A microprocessor-based real-time BASIC laboratory: A pulse motor-controlled visual stimulator

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Using the Commodore PET as a random pulse generator, an inexpensive visual stimulator for psychophysical experiments can easily be made at low cost. The PIA interface that connects the external experimental devices is easily accessed by PEEKing and POKEing its registers with BASIC. Using pulse motors, two independent stimulator wheels, having 24 different color filters and a 2.4 log (.1 log unit steps) unit range light attenuator, are controlled by a randomized string of pulses via a PIA port, and the responses of the observer as well as the stimulus parameters are automatically written onto the cassette memory for further data analysis.

The recent development of microprocessor-based technology (Milkman, Shapley, & Schick, 1978; Perera, 1978; Polson, 1978; Santa & Streit, 1978; Sidowski, 1978) has led to the experimental use of real-time laboratory computer systems that are inexpensive.

The recent trends in microcomputer uses in psychology are covered elsewhere (Sidowski, 1978).

Input/output (I/O) ports and interfaces for standard keyboards, CRT displays, and data file cassettes are now available at low cost for most microcomputers (Brown & Deffenbacher, 1978). However, more important has been the development of the capability of the microcomputer to communicate with the outside world, that is, laboratory interfaces for connecting switch inputs and outputs to power drivers. Although a one-board microprocessor coupled with a peripheral interface adaptor (PIA) with hexadecimal key inputs may be sufficient for real-time control of a visual stimulator (Brown & Deffenbacher, 1978; Kashinsky, Romanczyk, & Treiber, 1979) and data acquisition (Criswell & Babcock, 1978), the BASIC interpreter provided with the Commodore PET appears to be powerful for real-time laboratory experimentation (Durrett, 1978).

Using the PET 2001-8 (6502 CPU-based family with 8K RAM, 14K ROM, and 6-MHz/9-in. black-and-white CRT with 73 key inputs) as a random pulse generator (Osaka, 1978), a fully automated versatile random stimulator was designed for visual psychophysical experiments. The PET has BASIC accessible 8-bit parallel I/O ports for laboratory interfacing: The TTL-compatible pins (PA0 to PA7, CA1, and CB2) of the powerful MOS6522 PIA (VIA) remain free as the user port and are directly BASIC accessible using "PEEKing" and "POKEing" at each I/O register address (Commodore Business Machines, Inc., 1978, Note 1; Johnson, 1978; Yob, 1979).

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INTERFACING HARDWARE

The hardware logic is shown schematically in Figure 1.

Figure 1. Interfacing logic for the visual stimulator. The PET communicates with the outside devices via a 6522 PIA I/O port (inputs: CA1, PA0, PA1, PA2; outputs: CB2, PA4, PA5, PA6). PM = pulse motor, WH = color and ND wheels, M = mirror, L = lens. SP = speaker.

Figure 2. Front view of the stimulator. A randomized combination of the apertures of the color and ND wheels can be made using PET's randomized string of pulses.

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10 DIM X(50),Y(50):?"clr"
20 ?"REAL-TIME BASIC LAB AUTOMIZATION"
25 ?"HUE/BRIGHTNESS STIMULATOR FOR VISUAL PSYCHOPHYSICS"
30 GOSUB500:GOSUB550
40 W=W+1:GOSUB400
50 FORI=1TOHR:X(I)=I:NEXTI
55 FORJ=1TOBR:Y(J)=J:NEXTJ
60 N=0
70 GOSUB700
80 N=N+1
90 IFN=TRGOTO110
100 GOTO70
110 ?
120 IFW=SGOTO140
130 GOTO40
140 GOSUB1450
150 CLOSE1
160 END

400 FORM=1TO30:?"-";:NEXTM
410 ?:RETURN

500 A=59459:B=59464:C=59466:D=59467:E=59471
510 POKEA,112:POKEE,0:RETURN

550 OPEN1,1,1:PRINT#1,"---DATA---"
560 ?"DATE,TIME,OBS=":INPUTD$,T$,S$
565 ?"PRESENT CASE:TRL=HUE=LUM=24"
570 ?"SESSION,TRIAL,HUE,LUM=":INPUTS,TR,HR,BR
580 ?"FLASH,TONE(SEC)=":INPUTFS,SD
585 TND=SD*60:FLD=FS*60
590 TI$=T$
600 PRINT#1,"DATE=D$;"/TIME=T$;"/OBS=S$
610 PRINT#1,"SESSION=S$;"/TRIAL=TR;"/HUE=HR;"/LUM=BR;
"/FLASH=FS"SEC"
620 PRINT#1,"-----"
630 PRINT#1,"SESS/TRL/HUE/LUM/RES"
640 RETURN

700 R=INT(RND(1)*HR)+1
710 IFX(R)=0THEN700
715 RR=INT(RND(1)*BR)+1
718 IFY(RR)=0THEN715
720 ?"SESS=W;"/TRL="N+1
730 ?"HUE=X(R);"/LUM=Y(RR):RN=X(R):RA=Y(RR)
740 FORJ=1TORN:FORH=1TO50:NEXTH
750 POKEE,16:POKEE,0:NEXTJ
753 FORK=1TORA:FORQ=1TO50:NEXTQ
755 POKEE,32:POKEE,0:NEXTK
760 GOSUB1000:GOSUB1100:GOSUB1000
770 RD=(INT(RND(1)*10)+1)*60
772 KK=TI

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Interfacing to the PET is through the MOS6522 PIA port that yields 8 bits information exchange, the direction of which can be set under BASIC control, decimal address 59459 in the PET's memory map (McLean, 1978). In Figure 1, PA0, PA1, and PA2 ports of the PIA are each defined as input modes, whereas PA4, PA5, and PA6 ports are each defined as output modes. The TTL-level logic signal of each I/O port is buffered with Schmitt trigger action in order to isolate (protect) the PET's PIA from all of the external device lines.

Pushing (grounding) Microswitch 1 or 2 causes "yes" and "no" response input (logic "1") to the PA0 and PA1 ports, respectively. This response is scanned and latched by the PET's program (PEEK statement). Pushing Microswitch 3 initiates a "try-again" routine. Each microswitch is pulled up to Vcc (+5 V) by a 1K resistor, and each response signal is OR-gated to CA1 for input synchronization. The output logic pulse controls two independent pulse motors (Nippon Pulse Motor, Type PA62, and associated driver, Type PS-1LD-

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775 IFTI-KK>RDTHEN780
778 GOTO775
780 ?GOSUB1200:GOSUB1300
790 IFRS=4THEN760
800 GOSUB1400
810 FORU=1TO500:NEXTU
815 REM PULSE MOTOR REWIND (24-STEPS)
820 Q=24-RN
830 FORYH=1TOQ:FORZ=1TO20:NEXTZ
850 POKEE,16:POKEE,0:NEXTYH
860 X(R)=0
870 VX=24-RA
880 FORXB=1TOVX:FORZZ=1TO20:NEXTZZ
890 POKEE,32:POKEE,0:NEXTXB
900 Y(RR)=0
910 RETURN

1000 TM=TI
1010 IFTI-TM>120THEN1030
1020 GOTO1010
1030 RETURN

1100 POKED,16:POKEB,123:POKEC,151
1110 KK=TI
1120 IFTI-KK>TNDTHEN1140
1130 GOTO1120
1140 POKED,0
1150 ?TAB(8)"TONE="SD"SEC"
1160 RETURN

1200 POKEE,64
1210 FD=TI
1220 IFTI-FD>FLDTHEN1240
1230 GOTO1220
1240 POKEE,0:?"TAB(8)"FLASH="FS"SEC"
1250 RETURN

1300 F=TI
1305 IFTI-F>300THEN1365
1306 RS=PEEK(E)AND7
1310 IFRS=1THEN1370
1315 IFRS=2THEN1380
1320 IFRS=4THEN1390
1360 GOTO1305
1365 ?TAB(30)"MISS="RS:RETURN
1370 ?TAB(30)" YES="RS:RETURN
1380 ?TAB(30)" NO="RS:RETURN
1390 ?TAB(20)"TRY-AGAIN":?:RETURN

1400 PRINT#1,W;N;X(R);Y(RR);RS
1410 RETURN

1450 PRINT#1,"--DATA END--";"/TIME=TI$
1460 RETURN

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Figure 3. Sample program for the visual stimulator.

4),¹ high-voltage flash driver (+300 V, Type FL4D tube), and a warning sound generator (1 kHz; 8-ohm speaker). Since an output pulse from PA4 port rotates PM1 for a 15-deg step angle, 24 pulses result in one rotation (360 deg) of an associated color wheel (WH1). Similarly, PA5 port controls PM2 and, accordingly, the neutral density (ND) wheel (WH2). As shown in Figure 2, both wheels have 24 independent apertures (1 cm in diameter) so that a maximum of 24 (luminance levels) by 24 (hue levels) stimulus combinations can be made using the PET's randomized string of pulses. As the front view of the wheel shows, Kodak Wratten neutral density filters (.1 log unit steps) and Kodak Wratten color filters control 2.4 log units range luminance and 24 different hues in a random order. A simple optical path leads the light from the source tube to the observer's eye through the lens, the mirrors, and the apertures.

PROGRAMMING

Figure 3 provides an example BASIC program for the visual stimulator. The program consists of the main program (Lines 10-160) and five associated subroutines (Lines 400-910 and 1450-1460). Furthermore, an additional five nested subroutines (Lines 1000-1410) are each called by associated subroutines (Lines 700-910) as required. The program has several main components.

The main loop (Lines 40-130) is indexed by variables W and N, which count the numbers of the session and trial, respectively. Each subroutine (Lines 400-510) draws a line on the CRT and selects five decimal addresses² associated with different I/O functions in the PET. Since Data Lines PA0-PA7 are individually programmed to function for input or output as required, the user ports of PA4, PA5, and PA6 ($2^4 + 2^5 + 2^6 = 112$) are defined as output; the other ports remain as inputs. This is done by using a POKE 59459 statement to place a number into the data direction register.

The subroutines (Lines 550-640 and 1400-1460) control the cassette filing functions: The cassette is opened (Line 550), and the experimental parameters (such as the date, time in HHMMSS format, observer, session, trial, hue, luminance, and durations) are stored and written (PRINT#1 statement) onto the cassette. When the INPUT command is interpreted by the monitor the PET prints "?"³ on the CRT, asking the experimenter to input the variables (or string-\$-mixed variable) from keyboard. On Line 585, the duration of the flash and tone are converted into a second-based unit, since the PET's software timer indexed by TI (see Line 772) uses a 1/60-sec crystal-oscillated time base. It appears that this most powerful real-time BASIC function depends on the TI function.

The subroutine beginning on Line 700 generates a randomized string of pulses without replacement (randomized within a session: Lines 700-730) and controls the magnitude of the rotation angle of the pulse motors

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10 ?"clr":?"READ DATA FILE"
20 OPEN1
30 ?"FILE LENGTH UP TO N=":INPUTN
40 FORI=1TON
50 INPUT#1,X$
60 ?X$
70 NEXTI
80 CLOSE1
90 STOP

RUN

---DATA---
DATE=1978.12.20/TIME=130000/OBS=YK/M/19
SESSION=1/TRIAL=24/HUE=24/LUM=24/
FLASH=2SEC
-----*
SESS/TRL/HUE/LUM/RES*
1 0 20 20 2
1 1 16 17 2
1 2 22 19 2
1 3 15 12 2
1 4 5 16 2
1 5 11 2 1
1 6 18 10 2
1 7 8 3 1
1 8 4 13 2
1 9 14 18 2
1 10 10 21 1
1 11 6 8 2
1 12 2 7 2
1 13 17 11 2
1 14 12 1 2
1 15 24 14 2
1 16 19 15 2
1 17 3 24 2
1 18 21 6 2
1 19 1 9 2
1 20 13 4 2
1 21 7 22 1
1 22 9 23 1
1 23 23 5 2
--DATA END--/TIME=130853

* 1=YES
2=NO

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Figure 4. Sample program for reading-out from the data cassette.

(Lines 740-755). The subroutines (Lines 1000-1030 and 1100-1160) delay time for 2 sec in a loop (Lines 1010-1020) and trigger the sound signal (as a programmed 1-kHz square wave: Line 1100) for a programmed duration (at Line 580). After the randomized foreperiod time, which changes from 3 to 14 sec (Lines 760-778), a flash stimulates the observer's eye for a given time (Lines 580 and 1200-1250). Immediately after the offset of the flash, a call to the subroutine at Line 780 repetitively checks for the observer's responses for a maximum of 5 sec: PA0-2 ($2^0 + 2^1 + 2^2 = 7$) input ports of the PIA are consulted with a PEEK command (accessing these ports using logical AND function), and the response is printed on the CRT (Lines 1365-1390). Pushing Switch 3 causes a "try-again" loop to Line 760.

A call to the subroutine at Line 800 stores the session number (W), trial number (N), level of hue [X(R)] and of luminance [Y(R)], and responses into the RAM area for the cassette buffer until a block of data is ready to be written. Data are not double buffered, so that processing ceases while the block is written,

and it is difficult to predict exactly when the recording action will occur (McLean, 1978). Lines 810-910 set the angle of the pulse motors to initial position.

The subroutine on Line 1450 writes the data-end remark and the finishing time of the experimental job onto the cassette tape. Following these processes, the cassette file is closed (Line 150).

Figure 4 shows an example program that reads the data from the cassette file and prints it on the CRT for further data analysis. Two minor difficulties have been found during cassette handling and processing. First, as has been previously noted by McLean (1978), the program/data loading procedure has not always been successful. Second, the zero-page RAM sometimes malfunctions. These minor difficulties may be related, in part, to mechanical problems with the cassette unit and to the insufficient heat-sink problems with the RAM.

The stimulus parameters, as well as the response values, are printed on the CRT immediately after the action, informing the experimenter of the progress of the experiment. The use of this system in the animal psychophysics laboratory, for example, will make it possible to execute a hue/brightness discrimination experiment over a few days. The total interface cost of the visual stimulator is less than \$180.

REFERENCE NOTE

1. Commodore Business Machines, Inc. *MCS6522 versatile interface adaptor*. Preliminary data sheet, November 1977.

REFERENCES

- BROWN, E. L., & DEFFENBACHER, K. Microcomputers big and little: Selecting a low-cost laboratory computer network. *Behavior Research Methods & Instrumentation*, 1978, **10**, 241-245.
- COMMODORE BUSINESS MACHINES, INC. *PET communication with the outside world*. Palo Alto, Calif: Author, 1978.
- CRISWELL, H. E., & BABCOCK, B. A flexible low cost signal averager. *Electroencephalography & Clinical Neurophysiology*, 1978, **45**, 535-537.
- DURRETT, H. J., JR. Inexpensive microcomputer systems for research and instruction: A dream or reality? *Behavior Research Methods & Instrumentation*, 1978, **10**, 345-351.
- JOHNSON, R. N. Using the PET microcomputer. *Behavior Research Methods & Instrumentation*, 1978, **10**, 474-475.
- KASHINSKY, W. M., ROMANCZYK, R. G., & TREIBER, A. The presentation of visual stimuli: An inexpensive microcomputer-based system. *Behavior Research Methods & Instrumentation*, 1979, **11**, 64-66.
- MCLEAN, R. S. The Commodore PET: Using personal computers for experimental control. *Behavior Research Methods & Instrumentation*, 1978, **10**, 468-473.
- MILKMAN, N., SHAPLEY, R., & SCHICK, G. Experimental applications: A microcomputer-based visual stimulator. *Behavior Research Methods & Instrumentation*, 1978, **10**, 539-545.
- OSAKA, N. An inexpensive quasirandom interpulse interval generator. *Behavior Research Methods & Instrumentation*, 1978, **10**, 18-20.
- PERERA, T. B. A versatile microcomputer-based multiple-field tachistoscope. *Behavior Research Methods & Instrumentation*, 1978, **10**, 546-547.
- POLSON, P. G. Microprocessors: Their impact on real-time computing in psychology. *Behavior Research Methods & Instrumentation*, 1978, **10**, 463-467.
- SANTA, J. L., & STREIT, P. A. A microprocessor reaction time laboratory. *Behavior Research Methods & Instrumentation*, 1978, **10**, 352-355.
- SIDOWSKI, J. B. Microcomputers in psychology. *Behavior Research Methods & Instrumentation*, 1978, **10**, 463-467.
- YOB, G. PET user cookbook. *Kilobaud*, 1979, **27**, 62-73.

NOTES

1. For information on pulse motors contact Nippon Pulse Motor, Inc., 2-16-13 Hongo, Bunkyo-ku, Tokyo 112, Japan [Phone: (03)-813-8841]. Its total cost is approximately \$160 with associated drivers.
2. A practical I/O selection and associated addresses in the PET are: 59459 = data direction register, 59464 = timer 2, 59466 = serial I/O shift register, 59467 = auxiliary control register, 59468 = peripheral control register, 59471 = output register without handshaking.
3. A mark "?" is interpreted as an abbreviated command of "PRINT" by the PET BASIC.

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