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DECUS NO.	12-41
TITLE	BLOOPD - BLOOD PRESSURE DISPLAY PROGRAM
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ABSTRACT

The Blood Pressure Display Program is primarily for visual information only. This program displays either the blood pressure waveform on a calibrated scope, or the digitized values of four parameters of the blood pressure. A printout of the digitized values is also provided. All options are selected by teletype.

PRELIMINARY REQUIREMENTS

Equipment

This program will operate on a PDP-12A computer or, with modifications, a LINC-8. A Tektronix 561 or 502a oscilloscope, and a teletype in the research lab allow for remote display and control of the program. Signal conditioning is accomplished by a Beckman Dynograph (type RB). The analog signal for the computer is taken in parallel with the galvanometers, from the recorder output amplifier. Any signal conditioner with an output range of $\pm 1/2$ volts to ± 5 volts would do the job.

Storage

BLOOPD resides in memory segments 1 and 2. 1675 locations in Field 2 are filled by the main program instructions. 1016 locations are filled in Field 1. Field 1 contains two text strings using the TEXT pseudo-op, an ordered list of character display patterns, and the program FLOS*, the floating point package. The usual Data Field, Field .3, is not used.

Restrictions

All index registers are used. Register 12 must not be reused within either the Waveform Display routine or the Digitized Value Display Routine. It regulates the alternating sequence. Registers 7, 10, 13 and 15 must not be reused within the Value Display routine. They are used with the Threshold routine.

LOADING PROCEDURE

Put a tape containing the program "BLOOPD" on the tape unit $\emptyset$.

Start DIAL

      A) Set mode switch to LINC; press console switch STOP

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* Charles E. Molnar, FLOS and FLOD -- Single and Double Precision Floating Point Packages for the LINC. Technical Report No. 8, June, 1968, Computer Systems Laboratory, Washington University, St. Louis, Missouri

B) Press I/O PRESET switch
C) Set switch registers to Ø7Ø1   73ØØ
D) Press the DO switch, wait for the tape motion to stop
E) Press START 20 switch

Call BLOOPD

A) At the teletype, hit the ' line feed' key
B) Type "LO BLOOPD,Ø " then the 'Return' key
C) The program starts

OPERATING PROCEDURE

Options

Program control initially goes to the Option List Display:

```
TYPE
  C      CALIBRATE
  W      WAVEFORM
         F FASTER
         S SLOWER
  N      VALUE DISPLAY
  A      ALTERNATE WAVE AND VALUES
  P      PRINTOUT VALUES
```

Option keys are operative anytime, except during the Calibrate or Printout routine. Return to the Option Display by typing any key but one of the option keys.

Calibrate

The first option selected must be Calibrate. Type 'C.' The line displayed on the scope represents the current pressure value. Apply Ø mm Hg to the pressure transducer. Type 'Z.' Next apply 200 mm Hg. Type '2.' The program arrives at a scale factor value used to calibrate the waveform display and the digitized blood pressure parameter values. Program control returns to the Option List Display.

Waveform Display

The Waveform option displays two horizontal lines labeled Ø and 200 (mm Hg). The position of a third line, with its digitized value, is controlled by Knob Ø at the computer. (The values of the Knob Ø line are not available below the Ø line; letters, instead of numbers, are displayed with no harm to the program.) A moving point representing the current blood pressure is displayed. The display speed of the waveform can be adjusted. For fewer pressure peaks across the scope, type 'S.' For more peaks, type 'F.'

Digitized Value Display

Type 'N' to select the option which displays a list of digitized values of four blood pressure parameters:

```
                        MM      HG
      SYSTOLIC          ——
      DIASTOLIC         ——
      PULSATILE         ——
      MEAN              ——
      HEART RATE        XXX/SEC
```

The Value Display routine initially finds and waits through 20 simple peaks. This way, after the twentieth minimum value is found, the program "eases into" the main routine for true peak detection. The Threshold subroutine (always the initial step in the peak detection) uses the last four of these first 20 peaks to find the threshold value. The minimums, maximums and threshold value increase in accuracy the first minute of operation.

The routine repeatedly samples the input channel and then checks against the last sample, until a peak is found. It then checks this peak against subsequent samples until a higher peak is found or the threshold value is reached. The highest peak within the threshold is the True Maximum. At this point the detection stops to run through the Value List Display subroutine four times. Continuing, the routine similarly finds a True Minimum within the threshold.

A new threshold value is found before each detection of a maximum. Each new True Max and True Min value replaces the oldest value in two tables of the last four values of each. The Threshold subroutine uses these constantly updated tables. It subtracts the sum of the last four Mins from the sum of the last four Maxs. Dividing the result by sixteen (SCR 4) gives one-fourth of the average of the differences. This is the threshold value. The use of a threshold assures the rejection of noise and the dicrotic notch, with varying pusatile amplitudes.

Spaces within the text code of the list of parameters are filled with the codes for the decimal digits of the current values. The Value List Display subroutine uses this text code table to display the list. The Mean value is taken as one-third of the Pulsatile value plus the Diastolic value. The text line for heart rate was added only to the text code table used to display the list, for later convenience. The routine to find heart rate is not provided at this time as we are waiting to add a KW12 Real Time Clock to our facilities.

The display time is limited to only between the Min and Max detection routines -- thus, the flickering display. As is, the program displays for the maximum time for animals with heart rates of approximately 4 per sec. For animals with heart rates of less than 2 per second, the display time can be increased. Locations 4657 and 5144 can be incremented by -1 until display time is at maximum.

Alternate and Printout Options

Type 'A' to alternate displays of the Digitized Values and the Waveform. Each displays about 30 seconds. Select the Printout Options by typing 'P.' The teletype will print one list of the current values of the four blood pressure parameters. The Printout Option should be selected only during the Value Display routine or else the printed data will not be current. Control returns to the Value Display routine after the printout.

INTERNAL OPERATION

Overview

The Blood Pressure Display Program is a program of subroutines. There are two primary routines, the Waveform Display routine and The Digitized Value List Display routine. The latter includes the peak detection routines with self adapting thresholds. FLOS, the floating point package, is used throughout most of the program. It is located in memory segment 1. Also in Field 1, the TEXT pseudo-op is used to create two tables of character codes used to display the Option List and the Digitized Value List.

Calibration

The Calibrate routine waits for a 'Z' key strike (at $\emptyset$ mm Hg), samples the input channel, scales it down to 8 bits, and stores the octal value. It then waits for a '2' key strike (at 200 mm Hg), and then does the same. While waiting, the program displays a line, the current value of the input channel, indicating the rise from $\emptyset$ to 200 mm Hg.

To evaluate the input signal as a decimal value between $\emptyset$ and 200 mm Hg, the program arrives at a Scale Factor. Subtracting the $\emptyset$ mm Hg value from the 200 mm Hg value gives the number of bits between the two. Dividing 200_{10} (310_8) by this value gives the number of mm Hg per bit (bits correspond to vertical coordinates on the scope). This number is the Scale Factor. The following formula is used to calibrate subsequent samples:

(Sample - zero value) x Scale Factor = mm Hg (in octal)

The Calibrate routine used FLOS for the division to find the Scale Factor. It then returns to the Option List Display. One cannot return to other options until the 'Z' key and then the '2' key are struck. If a mistake is made or an equipment problem arises during the Calibrate routine, and a restart is desired, one must hit both keys, 'Z' and '2', to return to the Option List Display. Do not hit the '2' key at the zero value, as this will cause an error halt in FLOS (division by zero). To save time, the constant 3 is floated once in the Calibrate routine, then used often to calculate the Mean.

During the program's development, blood pressure was simulated electronically and a knob (one of lines $\emptyset$-7) was used to represent a manometer during the calibrate procedure. Within the Calibrate routine change the three SAM C2 instructions to sample a knob.

Waveform Display

The Waveform Display Routine repeatedly samples and displays the blood pressure signal from the input channel, incrementing the horizontal coordinate of the display at intervals. The intervals are determined by C(T1). T1 is set at the program beginning, but is made variable by subroutines that increase or decrease C(T1). Typing 'F' increments C(T1); the horizontal coordinate moves slower. Typing 'S' decreases C(T1); the horizontal coordinate moves faster. There is a check for the minimum value of T1 - one. The display will go no slower.

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At intervals during the Waveform Display control goes to a subroutine which chooses and runs one of three subroutines. It alternately chooses the display of either the 200 line and its value or the Ø line and its value or the line variable by Knob Ø and its value. The contents of register 7 (Ø, 1, or 2) decides which subroutine. C(7) is incremented after each of the first two subroutines and is reset to Ø after the third.

The blood pressure signal is input through Channel 20. To change the program to use another channel, see the first instruction, C2=20. Assign to C2 the number of the preferred channel. After every sample instruction (SAM C2) the accumulator is scaled right one, from 10 bits to 9 bits. This confines all values to the vertical limits of the scope, ±377.

Value Display and Peak Detection

The Peak Detection routine initially finds and waits through 20 sample peaks (subroutines MAX and MIN). The last four of the initial 20 peaks are used to find the Threshold value. This way, after the twentieth minimum value is found, the program "eases into" the main routine for true peak detection.

The routine repeatedly samples the input channel and then checks against the last sample, until a peak is found. It then checks this peak against subsequent samples until a higher peak is found or the threshold value is reached. The highest peak within the threshold is the True Maximum. At this point the detection stops to run through the Digitized Value List Display subroutine four times. Continuing, the routine similarly finds a True Minimum within the threshold. The zero value (from the Calibration) is then subtracted from each the Min and the Max. Using FLOS, these values are multiplied by the Scale Factor to give the octal equivalent of the digitized systolic and diastolic pressures. From these the pulsatile and mean pressure values are derived. The mean is taken as one-third of the pulse, plus the diastolic. These latest parameter values are now converted to decimal and the trimmed ASCII codes of the decimal digits are stored in the appropriate text code area for display of the list. The Value List Display subroutine is run twice, then control returns to the Maximum peak detection routine. The intermittent display of the Value List, dependent on the frequency of peaks, causes a flickering display with relatively slow heart rates. Four times through the display after the True Max and two times after the True Min is the maximum time available for display with fast heart rates. Increase C(17) within the Value Display routine for most display.

The TEXT pseudo-op is used in Field 1 to create 2 lists of trimmed ASCII codes representing the characters in the text strings for both the Option List and the Digitized Value List. These codes, six bits each, two per word, are used by the message display subroutine to choose and display character display patterns. The Value List Display subroutine simply initializes and calls the message display subroutine. There are spaces, initially represented by X codes, within the codes for the Value List. After once through the entire peak detection routine these spaces are filled with codes for the decimal digits of the parameter values. Therefore the code list is always ready for use in the display or printout of the current Value List.

A new threshold value is found before each Maximum peak detection. Each new True Max or True Min value replaces the oldest value in two tables of the last four values of each. The Threshold Subroutine uses these constantly updated tables. It subtracts the sum of the Mins from the sum of the Maxs. Dividing the result by sixteen (SCR 4) gives one-fourth of the average of the

differences. This is the threshold value. The use of a threshold assures the rejection of a dicrotic notch and noise with varying pulsatile values.

Secondard Subroutines

The Octal to Decimal Conversion Subroutine converts a three place octal number to decimal (maximums 777_8 and 511_{10}). Each decimal place digit is found, highest order first, by subtraction of the octal equivalents of decimal place values (144, 12, 1). After each digit is found control goes to one of two subroutines, M9 or H3, which stores the digit in the proper form and place and then returns to the O to D routine for the next decimal place digit.

Before entering the O to D subroutine, a jump instruction (either JMP M9 or JMP H3) must be stored within a small intermediate subroutine, Z8. The O to D subroutine exits, with the decimal digit, to Z8 which saves the jump return and the digit, then jumps to either M9 or H3. These subroutines exit back to Z8 which returns to within the O to D subroutine.

The subroutine tagged H3 is used to fill the text code spaces in Field 1 with trimmed ASCII code representing the decimal digits of the current parameter values. After the third entry into H3 from the O to D subroutine (3 digits entered in the text spaces), H3 increments by 7 the register addressing the text spaces. Upon the next entry in the O to D subroutine, with the next parameter's value, H3 is prepared to fill the text spaces for this parameter. The subroutine M9 is used during the Waveform Display. The O to D subroutine is entered with the octal value of Knob Ø. M9 fills a table with the display patterns of each decimal digit found by the O to D subroutine. These patterns are then used to display the decimal value of Knob Ø on the scope.

The subroutine used to display the Option List and the Digitized Value List is a modification of MSGDIS, Message Display Subroutine, James Hance, 1964, for LINC-8. It is modified to use the text codes and the character display patterns in Field 1. MSGDIS displays twenty characters, or until a EOL code is found, then returns to its calling program to decide whether to display another line or to continue in program sequence.

When the 'A' key is struck, for the Alternate option, a check location, Q8, is set to +1. The waveform and peak detection routines check for a positive Q8. If it is positive each routine lasts less than a minute then jumps to the other, and continues alternating. If the 'W' or 'N' keys are struck the program jumps to 3 locations before the beginning address of the waveform or peak detection routine. These locations set Q8 to minus 1, thereby preventing the alternating sequence.

The Printout Subroutine uses the text codes in Field 1, also used for the Value List Display. During the Value List Display routine the text always contains the number codes for the current values. The Printout routine checks for either letters, numbers, or special characters (SPACE, CR, HOR. TAB, /) and adds the appropriate constant to make whole ASCII code. The routine checks for the Horizontal Tab code (47), the last code in a line of text. The routine adds 143 to the Hor. Tab trimmed ASCII code to make the Line Feed code, for correct printing of the table. After six Hor. Tabs (six lines of printout) it returns to the Value Display.

FLOS, the floating point package, single precision, is in Field 1. So the calling sequence in the main program must be first a JMP to the chosen subroutine within FLOS followed by parameters, each plus 2000. In FLOS each subroutine begins with LDF 2, a change of data

fields. So, only in FLOS, the main program instructions, in Field 2, are now in the Data Field. This makes all needed parameters available, and addressable by tag + 2000, to FLOS. Modifications include LDF 2s in all needed FLOS subroutines, a RMF (restore memory field) before the return to the main program, and changing a constant, -6003, to -4003, besides redefining LAP-6 symbols undefined for DIAL.