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COMPUTER TECHNOLOGY

A stabilometer computerized analog recording system for studying gross motor skill learning

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The stabilomotor computerized analog recording system (SCARS) presents a unique data analysis and storage system for studying motor learning strategies. Graphic computer printouts, total time in balance, total number of contacts, time between contacts, standard deviation of the time between contacts, mean angle of balance, and standard deviation of the angle of balance for each trial are derived.

The stabilometer was originated in the 1930s and later revived and adapted for work in physical education by Henry.[1] The task requires the subject to stand on the stabilometer platform, bring it into a level horizontal position, and then hold the platform steady with as little motion as possible (Figure 1). There appears to be no correlation between height and weight and performance, and in the normal range of intelligence, no meaningful correlation has been found for IQ or school grades and performance.

Recently, there has been a renewed interest in the application of the stabilometer in measuring gross motor learning (Melnick, 1971; Ryan, 1965; Stelmach, 1969). With few exceptions, changes in the apparatus have involved mechanical improvements in the movable platform and few modifications have been made in the import recording system. An exception was Rivenes (1973) who recently adapted a photoelectric cell mechanism to the stabilometer for recording data. The most innovative recording technique to date, Wade and Newell (1972), employed a computerized analog system that encoded on an expensive FM tape recorder.

The stabilometer computerized analog recording system (SCARS) presents a unique data analysis and storage system that makes the stabilometer a much more versatile instrument than it has been in the past. It provides a graphic computer printout for each trial (Figure 2) and provides measures of total time in balance, total number of contacts, time between contacts, standard deviation of the angle of balance for each trial. The availability of several linear integrated circuits can reduce the cost of storing experimental data on an AM tape recorder. The SCARS system can be attached to most exisitng stabilometers.

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Design equations and complete descriptions of the integrated circuits can be found in catalogs and available literature from Signetics Corporation, 811 E. Arques Avenue, Sunnyvale, California 94086 or National Semiconductor Corporation, 2900 Semiconductor Drive, Santa Clara, California 95051. Estimated labor time: 60 hours; approximate cost of parts: $150.

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POSITION STANDING

The platform mounting shaft is connected to a position sensing potentiometer through a 1:4.5 gear train. A change in the output voltage of the potentiometer reflects a change in the angle of the stabilometer platform. This output voltage is processed to deliver 10.5 t 0.15 V to the input of the recording system.

RECORDING SYSTEM

The recording system allows analog and digital information to be stored together on a single channel audio tape recorder (Figure 3). The main components are the controller and encoder.

The controller (Figure 4, Table 1) consists of a trial timer and a relay. The timer is an integrated circuit (IC) that operates as a monostable multivibrator. When Pin 4 of ICI is connected to 12 V and the START switch is momentarily closed, the output of the timer rises

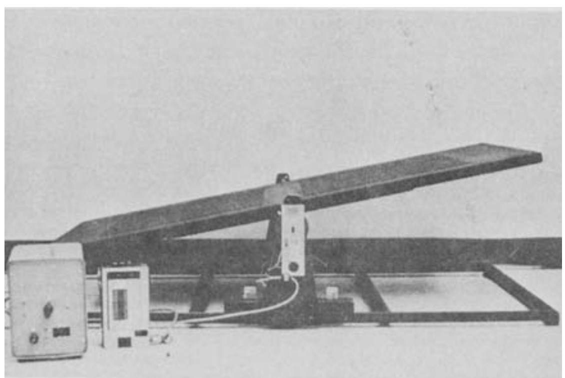

Figure 1. Stabilometer.

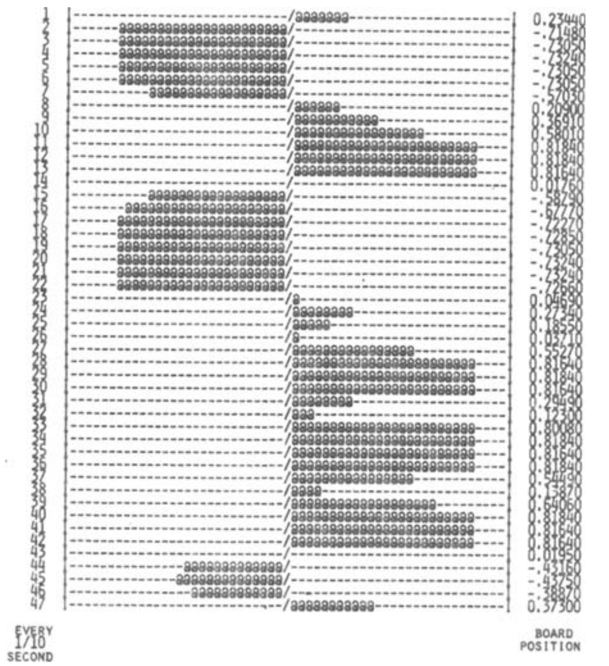

Figure 2. Graphic printout sample.

from 0 V to 12 V for the duration of the trial. The trial length may be varied from a few seconds to several minutes. The relay contacts that are closed during a trial activate the audio tape recorder used to store the information. A light-emitting diode (D2) signals the operator that a trial is in progress.

The heart of the encoder is an IC voltage controlled oscillator (VCO). The operating frequency of the VCO may be altered by an externally applied control voltage. The design of the device is such that oscillation may be inhibited by applying 0 V to Pin 6 of the IC. This feature is used to switch IC2 so that it generates a 400-Hz tone only during a trial. Transistors Q1 and Q2 form a noninverting buffer which inhibits IC2 except during a trial. The result is a circuit that stores digital information on a standard audio tape recorder.

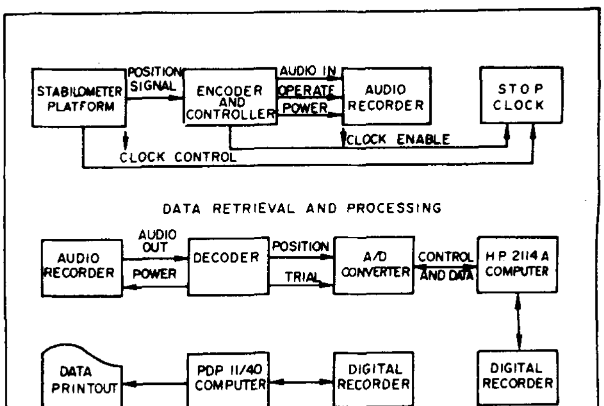

Figure 3. Data acquisition system.

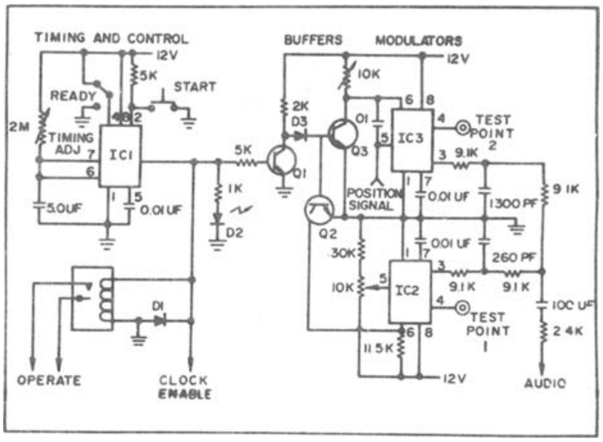

Figure 4. Encoder.

The analog modulator (IC3) is gated to the "on" state only during a trial. The position signal that represents the angle of the stabilometer platform is connected to Pin 5 of the VCO. As the input voltage varies from 10.3 V to 10.6 V, the frequency of the output signal varies from 6600 Hz to 5400 Hz.

The constant 400-Hz tone and the varying tone are mixed together and recorded on an audio recorder. We used a SONY Model TC-45 because it has servo tape speed control, a necessity since any frequency change due to tape speed variation cannot be distinguished from those changes which represent the analog information.

PLAYBACK SYSTEM

Once the data are stored on tape, they may be delivered to the computer center for processing. Here the frequencies on the tape are reconverted to voltages that are then converted to numeric form for computer manipulation.

The decoder (Figure 5) is also based upon voltage controlled oscillators. In this case, the oscillators are automatically varied until they match the incoming signal in both frequency and phase. The combination of a voltage controlled oscillator and the sensing and control

Table 1
Parts Identification for Figures 4 and 5

Timer	IC1	NE555
Voltage Controlled Oscillator	IC2, IC3	NE566
Phase Locked Loop	IC4	NE560B
Operational Amplifier	IC5	LM741
Tone Decoder	IC6	LM567
	Q1, Q2, Q3	2N3398
	D1, D3	1N4002
Light Emitting Diode	D2	5082-4882

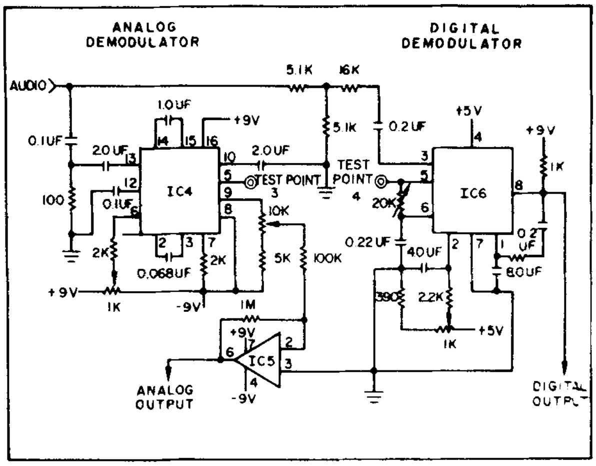

Figure 5. Decoder.

circuits necessary to perform this function is the phase locked loop.

A phase locked loop (PLL) operates as the analog demodulator. The signal from the recorder is fed into the PLL through a high pass-filter to remove interference from the 400-Hz oscillator. As the oscillator in the PLL tracks the input frequency over the range of 5400 Hz to 6600 Hz, the changing internal control voltage is directly proportional to the frequency and therefore to the angle of tilt. This voltage is amplified and filtered to remove high frequency components, resulting in a ± 6 V position signal.

The integrated circuit used in the digital demodulator contains a PLL and additional circuits. As long as the input frequency is being tracked by the oscillator in the PLL, these circuits cause the demodulator output to fall to 0 V. When no frequency within this detection band (360 Hz to 440 Hz) is apparent, the output of the IC is an open circuit. An external resistor then pulls the demodulator output voltage up to 9 V. The maximum transfer rate is limited to 20 bits per second by the choice of 400 Hz as the oscillator frequency.

DATA ANALYSIS

The recording system facilitates data reduction and analysis for computer handling. The continuous analog signal from the tape cassette is fed through the decoder and into a central patch board system to be distributed to peripheral analytic devices (Figure 6). The signal is channeled through an oscilloscope monitor for visual confirmation of data signal validity and then through a Hewlett-Packard (HP) analog-to-digital converter. The conversion enables the HP 2114A central processing unit (or any other comparable system) to monitor the signal at any predetermined rate and store these digital values as an unlabeled file on an industry compatible 9-channel magnetic tape. The tape may be processed by a larger computer such as the PDP 11/40, allowing rapid and unlimited analysis and storage. For the purpose of calculating the summary statistics, i.e., total time in balance, total number of contacts, time between contacts, standard deviation of angle of balance, the data points need not be stored on magnetic tape since this only facilitates more sophisticated data analysis and manipulation. If magnetic tape is used the stored data may be analyzed using a variety of computer languages and techniques.

After the data points (digital representations of analog signals) are placed in a real array, dimensioned for the total number of data points per trial, the summary statistics for the trial may be calculated. For data analysis, the summary statistics are defined as follows:

(1) Total number of contacts—the number of data points equal to the predefined left-and-right contact point limits.

(2) Total time in balance—the total number of data points minus the total number of contacts, multiplied

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      DIMENSION ITBFF (70)
      DIMENSION VALUE (300)
      WRITE (6,1000)
1000  FORMAT ("ENTER DATE AS MM/DD/YY")
      READ (1,1005) (ITBFF(I), I=1,8)
1005  FORMAT (70A1)
      WRITE (6,1010)
1010  FORMAT ("REMARKS?")
      READ (1,1005) (ITBFF(I), I=9,70)
C
C  ZER VALUES
C
      DO 5 I = 1,300
    5 VALUE (I)=100.
   15 FORMAT ("MOUNT CLEAN MAGNETIC TAPE")
      WRITE (6,15)
      PAUSE 1
      REWIND 7
   10 CALL VOLTS (10, TEST)
       IF (ABS(TEST) -.5) 20,20,10
   20 CALL STCLK (10)
      DO 100 I = 1,300
      CALL VOLTS (11, VALUE(I))
      CALL STCK2
   50 CALL RDCK2 (IWAIT)
      IF (IWAIT-1) 50,60,60
   60 CONTINUE
  100 CONTINUE
  200 CALL RDCLK (IRUN)
      I=I-1
      WRITE (2,300) I,IRUN
300   FORMAT (///"BILL CHASEY'S STABILOMETER"///
     2  "NUMBER OF DATA POINTS IS " 17/
     3  "LENGTH OF EXPERIMENT IS ", 17)
      WRITE (7,1005) ITBFF
      WRITE (7,1050) (VALUE(M), M=1,300)
 1050 FORMAT (10F7.4)
      ENDFILE 7
      REWIND 7
      WRITE (1,2000)
 2000 FORMAT ("ECHO VOLTAGE VALUES? (0=NO; 1=YES")
      READ (1,*) IFLAG
      IF (IFLAG) 5000,5000,3000
 3000 REWIND 7
      DO 4000 I=1,31
      READ (7,1005) ITBFF
 4000 WRITE (6,1005) ITBFF
      REWIND 7
 5000 PAUSE 5
      END
      END$
      END$
**END-OF-TAPE
```

Figure 6. Computer program.

by the rate at which the stabilometer signal is monitored (i.e., every 1/10 sec, 1/100 sec, etc.).

(3) Time between contacts–equal to the length of each intercontact period. This is defined as the time of contact minus the time of the onset of the last intercontact period.

(4) Standard deviation of the time between contacts requires both the number and length of each intercontact period, applied to the standard deviation formula.

(5) Angle of balance is calculated as any other mean score by summing all data points and dividing by the total number of data points. Mean score must then be converted to degrees by means of a manual conversion table or computer conversion system.

(6) Standard deviation of the angle of balance for each trial is calculated by deriving the standard deviation for all data points in a trial and converting that value to degrees.

A graphic computer representation of stabilometer performance (Figure 2) may be obtained by assigning each data point a position on a direction sensitive bar graph. This information proves useful when searching for trends and motor learning strategies.

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