomedical science curricula, it is also useful in general electronics, physics, or biology laboratories. (Author/RE)

B I P
USER'S MANUAL

THE BIOMEDICAL INTERDISCIPLINARY CURRICULUM PROJECT

SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION



1. pH input jack
2. amplifier gain control
3. variable voltage control
4. mA 0-100 dial
5. pH calibrate control
6. frequency control
7. pre-amplifier gain control
8. differential amplifier input jacks
9. frequency range switch
10. line cord socket
11. programming panel
12. diode lights

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SECTION 1

GENERAL INFORMATION AND CAUTIONS

1-1 The Biomedical Instrumentation Package (BIP) has been developed to provide a wide range of activities that are relevant to understanding colorimetry, sound, electricity and bioelectric phenomena. In addition, it can be used in wide range of measurements such as current, voltage, resistance, temperature, and pH. While it has been developed primarily as a part of the BICP Biomedical Science Curriculum, it should be equally useful in the general electronics, physics and biology laboratory.

1-2 Internally, the BIP consists of the following modules:

1. A power supply providing:

   •+13 vdc, ±, and -13 vdc, to 300 mA
   •+5 vdc regulated, to 1000 mA
   •+5 vdc to +7 vdc, adjustable and regulated, to 1000 mA

2. High gain differential preamplifier

   •gain up to 2000, low frequency response down to 1 cps

3. Power amplifier

   •up to 1 watt RMS output with low distortion

4. Current meter (which can also function as a volt meter and ohm-meter and perform other measurement functions)

   •measures current from 0 to 300 mA in 6 ranges: 0-1 mA, 0-3 mA, 0-10 mA, 0-30 mA, 0-100 mA, 0-300 mA

5. Audio generator

   •provides a continuously variable low distortion sine wave from 100 to 10,000 Hz in 2 ranges: 100-1,000 Hz and 1,000-10,000 Hz

6. pH meter

   •uses a commercially available single electrode pH probe to electronically measure pH from 2 to 10.

1-3 In operation, the modules will be combined in various configurations by external "programming" to provide whatever function or combination of functions is needed. Pins on a program board, identified from A to Z, are interconnected as required, using 24-gauge solid wire of appropriate length. To simplify wiring, the +13 to -13 vdc power supply is already connected internally to the various modules. When power is needed external to the instrument, it is available as:

+13 volts, ±, and -13 volts up to 0.3 amp (unregulated)

+5 volts up to 1.0 amp (regulated and short circuit protected)

+5 volts variable to 7 volts, up to 1.0 amp (regulated and short-circuit protected)

1-4 Before using the BIP, several points must be emphasized.

1. Use only a three-wire cord with a properly grounded power outlet.

2. When programming, the BIP should be disconnected from the power line.

3. If the control panel is removed from the bottom panel so that circuits are exposed, be sure that

   a. the line cord is disconnected

   b. the trimmers (blue discs about 5/8" in diameter in the printed circuit) are not changed in any way.

4. Each dial knob has two set screws. These should not be changed or adjusted unless factory instructions are followed.

5. Refer to "In Case of Difficulty" before attempting any repairs or alterations. The circuits are deceptively simple, and performance can be compromised by tinkering.

6. The modules are at least partially protected by design. However, improper programming can cause malfunction and possibly damage. Fuse protection is present on the main supply; a blow fuse can be replaced in the field. See "In Case of Difficulty."

1-5 PROGRAMMING: CAUTIONS

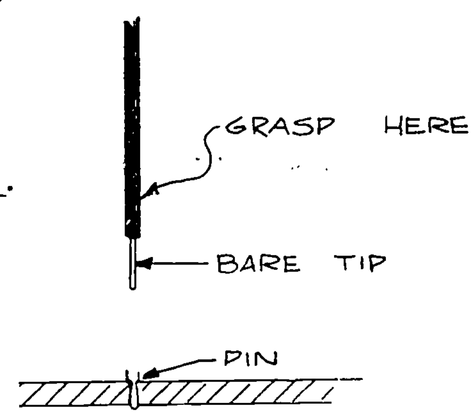
1. Be sure line cord is disconnected until program is known to be correct.

2. Use only 24-gauge solid wire with about 6 to 8 mm of insulation removed from either end.

3. Programming wire ends should be straight before they are pushed into the terminal

4. Wire strippers should be used to remove about 6 to 8 mm of insulation from each end of the wire. When cutting the wire to length, it is best to angle the cutters so the tip is beveled. The stripper should not cut into the wire itself; it it does, the wire will be weakened and may break off in the terminal. Proper adjustment of the "stop" on the stripper will prevent this.

5. Insert the wire by pushing the bare end straight into the pin connector (see diagram to right). If care is used, it should go smoothly in with moderate pressure. If the wire end bends, cut off bent part and re-strip the wire.



6. If larger than 24-gauge solid wire is used, the pin may be sprung open too wide and will not grasp a wire used later. Pins can be replaced, if necessary, by anyone able to use a small soldering iron (see "In Case of Difficulty").

7. Use care to obtain a good contact between all connections.

1-6 PROGRAM PANEL TERMINAL KEY

A	Pre-amp; DC output
B,C	Pre-amp; AC output with adjustable gain
D	Audio generator, 1.0 v output
E	Audio generator, 0.01 v output
F	pH meter output
G,H,I	Current meter input
J	Blank
K	1 mA (full scale-measurement dial)
L	3 mA (full scale-measurement dial)
M	10 mA (full scale-measurement dial)
N	30 mA (full scale-measurement dial)
O	100 mA (full scale-measurement dial)
P	300 mA (full scale-measurement dial)
Q	Power-amp input
R	Power-amp output
S	Voltage output for either fixed 5 vdc or variable 5 to 7 vdc
T	Common point in voltage regulator
U	Connection for variable 5 to 7 vdc
V,W,X	±
Y	-13 vdc
Z	+13 vdc

SECTION 2

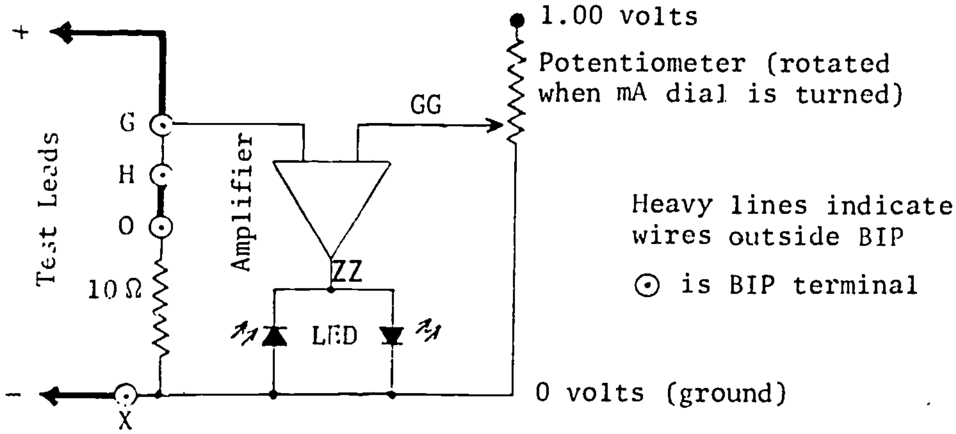
MEASUREMENT OF CURRENT, VOLTAGE, AND RESISTANCE

2-1 CURRENT METER

This is the basic measuring module for any function that can be ultimately related to current or voltage. It can be considered similar to a common 0-1 mA milliammeter, except that the dial must be rotated to a null indication (as contrasted with the movement of a meter pointer). The BIP current meter does offer advantages: (1) it is much more mechanically rugged than a meter movement; (2) the scale extends for about 25 cm as compared to about 10 cm for a meter scale; (3) it is much less likely to be damaged by excessive current.

The operation of the current meter can be understood by considering the schematic below.

2-1A



The amplifier functions as a very high gain differential amplifier (gain about 100,000) so that any voltage difference between points G and GG will result in several volts difference between point ZZ and ground. Depending on polarity, one of the two light diodes (LED) will be lit.

In the schematic shown above, the connections are made to measure up to 100 milliamperes in the test leads. Assume that 40 mA are flowing in the test leads. This results in 400 millivolts at one input of the amplifier (E = IR, E = 40 x 10 = 400). Now if the mA dial is turned to vary the voltage at GG, a point will be reached when its voltage is also 400 millivolts and neither light diode will be on. At this null condition the dial will read 40. Since the scale multiplier for this range is 1 (see section 2-2), the dial reading is the answer.

To provide a wide range of measurement, five other resistors are provided. For example, to measure up to 1.0 mA, the input resistor is 1000 Ω. A current of 1.0 mA would develop 1.0 volts at one amplifier input, the dial would be turned to develop 1.0 volt at the other amplifier input, and the dial reading would be 100. Division of the dial reading by 100 would give the correct answer of 1.00.

2-2 CURRENT

To measure current:

•Terminal H is connected to (select one):

K	(up to 1.00 mA)	scale x 0.01 = result
L	(up to 3 mA)	scale x 0.03 = result
M	(up to 10 mA)	scale x 0.10 = result
N	(up to 30 mA)	scale x 0.30 = result
O	(up to 100 mA)	scale x 1 = result
P	(up to 300 mA)	scale x 3 = result

•Test leads are connected to G (+) and V or W or X (- or ground)

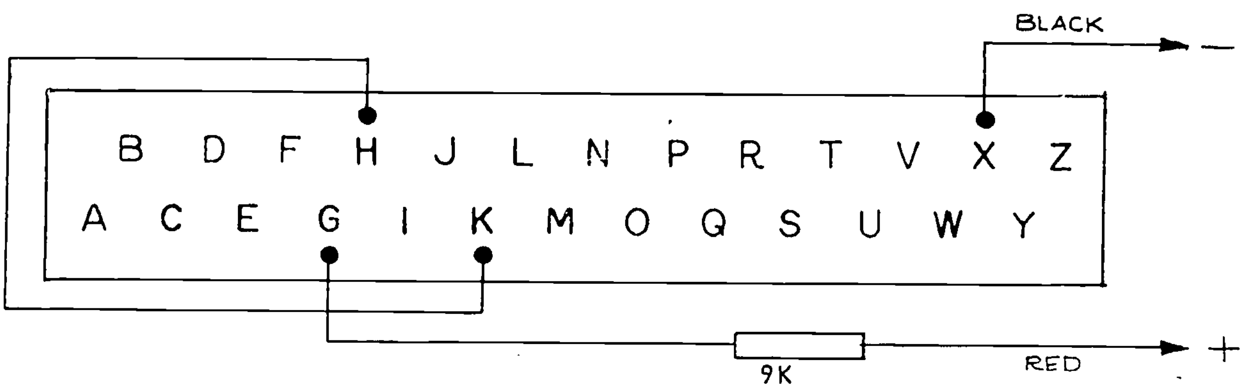
Measurement is made by rotating the mA dial until diode light null condition is indicated. It is a good precaution to use the highest range first (if the expected range of current is not known) and then go to lower ranges as necessary. Note that polarity must be observed: positive to G, negative to V or W or X. Accuracy is best if the result is above 30. For example, if the result is 9 ± 1 on a 10 mA connection (M), changing to the 1 mA connection (K) will give a reading of 90 ± 1.

Instrument accuracy is about ±2% (full scale) on the 1 mA range and about ±5% on all other ranges.

2-3 VOLTAGE

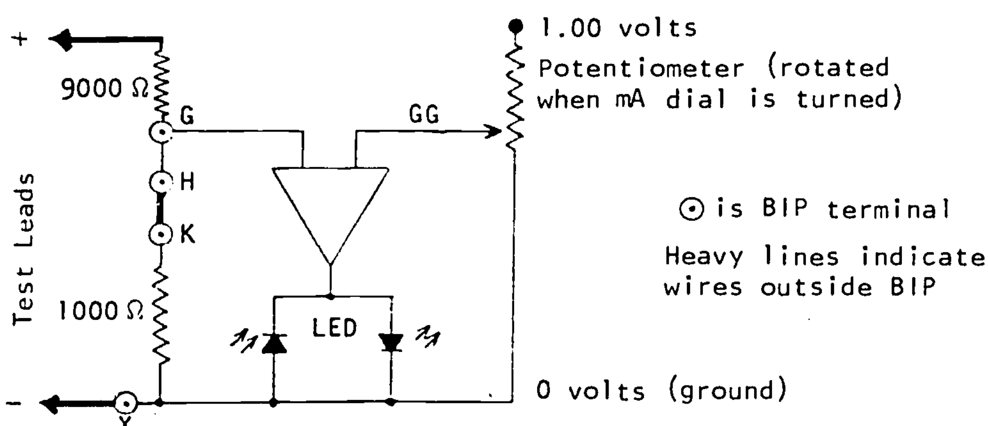
To measure voltage (0-10 volts d.c.), program the panel as shown below.

2-3A



The schematic is shown below.

2-3B



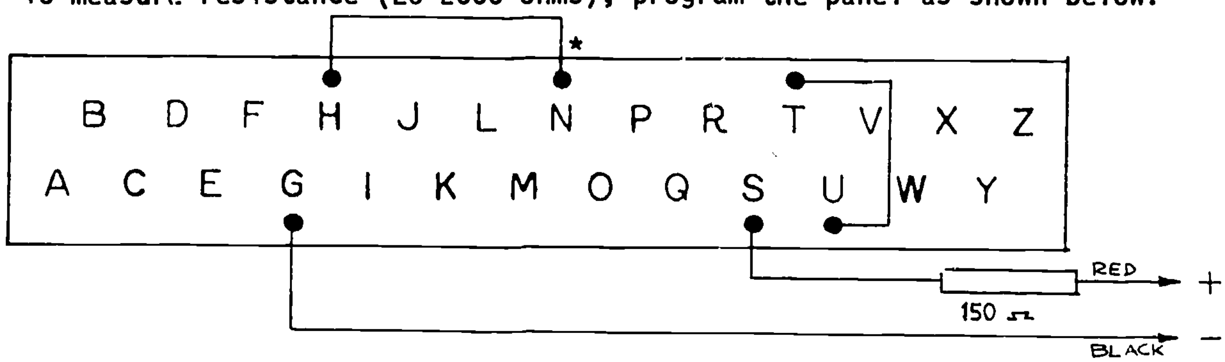
Assume that 5 volts is across the test leads. The external resistance is 9000 ohms (in the test lead) and 1000 ohms is in the BIP metering circuit. Nine-tenths of the voltage will appear across the external resistance (i.e., 9000 ÷ 9000 + 1000), and one-tenth of the voltage will appear across the internal resistance (i.e., 1000 ÷ 9000 + 1000). Therefore, 0.5 volt (1/10 x 5) appears at the amplifier input. The mA dial must be turned to 50 to indicate null condition (0.5 volt at other input). Since 10 volts is 100 on the dial, 5 volts will read as 50.

Other ranges may be selected by varying the resistor in the external probe. For example, a 99K resistor would allow measurement up to 100 volts. (Caution: measurement of voltages over 30 requires care to avoid a shock hazard.) With no resistor in the external lead, d.c. voltages up to 1 may be measured.

2-4 RESISTANCE

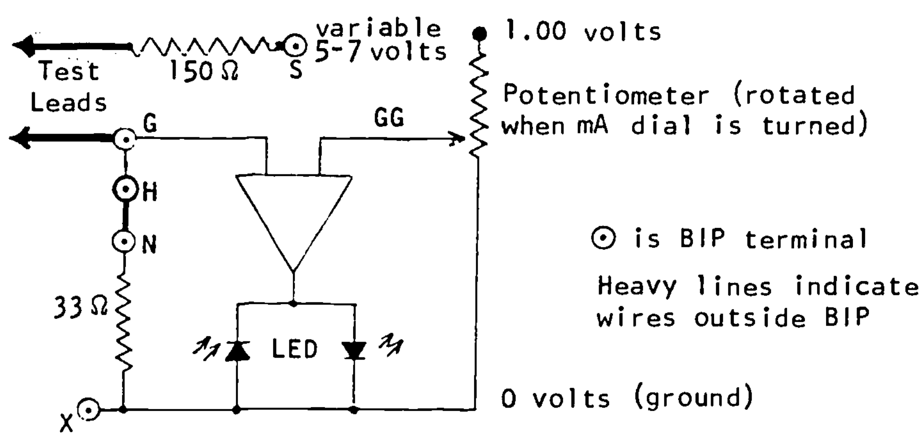
To measure resistance (20-2000 ohms), program the panel as shown below.

2-4A



The electrical schematic is shown below.

2-4B



Operation is as follows:

1. mA dial is set at 100.
2. Resistance test leads are touched together ("shorted").
3. The screwdriver slot control (the left-most control, labeled #3 on BIP sketch) is turned until diode lights indicate null.
4. With test leads open, the mA dial should null at or very near 0. This will indicate proper operation when step 5 is performed.
5. An unknown resistance is inserted between the test leads and mA dial is turned to null.

---

*Other BIP terminals will be used, depending on resistance range needed. See table 2-4C.

Resistance is calculated from this formula:

$$\text{ohms} = \frac{100 - \text{dial reading}}{\text{dial reading}} \times \text{known resistance}$$

(In this case, known resistance is 150 [resistor in lead] + 33 [resistor in BIP], or 183.)

For other resistance ranges, the procedure is the same except the range selected determines the external resistor value.

2-4C

H to BIP Terminal	Internal Resistance Ω	External Resistance Ω	Known Resistance (sum of both resistances)	Accurate Measurement Range Ω	Maximum Current Flowing in Unknown Resistance
K	1000	5100 ($\frac{1}{2}$ watt)	6100	600 - 60K	1 ma
L	330	1500 ($\frac{1}{2}$ watt)	1830	200 - 20K	3 ma
M	100	510 ($\frac{1}{2}$ watt)	610	60 - 6K	10 ma
N	33	150 ($\frac{1}{2}$ watt)	183	20 - 2K	30 ma
O	10	51 (1 watt)	61	6 - 600	100 ma
P	3.3	15 (2 watts)	18	2 - 60	300 ma

Notes: (1) The most accurate measurement will be when the unknown resistance value is fairly close to the known resistance. (2) When using the lower resistance ranges, enough current may flow in the unknown resistance to cause heating. This heating may alter the apparent resistance value.

To avoid calculations, the three ohms tables (2-4D, 2-4E, and 2-4F) may be used.

OHMS TABLE
High Resistance Ranges

BIP Dial Reading	K ext Ω = 5100	L ext Ω = 1500	BIP Dial Reading	K	L
0	∞	∞	50	6,100	2,030
1	600 K	200 K	51	5,860	1,950
2	300 K	100 K	52	5,630	1,880
3	197 K	66 K	53	5,410	1,800
4	146 K	49 K	54	5,200	1,730
5	116 K	39 K	55	4,990	1,660
6	96 K	32 K	56	4,790	1,600
7	81 K	27 K	57	4,600	1,530
8	70 K	23 K	58	4,420	1,470
9	62 K	21 K	59	4,240	1,410
10	55 K	18 K	60	4,070	1,360
11	49 K	16.5 K	61	3,900	1,300
12	45 K	14.9 K	62	3,740	1,250
13	41 K	13.6 K	63	3,580	1,190
14	37.5 K	12.5 K	64	3,430	1,140
15	34.6 K	11.5 K	65	3,280	1,090
16	32.0 K	10.7 K	66	3,140	1,050
17	29.8 K	9.93 K	67	3,000	1,000
18	27.8 K	9.26 K	68	2,870	957
19	26.0 K	8.67 K	69	2,740	914
20	24.4 K	8.13 K	70	2,610	871
21	22.9 K	7.65 K	71	2,490	831
22	21.6 K	7.21 K	72	2,370	791
23	20.4 K	6.81 K	73	2,260	752
24	19.3 K	6.44 K	74	2,140	714
25	18.3 K	6.10 K	75	2,030	678
26	17.4 K	5.79 K	76	1,930	642
27	16.5 K	5.50 K	77	1,820	607
28	15.7 K	5.23 K	78	1,720	574
29	14.9 K	4.98 K	79	1,620	541
30	14.2 K	4.74 K	80	1,530	508
31	13.6 K	4.53 K	81	1,430	477
32	13.0 K	4.32 K	82	1,340	446
33	12.4 K	4.13 K	83	1,250	416
34	11.8 K	3.95 K	84	1,160	387
35	11.3 K	3.78 K	85	1,080	359
36	10.8 K	3.61 K	86	993	331
37	10.4 K	3.46 K	87	911	304
38	9,950	3,320	88	832	277
39	9,540	3,180	89	754	251
40	9,150	3,050	90	678	226
41	8,780	2,930	91	603	201
42	8,420	2,810	92	530	177
43	8,090	2,700	93	459	153
44	7,760	2,590	94	389	130
45	7,460	2,490	95	321	107
46	7,160	2,390	96	254	85
47	6,880	2,290	97	188	63
48	6,610	2,200	98	124	42
49	6,350	2,120	99	62	21

100 reading = 0 ohms

OHMS TABLE
Medium Resistance Ranges

BIP Dial Reading	M ext Ω = 510	N ext Ω = 150	BIP Dial Reading	M	N
0	∞	∞	50	610	203
1	60 K	20 K	51	586	195
2	30 K	10 K	52	563	188
3	20 K	6.6 K	53	541	180
4	15 K	4.9 K	54	520	173
5	12 K	3.9 K	55	499	166
6	9,600	3,200	56	479	160
7	8,100	2,700	57	460	153
8	7,000	2,300	58	442	147
9	6,200	2,100	59	424	141
10	5,500	1,800	60	407	136
11	4,900	1,650	61	390	120
12	4,500	1,490	62	374	125
13	4,100	1,360	63	358	119
14	3,750	1,250	64	343	114
15	3,460	1,150	65	328	109
16	3,200	1,070	66	314	105
17	2,980	993	67	300	100
18	2,780	926	68	287	95
19	2,600	867	69	274	91
20	2,440	813	70	261	87
21	2,290	765	71	249	83
22	2,160	721	72	237	79
23	2,040	681	73	226	75
24	1,930	644	74	214	71
25	1,830	610	75	203	67
26	1,740	579	76	193	64
27	1,650	550	77	182	60
28	1,570	523	78	172	57
29	1,490	498	79	162	54
30	1,420	474	80	153	50
31	1,360	453	81	143	47
32	1,300	432	82	134	44
33	1,240	413	83	125	41
34	1,180	395	84	116	38
35	1,130	378	85	108	35
36	1,080	361	86	99	33
37	1,040	346	87	91	30
38	995	332	88	83	27
39	954	318	89	75	25
40	915	305	90	67	22
41	878	293	91	60	20
42	842	281	92	53	17
43	809	270	93	45	15
44	776	259	94	38	13
45	746	249	95	32	10
46	716	239	96	25	8
47	688	229	97	18	6
48	661	220	98	12	4
49	635	212	99	6	2

100 reading = 0 ohms

OHMS TABLE
Low Resistance Ranges

BIP Dial Reading	O ext Ω = 51	P ext Ω = 15	BIP Dial Reading	O	P
0	∞	∞	50	61.0	20.3
1	6,000	2,000	51	58.6	19.5
2	3,000	1,000	52	56.3	18.8
3	1,970	660	53	54.1	18.0
4	1,460	490	54	52.0	17.3
5	1,160	390	55	49.9	16.6
6	960	320	56	47.9	16.0
7	810	270	57	46.0	15.3
8	700	230	58	44.2	14.7
9	620	210	59	42.4	14.1
10	550	180	60	40.7	13.6
11	490	165	61	39.0	13.0
12	450	149	62	37.4	12.5
13	410	136	63	35.8	11.9
14	375	125	64	34.3	11.4
15	346	115	65	32.8	10.9
16	320	107	66	31.4	10.5
17	298	99.3	67	30.0	10.0
18	278	92.6	68	28.7	9.5
19	260	86.7	69	27.4	9.1
20	244	81.3	70	26.1	8.7
21	229	76.5	71	24.9	8.3
22	216	72.1	72	23.7	7.9
23	204	68.1	73	22.6	7.5
24	193	64.4	74	21.4	7.1
25	183	61.0	75	20.3	6.7
26	174	57.9	76	19.3	6.4
27	165	55.0	77	18.2	6.0
28	157	52.3	78	17.2	5.7
29	149	49.8	79	16.2	5.4
30	142	47.4	80	15.3	5.0
31	136	45.3	81	14.3	4.7
32	130	43.2	82	13.4	4.4
33	124	41.3	83	12.5	4.1
34	118	39.5	84	11.6	3.8
35	113	37.8	85	10.8	3.5
36	108	36.1	86	9.9	3.3
37	104	34.6	87	9.1	3.0
38	99.5	33.2	88	8.3	2.7
39	95.4	31.8	89	7.5	2.5
40	91.5	30.5	90	6.7	2.2
41	87.8	29.3	91	6.0	2.0
42	84.2	28.1	92	5.3	1.7
43	80.9	27.0	93	4.5	1.5
44	77.6	25.9	94	3.8	1.3
45	74.6	24.9	95	3.2	1.0
46	71.6	23.9	96	2.5	0.8
47	68.8	22.9	97	1.8	0.6
48	66.1	22.0	98	1.2	0.4
49	63.5	21.2	99	0.6	0.2

100 reading = 0 ohms

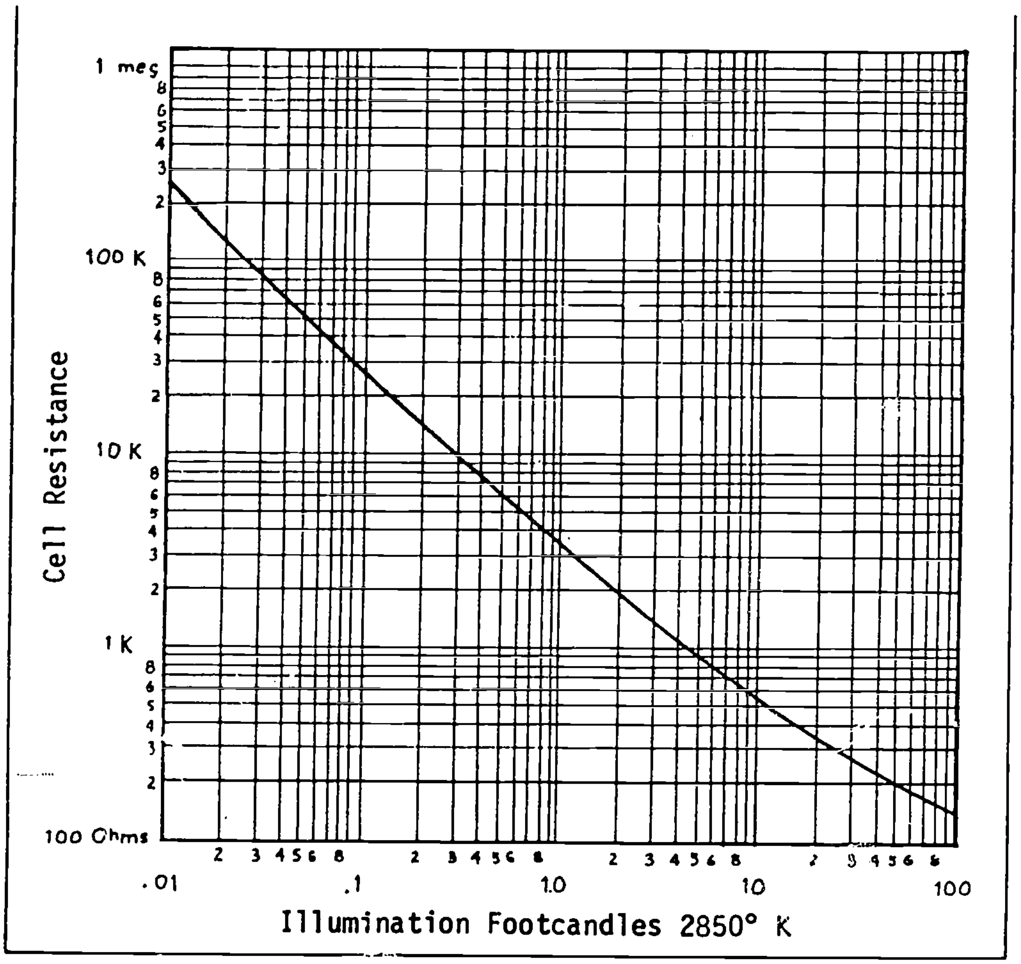
SECTION 3

MEASUREMENT OF LIGHT, COLORIMETRY, TEMPERATURE

3-1 LIGHT

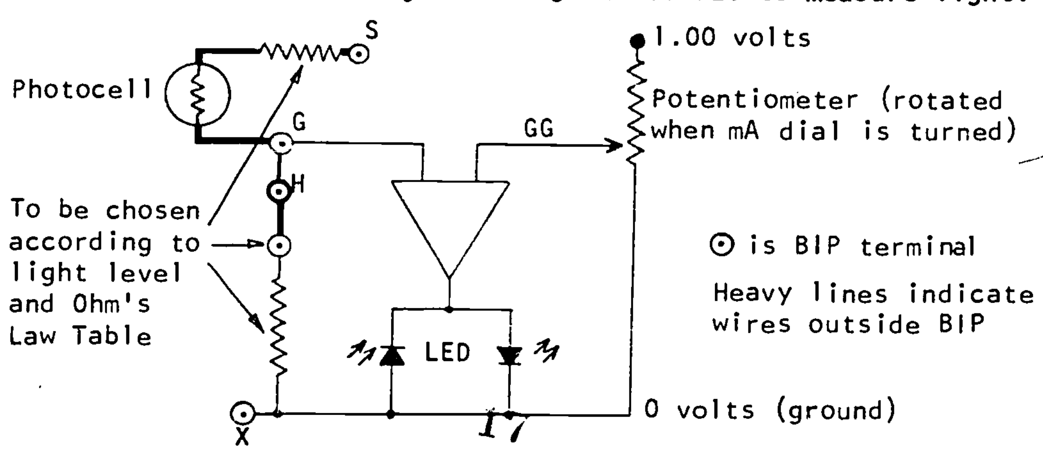
Since the BIP can easily measure resistance (section 2-4) we can easily measure light by using a photocell that varies in resistance depending on the intensity of light falling on it. Such cells are widely available, fairly stable, and low in cost. The table below shows the Vactec VT-721 photocell resistance response as a function of light.

3-1A



The schematic 3-1B shows one way of using the VT-721 to measure light.

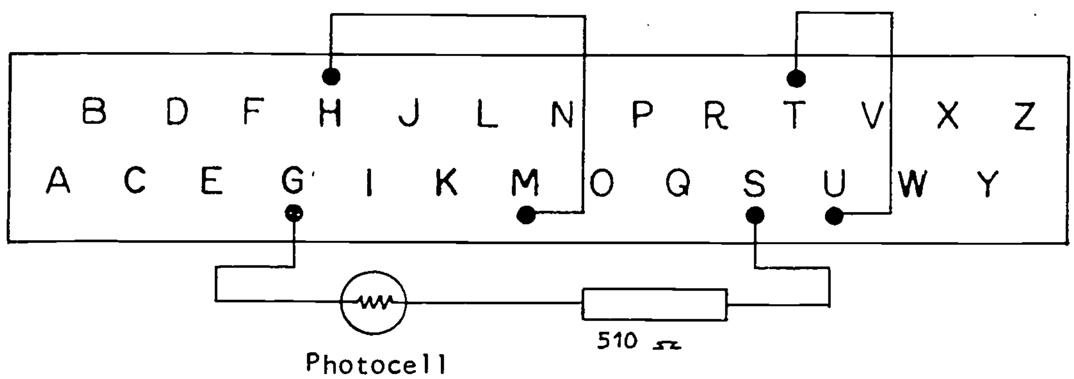
3-1B



Suppose we want to measure indoor light levels in the 10 to 20 footcandle range. The chart (section 3-1A) tells us that the photocell resistance will be around 500 Ω at 12 f.c. Referring to the Ohms Law Table (section 2-4E), scale M will allow us to measure 500 near the center of the scale. The external resistance (coming from pin S) should be 510 Ω (as seen in table 2-4C). Before the photocell is inserted in the circuit (see program below) the leads are shorted and, with the mA dial at 100, the slotted control is turned until the diode lights null.

To measure light intensity with a photocell, program as follows.

3-1c



The illumination falling on the photocell is determined by rotating the dial to null, reading resistance from Ohm's Table. This cell resistance can be related to light by referring to the table in section 3-1A. If other photocells are used, the appropriate light vs. illumination table must be used. Relative readings will be fairly accurate, but absolute illumination in footcandles will be off by as much as 35% (because of photocell variations). Calibrating against a standard light source will greatly improve accuracy.

3-2 COLOR DENSITY

The most common practical application of this is colorimetry, a very commonly used tool in biomedical analysis of body fluids. In fact, a large per cent of all medical laboratory procedures depend upon colorimetric analysis.

Details of colorimetry will not be presented here, so the reader is referred to any standard text in medical laboratory procedures. The basic principle behind colorimetry is the fact that the absorption of light (of a certain wavelength) by a colored solution is proportional to the concentration of the colored substance in the solution. This is also known as Beer's Law. Absorption of light is expressed mathematically as absorbance (sometimes called optical density). The formula for finding an unknown concentration becomes:

$$C = \frac{\text{absorbance of unknown concentration}}{\text{absorbance of known concentration}} \times \text{known concentration}$$

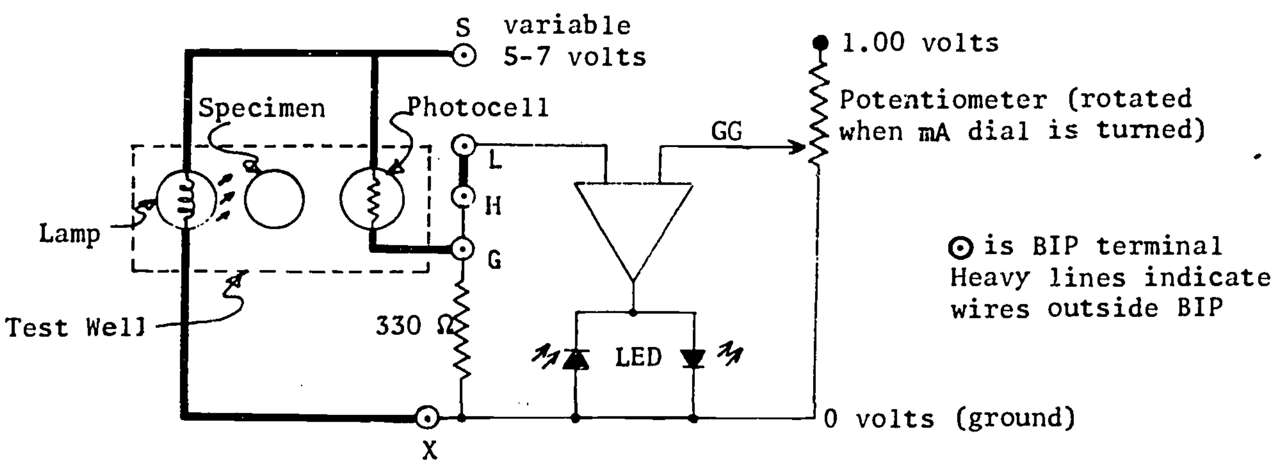
3-2A EXAMPLE OF MEDICAL COLORIMETRY

A very common clinical determination involves measurement of the very highly colored oxygen carrying substance in blood called hemoglobin. A deficiency of hemoglobin is known as anemia. (Ordinarily, almost all of the color of blood is due to hemoglobin.) To determine hemoglobin in blood, blood is diluted with a reagent to allow readings to be made near the middle of the scale (for greatest accuracy). Typical readings might be as follows:

$$\text{HgB concentration} = \frac{.50 \text{ (unknown absorbance)}}{.44 \text{ (known absorbance)}} \times 14.0\% \left(\begin{matrix}\text{known}\\ \text{concentration}\end{matrix}\right) = 15.9\%$$

The use of the BIP colorimeter in this and other colorimetric determinations can be seen by referring to the following schematic.

3-2B



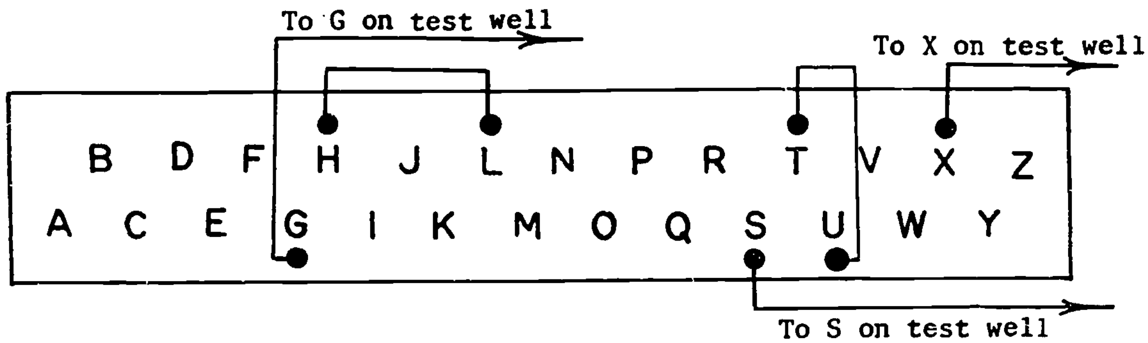
Assume that a colorless "blank" is in the specimen opening (so we have a reference of zero concentration). The mA dial is set to 100 (indicating 100% transmittance). The photocell acts as a variable resistance (see section 3-1). Varying the voltage to the lamp will change its brightness and therefore change the resistance of the photocell (as the light increases, the photocell resistance decreases). This is accomplished in the BIP by turning the slotted control #3 (which varies the lamp brightness) until null occurs. The "blank" is now replaced by a colored solution of known concentration. The mA dial is turned until null occurs. The dial reading is noted. This known concentration is then replaced by an unknown sample. Again the dial is turned until null occurs and the reading noted.

Assume the values of the hemoglobin example. The known concentration of 14% gives a reading of 36.5 (or per cent transmission). To be useful, this is converted to absorbance (see table, section 3-2D) which is .440. The known sample is then removed and replaced with the unknown sample. Again the mA dial is nulled, with a reading of 31.6. Converting to absorbance, the result is .50. The calculation to determine the unknown concentration is shown in section 3-2.

The wavelength used in the test well extends from about 530 to 580 nanometers (green-yellow spectrum).

3-2c To use the colorimeter:

1. Program as follows:



2. Plug in BIP and allow at least 10 minutes warm-up; the longer the better.

3. The test well should be placed in a position that will minimize the possibility of spillage onto the BIP.

4. Place a "blank" in the test well; the "blank" is specified by the actual procedure being performed. It is often only water in a clean test tube. Pyrex test tubes, 16 x 100 mm or 16 x 125 mm, have been found to be very satisfactory with the BIP test well. The blank must be replaced if it becomes discolored or changes in any way.

5. Adjust to 100% T by setting the dial at 100 and then turning the slotted control at 3 (see BIP diagram) with a small screwdriver until the diode lights "null." The setting can be verified as correct by rotating the mA dial slightly. The lights should null again, somewhere between 99 and 101.

6. The colorimeter is now standardized and ready for use. A repeat of steps 3 and 4 will be required every few minutes if the highest accuracy is required during the warm-up period.

7. Transmittance of known and unknown samples should be determined by the null procedure described earlier. Conversion of transmittance to absorbance will be necessary before calculations can be made.

If the test well is used in bright light, it may be advisable to shield the top of the test well from outside light. This is easily done by placing a cone of black construction paper over the exposed part of the test tube.

3-2D

ABSORBANCE-TRANSMITTANCE TABLE

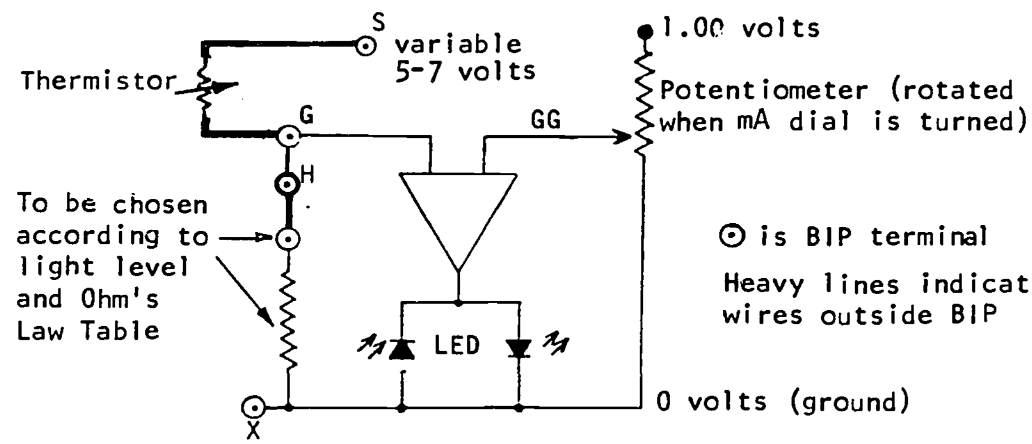
Trans. (%)	Absorbance	Trans. (%)	Absorbance	Trans. (%)	Absorbance	Trans. (%)	Absorbance
0.0	-----	25.0	.600	50.0	.300	75.0	.125
0.5	2.300	25.5	.595	50.5	.295	75.5	.120
1.0	2.000	26.0	.585	51.0	.290	76.0	.120
1.5	1.825	26.5	.575	51.5	.290	76.5	.115
2.0	1.700	27.0	.570	52.0	.285	77.0	.115
2.5	1.600	27.5	.560	52.5	.280	77.5	.110
3.0	1.525	28.0	.555	53.0	.275	78.0	.110
3.5	1.460	28.5	.545	53.5	.270	78.5	.105
4.0	1.400	29.0	.540	54.0	.270	79.0	.100
4.5	1.345	29.5	.530	54.5	.265	79.5	.100
5.0	1.300	30.0	.525	55.0	.260	80.0	.095
5.5	1.260	30.5	.515	55.5	.255	80.5	.095
6.0	1.220	31.0	.510	56.0	.250	81.0	.090
6.5	1.185	31.5	.500	56.5	.250	81.5	.090
7.0	1.155	32.0	.495	57.0	.245	82.0	.085
7.5	1.125	32.5	.490	57.5	.240	82.5	.085
8.0	1.095	33.0	.480	58.0	.235	83.0	.080
8.5	1.070	33.5	.475	58.5	.230	83.5	.080
9.0	1.050	34.0	.470	59.0	.230	84.0	.075
9.5	1.020	34.5	.460	59.5	.225	84.5	.075
10.0	1.000	35.0	.455	60.0	.220	85.0	.070
10.5	.980	35.5	.450	60.5	.220	85.5	.070
11.0	.960	36.0	.445	61.0	.215	86.0	.065
11.5	.940	36.5	.440	61.5	.210	86.5	.065
12.0	.920	37.0	.430	62.0	.210	87.0	.060
12.5	.905	37.5	.425	62.5	.205	87.5	.060
13.0	.885	38.0	.420	63.0	.200	88.0	.055
13.5	.870	38.5	.415	63.5	.200	88.5	.055
14.0	.855	39.0	.410	64.0	.195	89.0	.050
14.5	.840	39.5	.405	64.5	.190	89.5	.050
15.0	.825	40.0	.400	65.0	.185	90.0	.050
15.5	.810	40.5	.395	65.5	.185	90.5	.045
16.0	.795	41.0	.390	66.0	.180	91.0	.040
16.5	.785	41.5	.380	66.5	.175	91.5	.040
17.0	.770	42.0	.375	67.0	.175	92.0	.035
17.5	.755	42.5	.370	67.5	.170	92.5	.035
18.0	.745	43.0	.365	68.0	.165	93.0	.030
18.5	.735	43.5	.360	68.5	.165	93.5	.030
19.0	.720	44.0	.355	69.0	.160	94.0	.025
19.5	.710	44.5	.350	69.5	.160	94.5	.025
20.0	.700	45.0	.345	70.0	.155	95.0	.020
20.5	.690	45.5	.340	70.5	.150	95.5	.020
21.0	.680	46.0	.335	71.0	.150	96.0	.015
21.5	.670	46.5	.330	71.5	.145	96.5	.015
22.0	.660	47.0	.330	72.0	.145	97.0	.015
22.5	.650	47.5	.325	72.5	.140	97.5	.010
23.0	.640	48.0	.320	73.0	.135	98.0	.010
23.5	.625	48.5	.315	73.5	.135	98.5	.005
24.0	.620	49.0	.310	74.0	.130	99.0	.005
24.5	.610	49.5	.305	74.5	.130	99.5	.000
						100.0	.000

3-3 TEMPERATURE

Since the BIP can easily measure light by measuring resistance changes, it follows that temperature can be measured using an active element that has a resistance change with temperature. The commonest such device is called a thermistor. These typically have a 3 to 5 per cent resistance per degree Centigrade.

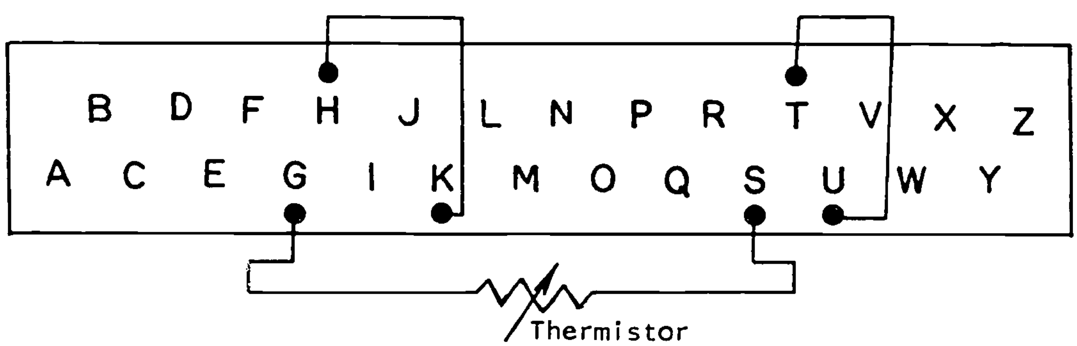
The schematic 3-3A shows one way using a common thermistor (Fenwal KP-41J2) to measure temperature. This device has a resistance of 10,000 ohms at 25° C.

3-3A



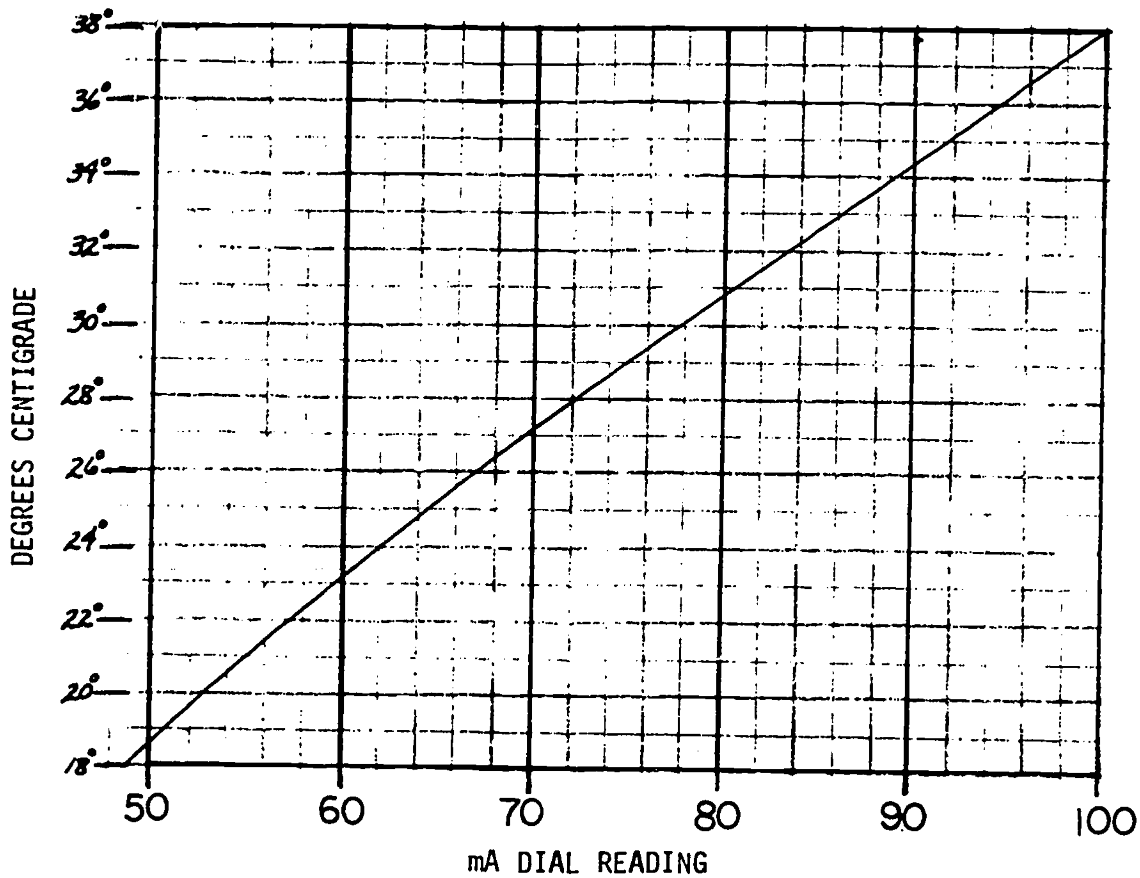
To measure temperature in the 20-38° C range (typical body temperature, from distal to central body areas) program as follows:

3-3B



To calibrate, a known temperature should be used. Refer to table 3-3C on the following page, which is approximate for a KP-41J2 thermistor.

3-3c



Suppose room temperature is known to be 24° C (taken with a laboratory thermometer). The mA dial should be set at 62. The slotted control at panel position 3 is turned until a null indication is obtained. The thermistor can then be moved into an unknown temperature (from 18° to 38° C), the mA dial nulled, and then the unknown temperature can be read from table 3-3C.

The above example is illustrative only. Different BIP connections would permit a wider temperature range. Different thermistors would permit different applications as well as different temperature ranges.

SECTION 4

BIO-ELECTRIC MEASUREMENT

4-1 PRE-AMPLIFIER

A high gain differential amplifier is required since many bio-electric signals are of very low voltage (the ECG signal is about 1 millivolt) and are completely swamped out by powerline 60 cycle AC, which is radiated from our electric environment (line cords, fluorescent lamps, appliances, etc.). The differential amplifier will not amplify a signal equally present at both inputs; only the difference signal appears at the output. Therefore, this arrangement rejects the 60 cycle signal and amplifies the difference signal which, in the case of the ECG, is being generated by the heart.

Care is needed to get maximum rejection of unwanted signals. Both of the input cables should be shielded. Care must be used to obtain low resistance contact; this is illustrated in the ECG applications listed below. The "neutral" or third lead must usually be used. Electrodes must be of suitable material (silver and non-magnetic stainless steel are usually satisfactory). The cable wire junction with the electrode must be protected by a sealant to avoid a local battery effect due to dissimilar metals and electrolyte.

4-2 ECG APPLICATION (USING OSCILLOSCOPE TO VIEW WAVEFORM)

See the drawing, section 4-2A. The two shielded electrodes are attached at 1 and 2 (right arm and left leg). The skin should be de-greased with acetone or detergent solution (to lower skin electrical resistance). A small amount of electrode paste is applied between the electrode and the skin. (A thin rectangle of cotton cloth soaked in 5% salt solution is also satisfactory.) The electrodes may be secured with elastic bandage, flexible guaze, or a wide rubber band. These electrodes go to the differential input jacks (8 on the BIP panel). A third unshielded electrode attaches at 3 (right leg) with the lead going to program panel terminal X.

To view ECG wave form on the oscilloscope, program the panel as follows:

- C to oscilloscope vertical input
- V or W to oscilloscope ground

Set oscilloscope sweep to a slow frequency (about two sweeps a second). Vary as needed. With some oscilloscopes, the sweep rate can be slowed with an external capacitor.

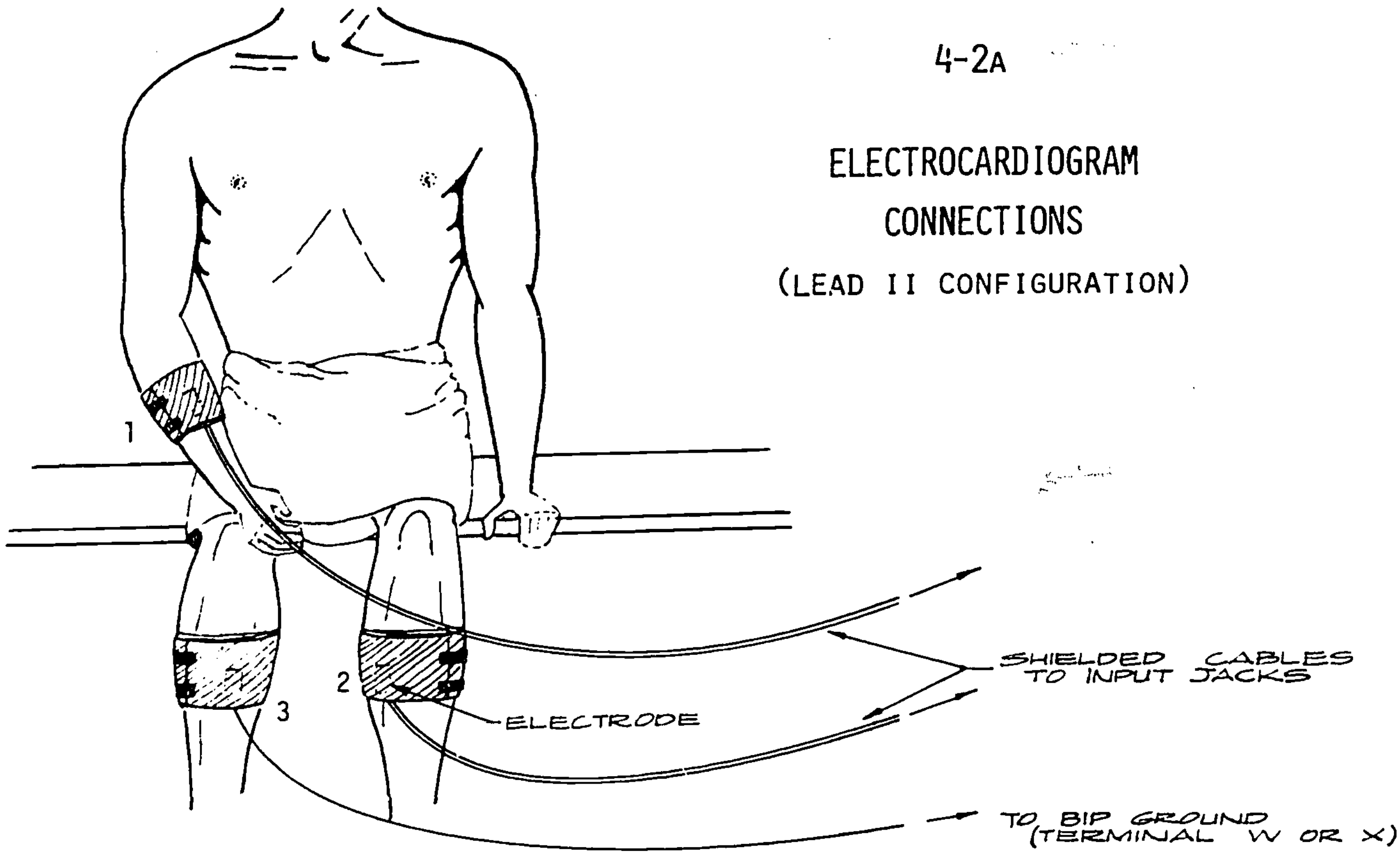
Vertical gain control on the scope should be set for about 2 cm per volt input.

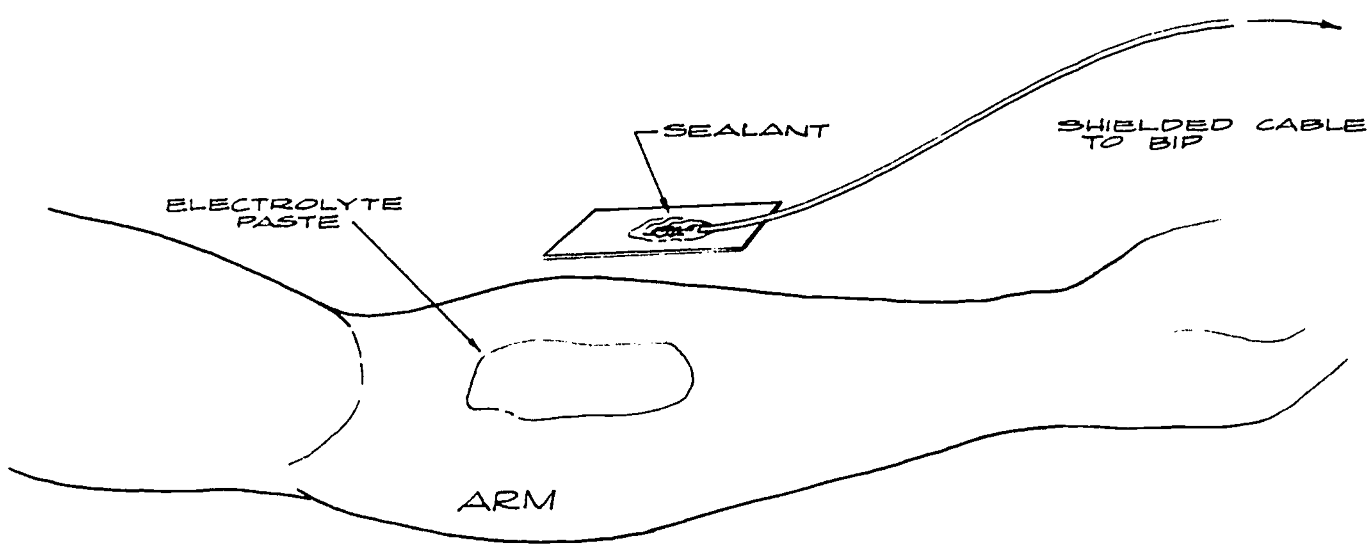
With all the terminals properly connected, the principal components of the ECG wave form should be seen on the screen. If more amplitude is needed, slotted control (screwdriver-adjust) at hole 7 on the panel may be adjusted (clockwise turn increases gain).

If the pattern is upside down, reverse the leads at input jacks at panel position 8. (In lead II, most of the QRS deflection is usually up or positive.) It should be possible to visualize the P wave, the QRS complex and the T wave. Section 4-2A is for lead II and should give a good display of all components in young people of thin to medium build. (Other electrode sites are possible but will not be discussed here. See BICP text materials or other information about the ECG.)

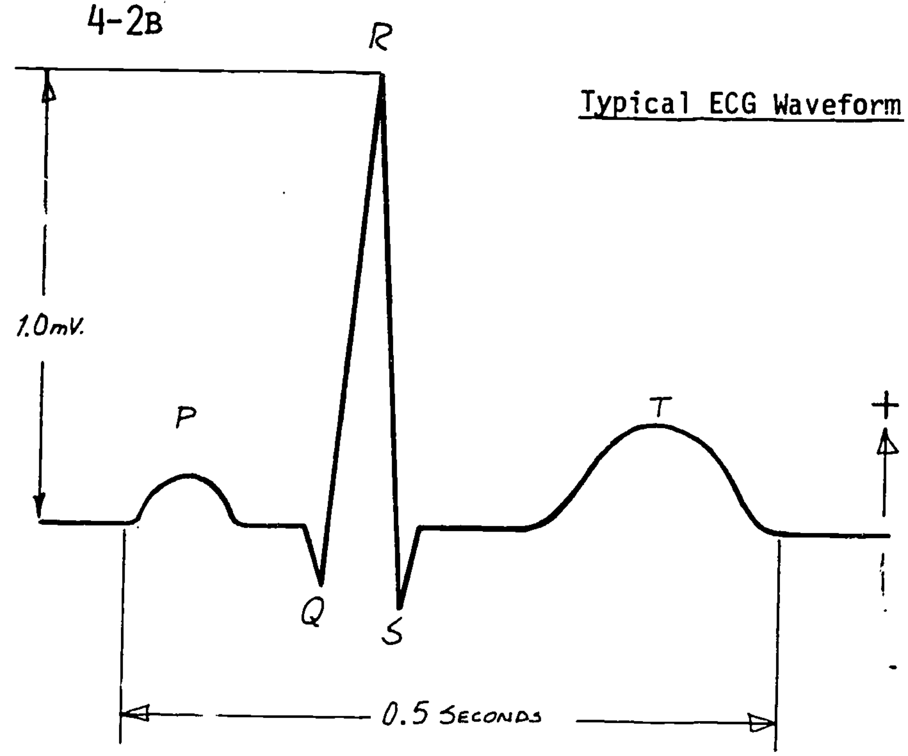
4-2A

ELECTROCARDIOGRAM
CONNECTIONS
(LEAD II CONFIGURATION)





4-2B



Typical ECG Waveform

P wave is due to depolarization of the atrium.

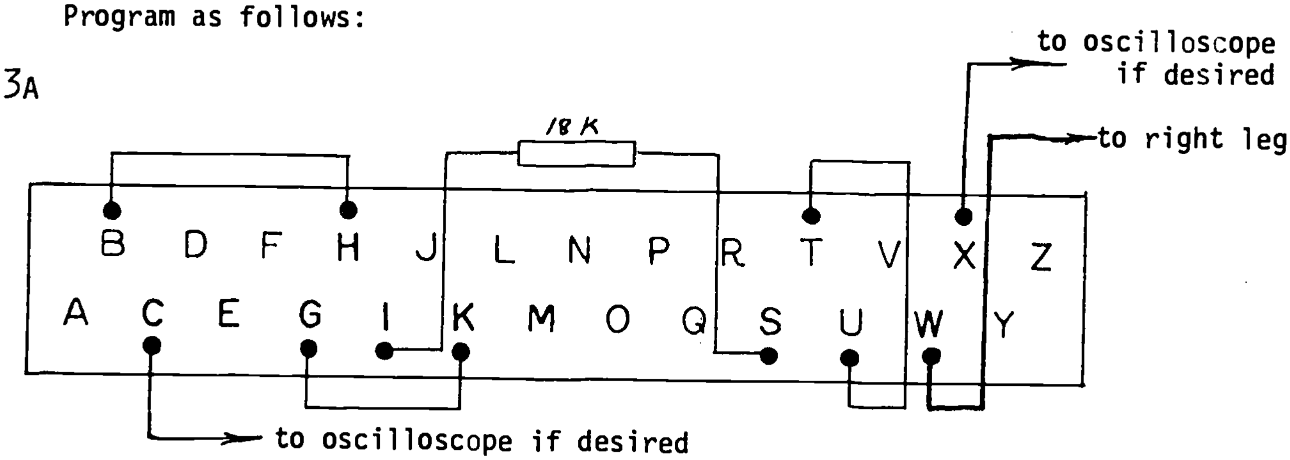
QRS complex is due to depolarization of the ventricles. The first negative deflection (Q wave) is often absent. The first positive deflection is called the R wave and the following negative deflection is the S wave.

T wave is due to repolarization of the ventricles.

4-3 ECG APPLICATION (USING DIODE LIGHTS TO VISUALIZE WAVEFORM)

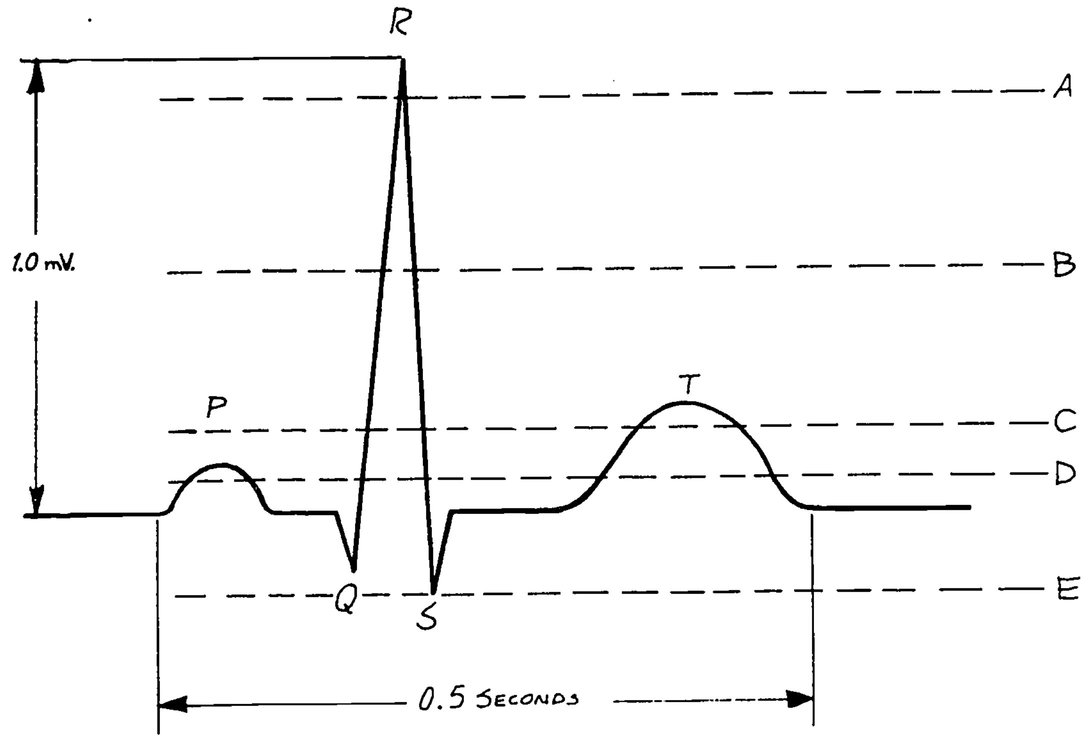
Program as follows:

4-3A



The connection from S through the resistor puts a bias into the current meter input so the null point will be away from zero. With the "patient" hooked up as in Section 4-2, turn the mA dial to null the diodes. The ECG signal is superimposed, so with each QRS complex the diode lights will flash. It is possible to demonstrate all the principal wave forms on the diode lights. Turn the mA dial toward zero so one diode light is just off all of the time and the other diode light is just on all of the time. Now turn the mA dial very slowly toward 100. As the setting just hits the top of the R wave, a very brief flash will be seen; as the dial is turned further, more and more R wave will be intersected. Two flashes will be seen when the setting reaches the T wave, and finally three flashes will be seen when the P wave is reached. (The following diagram will help you visualize what is happening as the milliamp setting is increased.)

4-3B



Referring to drawing 4-3B, when the bias is at "A" setting, the diode light that is normally off will flash very briefly each time the R wave occurs. At setting "B" the flash will be longer because the R wave is wider. At setting "C" the R flash will be longer but another flash will also occur due to the T wave. At setting D, a third flash, due to the P wave will be seen, followed by the R wave flash, and finally by a still longer T wave flash. The setting at D is fairly critical because if the bias is moved to setting "E" all flashes will be lost. (One diode light will remain on all the time and the other light will remain off all the time.)

The BIP differential pre-amplifier has been used successfully to visualize EEG (electroencephalogram--brain waves) and EMG (electromyogram). These will not be discussed here; refer to text materials.

SECTION 5

pH

5-1 MEASUREMENT OF pH

Read over this section carefully before attempting pH measurement.

The BIP provides a high impedance input (over 1000 megohms), for a standard single electrode pH probe. An internal amplifier provides the necessary inverting function. Standardization against a known pH value is accomplished by adjusting the slotted panel control at 5.

5-2 To standardize for pH determination:

1. First, be sure the electrode has been stored properly. (See section 5-4.) The pH probe unit selected to be used with the BIP is made by Analytical Measurements, Chatham, New Jersey, and is described as "pH probe unit--standard." To plug into the BIP, it should be fitted with a standard phono pin plug--the type commonly used in hi-fi systems.

2. Program F to G, H to K; plug in pH probe into jack at panel position 1, plug in BIP and allow a few minutes warm-up.

3. A small beaker should be filled to about 4 cm from the bottom with known pH solution (which ideally should be a pH near that to be measured). A pH solution at or near 7 is useful for pH measurement of many biological fluids such as urine, plasma, saliva, etc.

4. The pH probe should have the plastic cap removed from the bottom so that fluid can easily surround the electrode.

5. Rinse the electrode thoroughly with distilled water, allow to drain well, then place in the beaker containing the known buffer.

6. Gently stir the electrode a few seconds to insure good solution contact with the glass electrode.

7. Set the mA dial to the known pH (scale value ÷ 10 = pH).

8. The probe will take time to register a stable value. Allow one minute unless it is known that the electrode's response time is shorter.

9. The BIP can now be standardized by turning the slotted control at panel position 5 until the diode lights indicate a null condition.

5-3 To measure pH of an unknown solution:

1. Standardize the BIP and electrode before each series of determinations (section 5-2).

2. Rinse the electrode with distilled water and drain well, then place in a beaker or wide-mouth Erlenmeyer flask containing the unknown pH solution to a depth of about 4 cm.

3. Gently stir the electrode a few seconds. Wait one minute (or less, if it is known that the electrode will equilibrate sooner).

4. Turn the mA dial to obtain a null indication. The dial reading ÷ 10 = pH.

5-4 pH PROBE CAUTIONS

1. The glass probe itself is very delicate so do not touch it. It is given protection by the plastic housing. Do not drop it.

2. When not in use, the probe should be left in distilled water or a buffer. A probe that dries out may become very sluggish and may also require readjustment of the other trim control. Do not attempt this adjustment without special instructions. (This control is the unnumbered opening on the panel sketch between openings 5 and 7.)

3. A probe that has become dry should be soaked in 1% HNO_3 for a half-hour or longer, rinsed thoroughly with water, and left to soak overnight in water or buffer.

4. To prevent the electrode from tipping over the beaker or flask, it will be helpful to support the pH cable by a burette clamp about 20 cm from the probe handle.

NOTE: THE pH PROBE SHOULD BE USED WITH THE SAME NUMBERED BIP. IF A DIFFERENT PROBE IS USED, THE CONTROL BETWEEN PANEL POSITION 5 AND 7 MAY NEED TO BE ADJUSTED. SEE SECTION 8, FACTORY ADJUSTMENTS.

SECTION 6

WAVEFORM GENERATION

6-1 SINE WAVES

The audio-generator module provides low distortion sine waves, continuously variable in frequency from 100 to 10,000 Hz. Two ranges are provided: with the slide switch at panel position 9 in the "up" position, the reading is indicated on the dial; with the switch in the "down" position, the reading must be multiplied by 10. At pin D, a 1.0 volt output is available; at pin E the output is 0.01 volt. The other circuit lead is ground (terminals V,W or X).

6-2 Oscilloscope Display of Sine Waves:

- D to oscilloscope vertical input
- V, W or X to oscilloscope ground
- switch panel set to desired range (X1, X10)
- set frequency dial to desired frequency

Oscilloscope vertical gain and horizontal sweep should be adjusted to get best display.

6-3 Display of Lissajou Figures

This display is fascinating to many people and will provide a wide variety of interesting patterns. Two BIP's will be required.

Connect one BIP to an oscilloscope as in section 6-2.

Connect a second BIP to the same oscilloscope, except that D goes to the horizontal input.

Varying the two frequencies will result in many different Lissajou figures. With the horizontal and vertical oscilloscope gain settings equal, the same frequencies will produce a circle. With the frequencies in a 2:1 ratio, a figure 8 will be seen. Frequency ratios of 3:2, 3:1, 4:1, 5:2, etc. will produce still different patterns.

6-4 HEARING TESTING

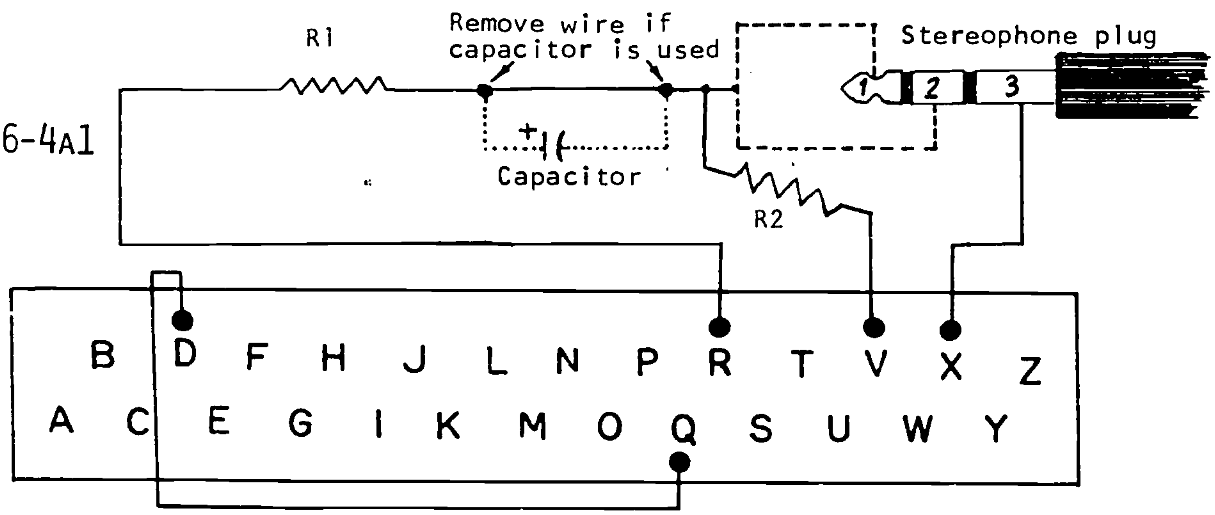
Testing to detect early hearing loss is widely used in industry to protect workers exposed to noisy environments. Many drugs (including aspirin) as well as loud rock music can temporarily or permanently damage hearing, so hearing testing is often a part of a complete medical examination. People needing a hearing aid may be counseled better after a detailed hearing test.

The commonest hearing test consists of an audiogram. This test measures the threshold sensitivity of each ear to a wide range of frequencies. This range is typically from 250 Hz to 8000 Hz. Hearing loss due to loud noise typically affects the 4000-6000 Hz range first; this early loss would not usually be noticed by the individual, but could be readily illustrated by an audiogram.

6-4A A BIP Audiogram

This testing method is only approximate and should not be used for clinical purposes. However, it will give a very good idea about the actual method used in medical practice and industry. A pair of stereo-earphones will be needed along with two external resistors (the exact values will be determined by some trial and error and will be largely dependent upon the sensitivity and impedance of the earphones). The test is set up as follows:

6-4A1



- The dB (panel position 2) should be set at 15, the frequency dial set at 100, and the slide switch in the "down" position (X10). This will give a frequency of 1000 cycles into one of the stereo-earphones.

- The value of R1 should be between 10 and 30 ohms.

- The value of R2 should be selected so that, in a quiet room, a person with good hearing can <u>just barely</u> hear the high pitched tone. The value will be typically about 1 to 2 ohms. (For convenience, a 5 ohm potentiometer could be used.) If the low frequency hum is bothersome, it can be markedly reduced by a capacitor inserted as shown by the dotted lines. Use just enough capacitance to get rid of the hum (typically 10 to 50 mfd, at least 10 volts rating). Attachment of the free lead (shown by the dashed lines) to 1 can test one ear; at 2 the other ear can be tested.

- The dB control is set at zero. (Nothing should be heard in the headphones, except possibly a faint low frequency hum--which is not coming from the sine wave generator.) The test frequency is selected by tuning the frequency dial as needed. (Frequencies typically used are given in 6-4A2.)

- The dB control should be slowly turned to higher values until the tone is just barely heard. This could be repeated and the results averaged. The same process should be followed for all the frequencies tested. A typical hearing scan is given in the table on the following page.

6-4A2

Frequency (Hz)	250	500	1000	2000	4000	6000	8000
Right Ear (dB)	30	20	10	5	15	20	20
Left Ear (dB)	20	15	5	5	35	50	15

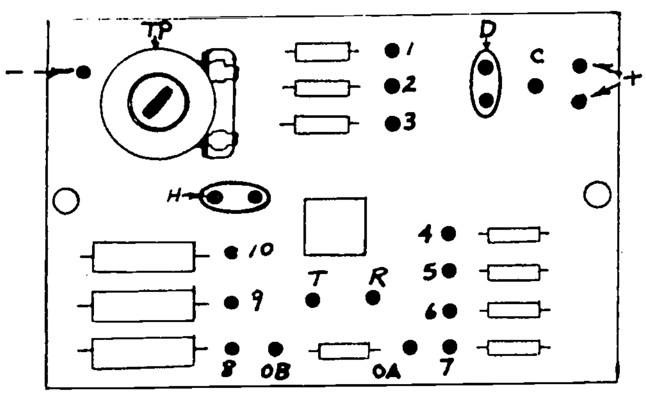
The lower the dB value, the better the hearing. The most sensitive hearing is usually near 2000 Hz with only slight reduction at 1000 Hz and 4000 Hz. Hearing at the extremes of frequency (250 and 8000 Hz) is typically 15 to 25 dB higher than at the most sensitive tone (2000 Hz).

In the audiogram table (section 6-4A2), the right ear shows a normal "curve." The left ear shows a probable loss at 4000 and 6000 Hz and suggests hearing damage due to excessive exposure to loud noise, since the 8000 Hz sensitivity is normal.

6-5 SQUARE WAVES

To generate square waves the BIP is connected to a single external computer timer card. The application below, developed for timing an exercise step test, is illustrative only because a wide variety of different activities are possible with this card. Some of these will be covered in text materials or in the computer manual.

To program for square waves with diode light indication:



6-5A

Timer Card

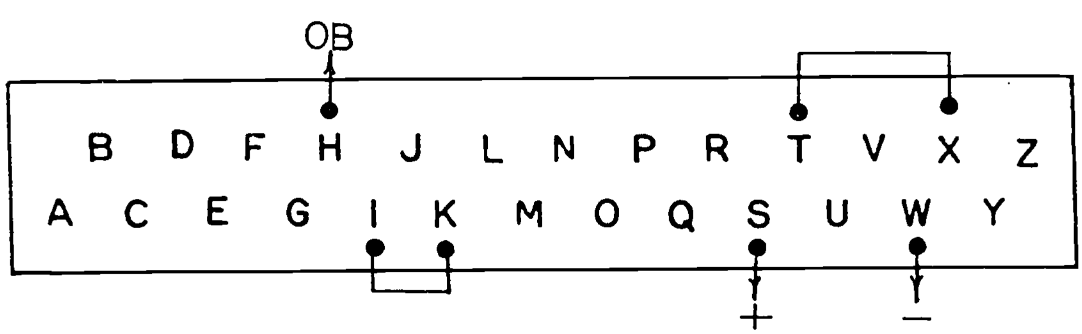
Programming the timer card:

T to H

8 to H

7 to D

3 to D



The diode lights on the BIP should alternately flash about every two seconds. Flashing rates may be speeded up by changing H to 9 instead of 8 (X10) or H to 10 instead of 8 (X100). Further changes may be made by selecting 4, 5 or 6 instead of 7 or by selecting 1 or 2 instead of 3. The trim pot (TP) may also be adjusted to give a vernier control.