A microcomputer system for temperature biotelemetry

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A microcomputer (Apple II) system for recording body temperature measured by a commercially made, implantable biotelemetry device (Mini-Mitter) is described. The system includes an inexpensive radio receiver interface circuit and software written in BASIC and 6502 assembly language. The utility of the system is illustrated in a study that shows that various handling procedures (including that normally involved in rectal temperature measurement) elevate body temperature in rats.

Body temperature often serves as the primary dependent variable in studies of thermoregulation, circadian rhythms, and drug action. In recent years, it has become an increasingly popular measure in studies of drug tolerance and the role of behavioral processes (e.g., learning) in the development of tolerance (see review by Cunningham, Crabbe, & Rigter, in press). However, the most common technique for recording core body temperature from rodents over extended periods of time is rather tedious and time-consuming, inasmuch as it requires repeated manual insertion of a rectal probe (see, e.g., Mansfield & Cunningham, 1980; Siegel, 1978). Not only is this technique prone to error from several sources (e.g., variability in depth and duration of probe insertion, incorrect reading of thermometer), but there also is evidence that the handling involved in taking a rectal temperature actually alters body temperature (see, e.g., Briese & de Quijada, 1970).

This paper describes a microcomputer-based system for using a commercially made, implantable biotelemetry device to record body temperature automatically in freely moving rats. The system uses an inexpensive transistor radio that has been modified in a simple way to provide a digital signal input to an Apple II microcomputer. A software package consisting of an Applesoft BASIC program and a clock-interrupt-driven machine language routine permits continuous real-time evaluation of body temperature, both for visual display and permanent storage on floppy disk. In order to illustrate the utility of the system and to show the advantage of using biotelemetry to record body temperature, we also report data on the thermic effects of various handling procedures, including rectal temperature measurement.

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BIOTELEMETRY DEVICE

The biotelemetry device (Mini-Mitter Co., Inc., Sunriver, Oregon, Model M; approximate cost = \$38) consists of two thermistors and a battery-operated transmitter contained in a small, nontoxic, waterproof plastic capsule (12 x 19 mm, 2.3 g). The device emits an AM band signal at a rate proportional to the surrounding temperature (approximately 2.4 Hz between 35-40 °C). Each Mini-Mitter unit must be calibrated beforehand in a heated water bath, and the time interval between signal pulses (or the number of pulses per unit time) can be used to index temperature (.1°C resolution). The manufacturer specifies a transmission range of 2-3 ft and a battery life of 2-3 months.

RECEIVER INTERFACE CIRCUIT

The signal transmitted by the Mini-Mitter can be detected as a clicking sound from the speaker of an ordinary AM radio. In order to provide a digital input signal for the Apple II, the speaker from a 9-V transistor radio was replaced by a small board containing an IC circuit. This circuit (shown in Figure 1) detects the Mini-Mitter signal and outputs a short, positive square-wave pulse that can be delivered directly to a TTL ("pushbutton") input on the Apple II game-connector port.

The circuit consists of two main stages. In the first stage, a 20-ohm resistor (R1) has replaced the radio speaker, and the signal is capacitively coupled to the inverting input of a precision op-amp (LM308N) that is wired for single-polarity operation. The noninverting input is tied directly to the positive side of the power supply, which results in a normally high output level in the absence of an input signal. An input signal of sufficient magnitude will drive the output of the op-amp low. This will trigger the second stage of the circuit, a simple one-shot (NE555) that provides a timed output pulse for the computer. The duration of the one-shot

Figure 1. Circuit diagram for the radio receiver interface. The numbers next to the leads from each IC indicate the pin numbers on 8-pin DIPs. The output lead, +5-V, and ground terminals all connect to pins on the Apple II game-connector port.

pulse must be shorter than the shortest interval between signal pulses, but of sufficient duration to be detected by the computer program (see Software section). In the circuit shown in Figure 1, the duration of the output pulse is approximately 30-40 msec and can be varied by changing the values of the resistor and capacitor connected to Pins 6 and 7. The output pulse also activates an LED mounted on the side of the radio. This provides visual feedback that is helpful for adjusting the radio controls.

In order to minimize noise, the radio should be tuned to a relatively "quiet" part of the AM band (the lowest frequency, 550 kHz, works well). Sensitivity (range) can be controlled simply by adjusting the volume knob on the radio. The entire circuit, including the radio, can be powered by the +5-V supply available at the game-connector port of the Apple II. The range of the receiver can be increased somewhat by increasing the supply voltage, up to 9-10 V. However, this requires an external power supply and additional circuitry to convert the one-shot pulse to TTL levels.

The radio used in this application (Dyna-Tone, Model 768) was obtained from a local variety store at a cost under \$4.00. The two IC chips are available in 8-pin DIPs and can be mounted end to end in a single 16-pin DIP socket on a small circuit board (e.g., Radio Shack No. 276-159) that fits inside the radio case. The total cost for the radio and parts was less than \$9.00.

SOFTWARE

The software for recording body temperature consists of an Applesoft BASIC program (SAMPLE.MITTER) and a clock-interrupt routine written in 6502 assembly language (MINIMITTER.1). Complete commented listings appear in the Appendix. These programs were developed for an Apple II+ microcomputer with 48K RAM memory and at least one disk drive (DOS 3.3). In addition to the receiver interface circuit, the only

other required hardware is a clock card capable of providing a 100-Hz interrupt pulse. The system uses a simple homemade clock card plugged into peripheral slot 4, but it also works with a Mountain Hardware or similar commercially made clock card.

The software is designed to run an experimental session in which multiple timed samples (up to 255 samples, each 1-256 sec long) are taken at fixed intervals (0-255 sec) and stored in memory. The raw datum is the average interval between signal pulses during each sample period (.01-sec resolution). Using the slope and intercept of the Mini-Mitter's calibration curve, these values are transformed to temperature (in °C), and both the mean interval and the temperature are displayed on the monitor screen at the end of each sample period. The program also displays a countdown timer (showing the number of seconds remaining in the sample or intersample period), a signal counter, the duration of the most recent intersignal interval (in milliseconds), the sample number, and whether the sample is "on" or "off." The session terminates automatically after the appropriate number of samples has been collected, and the experimenter is given an opportunity to store the data on disk.

The heart of the program is the machine language clock-interrupt routine that is responsible for precise timing of the sample and intersample periods and for timing and evaluating the intervals between Mini-Mitter signals. This routine is loaded into memory (as a binary file) by the Applesoft BASIC program (Line 90). After the BASIC program receives the session parameters from the experimenter and initializes the program variables, the interrupt routine is initialized (Line 220). A screen message then prompts the experimenter to "press any key" to begin the session. The session actually begins 2-3 sec later with the first sample period. At this point, the BASIC program enters a loop (Lines 250-370) that provides a continuous updating of the screen information described earlier.

While Applesoft executes the BASIC program loop, the clock-interrupt pulse "simultaneously" enables the machine language routine to be executed 100 times per second. Each time it is entered, this routine checks the status of the Mini-Mitter signal and updates the session timers. The interval between successive Mini-Mitter signals is timed simply by counting the number of clock pulses that occur between the onsets of one-shot pulses from the receiver interface. Because those pulses will not be synchronized with the clock card, their duration must be at least as long as the interval between clock pulses. Otherwise, input signals may be missed. Since the program looks for signal onsets, longer duration input pulses will cause no problem as long as there is at least one clock period (10 msec) between the offset of one input pulse and the onset of the next.

While monitoring Mini-Mitter signals, the clock-interrupt routine does more than simply count the number of input pulses. It also provides a way of dealing with the two major kinds of signal error. One kind of error comes from sources of radio interference in the laboratory environment. For example, the operation of an electromechanical device (relay, solenoid) in the same room as the receiver is quite capable of triggering an output pulse. The other kind of error occurs when the Mini-Mitter is temporarily out of range (i.e., a missing signal). Changes in the orientation of the transmitter coil relative to the antenna coil can sometimes result in signal loss when the animal moves around the chamber. Reception is best when the loops of both coils are in the same plane. To combat these problems, the program evaluates the time interval between successive input pulses against two kinds of criteria—one based on the absolute value of the intersignal interval and the other based on the relative change in interval duration from one signal to the next. If the interval of time preceding a given input signal does not meet both criteria, it is not included in the computation of average intersignal interval for that sample period. Thus, when errors occur, the sample value is based on less than 100% of the specified sample period.

The criterion values are passed to the machine language routine during the initial portion of the BASIC program (Line 200) and, if necessary, can be changed easily by the experimenter. In our studies, the absolute lower and upper limits for intersignal intervals have been set at 200 and 500 msec, respectively. On average, across Mini-Mitters, this permits temperatures ranging between 33-43°C. The relative change criterion has been set at 20 msec. In other words, a given interval is accepted only if it is within 20 msec (in either direction) of the most recent "good" interval (and within the absolute limits). If the error condition persists for a long period of time, it is possible for the program to begin to reject legitimate inputs on the basis of the relative-change criterion. To minimize this problem, the program automatically readjusts the criterion signal interval whenever an error condition lasts longer than 2 con-

secutive seconds (i.e., the most recent interval is used as the value for the "last good interval"). This ordinarily corrects any problem in a matter of seconds if the signal is good. So far, this overall approach for handling signal errors has been quite useful.

At the end of each sample period, the machine language routine automatically passes the sample data (i.e., sample number, signal count, sum of "good" intersignal intervals) to BASIC integer variables (SN%, LC%, and LS%, respectively). The BASIC program then computes the mean intersignal interval, converts that to temperature, and stores the information in a two-dimensional array, D() (Lines 310-360). The BASIC program also provides feedback on the extent of any error problems by displaying and storing the percentage of time during each sample period in which "acceptable" signals were recorded.

The session ends when the sample number equals the number of samples originally requested by the experimenter (Line 370). If desired, the contents of the data array can then be transferred to a sequential text file stored on floppy disk (Lines 390-440). The BASIC program shown in the Appendix can be expanded easily to provide summary statistics and a high-resolution graphics display of successive sample values.

EFFECT OF HANDLING ON BODY TEMPERATURE

In order to illustrate the utility of the present system and to show the advantages of biotelemetry, body temperature was recorded automatically from implanted Mini-Mitters in rats after they were picked up, pricked with a hypodermic needle, handled for rectal temperature measurement, or left undisturbed.

Method

The subjects were 12 adult male albino rats weighing an average of 638 g. Each rat was anesthetized with halothane gas, and a Mini-Mitter was implanted surgically. The device was coated with Parafin/Elvax® to protect it from corrosion and had been previously calibrated in a heated water bath (range = 35-41°C). A 1-2-cm ventral midsagittal incision was made about 5 cm below the diaphragm through both the skin and peritoneum, and a Mini-Mitter was inserted into the intraperitoneal cavity.

Temperature monitoring took place inside one of four identical clear plastic cages (23 x 20.5 x 21 cm) centered on an acrylic platform over the transistor radio. With this arrangement, an implanted Mini-Mitter always remained less than 21 cm from the radio antenna. Each cage was contained in a darkened, ventilated, sound-attenuating chamber (ambient temperature = 24°C).

On each of 7 consecutive days, each rat was placed in the experimental chamber for 150 min. On the first 3 days and on the final day, the animals were not disturbed. On the other days, each rat was subjected to one of three handling procedures 60 min after the session began. In one condition (Handled), the rat was picked up, placed in a plastic shoebox cage for 75 sec, and then returned to the test chamber. A second condition (Handled/Injection) involved a similar sequence, but after 60 sec in the shoebox, the rat was picked up and a 25-ga, 5/8-in.

hypodermic needle was inserted into the abdomen for 15 sec to mimic an ip injection (no fluid was actually injected). In the third condition (Handled/Rectal Probe), the rat was picked up and wrapped in a towel for 60 sec while a lubricated, flexible thermistor probe (YSI Model 402) was inserted 6 cm into the rectum. The rats were assigned randomly to groups of four, and each group received these three treatments in a different order.

The Mini-Mitter output was sampled during consecutive 1-min periods (i.e., 0-sec intersample interval), and temperature was averaged over 5-min blocks during each session. These data were collected with a version of our software written for the PDP-8/F, such that four subjects could be monitored simultaneously.

Results

On the handling treatment days, an average of 80.5% (SEM = 2.4) of each sample period was found to be acceptable according to the error-detection criteria. Body temperatures were elevated at the beginning of each session (mean = 38.6°C), presumably due to the handling involved in transporting the rat to the experimental room and placing it in the test chamber. After the animal was placed in the chamber, temperatures declined gradually over time within each session, with the greatest changes occurring during the 1st hour (about 0.8°C).

Figure 2 shows mean body temperatures recorded for 5-min periods just before and for 90 min after each of the handling treatments. The data shown for the Not Handled comparison were obtained by averaging temperatures recorded on the days just before and just after the handling-treatment days. As can be seen, body temperatures continued to decline under the Not Handled

condition. However, each of the three handling treatments produced a hyperthermic reaction that persisted long after the animal was returned to the test chamber. Furthermore, the magnitude and duration of the increase in temperature varied as a function of handling treatment. Rectal temperature measurement (Handled/Rectal Probe) produced the largest and most persistent elevation.

The data shown in Figure 2 were subjected to a treatment $\times$ time periods analysis of variance that yielded a significant main effect of time periods [$F(18,198) = 25.4$] and a significant interaction [$F(54,592) = 2.3$]. Follow-up analyses that separately compared each handling treatment with the Not Handled condition also revealed statistically significant interactions, indicating that each handling procedure affected body temperature.

CONCLUSION

The microcomputer-controlled biotelemetry system described here offers a relatively inexpensive means of obtaining continuous measures of core body temperature. This approach not only eliminates the need to handle the animal, but it also reduces the experimenter's labor and increases the reliability of the temperature measurements. The data presented here establish the utility of this system and confirm previous findings that handling (including that commonly used to obtain rectal temperature measurements) can have a dramatic impact on core temperature (Blasig, Holtt, Bauerle, & Herz, 1978; Briese, 1965; Briese & de Quijada, 1970; Miles, 1962).

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Figure 2. Mean body temperature (in °C) recorded for 5-min periods just before (B) and for 90 min after various handling treatments (n = 12).

APPENDIX Program Listings

```

10 REM SAMPLE.MITTER
20 REM C.L. CUNNINGHAM (1983)
30 REM
40 LCZ = 0:LSZ = 0:SNZ = 0: REM RESERVE FOR DATA STORAGE
50 VARIABLES = 37376: REM VARIABLE LIST
60 HIMEM: VA = 1: REM PROTECT INTERRUPT ROUTINE
70 DEF FN A(X) = 5 - LEN ( STR$ (X))
80 D$ = CHR$ (4):G$ = CHR$ (7)
90 PRINT D$;"BLOAD MINIMITTER.1.OBJO": REM LOAD MACHINE CODE
100 SESFLG = VA:SD = VA + 2:IS = VA + 3:SF = VA + 4:HS = VA + 5:TI = VA + 6:ES = VA + 7:C = VA + 8:L = VA + 13
110 TEXT : HOME : INVERSE : PRINT "SAMPLE.MITTER": NORMAL : PRINT
120 REM X=INTERVAL IN MSEC; Y=TEMP IN DEGREES C
130 PRINT : PRINT "ENTER CALIBRATION PARAMETERS:"
140 PRINT "      SLOPE = ";G$;: INPUT SLOPE: PRINT "      INTERCEPT = ";G$;: INPUT INERCEPT
150 REM INPUT SESSION PARAMETERS
160 PRINT : PRINT "TOTAL # OF SAMPLES (<256) = ";G$;: INPUT TN
170 PRINT : PRINT "SAMPLE DURATION (SEC)(1-255) = ";G$;: INPUT D: POKE SD,D
180 PRINT : PRINT "SECONDS BETWEEN SAMPLES (<256) = ";G$;: INPUT X: POKE IS,X
190 DIM D(TN,2): REM DATA STORAGE (DEGREES, MEAN INTERVAL, % REJECT)
200 POKE VA + 14,50: POKE VA + 15,20: POKE VA + 16,2: POKE VA + 20,1: REM SET REJECTION LIMITS & RESET FLAG
210 FOR X = C TO C + 3: POKE X,0: NEXT : POKE HS,1: POKE TI,3: REM CLEAR DATA STORAGE AND SET TIMERS
220 CALL VA + 21: REM SETUP INTERRUPT & CLEAR FLAGS
230 PRINT : PRINT "PRESS ANY KEY TO BEGIN SESSION:";G$;: GET AS: POKE SE,1: REM BEGIN SESSION WITH A SAMPLE
240 HOME : INVERSE : PRINT "SAMPLE.MITTER": NORMAL
250 POKE 36,0: POKE 37,3: PRINT : IF PEEK (SF) = 0 THEN PRINT "SAMPLE OFF";: GOTO 270
260 INVERSE : PRINT "SAMPLE ON ";: NORMAL
270 X = PEEK (TI): PRINT " (SECONDS REMAINING = "; SPC( FN A(X));X;"")
280 X = PEEK (C) + PEEK (C + 1) * 256: PRINT : PRINT "CURRENT SIGNAL COUNT = "; SPC( FN A(X));X
290 X = PEEK (L): PRINT : PRINT "CURRENT SIGNAL INTERVAL (MSEC) = "; SPC( FN A(X));X * 10
300 IF PEEK (ES) = 0 THEN 250: REM LOOP TIL END OF SAMPLE
310 POKE ES,0: PRINT : PRINT : PRINT "LAST SAMPLE DATA <#";SNZ;">": PRINT
320 IF LCZ = 0 THEN X = 0: GOTO 340
330 X = INT (LSZ / LCZ * 10): REM COMPUTE MEAN INTERVAL
340 PRINT "MEAN INTERVAL (MSEC) = "; SPC( FN A(X));X:D(SNZ,1) = X
350 X = SLOPE * X + INERCEPT: X = INT (X * 10): PRINT "MEAN TEMPERATURE (C) = "; SPC( FN A(X));X / 10:D(SNZ,0) = X / 10
360 X = INT (LSZ * 10 / (D * 10)): PRINT "SAMPLE PERIOD ACCEPTED = "; SPC( FN A(X));X;"X":D(SNZ,2) = X
370 IF SNZ < > TN THEN 250: REM LOOP TIL END OF SESSION
380 PRINT : PRINT "SESSION OVER": PRINT "STORE DATA TO DISK? (Y/N) ";G$;: INPUT AS: IF AS < > "Y" THEN END
390 PRINT : PRINT "FILENAME = ";G$;: INPUT FS
400 PRINT : PRINT "INSERT STORAGE DISK IN DRIVE AND": PRINT "PRESS ANY KEY TO SAVE DATA: ";G$;: GET AS: PRINT
410 PRINT D$;"OPEN ";FS
420 PRINT D$;"WRITE ";FS
430 FOR X = 1 TO TN: FOR Y = 0 TO 2: PRINT D(X,Y): NEXT : NEXT
440 PRINT D$;"CLOSE ";FS
450 END

```

SOURCE FILE: MINIMITTER.1

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1 *****
0000: 2 *
0000: 3 * MINIMITTER.1
0000: 4 * CLOCK-INTERRUPT ROUTINE
0000: 5 * C.L. CUNNINGHAM (1983)
0000: 6 *
7 *****
C061: 8 PBO EQU $C061 ;GAME PORT PBO INPUT
C400: 9 CLRCLK EQU $C400 ;CLOCK IN SLOT 4
----- NEXT OBJECT FILE NAME IS MINIMITTER.1.OBJO
9200: 10 ORG $9200
9200:00 11 SESFLG DFB $0 ;SESSION FLAG
9201:00 12 SMPNUM DFB $0 ;SAMPLE # (MAX=255)
9202:00 13 SMPDUR DFB $0 ;SAMPLE DURATION (1-256 SEC)
9203:00 14 INTSMP DFB $0 ;INTER-SAMPLE INTERVAL (0-255 SEC)
9204:00 15 SMPFLG DFB $0 ;SAMPLE FLAG
9205:00 16 HNDSEC DFB $0 ;10-MSEC TIMER
9206:00 17 TIMER DFB $0 ;SECONDS TIMER
9207:00 18 EOSFLG DFB $0 ;END-OF-SAMPLE FLAG
9208:00 00 19 COUNT DFB $0,$0 ;SIGNAL COUNTER
920A:00 00 20 SUMISI DFB $0,$0 ;SUM SIGNAL INTERVALS
920C:00 21 SIGTIM DFB $0 ;SIGNAL TIMER (10-MSEC)
920D:00 22 LASTIM DFB $0 ;LAST SIGNAL INTERVAL
920E:00 23 HILIM DFB $0 ;HIGH INTERVAL LIMIT
920F:00 24 LOLIM DFB $0 ;LOW INTERVAL LIMIT
9210:00 25 RELTIM DFB $0 ;RELATIVE CHANGE LIMIT
9211:00 26 INPUT DFB $0 ;CURRENT INPUT
9212:00 27 LSTIMP DFB $0 ;LAST INPUT
9213:00 28 SUMREJ DFB $0 ;SUM REJECTED INTERVALS
9214:00 29 RESET DFB $0 ;CRITERION RESET FLAG
30 *****
9215:A9 2F 31 SETUP LDA #>CLOCK ;SETUP INTERRUPT POINTERS
9217:8D FE 03 32 STA $3FE
921A:A9 92 33 LDA #<CLOCK
921C:8D FF 03 34 STA $3FF
921F:A9 00 35 LDA #0 ;CLEAR FLAGS
9221:8D 00 92 36 STA SESFLG
9224:8D 04 92 37 STA SMPFLG
9227:8D 07 92 38 STA EOSFLG
922A:8D 00 C4 39 STA CLRCLK ;CLEAR CLOCK INTERRUPT
922D:58 40 CLI ;ENABLE INTERRUPT
922E:60 41 RTS
42 *****
922F:98 43 CLOCK TYA ;SAVE Y REGISTER
9230:48 44 PHA
9231:AD 00 92 45 LDA SESFLG ;SESSION ON?
9234:D0 03 46 BNE RUN
9236:4C 28 93 47 JMP EXIT ;NO:EXIT INTERRUPT ROUTINE
9239:EE 0C 92 48 RUN INC SIGTIM ;YES:INCREMENT SIGNAL TIMER
923C:AD 61 C0 49 LDA PBO ;INPUT SIGNAL ON?
923F:8D 11 92 50 STA INPUT
9242:30 03 51 BMI CHKSIG
9244:4C C6 92 52 JMP CHKTIM ;NO:CHECK TIMING

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9247:AD 12 92 53 CHKSIG LDA LSTINP ;YES:OFF-ON TRANSITION?
924A:10 03 54 BPL NEWSIG ;NO:CHECK TIMING
924C:4C C6 92 55 JMP CHKTIM ;YES:CHECK SIGNAL LIMITS
924F:AD 0C 92 56 NEWSIG LDA SIGTIM ;CHECK VS ABSOLUTE LIMITS
9252:CD 0F 92 57 CMP LOLIM ;CHECK VS RELATIVE LIMITS
9255:90 4E 58 BCC REJECT
9257:CD 0E 92 59 CMP NILIM
925A:B0 49 60 BCS REJECT
925C:CD 0D 92 61 CMP LASTIM ;CHECK VS RELATIVE LIMITS
925F:F0 1C 62 BEQ OKSIG
9261:B0 0B 63 BCS LONGER
9263:6D 10 92 64 SHRTER ADC RELLIM
9266:CD 0D 92 65 CMP LASTIM
9269:B0 12 66 BCS OKSIG
926B:4C A5 92 67 JMP REJECT
926E:18 68 LONGER CLC
926F:AD 0D 92 69 LDA LASTIM
9272:6D 10 92 70 ADC RELLIM
9275:CD 0C 92 71 CMP SIGTIM
9278:B0 03 72 BCS OKSIG
927A:4C A5 92 73 JMP REJECT
927D:EE 08 92 74 OKSIG INC COUNT ;"GOOD" SIGNAL
9280:D0 03 75 BNE OK ;INCREMENT COUNTER
9282:EE 09 92 76 INC COUNT+1 ;(DOUBLE PRECISION)
9285:18 77 OK CLC
9286:AD 0C 92 78 LDA SIGTIM ;RESET CRITERION
9289:8D 0D 92 79 STA LASTIM
928C:6D 0A 92 80 ADC SUMISI ;UPDATE SUM OF SIGNAL INTERVALS
928F:8D 0A 92 81 STA SUMISI
9292:A9 00 82 LDA #0
9294:6D 0B 92 83 ADC SUMISI+1 ;(DOUBLE PRECISION)
9297:8D 0B 92 84 STA SUMISI+1
929A:A9 00 85 LDA #0 ;CLEAR RESET VARIABLES
929C:8D 13 92 86 STA SUMREJ
929F:8D 14 92 87 STA RESET
92A2:4C C1 92 88 JMP CLEAR ;CLEAR SIGNAL TIMER
92A5:AD 14 92 89 REJECT LDA RESET ;RESET FLAG SET?
92A8:D0 11 90 BNE RSET ;YES:READJUST CRITERION
92AA:18 91 CLC ;NO:SUM REJECT INTERVALS
92AB:AD 0C 92 92 LDA SIGTIM
92AE:6D 13 92 93 ADC SUMREJ
92B1:8D 13 92 94 STA SUMREJ
92B4:C9 C8 95 CMP #200 ;<2 CUMULATIVE SEC ERROR?
92B6:90 09 96 BCC CLEAR ;YES:CLEAR SIGNAL TIMER
92B8:EE 14 92 97 INC RESET ;NO:SET RESET FLAG
92BB:AD 0C 92 98 RSET LDA SIGTIM ;READJUST CRITERION
92BE:8D 0D 92 99 STA LASTIM
92C1:A9 00 100 CLEAR LDA #0
92C3:8D 0C 92 101 STA SIGTIM ;CLEAR SIGNAL TIMER
92C6:CE 05 92 102 CHKTIM DEC HNDSEC ;DECREMENT TIMERS
92C9:D0 5D 103 BNE EXIT ;EXIT UNLESS INTERVAL IS OVER
92CB:A9 64 104 LDA #100
92CD:8D 05 92 105 STA HNDSEC
92D0:CE 06 92 106 DEC TIMER

92D3:D0 53 107 BNE EXIT
92D5:AD 04 92 108 LDA SMPFLG ;END OF INTERVAL:A SAMPLE PERIOD?
92D8:D0 1D 109 BNE STOP ;YES:END SAMPLE
92DA:EE 04 92 110 START INC SMPFLG ;NO:START SAMPLE (SET FLAG)
92DD:EE 01 92 111 INC SMPNUM ;INCREMENT SAMPLE COUNTER
92E0:AD 02 92 112 LDA SMPDUR
92E3:8D 06 92 113 STA TIMER ;SET SAMPLE DURATION TIMER
92E6:A9 00 114 LDA #0 ;CLEAR DATA REGISTERS
92E8:8D 08 92 115 STA COUNT
92EB:8D 09 92 116 STA COUNT+1
92EE:8D 0A 92 117 STA SUMISI
92F1:8D 0B 92 118 STA SUMISI+1
92F4:4C 28 93 119 JMP EXIT ;AND EXIT
92F7:A9 00 120 STOP LDA #0 ;END SAMPLE (CLEAR FLAG)
92F9:8D 04 92 121 STA SMPFLG
92FC:EE 07 92 122 INC EOSFLG ;SET END-OF-SAMPLE FLAG
92FF:A0 02 123 LDY #2 ;TRANSFER DATA TO APPLESOFT
9301:AD 09 92 124 LDA COUNT+1
9304:91 69 125 STA ($69),Y
9306:C8 126 INY
9307:AD 08 92 127 LDA COUNT
930A:91 69 128 STA ($69),Y
930C:A0 09 129 LDY #9
930E:AD 0B 92 130 LDA SUMISI+1
9311:91 69 131 STA ($69),Y
9313:C8 132 INY
9314:AD 0A 92 133 LDA SUMISI
9317:91 69 134 STA ($69),Y
9319:A0 11 135 LDY #17
931B:AD 01 92 136 LDA SMPNUM
931E:91 69 137 STA ($69),Y
9320:AD 03 92 138 LDA INTSMP ;IF INTERSAMPLE INTERVAL = 0,
9323:F0 85 139 BEQ START ;THEN START NEXT SAMPLE
9325:8D 06 92 140 STA TIMER ;OTHERWISE, SET INTERVAL TIMER
9328:AD 11 92 141 EXIT LDA INPUT ;UPDATE INPUT MEMORY
932B:8D 12 92 142 STA LSTINP
932E:68 143 PLA ;RESTORE Y-REGISTER
932F:A8 144 TAY
9330:AD 00 C4 145 LDA CLRCLK ;CLEAR CLOCK INTERRUPT
9333:A5 45 146 LDA $A5 ;RESTORE A
9335:40 147 RTI ;RETURN FROM INTERRUPT

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*** SUCCESSFUL ASSEMBLY: NO ERRORS