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MEASURING SLEEP BY WRIST ACTIGRAPH

ANNUAL REPORT

Daniel F. Kripke, John B. Webster,

Daniel J. Mullaney, Sam Messin, and William Mason

March 1981

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In the period from April 1980-March 1981, we have programmed, tested, and begun evaluations of a wearable digital activity system, and we have refined a computer process for recognizing sleep from this system. Together, these efforts enable us to collect data from freely ambulatory subjects which can be scored automatically for sleep/wake with accuracy comparable to EEG scoring. The system is ready for miniaturization leading to field use.

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Current results now allow us to specify design criteria for a miniaturized wrist-mounted activity monitor suitable for field or combat use.

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SUMMARY

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Current results now allow us to specify design criteris for a miniaturized wrist-mounted activity monitor suitable for field or combat use.

FORWORD

For the protection of human subjects the investigator has adhered to policies of applicable Federal Law 45CFR46.

INTRODUCTION

Sleep loss and combat fatigue are increasing concerns for the modern army. A future war is likely to be extremely brief and intense, with victory and defeat determined in a few days or weeks. Soldiers using technically sophisticated modern weaponry will have little time for sleep, and plans must be made to enable personnel to perform effectively throughout the duration of a combat of unprecedented intensity. American troops may have to enter combat immediately after airlift to remote parts of the world, and plans must be developed to minimize the effects of jet-lag on personnel performance.

Military medicine therefore needs a practical method of quantifying sleep both to design personnel strategies and for potential monitoring of troops in actual field deployments.

Traditional physiologic methods for monitoring sleep through EEG-EOG-EMG recordings are completely impractical in actual or simulated combat settings, and subjective monitoring has been shown to be unreliable (1). In addition, both physiologic measures and observational methods for measuring sleep are costly, and considerable time is necessary to quantify sleep by scoring polygraph records.

We are developing a wrist activity monitoring technique as a solution to these problems.

Employing Delgado's (2) telemetric activity recording device, Kupfer et al (3) and Foster et al (4,5) described the use of activity data for quantifying sleep and assessing sleep quality in humans. Encouraged by the high correlations between EEG and actigraphic estimates of sleep -- 0.84 and 0.88 in two separate studies (6,7) -- Kripke et al (8) developed a system in which a piezoceramic activity transducer worn on a watchband recorded wrist activity onto a Medilog cassette tape recorder worn on a belt. With this transducer, Kripke et al (8) obtained a correlation of 0.98 between sleep duration determined from wrist activity and the EEG in five subjects.

A more exhaustive study of 63 nights of normal subjects and 39 nights in hospital patients with various sleep disorders was conducted under the first year of our contract (DAMD-17-78-C-8040, 1978-1979). All-night recordings of wrist activity, EEG, EMG and EOG were collected simultaneously on a 4-channel cassette. Each minute was scored as either sleep or wake by one rater using only activity data, and a second rater using only EEG-EOG-EMG data. The raters agreed on 94.5% of the minutes (96.3% for non-patients). Estimates of each subject's total sleep time with the two methods were correlated 0.89 (0.95 for non-patients). These results indicate that the wrist actigraphic analog recording contains sufficient information to produce a highly reliable scoring of sleep.

Having shown that sleep can be identified from activity data, we proposed in 1979 to design a 2-part sleep monitoring system. A digital activity monitor, consisting of an activity transducer, microprocessor and digital memory, would be worn on the wrist. A portable readout device, also microprocessor based, would read and reset the monitors, then interpret their data and generate a sleep report.

To realize this design, a first priority was to establish the optimal design, orientation and placement for the activity transducer. We found the piezo-ceramic transducer used in our previous research to be more sensitive than other available transducers and to be adequately omnidirectional. We also found the wrists to be more active than an ankle or the head, and therefore a better site for locating a transducer. The choice of wrists does not seem crucial, but the non-dominant wrist seems slightly superior (e.g., the left wrist).

Having established optimal transducer design characteristics, we turned our attention to digitizing, preprocessing and storing activity data. As reported in our 1979-1980 report, we found that digitizing at 240 Hz and summing every four digital conversions cancelled 60 Hz noise which sometimes contaminates activity recordings. We also found that a preprocessing algorithm which emphasized changes in activity level provided the best data for automatic sleep recognition. Our 1979-1980 report described our approach to empirically developing an algorithm to recognize sleep from digitized activity data. The further refinement of that approach, and its implementation in a wearable system will be described below.

FURTHER PROGRAM DEVELOPMENTS

Method

Data were obtained from subjects participating in studies involving EEG recording during both wake and sleep. A wrist activity transducer signal was sampled during both wake and sleep. The wrist activity transducer signal was sampled by the analog-to-digital (A/D) converter of our laboratory computer system at a conversion rate of 240 Hz. The analog data was digitized and stored as described in our 1979-1980 report, but only the optimal preprocessing transformation selected in that report was used in data analysis. A total of 20 records (13,488 minutes) were analyzed.

Development of the sleep recognition algorithm began with expressions incorporation a weighted sum of combinations of the digital data with potential for discriminating sleep from wake. Specifically, the expression took the form:

$$D = S \times (W_1T_1 + W_2T_2 + W_3T_3 + W_4T_4 + W_5T_5 + W_6T_6)$$

where S was a scale factor, W's were weights, and:

T_1 = the sum of the digital activity values for all 30 2-second data epochs in a minute,

T_2 = the activity value for the single most active epoch,

T_3 = the sum of the activity values in the two most active epochs separated by at least 30 seconds,

T_4 = the sum of the activity values in the most active 8 epochs.

Terms T_5 and T_6 were themselves weighted sums of term T_1 over the preceding 4 and following 2 minutes:

$$T_5 = W_{51} T_{1,i-1} + W_{52}T_{1,i-2} + W_{53}T_{1,i-3} + W_{54}T_{1,i-4}$$

$$T_6 = W_{61}T_{1,i+1} + W_{62}T_{1,i+2}$$

where $T_{1,i-1}$ is the maximal epoch value for the preceding minute, $T_{1,i+1}$ for the following minute, etc.

A minute was scored 'wake' if $D \geq 1.0$. For each given combination of weights, a range of weights (W) and scale factors (S) was substituted into the above expression for each minute, and the resulting sleep/wake score for all minutes. The proportion of minutes for which the automatic score and EEG score agreed was then computed for each scale value, and the maximum agreement served as a retrospective measure of the effectiveness of the weighting. The computer program (Appendix 1) varied the weighting of one term at a time, and searched for the combination of weights which produced the highest agreement.

As preliminary results became available, it became apparent that better agreement was obtained when $W_1 = W_3 = W_4 = 0$, i.e., the maximal epoch value in each minute was the best discriminator of sleep and wake. This unexpected result was extremely fortunate, since it permitted reducing the data required for sleep scoring by an order of magnitude compared to our prior expectation. We had expected that all 2-second epoch values for each minute would have to be stored.

Accordingly, a second expression was developed:

$$D = S \times (W_1T_{2,i-4} + W_2T_{2,i-3} + W_3T_{2,i-2} + W_4T_{2,i-1} + W_5T_{2,i} + W_6T_{2,i+1} + W_7T_{2,i+2})$$

where W's represent weights and $T_{2,i}$ represents the maximal epoch value (T_2 in the previous expression) for the current minute, $T_{2,i-1}$ for the previous minute, $T_{2,i+1}$ for the succeeding minute, etc. Again, the computer varied the weighting and compared the resulting sleep/wake score with the EEG score until maximal agreement was obtained.

Seventeen of the 20 records were used in the algorithm development phase described above. The reamining three records were scored prospectively, i.e. each of the three records was scored individually with the single weighting and scale factor found optimal in the development phase. In this test, the laboratory computer simulated the actual deployment of an automatic sleep scoring system, with the results compared to EEG scoring.

Results

The optimal algorithm reached after analysis of the 17 records was:

$$D = .025 \times (.15T_{2,i-4} + .15T_{2,i-3} + .15_{2,i-2} + .08T_{2,i-1} + .21T_{2,i} + .12T_{2,i+1} + .13T_{2,i+2})$$

where $T_{2,i}$ represents the maximal epoch value in minute i, etc. If $D \geq 1.0$, the minute was scored 'wake', otherwise 'sleep'. The best retrospective agreement between sleep/wake scored automatically with this algorithm and scoring from

EEG records was 94.46% -- that is, 94.46% of all minutes from the 17 subjects were in agreement with the 'true' sleep/wake score. Agreement scores and the proportion of the record scored as sleep by EEG and by the automatic algorithm for each individual subject are shown in Table 1. Again, it should be noted that this is retrospective agreement, the data for these individuals already having been used to select the optimal algorithm.

The ability of this algorithm to score sleep/wake prospectively was tested with the remaining three records. For these records, only the single expression found optimal in the algorithm development phase was chosen prospectively to automatically score sleep/wake. Overall agreement of these three records with EEG scoring was 96.02%. Agreement and the proportion of each individual record scored sleep by both procedures is also shown in Table 1.

In order to understand the remaining shortcomings of the automatic sleep/wake scoring algorithm, data for all minutes mis-scored were listed and compared with the paper record. In general, the conditional probability of mis-scoring wake as sleep was higher (.062) than mis-scoring sleep as wake (.039). A major reason for the higher probability of mis-scoring wake was the tendency of some subjects to lie in bed quietly for up to half an hour before falling asleep, while generating alpha-frequency EEG. On the other hand, while most examples of mis-scoring sleep were due to the presence of activity during sleep, the source of error in these cases was not so much a failure of the actigraphic scoring concept as a problem with the 1-minute scoring epoch chosen for this study. Many of the 'activity during sleep' errors actually represented arousals, but the EEG record showed that the period of wakefulness was less than the one-half minute required to score a 1-minute epoch as wake.

Since mis-scoring occurred in both directions, the estimates of total sleep duration were better than might be inferred from the minute-by-minute agreement figures. The correlation coefficient between the proportion of the record scored as sleep automatically from activity and as hand-scored from EEG were $r=0.9889$ (for the 17 records scored retrospectively) and $r=0.9982$ (for the 3 prospective records). Thus, the automatic scoring represents the relative duration of sleep extremely accurately. Since sleep duration is the dimension of sleep most crucial to sustaining performance, we feel that the automatic sleep recognition procedure described here represents a very effective scoring technique.

A further test conducted with these data sought to determine the resolution in the stored data necessary to achieve these levels of accuracy. The digital activity value was stored on disk as a 16-bit word, i.e. a number in the range of 0-32767. To investigate the resolution requirement, the sleep recognition program was repeated with the same data, but the resolution was reduced by dividing by powers of 2 and truncating. There was no decrease in agreement with 4-bit data (0-15) and a decrease of only 0.1% with 3-bit data (0-7). This surprising result is important, since it means that more data can be stored in a given memory capacity of the wearable activity monitor, providing appropriate scale factors are chosen.

TESTING THE DIGITAL ACTIVITY MONITOR

In our original proposal to produce a wearable digital activity monitor, we suggested a design in which the signal from a piezo-ceramic activity transducer would be entered through an analog-to-digital converter into an IM6100 microprocessor, and the processed activity values stored in random-access memory. All electronic components of this proposed system would be CMOS for minimal power consumption.

As noted in our 1979-1980 Annual Report, we found that these components could be assembled by the Vitalog Corporation*. After extensive discussions with Vitalog, we ordered a prototype monitor consisting of an IM6100 microprocessor, IM6001 Parallel Interface Element, 6K x 12 RAM memory, 512 word EPROM memory, 8-channel A/D converter, crystal clock and an LED indicator light. The unit is powered by rechargeable 5.6 volt batteries. It is enclosed in a 15 cm x 9 cm x 5½ cm plastic case. Vitalog also provided an interface between the monitor and our Apple microcomputer.

After receiving the monitor, we designed and built an external transducer incorporating a piezo-ceramic element, a photocell, a battery and amplification circuitry necessary to match the A/D input requirements. (The photocell was included to permit an objective measure of "lights out" and "lights on" and potentially to investigate sleep onset latency.) This external transducer, 7 cm x 4 cm x 2 cm, is worn on a wrist band like a watch. It is attached to the monitor by a cable. A schematic diagram of the transducer circuitry is presented as Figure 1.

Having assembled and tested the monitor system, we began by investigating its technical capabilities. One very important technical consideration was the useful life of the battery charge, since this limits the duration of a recording session. Battery drain was found to be 3.4 mA when the processor was halted and 8.5 mA when running. Since in most applications the processor is idling much of the time, a third state (WAIT) can be entered which keeps the processor running, but not executing instructions, at a drain of about 5.2 mA. The battery life was found to be 70 hours at 8.5 mA (running continuously) and 180 hours at 5.2 mA (running with WAIT). We subsequently devised a system for changing batteries without disturbing the recording, removing this limit to recording duration. We also investigated the accuracy of the crystal clock, and found that it lost 1.2 seconds each hour, well within acceptable limits. While considerable improvement in battery life can probably be obtained in any future model, the Vitalog system already demonstrates the feasibility of powering a microprocessor-based wrist activity monitor.

The majority of our effort in preparing the monitor system for use has been in development of a monitor program to direct the collection and storage of activity data. The algorithms for converting the continuous analog signal from the activity transducer to a value representing activity for each minute were equivalent to those discussed above. The monitor program that was ultimately developed, tested, and used to collect digital activity records digitized the signal from the transducer at 240 Hz, and 4 consecutive values were summed to provide a measure of activity free of 60 Hz noise. The sum was then transformed

*Vitalog Corporation, 1056 California Avenue, Palo Alto, CA 94306.

to a difference score, and 120 such scores summed to produce an activity value for each 2-second data epoch. Every minute, the greatest 2-second activity value in that minute was stored. A voltage indicating the illumination level of the photocell was also digitized and stored each minute and a time code was signaled through the LED. The monitor program (Appendix 2) fills 448 memory locations, leaving 5696 locations available for data storage. This allows us to store two 12-bit data words (activity and illumination) each minute for 47 hours and 28 minutes. Since 4-bit resolution would be adequate, up to 6 times this duration or about 12 days sleep data could be stored were the illumination data sacrificed and battery changes feasible.

For test recordings, where it is necessary to compare digital activity records with EEG recordings, the LED was coupled through a receiving photocell to the polygraph to provide a time reference each minute on the paper record. The EEG recordings were scored, and both EEG and activity monitor scores were transferred to our laboratory computer system. To date, 25 laboratory recordings totalling over 27,000 minutes have been collected, and 14 have been fully analyzed retrospectively. Results are presented in Table 2. Retrospective agreement of these 14 records (12,739 minutes) is 93.6% with EEG scoring. The correlation coefficient between the proportion of each record scored as sleep by the two techniques is r=.9760.

In the final months of our 1980-1981 contract year, we plan to analyze a series of activity-monitored nights with prospective scoring to complete validation of our sleep scoring methodology. In addition, we will prepare a complete technical specification of the methodology from which a microminiaturized monitor wearable entirely on the wrist could be built. Our Vitalog digital monitor is fully programmable and in no way limited by the program described above. Any number of control programs could be written to record activity or illumination data differently and to monitor other functions through the unused A/D channels. These extended capabilities of the instrument can be utilized in our proposed 1981-1982 contract.

CONCLUSION

Mullaney, Kripke and Messin (9) have shown that a trained scorer can score wrist activity data for sleep/wake with accuracy approaching EEG scoring. In the present study, we have shown that wrist activity data can be digitized and scored automatically by computer with no loss in accuracy. Mullaney et al estimated that their activity scoring system was 5 to 10 times less costly than EEG scoring, and that the marginal decrease in accuracy was more than compensated by the greater amount of data that could be collected for a given expense. We feel that the automatic scoring system described here further improves the cost-benefit relationship by replacing the largely mechanical analog recording and playback system, including the polygraph, with an all-digital system. Automatic scoring is accomplished in seconds, eliminating the hours of skilled labor needed for writing out a polygraph record and the many minutes needed for visually scoring the record. Elimination of a scorer further reduces costs and for the first time makes the identification of sleep and wake fully objective, without the many opportunities for error and variability presented by human scoring. We are continuing with further algorithm refinements and testing, but it is unlikely much improvement can be obtained over the current results, nor is much improvement needed.

As of March, 1981, we have completed the major technical goals of our contract. Specifically, we have designed, built, tested, and evaluated a wearable digital activity monitor usable for sleep/wake scoring. Preliminary validation studies (using a retrospective technique) produced a r=.9760 correlation of automatic scoring of total sleep duration versus EEG scoring. This far exceeds our 90% design specification. Our technical development has been extremely successful. Judging from our experience with the same algorithm utilized with the laboratory computer, we believe there will be little or no degradation of validity in prospectively scored records, nevertheless, we are completing prospective validation in the remaining months of our 1980-1981 contract. In addition, we will submit an exact technical specification giving hardware and software specifications for a miniaturized microprocessor-controlled activity monitor. With this specification, a miniaturized monitor wearable entirely on the wrist could be designed and produced with currently available technology.

A miniaturized wrist-mounted sleep monitor could be used in field trials or in actual combat to monitor the fatigue and sleep-loss of Army troops.

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Figure 1. Schematic diagram of external activity transducer, photocell and level-matching amplification circuitry

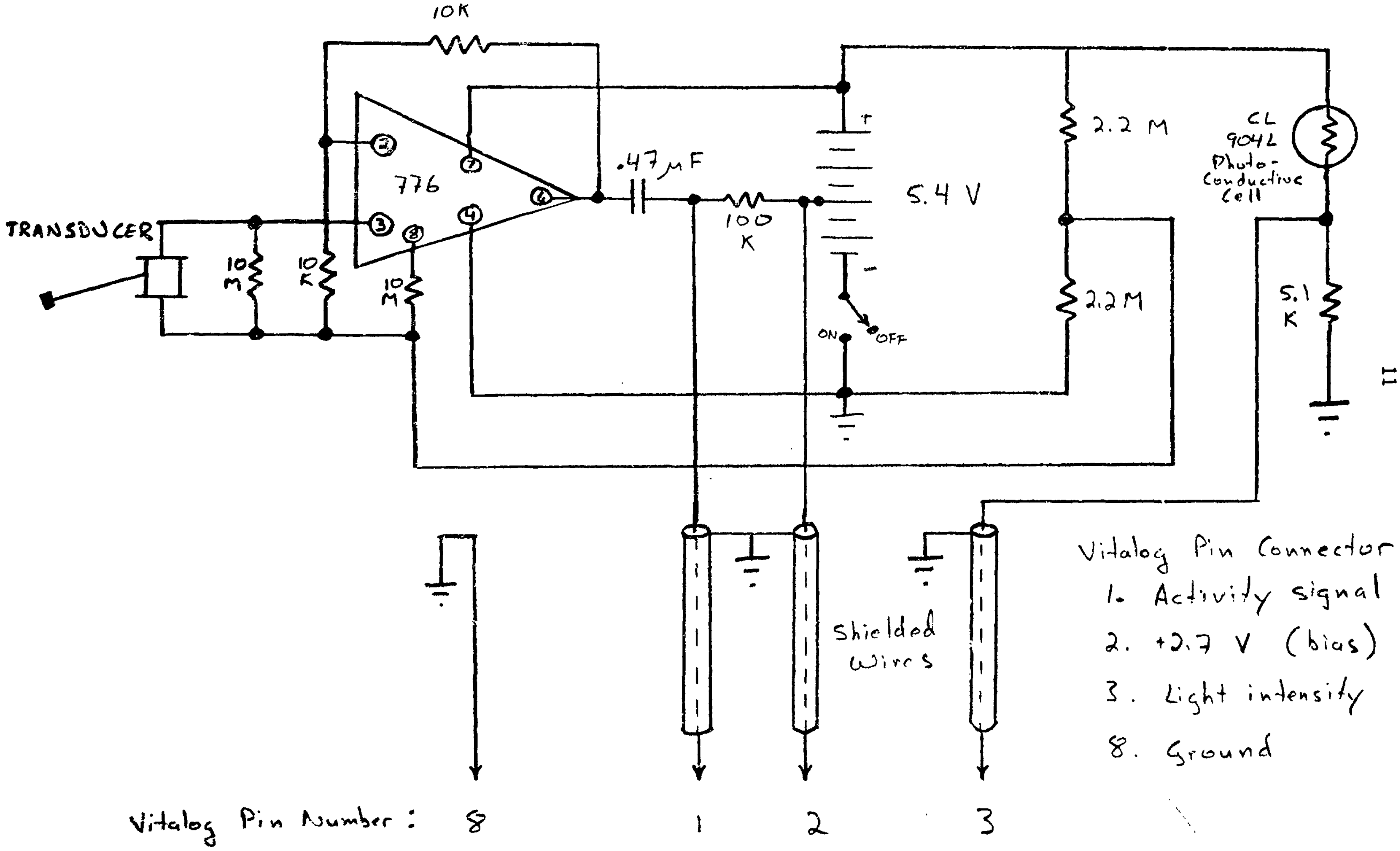

TABLE 1

Subject	Recording Duration (minutes)	% Agreement	% Sleep (EEG)	% Sleep (Act.)
1	353	97.17	0.00	2.83
2	574	96.17	45.47	46.86
3	632	95.89	56.80	59.65
4	903	83.82	29.57	34.33
5	660	97.42	54.55	56.21
6	798	95.36	41.73	44.11
7	845	96.80	37.99	40.95
8	1129	96.19	30.65	31.62
9	644	96.89	50.47	51.40
10	553	88.79	56.06	48.10
11	371	96.77	92.72	95.96
12	527	96.96	14.99	16.13
13	226	89.82	93.81	93.36
14	673	91.98	50.67	45.62
15	593	95.78	56.49	59.36
16	829	91.19	40.17	47.77
17	692	94.08	15.17	20.18
Total Retrospective	11002	94.46	42.09	43.98
18	369	93.50	70.19	76.69
19	846	93.62	28.84	31.68
20	1271	98.35	36.82	37.69
Total Prospective	2486	96.02	39.06	41.39

Table 1. Record duration, proportion of the record for which hand-scored EEG and automatically scored activity scores agree, and proportion of the record scored as sleep by the two techniques. Total duration and overall proportions for the records scored retrospectively and those scored prospectively are also presented.

TABLE 2

Subject	Recording Duration	% Agreement	% Sleep (EEG)	% Sleep (Act.)
1	366	89.92	85.71	95.80
2	2847	95.67	18.68	20.89
3	1472	97.95	24.27	25.91
4	2848	96.90	20.61	23.42
5	461	90.93	97.35	92.70
6	344	95.52	97.61	97.31
7	465	83.55	88.16	79.61
8	500	91.65	91.85	88.39
9	502	91.89	90.06	85.19
10	487	92.68	96.03	96.65
11	483	94.39	82.70	97.05
12	503	83.20	81.58	93.52
13	1100	92.12	35.47	39.32
14	487	90.17	89.33	98.33
Total Retrospective	12739	93.61	46.38	48.87

Table 2. Record duration, proportion of the record for which hand-scored EEG and automatically scored activity scores agree, and proportion of the record scored as sleep by the two techniques. Total duration and overall proportions are also presented.

APPENDIX 1

For Hewlett-Packard 1000

```
&WHEEL T=ØØØØ4 IS ON CRØØ334 USING ØØØ26 BLKS R=ØØØØ

FTN4
      PROGRAM WHEEL(3,999)
     .,Finds parameters yielding best agreement for s/w.
C-------------------------------------------------------
C
C     AUTHOR:  JOHN WEBSTER
C
C       VA Medical Center - San Diego
C       Mail Code V-116
C       La Jolla, California  92Ø93
C       Telephone: (714) 453-75ØØ X-3881
C
C     DATE OF CREATION:
C      <<11:34 PM  THU., 19  FEB., 1981>>
C
C     DATE OF CURRENT REVISION:
C      <1Ø:55 AM  FRI.,  6  MAR., 1981>
C
C     DATE OF LAST ACCESS:
C      <1Ø:55 AM  FRI.,  6  MAR., 1981>
C
C     FILE IDENTIFIER:
C       &WHEEL
C
C     ABSTRACT:  Finds parameters yielding best agreement for s/w.
C
C     CALLING SEQUENCE:
C       WHEEL[,LUI,LUO,S/R]
C
C     PARAMETERS OR ARGUMENTS:
C       LUI is interactive terminal, LUO is output device.
C       S/R is single pass (Ø)/repeat (1) feature
C       Default: Input=1 (System terminal)
C                Output=6 (Versatec)
C                S/R=Ø (Single pass)
C
C     DETAILED DESCRIPTION:
C
C-------------------------------------------------------
      DIMENSION IDCB(3Ø88),ISTAT(1Ø),C(2Ø),W(2Ø)
      DIMENSION IPO(81,2Ø,4),LU(5),IFILE(3),NW(5),CX(2Ø)
      DIMENSION IBUF(3Ø72),VECTR(2Ø),PP(8),CW(2Ø)
      DATA IFILE/2HHD,2HAT,2HØØ/
C----------
C  ASSIGN I/O DEVICES
C----------
      CALL RMPAR (LU)
      IF (LU.EQ.Ø) LU=1
      LUI=LU
      IF (LU(2).EQ.Ø) LU(2)=6
      LUO=LU(2)
C----------
C  INPUT PARAMETERS
C----------
   5Ø WRITE (LUI,1ØØ)
  1ØØ FORMAT (/" 'HP' OR 'VI'?: _")
      READ (LUI,8Ø9Ø) NA
      IF (NA.NE.2HHP) GO TO 11Ø
      IFILE=2HHD
      LO=16
      LIM=35
      YMULT=1.
```

```
      GO TO 15Ø
  11Ø IF (NA.NE.2HVI) GO TO 5Ø
      IFILE=2HVD
      LO=66
      LIM=65
      WRITE (LUI,125)
  125 FORMAT (" MULTIPLY VITALOG SCORE BY:_")
      READ (LUI,*) XMULT
      LO=LO-XMULT*1Ø
      LIM=LIM-XMULT*1Ø
  15Ø WRITE (LUI,2ØØ)
  2ØØ FORMAT (/" NUMBER OF MINUTES FORWARD: _")
      READ (LUI,*) IFW
      KJ=IFW+1
      WRITE (LUI,25Ø)
  25Ø FORMAT (" NUMBER OF MINUTES BACKWARD: _")
      READ (LUI,*) IBW
      IW=IBW+IFW+1
      IF (IW.LE.1Ø) GO TO 35Ø
      WRITE (LUI,3ØØ)
  3ØØ FORMAT (" *** 1Ø MINUTES MAX *** ")
      GO TO 15Ø
  35Ø WRITE (LUI,4ØØ)
  4ØØ FORMAT (//" ENTER WEIGHTS FOR MINUTE. . ."/)
      K=Ø
      DO 5ØØ I=-IBW,IFW
      K=K+1
      IF (I.GE.Ø) GO TO 48Ø
      WRITE (LUI,47Ø) K,I
  47Ø FORMAT (3ØX,I2") I"I2": _")
      GO TO 495
  48Ø IF (I.GT.Ø) GO TO 49Ø
      WRITE (LUI,481) K
  481 FORMAT (3ØX,I2") *I*: _")
      GO TO 495
  49Ø WRITE (LUI,491) K,I
  491 FORMAT (3ØX,I2") I+"I1": _")
  495 READ (LUI,*) W(K)
  5ØØ CONTINUE
  545 DO 55Ø I=1,4
      NW(I)=Ø
  55Ø CONTINUE
      WRITE (LUI,56Ø)
  56Ø FORMAT (/" ENTER UP TO 4 WEIGHTS TO BE 'BRACKETED' : _")
      READ (LUI,*) NW(1),NW(2),NW(3),NW(4)
      WRITE (LUI,58Ø)
  58Ø FORMAT (//)
  6ØØ LK=4
      IF (NW(4).EQ.Ø) LK=3
      IF (NW(3).EQ.Ø) LK=2
      IF (NW(2).EQ.Ø) LK=1
      IF (NW(1).EQ.Ø) LK=Ø
      LN=3**LK
      DO 76Ø I=1,IW
      CW(I)=W(I)
  76Ø CONTINUE
  775 DO 8ØØ K=1,61
      DO 8ØØ J=1,2Ø
      DO 8ØØ I=1,4
      IPO(K,J,I)=Ø
  8ØØ CONTINUE
      IF (LU(3).EQ.1) GO TO 875
      IF (LUO.EQ.5) WRITE (LUO,85Ø)
```

```
  875 DO 4200 IQ=101,126
      IF (NA.EQ.2HVI) GO TO 900
      IF (IQ.EQ.101) GO TO 4200
      IF (IQ.EQ.107) GO TO 4200
      IF (IQ.EQ.108) GO TO 4200
      IF (IQ.EQ.114) GO TO 4200
      IF (IQ.EQ.115) GO TO 4200
      IF (IQ.EQ.117) GO TO 4200
      GO TO 950
  900 IF (IQ.GE.115) GO TO 4200
  950 IFILE(3)=KCVT(IQ)
C----------
C  READ DATA FILE
C----------
 1000 CALL OPEN (IDCB,IER,IFILE)
      IF (IER.LT.0) GO TO 9900
      CALL READF (IDCB,IER,IBUF)
      IF (IER.LT.0) GO TO 9910
      LEN=IBUF*256+IBUF(2)
      IL=LEN+2
      CALL READF (IDCB,IER,IBUF,IL,JL,-1)
      IF (IER.LT.0) GO TO 9920
      IF (LU(3).EQ.1) GO TO 2100
      WRITE (LUO,2000) IFILE,LEN
 2000 FORMAT (2H  ,3A2,I8" MINUTES-")
C----------
C  PROCESS DATA
C----------
 2100 DO 4000 I=3,IL
      DO 2200 J=IW,2,-1
      VECTR(J)=VECTR(J-1)
      ISTAT(J)=ISTAT(J-1)
 2200 CONTINUE
      ISTAT=1
      IF (NA.EQ.2HVI) GO TO 2300
      IF (IBUF(I).LE.0) IBUF(I)=63
 2300 IF (IBUF(I).LT.128) GO TO 2500
      IBUF(I)=IBUF(I)-128
      ISTAT=0
 2500 VECTR=FLOAT(IBUF(I))*XMULT
      IF (VECTR.GT.63) VECTR=63
      DO 3900 IZL=1,LN
      D=0.
      DOT=0.
      IF (I-2.LT.IW) GO TO 4000
      IF (NW(4).EQ.0) GO TO 3002
      CW(NW(4))=W(NW(4))+((IZL-1)/27-1)
 3002 IF (NW(3).EQ.0) GO TO 3004
      CW(NW(3))=W(NW(3))+(MOD((IZL-1),27)/9-1)
 3004 IF (NW(2).EQ.0) GO TO 3006
      CW(NW(2))=W(NW(2))+(MOD((IZL-1),9)/3-1)
 3006 IF (NW(1).EQ.0) GO TO 3020
      CW(NW(1))=W(NW(1))+(MOD((IZL-1),3)-1)
 3020 WW=0
      DO 3040 IZ=1,IW
      WW=WW+CW(IZ)
 3040 CONTINUE
      DO 3060 IZ=1,IW
      C(IZ)=CW(IZ)/WW
 3060 CONTINUE
C (DOT PRODUCT LOOP)
 2600 DO 2700 K=1,IW
      DOT=DOT+VECTR(K)*C(K)
 2700 CONTINUE
```

```
      DO 3900 JJ=LO,LIM
      SCALE=JJ/1000.
      D=DOT*SCALE
      L=JJ-(LO-1)
      KS=0
      IF (D.GE.1.0) KS=2
      LS=ISTAT(KJ)
      KLS=KS+LS+1
      IPO(IZL,L,KLS)=IPO(IZL,L,KLS)+1
 3800 CONTINUE
 3900 CONTINUE
 4000 CONTINUE
 4200 CONTINUE
 4300 NS=IPO(1,1,1)+IPO(1,1,3)
      NN=IPO(1,1,1)+IPO(1,1,2)+IPO(1,1,3)+IPO(1,1,4)
      NNMAX=0
      DO 4700 J=1,LN
      NMAX=0
      DO 4600 I=LO,LIM
      L=I-(LO-1)
      NC=IPO(J,L,1)+IPO(J,L,4)
      NNMAX=MAX0(NNMAX,NC)
      IF (NNMAX.NE.NC) GO TO 4510
      SSMAX=I/1000.
      MAXJ=J
 4510 NMAX=MAX0(NMAX,NC)
      IF (NMAX.NE.NC) GO TO 4600
      MAXC=NC
      SMAX=I/1000.
      MAXI=L
 4600 CONTINUE
      IF (NW(4).EQ.0) GO TO 4602
      CW(NW(4))=W(NW(4))+((J-1)/27-1)
 4602 IF (NW(3).EQ.0) GO TO 4604
      CW(NW(3))=W(NW(3))+(MOD((J-1),27)/9-1)
 4604 IF (NW(2).EQ.0) GO TO 4606
      CW(NW(2))=W(NW(2))+(MOD((J-1),9)/3-1)
 4606 IF (NW(1).EQ.0) GO TO 4608
      CW(NW(1))=W(NW(1))+(MOD((J-1),3)-1)
 4608 WW=0
      DO 4650 I=1,10
      WW=WW+CW(I)
 4650 CONTINUE
      DO 4675 I=1,10
      CX(I)=CW(I)/WW
 4675 CONTINUE
      PC=100*FLOAT(NMAX)/FLOAT(NN)
      IF (LU(3).EQ.1) GO TO 4700
      WRITE (LUO,4690) (CW(I),I=1,10),SMAX,PC
 4690 FORMAT (1H ,10F6.1,F7.4,F7.2)
 4700 CONTINUE
      PS=100*FLOAT(NS)/FLOAT(NN)
      PCC=100*FLOAT(NNMAX)/FLOAT(NN)
      DO 4850 LM=1,4
      PP(LM)=100*FLOAT(IPO(MAXJ,MAXI,LM))/FLOAT(NN)
 4850 CONTINUE
      IF (LU(3).EQ.1) GO TO 4950
      WRITE (LUO,4048)
 4048 FORMAT (//)
      WRITE (LUO,4900) PCC,NN,PS,(PP(I),I=1,4)
 4900 FORMAT (//" PERCENT CORRECT: "F6.2" %"
     1/" MINUTES SCORED: "I6
     2/" PERCENT SLEEP: "F6.2" %"/
     3/" 
```

```
 4950 IF (NW(4).EQ.0) GO TO 5002
      W(NW(4))=W(NW(4))+((MAXJ-1)/27-1)
 5002 IF (NW(3).EQ.0) GO TO 5004
      W(NW(3))=W(NW(3))+(MOD((MAXJ-1),27)/9-1)
 5004 IF (NW(2).EQ.0) GO TO 5006
      W(NW(2))=W(NW(2))+(MOD((MAXJ-1),9)/3-1)
 5006 IF (NW(1).EQ.0) GO TO 5008
      W(NW(1))=W(NW(1))+(MOD((MAXJ-1),3)-1)
 5008 WRITE (LUO,5010) (W(I),I=1,10),SSMAX,PCC
 5010 FORMAT (1H ,10F5.1,F6.3,F6.2)
      IF (LU(3).EQ.0) GO TO 9050
      DO 9040 I=1,4
      IF (NW(I).EQ.0) GO TO 9040
      NW(I)=NW(I)+1
      IF (NW(I).GT.IW) NW(I)=1
 9040 CONTINUE
      GO TO 600
 9050 WRITE (LUI,8089)
 8089 FORMAT (" MORE?: _")
      READ (LUI,8090) IANS
 8090 FORMAT (A2)
      IF (IANS.EQ.2HYE) GO TO 545
 9000 STOP 7777
 9900 WRITE (LUI,9990) IER
      STOP 1
 9910 WRITE (LUI,9990) IER
      STOP 2
 9920 WRITE (LUI,9990) IER
      STOP 3
 9990 FORMAT (" *** ERROR"I6" *** ")
 9999 STOP
      END
      END$
```

APPENDIX 2

For Vitalog IM6100 microprocessor

```
*ACTLD T=P0004 IS ON CP00334 USING 00000 BLKS R=0000

                    /ACTICORD


                    /RECORDS OUTPUT OF ACTIGRAPH TRANSDUCER AND PHOTOCELL
                    /RESOLUTION=1 MINUTE, DURATION=47HR,28MIN
                    /TIME CODE EACH MINUTE THRU L.E.D.

                    /AUTHOR: JOHN WEBSTER





                    STORE = JMS I STORE

                    /PAGE 0

                    *0

000   0000          RTNADR,   0                   /INTRPT RETURN ADDR
001   5026          INTRPT,   JMP       INTSPV    /INTRPT PNTR


                    /AUTOINDEX REGISTERS
                    *13
013   0000          A13,      0                   /RESERVED FOR A/D. . .
014   0000          A14,      0                   /BUFFER POINTER
015   0000          A15,      0                   /RESERVED FOR DIFF. . .
016   0000          A16,      0                   /SCORE POINTERS
017   0000          DATAP,    0                   /DATA STORE POINTER


                    /INTERRUPT SERVICE ROUTINE
                    *26
026   3106          INTSPV,   DCA       ACSAVE    /SAVE REGISTERS
027   7004                    RAL
030   3107                    DCA       LKSAVE
031   6504                    RCRA
032   3110                    DCA       CRASAV
033   4P44                    JMS       GETACT    /GET ACTIVITY SCORE
034   1110                    TAD       CRASAV    /RESTORE REGISTERS
035   6505                    WCRA
036   6007                    CAF
037   1107                    TAD       LKSAVE
040   7010                    RAR
041   1106                    TAD       ACSAVE
042   6001                    ION                 /ENABLE INTRPT
043   5400                    JMP  I    RTNADR


                    /ACTIVITY SCORE SET-UP
```

```
045  1113          TAD         AWORD       /SET UP PIE FOR A /D
046  6505          WCRA
047  7201          CLA IAC                 /START WITH CH.1 (BIAS)
050  4066          JMS         A2D
051  7041          CIA
052  3121          DCA         BIAS        /NEGATE AND SAVE
053  4066          JMS         A2D         /THEN CH.0 (ACT)
054  1121          TAD         BIAS        /FIND DIFFERENCE
055  3413          DCA   I     A13         /PACK INTO BUFFER
056  1013          TAD         A13         /RESET BUFFER PNTR. . .
057  1114          TAD         STKEND      /IF AT END (EOB)
060  7640          SZA CLA
061  5064          JMP         .+3
062  1111          TAD         STKBEG
063  3013          DCA         A13
064  5444          JMP   I     READAD


               /ANALOG TO DIGITAL CONVERSION
               *66
               A2D,    HLT
066  7402              WRITE1                  /CHAN. SELECT
067  6501              CLA CLL
070  7300              TAD         MCNT        /SET UP BACKUP CNTR
071  1115              DCA         MCNTR
072  3116              WRITE2                  /START CONVERSION
073  6511              SKIP2                   /DONE (EOC)?
074  6513              SKP
075  7410              JMP         DONE
076  5073              ISZ         MCNTR       /NO. INCR. BACKUP
077  2116              JMP         .-4
100  5074                                      /YES
101  6500      DONE,   READ1                   /MASK GARBAGE &
102  0117              AND         X377        /EXIT
103  5466              JMP   I     A2D


               /CONSTANTS AND VARIABLES
104  0000      MAXEP,  0           /ACCUMULATES MAXIMAL EPOCH SCORE
105  0000      LITE,   0           /HOLDS LITE LEVEL VALUE
106  0000      ACSAVE, 0           /SAVES AC DURING INTRPT
107  0000      LKSAVE, 0           /SAVES LINK DURING INTRPT
110  0000      CRASAV, 0           /SAVES CRA DURING INTRPT
111  0547      STKBEG, 547         /POINTS TO ACT SCORE BUFFER
112  0000      ERROR,  0
113  0201      AWORD,  201         /INITIAL CRA VALUE
114  7221      STKEND, 7221        /-END OF ACT SCORE BUFFER
115  7766      MCNT,   7766        /TIME DELAY FOR A/D
116  0000      MCNTR,  0           /COUNTER FOR TIME DELAY
117  0377      X377,   377         /USED TO MASK A/D CONV
120  7772      M6,     -6
121  0000      BIAS,   0           /HOLDS TRANS. BIAS VALUE
122  4220      BWCRB,  4220        /INITIAL CRB VALUE
123  0577      DATBEG, 577         /POINTS TO START OF RECORDER MEM.
```

```
125  0000   MINCNT.   0         /MINUTE COUNT
126  0000   TCODE.    0         /TIME CODE
127  7775   M3.       -3
130  0000   GPPS.     0         /COUNTER FOR TIME CODE
131  0000   CCNTP.    0         /
132  7773   M5.       -5
133  0000   TCNTP.    0         /
134  0000   CODE1.    0         /TIME CODE '0' OR '1'
135  0000   TFLAG.    0         /TIME CODE FLAG
136  7742   M30.      -30
137  0000   MINDIV.   0         /MINUTE DIVIDER
140  0000   EPSUM.    0         /ACCUMULATES EPOCH SUM
141  0000   DFSUM.    0         /ACCUMULATES DIFSCR SUMS
142  7610   M120.     -120
143  0000   EPDIV.    0         /EPOCH DIVIDER
144  0000   SUM4.     0         /ACCUMULATES SUM TO 4
145  7774   M4.       -4
146  0000   CNT4.     0         /COUNTS 4
147  0177   X177.     177       /MASK FOR DIFSCR
150  7700   X7700.    7700
151  0000   DATWPD.   0         /HOLDS DATA PRIOR TO STORE
152  0600   CODETS.   CODET     /POINTS TO TIME CODE RTN
153  0400   DFSC.     DIFSCR    /POINTS TO DIFSCR RTN
154  0000   CRATMP.   0         /TEMP CRA STORE
155  1000   FLD1.     1000      /WCRA TO GET FIELD 1
156  2001   MEMLIM.   2001      /- END OF FIELD
157  7776   M2.       -2
160  7766   M10.      -10
161  7600   T200.     7600
162  4000   O4000.    4000      /WCRA TO WAIT
163  0000   LATEST.   0         /HOLDS MOST RECENT SUM4
164  0557   BUFLOC.   557       /POINTS TO DIFSCR BUFFER
165  0000   BUFN.     0         /BUFFER LOC
166  0000   MINUS.    0
167  0000   OFLOW.    0
170  0000   PRDCT.    0
171  0640   STORE.    STORES    /POINTS TO STORE RTN
172  0000   DIFOUT.   0
173  0000   BUMP.     0
174  7765   M11.      -11
175  7770   M8.       -8
176  7777   M1.       -1
177  0077   X77.      77
```

```
                  /PAGE 1

                  /START-UP
                  *200
200  6007         START,  CAF
201  1113                 TAD      AWORD     /SET UP PIE
202  6505                 WCRA
203  7300                 CLA CLL
204  1122                 TAD      BWORD
205  6515                 WCRB
206  7300                 CLA CLL
207  1123                 TAD      DATBEG    /ZERO MEMORY
210  3017                 DCA      DATAP
211  3151                 DCA      DATWRD
212  4571                 STORE
213  7410                 SKP
214  5212                 JMP      .-2
215  7201         WAIT,   CLA IAC            /WAIT FOR 'ON'
216  4060                 JMS      A2D
217  1150                 TAD      M100
220  7700                 SMA CLA            /IS SWITCH ON?
221  5226                 JMP      GO
222  6504                 RCRA               /NO, WAIT
223  1162                 TAD      04000
224  6505                 WCRA
225  5215                 JMP      WAIT
226  1113         GO,     TAD      AWORD     /YES, INIT & GO
227  6505                 WCRA
230  7000                 NOP
231  7300                 CLA CLL
232  1123                 TAD      DATBEG
233  3017                 DCA      DATAP
234  3124                 DCA      FLDFLG
235  3125                 DCA      MINCNT
236  1111                 TAD      STKBEG
237  3013                 DCA      A13
240  1111                 TAD      STKBEG
241  3014                 DCA      A14
242  1125         MINIT,  TAD      MINCNT    /ENTER EACH MINUTE
243  3126                 DCA      TCODE     /LOAD TIME CODE
244  1145                 TAD      M4
245  3130                 DCA      GRPS
246  1145                 TAD      M4
247  3131                 DCA      BCNTR
250  1176                 TAD      M1
251  3133                 DCA      TCNTR
252  1176                 TAD      M1
253  3134                 DCA      CODE1
254  2135                 ISZ      TFLAG     /SET TIME CODE FLAG
255  2125                 ISZ      MINCNT
256  1136                 TAD      M30
257  3137                 DCA      MINDIV
```

```
261  3105              DCA       MINTOT
262  3140   EPOCH,     DCA       EPSUM      /ENTER EACH EPOCH
263  3141              DCA       DFSUM
264  1142              TAD       M120
265  3143              DCA       EPDIV
266  3144   FOUR,      DCA       SUM4       /ENTER EACH FOUR A/D'S
267  1145              TAD       M4
270  3146              DCA       CNT4
271  1135              TAD       TFLAG
272  7640              SZA CLA
273  4552              JMS  I    CODETS
274  6001              ION
275  7300   EACH,      CLA CLL              /ENTER EACH A/D
276  1013              TAD       A13
277  7041              CIA
300  1014              TAD       A14
301  7440              SZA                  /IS A/D BUFFER EMPTY?
302  5315              JMP       NEW
303  6504              RCRA                 /YES. ENTER WAIT STATE
304  7421              MQL
305  7501              MQA
306  1162              TAD       04000
307  6505              WCRG
310  7701              ACL
311  6505              WCPA
312  7000              NOP
313  7000              NOP
314  5275              JMP       EACH
315  7300              CLA CLL              /NO. READ NEXT VALUE
316  1414              TAD  I    A14
317  1144              TAD       SUM4       /AND SUM TO 4
320  3144              DCA       SUM4
321  1014              TAD       A14        /RESET BUFFER IF AT END
322  1114              TAD       STKEND
323  7640              SZA CLA
324  5327              JMP       .+3
325  1111              TAD       STKBEG
326  3014              DCA       A14
327  2146              ISZ       CNT4       /SUMMED 4 YET?
330  5275              JMP       EACH       /NO
331  1144              TAD       SUM4       /YES. FIND DIFF. SCR.
332  4553              JMS  I    DFSCP
333  7100              CLL
334  1141              TAD       DFSUM      /ADD TO DIFSUM
335  7430              SZL
336  7240              STA
337  3141              DCA       DFSUM      /TRUNCATE IF TOO LARGE
340  2143              ISZ       EPDIV      /IS IT AN EPOCH YET?
341  5266              JMP       FOUR       /NO
342  1141              TAD       DFSUM      /YES. FIND MAXIMAL. . .
343  7110              CLL RAR              /EPOCH EACH MINUTE
344  7041              CIA
345  1104              TAD       MAXEP
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```
347   5353   JMP     .+4       /NO
350   1141   TAD     DFSUM     /YES. REPLACE OLD
351   7110   CLL RAR
352   3104   DCA     MAXEP
353   2137   ISZ     MINDIV    /IS IT A MINUTE YET?
354   5262   JMP     EPOCH     /NO
355   6002   IOF               /YES, READ LITE LEVEL
356   1363   TAD     .+5       /FROM A/D, CH.2
357   4066   JMS     A2D
360   3151   DCA     DATUPD
361   6001   ION
362   5367   JMP     .+5
363   0002   2
364   7000   NOP
365   7000   NOP
366   7000   NOP
367   4571   STORE             /AND STORE IN RECORDER
370   7402   HLT               /MEMORY
371   1104   TAD     MAXEP     /NOW GET MAXIMAL EPOCH
372   3151   DCA     DATUPD    /AND STORE IT IN NEXT
373   4571   STORE             /MEMORY LOCATION
374   7402   HLT
375   5242   JMP     MINIT
```

```
                    /PAGE 2


                    /COMPUTE DIFFERENCE SCOPE
                    *400
400  7402           DIFSCR,  HLT
401  3163                    DCA      LATEST     /STORE MOST RECENT SUM
402  1164                    TAD      BUFLOC     /SET UP BUFF PNTRS
403  3016                    DCA      A16
404  1174                    TAD      M11
405  3165                    DCA      BUFN
406  3340                    DCA      MINLO      /CLEAR DP ADDER
407  3341                    DCA      MINHI
410  7300           SUM,     CLA CLL             /SUM LAST 11 SUM4'S
411  1416                    TAD  I   A16
412  7510                    SPA
413  5223                    JMP      NEG
414  1340                    TAD      MINLO
415  3340                    DCA      MINLO
416  7430                    SZL
417  7001                    IAC
420  1341                    TAD      MINHI
421  3341                    DCA      MINHI
422  5231                    JMP      NEXT
423  1340           NEG,     TAD      MINLO
424  3340                    DCA      MINLO
425  7420                    SNL
426  7240                    STA
427  1341                    TAD      MINHI
430  3341                    DCA      MINHI
431  2165           NEXT,    ISZ      BUFN
432  5210                    JMP      SUM
433  1174                    TAD      M11
434  3165                    DCA      BUFN
435  3342                    DCA      PRDLO
436  3343                    DCA      PRDHI
437  7000                    NOP
440  7300           LX10,    CLA CLL             /MUY CURR VAL
441  1365                    TAD      BUFR+5     /BY 11
442  7510                    SPA
443  5253                    JMP      LNEG
444  1342                    TAD      PRDLO
445  3342                    DCA      PRDLO
446  7430                    SZL
447  7001                    IAC
450  1343                    TAD      PRDHI
451  3343                    DCA      PRDHI
452  5261                    JMP      LNXT
453  1342           LNEG,    TAD      PRDLO
454  3342                    DCA      PRDLO
455  7420                    SNL
456  7240                    STA
457  1343                    TAD      PRDHI
```

```
461  2165        LNXT.   ISZ      BUFN
462  5240                JMP      LX10
463  7100                CLL
464  1340                TAD      MINLO
465  7041                CIA
466  3340                DCA      MINLO
467  7430                SZL
470  7001                IAC
471  1341                TAD      MINHI
472  7041                CIA
473  3341                DCA      MINHI
474  7100                CLL
475  1342                TAD      PRDLO
476  1340                TAD      MINLO
477  3342                DCA      PRDLO
500  7430                SZL
501  7001                IAC
502  1343                TAD      PRDHI
503  1341                TAD      MINHI
504  3343                DCA      PRDHI
505  1164                TAD      BUFLOC
506  3016                TAD      A16
507  1164                TAD      BUFLOC
510  3015                DCA      A15
511  1174                TAD      M11
512  3165                TAD      BUFN
513  1415        SHUFL.  TAD   I  A15
514  3173                DCA      BUMP
515  1163                TAD      LATEST
516  3416                DCA   I  A16
517  1173                TAD      BUMP
520  3163                DCA      LATEST
521  2165                ISZ      BUFN
522  5313                JMP      SHUFL
523  1342                TAD      PRDLO
524  7510                SPA
525  7041                CIA
526  7002                BSW
527  7004                RAL
530  0147                AND      X177
531  5600                JMP   I  DFSCR


                 /
                 *540
540  0000        MINLO.  0
541  0000        MINHI.  0
542  0000        PRDLO.  0
543  0000        PRDHI.  0
544  0000        SCNT.   0
545  0000                0
546  0000                0
547  0000                0
```

```
551   0000            0
552   0000            0
553   0000            0
554   0000            0
555   0000            0
556   0000            0
557   0000            0
560   0000      BUFR, 0
561   0000            0
562   0000            0
563   0000            0
564   0000            0
565   0000            0
566   0000            0
567   0000            0
570   0000            0
571   0000            0
572   0000            0
```

```
                /PAGE 3

                /GENERATE TIME CODE (OCTAL MINUTES)
                *600
600   7402      CODET,  HLT             /ENTER EACH 4 A/D'S IF TFLAG SET
601   2133              ISZ     TCNTR   /TIME FOR ANOTHER DIGIT
602   5225              JMP     TOUT    /NO
603   1160              TAD     M10
604   3133              DCA     TCNTR
605   2131              ISZ     OCNTR   /YES, START OCTAL GROUP
606   5215              JMP     FLASH   /NO, OUTPUT DIGIT
607   1145              TAD     M14     /YES, SKIP DIGIT
610   3151              DCA     OCNTR
611   2130              ISZ     GRPS    /4 OCTAL GROUPS YET?
612   7410              SKP
613   3135              DCA     TFLAG   /YES, CLEAR TFLAG
614   5225              JMP     TOUT
615   6506      FLASH,  STLITE          /LITE ON
616   1126              TAD     TCODE
617   7104              CLL RAL         /GET NEXT MSB
620   3126              DCA     TCODE
621   7430              SZL             /BINARY 1 OR 0?
622   1127              TAD     M4      /1:HOLD LITE 5 UNITS
623   1176              TAD     M1      /0:HOLD LITE 1 UNIT
624   3134              DCA     CODE1
625   1134      TOUT,   TAD     CODE1   /HOLD LITE ON?
626   7500              SMA
627   6507              CLLITE          /NO, CLEAR IT
630   7001              IAC             /YES
631   3134              DCA     CODE1
632   5600              JMP I   CODET


                /STORE DATA
                *640
640   7402      STORES, HLT
641   6504              RCRA            /SAVE CRA
642   3154              DCA     CRATMP
643   1124              TAD     FLDFLG  /WHICH FIELD?
644   7650              SNA CLA
645   5251              JMP     .+4
646   1155              TAD     FLD1    /IF FLD 1 CHANGE FLDS
647   6505              WCRA
650   7300              CLA CLL
651   1151              TAD     DATWRD  /GET DATA
652   3417              DCA I   DATAP   /STORE IT
653   1154              TAD     CRATMP  /RESTORE CRA
654   6505              WCRA
655   7300              CLA CLL
656   1017              TAD     DATAP   /IS MEMORY FULL?
657   1156              TAD     MEMLIM
660   7650              SNA CLA
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662  2240        ISZ     STORES
663  5640        JMP I   STORES    /NO, RETURN +1
664  1124        TAD     FLDFLG    /YES, WHICH FLD?
665  7440        SZA
666  5640        JMP I   STORES    /FLD 1, RTRN & END
667  2124        ISZ     FLDFLG    /FLD 0, SWITCH TO FLD 1
670  7240        STA
671  3017        DCA     DATAP     /RESET DATA PNTR TO TOP
672  2240        ISZ     STORES
673  5640        JMP I   STORES    /RTRN +1


           /RECORDER MEMORY

           /MAXIMAL EPOCH ACTIVITY SCORE AND
           /LITE LEVEL FOR EACH MINUTE ARE
           /STORED IN ALTERNATE MEMORY LOCS
           /FROM LOC. 700 TO 5777 (FLD 0)
           /AND 10000 TO 15777 (FLD 1)

           *700



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