A broadband digitizing rat detector: Simultaneous recording from all sound frequencies in the range of rat ultrasonic vocalizations

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A system is described that digitizes rodent vocalizations after the signals have passed through a spectrum analyzer. The system's capacity to record simultaneously from all frequencies in a range selected by the experimenter is demonstrated. In the graphic display, both single and simultaneous multiple vocalizations of rats ranging freely in large experimental rooms are presented. The capacity of this system to record simultaneous vocalizations in a form that permits rapid analysis of many of the parameters of the signals is especially useful in the analysis of rodent social behavior.

A number of recording and analysis methods have been developed to study rodent ultrasonic vocalizations. The majority of these techniques use either analog recordings or presence-absence signals associated with the use of narrow-band detection equipment. The more notable methods currently reported have included (1) inspection of oscilloscope tracings, (2) magnetic tape recording and replay at a slower speed, (3) application of narrow-band heterodyne circuitry that translates ultrasound signals into audible sound, (4) use of multichannel circuits tuned to several localized frequency bands having multiple output pulses amenable for use with either analog tape or digital inputs, and (5) application of sonographic instrumentation as a display medium for subsequent analysis and presentation (Griffin, 1958; Harrison & Holman, 1978; Pye & Flinn, 1964; Sales & Pye, 1974).

The hardware/software system described here was

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developed utilizing fast Fourier transform hardware in combination with a real-time computer data acquisition system. The resulting system encompasses broadband frequency spectra analyses (e.g., 0-50 or 0-100 kHz) with the ability to control sampling based on selective criteria selected during the computer start-up sequence.

HARDWARE DESIGN AND OPERATION

The hardware system schematic is shown in Figure 1. A 47.5-cm-diameter transparent parabolic microphonic (Dan Gibson) is modified and fitted with a Brüel and Kjaer (B&K) precision microphone (Type 4135) and preamplifier (Type 2618). This assembly is then mounted on a movable boom, providing directional orientation of the microphone. An audio output transformer/power supply (B&K Type 2801) furnishes power to the microphone and preamplifier. The output transformer, strapped for 50-ohm unbalanced operation, is connected to a Tektronix spectrum analyzer (Type 5L4N) with oscilloscope module (Type R5110).

The spectrum analyzer provides two important output signals that serve as input for the interface signal conditioning unit. These two signals are (1) video out,

Figure 1. Hardware system schematic.

a +2-V full-scale signal that is proportional to the amplitude of the applied signal, and (2) external in/out, which is a 0- to 5-V ramp on which 0 V is coincident with the initiation of a spectrum sweep. In all, the time associated with the retrace of the ramp signal accounts for a 14-msec hysteresis added to the total time base when a 100-msec full-scale spectrum sweep is selected.

Triggering the Digital Equipment Corporation (DEC) PDP-11/04 computer's real-time clock (KW11-K) at the commencement of each frequency/sweep of the spectrum analyzer requires converting the retrace portion of the ramp signal to a positive-pulse 0- to +5-V TTL signal. This is accomplished by differentiating the sweep ramp voltage. The differentiating circuit, consisting of the inductance of the input transformer and the appropriate phasing of the primary and secondary windings, gives a positive-pulse voltage at retrace time. The 2N3415 buffer transistor amplifier provides a positive-going transition when the ramp is zero, which triggers the positive input of the 74L123 one-shot. The output pulse of the one-shot is long enough for the computer's real-time clock Schmitt trigger input.

The computer's analog-to-digital converter utilizes an analog range of 10 V full scale. A 741 operational amplifier is wired in a noninverting configuration with an adjustable gain from 2 to 11. (The amplifier circuit is also offset by -5 V to allow the utilization of the full-range analog-to-digital converter.) The back-to-back 1N914 diodes provide input protection to the 741, and a 100-ohm resistor is employed for output current sinking limitation.

The signal conditioning PDP-11 macro program (Program 1; see appendix) is an interrupt-driven series of routines that performs analog-to-digital conversions of the video output signal from the Tektronix 5L4N

spectrum analyzer contingent upon real-time clock interrupts. Because the Tektronix 5L4N's time base is equivalent to the frequency spectra, the sampling rate determines the resolution of the sound spectra collected. In this program, a 1-msec sample interval yields 100 equal-interval samples per 100-msec epoch. An epoch, in this case, denotes the duration of the interval of time required to translate incoming sound spectra into a frequency-by-amplitude graph, preceded by a 14-msec hysteresis. By selecting a 0- to 50-kHz full-scale bandwidth setting (i.e., one point per 500 Hz), a good trade-off can be achieved between well resolved sampling of sound spectra and limiting measurement artifacts associated with increased frequency bandwidth and sampling rate.

Upon start-up of Program 1, the user is first presented with several lines of text describing the program's operation, followed by the time and date from the command file of the system's monitor program. The program prompts the user to "make sure date and time are correct" and asks for the output file name. Upon receipt of these data, the program sets the system clock, if necessary, and assigns an output channel and file name to the user's disk directory in preparation for output. The user is then informed of the maximum output file length available, in 256 16-bit-word blocks, and is queried for the 5L4N spectrum analyzer's frequency span per division setting (in kilohertz, with 5 kHz as the default) and the input amplitude thresholds for 6- to 15-kHz, 16- to 25-kHz, and 26- to 35-kHz frequency bands. These three threshold settings provide the user with the capability of differentially weighting each of the three frequency bands, in order to maximize the collection of a given bandwidth of sound spectrum. The values to be input range from 0 (highest sensitivity) to

255 per each 500 Hz within the bandwidth (lowest sensitivity). A zero setting is the system's default condition. Following this, the user is asked for the number of epochs to be skipped. This action allows the user an additional means of controlling the sample density of incoming spectral epochs eligible for storage (the default condition is one skipped epoch). Finally, this is followed by a prompt for comments and notations about the recording session (a maximum of 70 alphanumeric characters is allowed).

Upon completion of the interactive prompt sequence, the program writes these data into the first block of the disk file. Subsequently, the program establishes the necessary memory space to store the incoming sound spectra data. The program then establishes a series of interrupt vector addresses for all the interrupt service routines, enables them for operation, and then jumps to an idling loop to await interrupt processing. There are four interrupt service routines that function as the core of the data acquisition system: (1) the analog-to-digital conversion and amplitude threshold acceptance interrupt service routine, (2) the Tektronix 5L4N start pulse/Schmitt trigger/real-time clock timing routine, (3) a 60-Hz line clock interrupt service routine, and (4) a console keyboard input service routine.

At the onset of a typical data capture event, the Tektronix 5L4N issues a negative-going pulse. As 0 V is intersected, the interface circuit translates this into a positive-going step, which fires the real-time clock's Schmitt trigger and enables the start pulse/real-time clock's interrupt service routine. This routine complies by loading a 1-msec duration delay into the real-time clock's countdown timing register and establishes a repeat mode of operation for the clock. The analog-to-digital converter is also enabled to allow the real-time clock interrupts to initiate a conversion, followed by a return into the main idling loop. When the real-time clock generates an interrupt, the analog-to-digital converter starts a conversion. When the conversion process is completed, the analog-to-digital converter in turn generates another interrupt, initiating the transfer of the content of the analog-to-digital output data register into the memory space. This routine also determines whether or not the epoch currently being digitized is finished (i.e., the first 98 points have been taken), followed by a return to the main idling loop. If the epoch has been completely digitized, this routine will test the collected data to determine if they conform to the selection criteria input during system start-up. If all of the criteria are met, the current record is kept; otherwise, it is ignored. This routine also determines if a data block is filled and sets a flag signifying that the data are to be transferred to disk upon exiting to the main idling loop. In addition, the analog-to-digital conversion routine also redirects its data buffer pointer to an alternate memory space in lieu of the completion of a memory-to-disk transfer. The last two interrupt service

routines mainly serve to increment the 32-bit system line time clock. Finally, the keyboard interrupt routine sets a flag that is subsequently tested in the idle loop to determine whether or not to write an end-of-file mark to the disk and halt the program when an appropriate console key is input.

SYSTEM DEMONSTRATION

Method

This spectrum analysis recording system has been part of an ongoing program to study social behavior of free-ranging rats in large enclosures. The enclosures, measuring 2.74 x 5.49 x 3.66 m (Calhoun, 1976), contain food and water acquisition hardware in addition to an animal motion and identification system (Friauf, 1969; Olson, 1974). Each enclosure also contains two sets of three levels of shelving, with eight nest boxes at each level. Animals gain access to the nest sites by climbing staircases at the ends of each shelf. Recordings are obtained by placing the recording system's parabolic microphone into the enclosure via overhead observation windows.

Four rodent vocalizations were selected for presentation. In all cases, these recordings were in excess of 10 sec in duration. Three of the observations followed the experimenter's (J.L.H.) disturbance of an ongoing behavior by holding open the door to an enclosure for 1 min; the fourth was recorded near the end of and following a series of copulatory bouts between two males and a female. A series of graphical analysis programs was developed that generated plots of these vocalizations, either to emulate sonographic presentation (i.e., a format frequently found in the literature) or to further characterize the observed "songs" in more detail.

Results and Discussion

Figure 2, Column 1, A, B, C, and D, shows a frequency by time by amplitude (shading) sonographic presentation of all four calls. The first plot (A1) shows the postejaculatory song tracing; the second (B1) and third (C1) show calls emitted following an experimental disturbance. In both cases, the calls were quite similar in form, in addition to being comparable to the observed postejaculatory song. In the fourth plot (D1) is an incidence in which, apparently, two animals began to sing simultaneously following an experimental disturbance. It appears that both animals began singing at about 22 kHz; however, the two signals split into two separate frequency bands, an 18- to 22-kHz band and a 23- to 30-kHz band, respectively. Further, recordings subsequent to this initial set have shown that multiple songs similar to the one shown here are a relatively frequent occurrence.

In order to further analyze these songs, a series of programs were written to scan each spectrum sweep of each song's data file, identify the frequency of the maximum sound amplitude, and plot them as shown in Figure 2, Column 2, Plots A2-D2. These data were then sorted into bins of 500-Hz width and plotted as frequency polygons in Column 3, Plots A3-D3. This procedure produced a collective facsimile analogous to performing a Fourier transform over the entire vocaliza-

Figure 2. Graphic representation of four rat vocalizations, A, B, C, and D. See text for a description of the three types of presentation of each vocalization. Standard format for each graph is 8.5 x 11 in.

tion interval for each song. It is interesting to note that Plots A3 and B3 show a lower amplitude, lower frequency sideband, indicative of repetitive upswEEPing tonal changes within calls. In C3, there is a suggestion of a lower amplitude, but higher frequency sideband that may indicate only occasional upswEEPing tonal changes. The small sample size in C (145 records vs. more than 400 for the others) may be a contributing factor to the apparent difference. In Plot D3, there is extensive frequency shifting in both modes; the upper mode has a lower overall amplitude in this plot because the frequency shifted over a broader range than in the lower mode.

It was further observed that during emission of these and subsequent rodent calls, both the frequency and amplitude tended to modulate over time within and

between calls. To verify this observation, the data were analyzed as to each call's periodicity in amplitude and frequency, and the combined periodicities (i.e., the duration of a peak-to-peak amplitude or frequency interval) of the four recordings were compared. The modal value of the prevalent peak-to-peak durations of all calls reaching a comparable amplitude and of all those reaching a comparable frequency was about 1.5-2.5 sec. These variations in periodicity support the experimenter's direct observation of frequency and amplitude shifts during vocalization, and they are also corroborated by the findings of others (Barfield & Geyer, 1972, 1975). The signal value of the frequency and amplitude modulation within and between calls is as yet unknown.

The data collection system described here permits

the simultaneous monitoring of all frequencies for relative signal strength from 0 to 100 kHz (or a smaller range at the experimenter's option). Without this capability, we may not have been able to detect and record the multiple, simultaneous vocalizations evidenced in D3, which, to our knowledge, represent the first report of this type of vocalization pattern. Also, it is significant that all of the vocalizations described were emitted by free-ranging rats in large experimental rooms in which the minimum rat-to-microphone distance was about 2.7 m.

REFERENCES

- BARFIELD, R. J., & GEYER, L. A. Sexual behavior: Ultrasonic postejaculatory song of the male rat. *Science*, 1972, 176, 1349-1350.
- BARFIELD, R. J., & GEYER, L. A. The ultrasonic postejaculatory

Appendix Program 1

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      .TITLE SQUEAK: CONTROLLED SAMPLING TO FLOPPY DISK
      DATA ACQUISITION PROGRAM FOR SPECTRUM ANALYSIS
      USING TEKTRONIX 564N SPECTRUM ANALYZER.
      SAMPLING PERIOD= 1 MILLISECOND.
      6 RECORDS PER BLOCK
      RECORD=(96 BYTE FREQ.SCAN * 2 TIMING WORDS)
      THIS REQUIRES AN EXTRA WORD AT THE END OF EACH BLOCK.
      OUTPUT BUFFER LENGTH = 256 WORDS
      SAMPLE GROUPS ARE SPACED AT MULTIPLES OF 114 MILLISECONDS APART.
      EACH GROUP COVERS 100 MILLISECONDS IN REAL TIME.
      USES A/D CHANNEL 17(OCTAL) OF AM11.
      INTERRUPTS ACTIVE:
      A/D CONVERSION COMPLETE
      (A/D CONVERSION INITIATED BY CLOCK OVERFLOW)
      DISK TRANSFER COMPLETION INTERRUPT
      TELETYPE KEYBOARD INTERRUPT IS INTERCEPTED
      AS PROGRAM TERMINATION. ('Q' IS IMMEDIATE. ANYTHING ELSE WAITS
      UNTIL THE PRESENT RECORD IS COMPLETED.)
      SCHMITT TRIGGER 1 ON THE AD-11L IS USED TO TRIGGER EACH FREQ.
      SWEEP.
      .FCALL .TTIME, .PRINT, .SRESET, .DEVICE
      .FCALL .EXIT, .READW, .GETC, .GSTAT
      .FCALL .CSICER, .BTRNO, .WRITE
      .FCALL .WAIT, .CLOSE, .GRTS, .DATE, .CTIM
      .GLOBL .INSTR, .TYPE, .DETL, .TIME$C
      AR=11 REGISTERS (ALSO AD=11K AND KW=11K)
      ADSTAT=170400
      ADBUF=ADSTAT+2
      ADVECT=380
      ACLC=170404
      APRE=ACLC+2
      AVEC=344
      BCLE=170402
      BPRE=BCLE+2
      BVLC=264
      CONSOLE TERMINAL REGISTERS
      VTCNR=177560
      VTBUF=VTCNR+2
      SCOP=VTCNR+4
      OUTBUF=VTCNR+6
      VTVECT=60
      60 HZ CLOCK REGISTER
      CLK60=177546
      VEC60=100
      THE SYMBOL 'PDPA0' IS DEFINED WHEN USING THE 11/40 INSTEAD
      OF THE 11/04.
      .ASPECT
      .F42
      1000 ;STACK POINTER
      RESTORE LINE CLOCK BY EXECUTING TIME COMMAND UPON EXIT
      .F310
      .WORD X1-Y1
      .ASCIZ "TIME "
      .ASCIZ "00:00:00"
      .BYTE 15,12
      .ASCIZ "DATE"
      .CVER
      X1,
      .F1000
      SQUEAK: JNP INIT ;INITIALIZATION SECTION AT END.
      COMMON AREA
      HPTR: 0 ;INPUT BUFFER POINTER
      NPPOINT: 0 ;INPUT BUFFER LENGTH
      NCRT: 0 ;NUMBER OF GROUPS/INPUT BUFFER
      DATA: 0 ;DATA POINTS/STEP
      SKIP: 0 ;POINTS SKIPPED - 10 GROUPS.
      PRESET: 0 ;BUFFER PRESET FOR CLOCK.
      S6T015: 0 ;6-15 KHZ SIGNAL THRESHOLD
      S16T25: 0 ;16-25 KHZ SIGNAL THRESHOLD
      S26T35: 0 ;26-35 KHZ SIGNAL THRESHOLD
      S36T49: 0 ;36-49 KHZ SIGNAL THRESHOLD
      LCNT: 0 ;LINE CLOCK COUNT DOWN
      ABSET: 0 ;A/D SETTING
      H11CZ: 0 ;TIME COUNTER STORAGE
      LTIME: 0 ;
      HTRF: 0 ;KEEPS TABS OF 60 HZ CLOCK TIME
      LTRF: 0 ;
      RT11DT: 0 ;RT-11 DATE CODE
      FLDB: 0 ;#0 WHILE BUFFER 1 IS BEING TRANSFERRED
      FLG2: 0 ;#0 WHILE BUFFER 2 IS BEING TRANSFERRED
      EXFLG: 0 ;EXIT FLAG
      DBRE: 0 ;FINALLY DONE FLAG
      SUPCT: 0 ;SAVE BEGINNING RECORD
      SUP60: 0 ;PRESENT STEP
      EXLNR: 0 ;MINIMUM NUMBER OF RECORDS POSSIBLE
      SAVEPT: 0 ;SAVE STACK POINTER
      SARK: 0 ;STORE NO
      TOP: 0 ;STORE TOP OF PROGRAM ADDRESS
      BLK: 0 ;PRESENT BLOCK NUMBER
      BLKSA: 0 ;MINIMUM BLOCK COUNT
      B16CH: 0 ;BLOCK INCREMENT
      COUNT: 0 ;GROUP SAMPLE COUNTER
      PRECNT: 0 ;NUMBER OF PRE-SAMPLES
      PLEN: 0 ;NUMBER OF INITIAL POINTS TO SKIP
      N11R: 0 ;NUMBER OF MAIN CYCLES, 3 GROUPS/CYCLE
      GRP: 0 ;NUMBER OF EPGRS TO SKIP
      CHRG: 0 ;PRESENT I/O CHANNEL IN USE.
      N11GR: 0 ;HIGH ST I/O CHANNEL (0,1,2)
      OUT1: 0 ;ADDR OF FIRST OUTPUT BUFFER
      OUT2: 0 ;ADDR OF SECOND OUTPUT BUFFER
      HEADER: 0 ;HEADER BLOCK POINTER
      EXCPTR: 0 ;RECORD INDEX POINTER
      KTY: 0 ;
      L51R: 0 ;
      H11R: 0 ;
      H11N: 0 ;
      SECT: 0 ;
      T11CR: 0 ;
      SVTVEC: 0 ;SAVE MONITOR'S VT VECTOR
      SVR: 0 ;STORE BEGINNING OF EACH EPOCH TEMP.
      STR: .ELIM 20.
      ARFA: .ELIM 5
      ARMB: .ELIM 5
      ARMC: .ELIM 5
      ARMD: .ELIM 5
      ARME: .ELIM 5
      ARMF: .ELIM 2
      CST: .ELIM 2
      L11: .ELIM 4
      D11N: .RMB0 /DAT/
      .RMB0 /DAT/
      .RMB30 /DAT/
      .RMB50 /DAT/
      TEMPARY STORAGE FOR SPECTRUM INTERVAL
      FREQUENCY READINGS ARE FOR EACH 114 DIVISION SETTING
      SPTR: 0
      SUB: .ELIM 9.
      TEST1: 0
      TEST2: .ELIM 19.
      TEST3: 0
      TEST4: .ELIM 19.
      TEST5: 0
      TEST6: .ELIM 19.
      TEST7: 0
      TEST8: .ELIM 19.
      TEST9: 0
      TEST10: .ELIM 19.
      TEST11: 0
      TEST12: .ELIM 19.
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      TEST224: .ELIM 19
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TESTS: 0 .BLKW 5. ;36KHZ TO 49KHZ
MD1: 2 ;PARANOIA
      M12
      SWPCNT
      .BLKE 8.
MD2: .BYTE 200
MD2: .EVEN
LL2: 2
      H7ME
      M12

; MAIN PROGRAM 'IBLE' LCCT

LOOP: JSR PC,EX ;SET IF BUFFER READY
      TST FLGB1
      BEQ LGGB1
      TST FLGB2
      BEQ LGGB2
      JSR PC,FAST
      ADD BINC,BLK ;UPDATE BLOCK POINTER

      .WRITE *AREA1,CHAN,CUT1,RCOUNT,*CR1,BLK

      JSR PC,TYPOUT
      TST BONE
      BNE FIRSTS

LOOP1: JSR PC,EX ;SET IF BUFFER READY
       TST FLGB2
       BEQ LGGB2
       TST FLGB1
       BEQ LGGB1
       JSR PC,FAST
       ADD BINC,BLK

       .WRITE *AREA2,CHAN,CUT2,RCOUNT,*CR2,BLK

       JSR PC,TYPOUT
       TST BONE
       BNE FIRSTS
       BR LGGB2

; PRINT OUT TIME AND RECORD COUNT

TYP0UT: MOV #LL2,R5
        JSR PC,TIMASC
        MOVB #200,M12
        MOVB #M11,R5
        JSR PC,TYPE
        RTS PC

; ERROR IF DATA RATE TOO FAST

FAST: JSR PC,STOP
      BR A1
B1: .ASCIZ "DATA RATE IS TOO FAST"
    .EVEN
A1: MOVB #B1,R5
    .PRINT R5
    RTS PC

; STOP ROUTINE

STOP: CLR ADSTAT
      CLR ACLK
      CLR CLK60
      MOV #1,EXFLG
      WAIT CHAN
      RTS PC

; EXIT SEQUENCE
; CLOSE FILE AND RETURN TO MONITOR

EX: TST EXFLG
    BEQ RT
    CLR ADSTAT
    CLR ACLK
    CLR CLK60
    WAIT CHAN
    MOV #1,DONE
    RTS PC
    MOV BPTR,R4
    TST COUNT
    BEQ 20
    MOV (R4)+,COUNT
    DEC BNE 10
    MOV DATA,COUNT
    CLR (R4)+
    CLR (R4)+
    DEC MAIN
    BNE 10
    CLR (R4)+
    MOV (R4)+,BPTR
    INC @0(R4)
    RTS PC

; WAIT FOR LAST WRITE AND THEN CLOSE FILE

FINIS: .CLOSE CHAN

; RESTORE LINE CLOCK VECTOR AND UPDATE MONITOR'S TIME

MOV SVTVEC,VTVECT
MOV #L2,R5
JSR PC,TIMASC
MOV #8,R5
MOV #STR2,R4
MOV #TSTR,R3
10: MOVB (R4)+,(R3)+
    DEC R5
    BNE 10
    BIC #100,CLK60
    MOV SV60,VEC60
    BIC #100,CLK60
    MOV #340,*266 ;RESET FLOPPY PRIORITY
    BIC #4000,*44
    CLR R0
    .EXIT

; COMPLETION ROUTINES

CR1: CLR FLGB1 ;ENTERED WHEN BUFFER 1 WRITTEN
     BR CON
CR2: CLR FLGB2 ;ENTERED WHEN BUFFER 2 WRITTEN
CON: CMP FLGB,BLKSV

```

```

BLT      2#
CLR      ADSTAT
CLR      ACKL
CLR      CLK#0
MOV      #1,EXFLC
2#:      RTS      PC

;
;      INTERRUPT ROUTINES
;
;      KEYBOARD INTERRUPT ROUTINE
QUITVT:  MOVVB  VTBUF,KEY
          BICB   #240,KEY
          CNPB   KEY,#'Q
          BNE    1#
          CLR    ADSTAT
          CLR    ACKL
          CLR    CLK#0
          MOV     #1,EXFLC
1# :      RTI

;
;      A/D CONVERSION INTERRUPT
ADCONV:  DEC     PRECNT
          BNE     RR
          INC     PRECNT
          MOV     R4, -(SP)
          MOV     R5, -(SP)
          MOV     BPTR, R4
          MOV     ADBUF, R5
          .11F    NDF      PDP40    ASR      R5
          .11F    NDF      PDP40    ASR      R5
          ASR     R5
          ASR     R5
          MOVVB   R5, (R4) +
          MOV     R4, BPTR
          MOV     SPTR, R4
          ADD     (R4) +, R5
          MOV     R5, (R4)
          MOV     R4, SPTR
          DEC     COUNT
          BNE     RET

;
;      TEST REJECTION CRITERION
TEST:    CLR      ADSTAT
          .11F    NDF      PDP40
          .11F    DF       PDP40    CLR      #137777, ACLK
          SUB     TEST4, TEST5
          SUB     TEST3, TEST4
          SUB     TEST2, TEST3
          SUB     TEST1, TEST2
          CNP     TEST2, SGT015
          BGE     OK
          CNP     TEST3, S16T25
          BGE     OK
          CNP     TEST4, S23T35
          BGE     OK
          CNP     TEST5, S36T49
          BLT     FAIL
          MOV     BPTR, R4
          MOV     HTIME, (R4) +
          MOV     LTIME, (R4) +
          MOV     R4, BPTR
          MOV     R4, SVR4
          INC     SWCNT
          DEC     MAIN
          BNE     RET
          MOV     MCNT, MAIN
          MOV     BPTR, R4
          CLR     (R4) +
          MOV     (R4) +, EPTR
          INC     60(R4)
          MOV     BPTR, SVR4
          BR      RET
          MOV     SVR4, BPTR
          MOV     #1, SKIPP
          RET:    MOV     (SP) +, R5
          MOV     (SP) +, R4
          RR:     RTI

;
;      SCHMITT TRIGGER 1 INTERRUPT
ST1:     .11F    DF       PDP40
          DEC     LCNT
          BNE     1#
          MOV     #6, LCNT
          .ENDC
          .11F    NDF      PDP40    BIC      #100000, ACLK
          DEC     SKIPP
          BNE     1#
          MOV     PRESET, APRE
          BIC     #405, ACLK
          MOV     ADSET, ADSTAT
          MOV     CRP, SKIPP
          MOV     DATA, COUNT
          MOV     PCNT, PRECNT
          MOV     #SUM-2, SPTR
          MOV     LTIME, LTIME
          MOV     HTIME, HTIME
1# :

;
;      LINE CLOCK INTERRUPT
LINE60:  ADC     LTIME
          ADC     HTIME
          RTI

;
;      INITIALIZE PROGRAM AND GET INPUT FILE SPEC'S
INIT:    .RCTL0
          .SRES
          .QSET   #Q, #7
          MOV     VEC60, SV60
          .DEVICE #LIST
          BR      A0
          .BYTE   0, 14
          DEV
          DEV:    ADSTAT
                   0
                   ACKL
                   0
                   CLK60
                   100
                   VEC60

```

```

SV60: 0
A0: CLR ADSTAT
CLR ACKL
DATE
MOV R0,RT11DT
BR S1
L1: 1
S1: STR1
MOV #L1,R5
JSR PC,DATE
MOV #C0,F1
MOV #STR1,R0
CMPB (R0),#0
BNE 10
CMPB (R0),#0
BNE 10
PRINT
EXIT
10: MOV #L1,R0
CTIM
BR S2
L2: 2
HTIME
STR2
MOV #L2,R5
JSR PC,TIMEASC
MOV #L5,F2
JMP A2
ASCIZ "ENTER CORRECT DATE AND TIME. THEN RERUN PROGRAM."
B2: ASCIZ "SELECTIVE SAMPLING OF SPECTRUM DATA "
ASCIZ "FINISH SLASH USING CHANNEL 17."
BYTE 15,12
ASCIZ "50 POINTS/RECORD WITH 8 BITS/POINT."
BYTE 15,12
ASCIZ "EACH RECORD SPANS 114 (SEC. OF REAL TIME."
BYTE 15,12
ASCIZ "DATE: "
STR1: BLK 0
F1: BYTE 40
ASCIZ " TIME: "
STR2: BLK 0
F2: BYTE 15,12
ASCIZ "PLEASE SURE DATE AND TIME ARE CORRECT."
F3: ASCIZ "OUTPUT FILE: "
BYTE 200
EVEN
A2: PRINT #B2
BR A100
C100: 2
STR
N16
A100: PRINT #C0
MOV #C100,R5
JSR PC,INSTR
TST R0
BEQ A100
CMP R0,(PC)+
WORD 16
BCC A100
ADD #STR,R0
MOV #1,(R0)+
MOV #1,(R0)+
MOV #1,(R0)+
MOV #1,(R0)+
MOV SP,SAVE$P
MOV @#50,TOP
CSIGEN TOP,#EXT,#STR
MOV R0,TOP
MOV SAVE$P,SP
CLR CHAN
CLR MAXCH
WAIT CHAN
BCC FINE
BR A3
B3: ASCIZ "OPEN ERROR."
EVEN
A3: PRINT #B3
EXIT
FINE: WAIT #1
BCS TRY2
MOV #1,MAXCH
TRY2: WAIT #2
BCS 10
MOV #2,MAXCH
10: CSTAT #AREA5,CHAN,#CST
: GET LENGTH OF FILE OPENED
MOV #256,,NPOINT
MOV NPOINT,R0
SWAB R0,BINC
DEC R0
MOV R0,BINC
MOV R0,BINC
DEC R1
DEC R1
SUB BINC,R1
MOV R1,BINC
BR A4
B4: ASCIZ "NUMBER OF BLOCKS: "
BYTE 200
EVEN
C4: 2
B4
LEB
MOV #C4,R5
JSR PC,TYPE
: GET ALL THE INPUT PARAMETERS
BR A5
ASCIZ "22 KHZ SETTING (KHZ) (5): "
BYTE 200
EVEN
C5: 2
B5
SPAN: 5
A5: MOV #C5,R5
JSR PC,TYPE
TST SPAN
DEC A5
A5: MOV #C5,R5
JSR PC,TYPE
: FREQUENCY RANGE IS 0-50KHZ.
B6: ASCIZ "SIGNAL (6-15KHZ) (0): "
BYTE 200
EVEN
C6: 2
B6
A6: MOV #C6,R5
JSR PC,TYPE
BR B6
ASCIZ "SIGNAL (16-25KHZ) (0): "
BYTE 200
EVEN
C6: 2
B6
A6: MOV #C6,R5
JSR PC,TYPE
BR B6
ASCIZ "SIGNAL (26-35KHZ) (0): "
BYTE 200
EVEN
C6: 2
B6
A6: MOV #C6,R5
JSR PC,TYPE
BR B6
ASCIZ "SIGNAL (36-45KHZ) (0): "
BYTE 200
EVEN
C6: 2
B6
A6: MOV #C6,R5
JSR PC,TYPE
BR B6
ASCIZ "POINTS TO DELAY (14): "
BYTE 200
EVEN
C8: 2
B8
PCNT
A8: MOV #C8,R5
JSR PC,TYPE
TST PCNT
BNE 10
MOV #14,,PCNT
10: MOV PCNT,PCNT
MOV #100,,PRESET
MOV #17,R0
SWAB R0
BIS #140,R0
MOV R0,ADSET
: ENTER COMMENTS
BR A9
B9: ASCIZ "COMMENTS/NOTATIONS: "
BYTE 200
EVEN
A9: MOV #B9,R5
PRINT R5
: CLEAR BUFFERS AREAS
TRANS: MOV TOP,R0
MOV #256,,R1
10: CLR (R0)+
DEC R1
BNE 10
MOV TOP,R1
ADD #40,R1
MOV R1,ARG2
BR A10
C10: 2
ARG2: 0
N70
A10: MOV #C10,R5
JSR PC,INSTR
CMP R0,(PC)+
WORD 70
BLE 10
MOV N70,R0
10: MOV R0,LSTR
: INITIALIZE SOME PARAMETERS
MOV BINC1,R0
NEG R0
MOV R0,BLK
CLR FLGB1
CLR FLGB2
CLR EXFLC
MOV #5,MCNT
MOV MCNT,MAIN
MOV #90,,DATA
MOV DATA,COUNT
MOV #SUM-2,SPTR
MOV #6,LCNT
: COUNTDOWN FOR 60 CYCLE CLOCK
: TRANSFER SOME PARAMETERS TO HEADER BLOCK.
MOV TOP,R0
MOV RT11DT,(R0)+
MOV R0,SPAN
MOV HTIME,(R0)+
MOV LTIME,(R0)+

```