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PET Flasher: A machine language subroutine for timing visual displays and response latencies

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PET Flasher presents a one-line stimulus display at any location on a PET/CBM (Commodore Business Machines) screen and measures reaction time from display onset. Display duration is accurately controlled in 16.7-msec steps, and reaction time measurement is accurate within ±1 msec. PET Flasher is easily incorporated within any PET/CBM BASIC program, since as a subroutine, it is called only when precise timing operations are required.

A serious problem encountered by anyone who attempts to use a PET/CBM microcomputer to present brief visual displays or to time response latencies is that programs written in BASIC cannot provide accurate timing. The timing accuracy possible with BASIC programs is limited by two factors. First, the most precise clock available within a BASIC program is the jiffy clock, which increments once every 16.7 msec. Second, even if the jiffy clock is considered to provide sufficient precision for some experimental applications, certain characteristics of the PET/CBM operating system make it impossible to use the jiffy clock within a BASIC program to provide consistent control of display duration. For any BASIC program involving the presentation of a visual display, the timing accuracy is considerably less than ±16.7 msec, and more important, the accuracy of any such timing operation programmed in BASIC varies in an inconsistent and indeterminant manner from trial to trial (Lincoln & Lane, 1980). The way to overcome these limitations of PET/CBM BASIC programs is to measure all critical temporal intervals by a machine language subroutine.

PET Flasher represents one method for accurately timing visual displays and response latencies to these displays. The subroutine is written for a PET/CBM 2001 microcomputer with Revision 3 ROMs, and according to available memory maps (Osbourne & Donahue, 1980), it should run with slight modification on older PETs containing Revision 2 ROMs.[1] The major characteristics of PET Flasher are as follows: (1) A one-line stimulus display, consisting of 1-31 characters, is presented at the center of the screen; (2) all characters available on the PET/CBM keyboard may be displayed, including mixed upper- and lowercase letters; (3) display duration can vary from 16.7 msec to 4,250 msec; (4) the time from display onset to the closure of a switch connected to the parallel user port is measured with ±1-msec accuracy to a maximum response latency of 16.7 sec; (5) switch closure terminates the display, if it occurs prior to the specified display duration; and (6) multiple switches may be connected to the parallel user port, and the program records which switch was closed.

PET Flasher has two distinctive characteristics, which are illustrated in the assembled machine code shown in Figure 1. First, millisecond timing accuracy is achieved through the use of the PET/CBM microsecond timer (T2) located at $E848 and $E849. However, since these counters have a 65.5-msec limit, an additional counter ($03D5) is incremented via the interrupt system whenever T2 times out (see DeJong, 1979). In this way, it is possible to measure response latencies up to a maximum of 16.7 sec. The second distinctive characteristic concerns the method used to coordinate presentation of the visual displays with the CRT sweep. Since the rollover of the PET/CBM jiffy clock ($8F) is synchronized with the beginning of the CRT sweep, the program waits for the jiffy clock to roll over and then sets a microsecond counter (T1) to time out every 16.7 msec, which is the time required for each sweep of the CRT screen. Thus, display duration is controlled in steps of 16.7 msec, and this is the maximum possible resolution when a standard CRT is used.

These two characteristics of PET Flasher distinguish it from previous proposals for obtaining accurate timing and display-CRT coordination with microcomputers. Since PET Flasher utilizes the microsecond timer within the 6522 versatile interface adapter, software timing subroutines, such as those proposed by Price (1979), are not required. In addition, the hardware modification suggested by Reed (1979) to achieve display-CRT coordination is not necessary, since PET Flasher synchronizes display presentation with the rollover of the jiffy clock. These distinguishing characteristics of PET

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```
HEX   ASSEMBLY   MACHINE
ADDR  LANGUAGE   LANGUAGE   COMMENTS

033A  LDA #00    A9 00
033C  STA 03D5   8D D5 03 - RESET HIGH BYTE COUNTER
033F  STA E843   8D 43 E8 - SET PARALLEL PORT TO INPUT
0342  LDA #FF    A9 FF    - RESET T2 LOW ORDER BYTE
0344  STA E848   8D 48 E8
0347  LDA 03D9   AD D9 03 - SUM DISPLAY LOCATION WITH # OF
034A  CLC        18         STIMULUS CHARACTERS
034B  ADC 03DA   6D DA 03
034E  TAY        A8
034F  LDX 03DA   AE DA 03 - LOAD # OF CHARACTERS IN X
0352  LDA E84B   AD 4B E8 - ADJUST AUXILLARY CONTROL
0355  AND #5F    29 5F      REGISTER BY SETTING
0357  ORA #40    09 40      BITS 5,6 & 7
0359  STA E84B   8D 4B E8
035C  LDA #1A    A9 1A    - RESET T1 LOW ORDER BYTE
035E  STA E844   8D 44 E8
0361  LDA 8F     A5 8F    - WAIT FOR JIF CLOCK ROLLOVER
0363  CMP 8F     C5 8F    - LOOP UNTIL ROLLOVER
0365  BEQ 0363   F0 FC
0367  LDA #41    A9 41    - CO-ORDINATE T1 WITH CRT
0369  STA E845   8D 45 E8
036C  LDA 03DA,X BD DA 03 - LOAD ONE CHARACTER
036F  AND #BF    29 BF    - CHANGE ASCII CODE TO SCREEN
0371  BPL 0377   10 04      CODE
0373  AND #7F    29 7F
0375  ORA #40    09 40
0377  STA 81DF,Y 99 DF 81 - DISPLAY CHARACTER
037A  DEY        88
037B  DEX        CA
037C  BNE 036C   D0 EE    - LOOP FOR REMAINING CHARACTERS
037E  LDA #FF    A9 FF    - START T2 (MSEC TIMER)
0380  STA E849   8D 49 E8
0383  LDA E84F   AD 4F E8 - CHECK FOR RESPONSE
0386  CMP #FF    C9 FF
0388  BNE 03CB   D0 41    - IF RESPONSE, JUMP
038A  LDA E84D   AD 4D E8 - LOAD INTERRUPT FLAG REGISTER
038D  STA E84D   8D 4D E8 - CLEAR FLAGS
0390  TAY        A8
0391  AND #20    29 20    - CHECK FOR T2 INTERRUPT
0393  BEQ 039E   F0 09    - IF NO INTERRUPT, JUMP
0395  LDX E849   AE 49 E8 - RESET T2 INTERRUPT
0398  STX E849   8E 49 E8
039B  INC 03D5   EE D5 03 - INCREMENT HIGH BYTE COUNTER
039E  TYA        98
039F  AND #40    29 40    - CHECK FOR T1 INTERRUPT
03A1  BEQ 0383   F0 E0    - IF NO INTERRUPT, LOOP
03A3  DEC 03D8   CE D8 03 - DECREMENT DURATION COUNTER
03A6  BNE 0383   D0 DB    - LOOP UNTIL COUNTER = 0
03A8  LDX #28    A2 28
03AA  LDA #20    A9 20    - LOAD BLANK
03AC  STA 81DF,X 9D DF 81 - DISPLAY BLANK
03AF  DEX        CA
03B0  BNE 03AC   D0 FA    - LOOP UNTIL ENTIRE LINE BLANK
03B2  LDA E84F   AD 4F E8 - CHECK FOR RESPONSE
03B5  CMP #FF    C9 FF
03B7  BNE 03CB   D0 12    - IF RESPONSE, JUMP
03B9  LDA E84D   AD 4D E8 - LOAD INTERRUPT FLAG REGISTER
03BC  AND #20    29 20    - CHECK FOR T2 INTERRUPT
03BE  BEQ 03B2   F0 F2    - IF NO INTERRUPT, LOOP
03C0  LDX E849   AE 49 E8 - RESET T2 INTERRUPT
03C3  STX E849   8E 49 E8
03C6  INC 03D5   EE D5 03 - INCREMENT HIGH BYTE COUNTER
03C9  BNE 03B2   D0 E7    - IF NO OVERFLOW, LOOP
03CB  LDY E849   AC 49 E8 - STORE LOW BYTE COUNTER
03CE  STY 03D6   8C D6 03
03D1  STA 03D7   8D D7 03 - STORE RESPONSE CODE
03D4  RTS        60        - RETURN
```

Figure 1. Assembled machine code for PET Flasher.

Flasher have a price, however, in that by using unique characteristics of PET/CBM microcomputers, PET Flasher works only on Commodore Business Machines microprocessors.

An example of how PET Flasher can be used within a BASIC program is shown in Figure 2. Initially, the program READs the machine code from DATA statements and POKEs it into the second-cassette buffer, which is a protected area. Display location (985) specifies the number of spaces from the left side of the screen to the leftmost character in a display, and display duration (984) is specified in multiples of 16.7 msec. Before a stimulus display is presented, the display buffer, which occupies the top 31 locations in the second-cassette buffer (987-1017), is loaded with the ASCII code for each character in the display. Following presentation of the fixation point, a switch connected to the parallel user port must be closed (Line 310) and opened (Line 320) before PET Flasher is called (SYS 826). Since PET Flasher initiates display presentation prior to checking for a response, any responses that may occur prior to display onset have no effect. Once a response does occur, control returns to the BASIC program, which first clears the screen and then computes the reaction time from display onset. If no response occurs within 16.7 sec after display onset, control returns automatically to the BASIC program and the calculated reaction time is 0 msec.

The response keys necessary to use PET Flasher are connected to the parallel user port. Any reasonable quality SPST switch may be used, and each switch simply grounds one of the input/output lines (PA0 to PA7). The exact pin connections are given in the *CBM User Manual* (Commodore Business Machines, 1979). Since there are eight input/output lines, up to eight different switches may be used. Closure of each switch produces a unique code, and these codes are accessible

```
100 REM READ SUBROUTINE INTO MEMORY
110 REM START LOCATION IS $033A(826)
120 FOR I=0 TO 154
130 READ A
140 POKE 826+I,A
150 NEXT I
160
170 POKE 985,16  REM DISPLAY LOCATION
180 POKE 984,10  REM DISPLAY DURATION
190
200 REM PUT STIMULI INTO DISPLAY BUFFER
210 A$="STIMULI"
220 L=LEN(A$)
230 POKE 986,L  REM # OF CHARACTERS
240 FOR I=1 TO L
250 POKE 986+I,ASC(MID$(A$,I,1))
260 NEXT I
270
280 REM CALL SUBROUTINE
290 PRINT"□"  REM CLEAR SCREEN
300 POKE 33267,46  REM FIXATION POINT
310 IF PEEK(59471)=255 GOTO 310
320 IF PEEK(59471)<>255 GOTO 320
330 PRINT"□"  REM CLEAR FIXATION POINT
340 SYS 826
350 PRINT"□"  REM CLEAR SCREEN
360
370 REM CALCULATE REACTION TIME
380 SH=PEEK(981)  REM HIGH BYTE
390 H=PEEK(982)  REM LOW BYTE
400 RT=((255-H)+(SH*256))*.256
410 IF INT(RT)<5 THEN RT=0  REM OVERFLOW CHECK
420 RC=PEEK(983)  REM RESPONSE CODE
430 PRINT"■■■■"
440 PRINT"REACTION TIME WAS..";INT(RT)
450 PRINT"RESPONSE CODE WAS..";RC
460 END
470
480 DATA 169,0,141,213,3,141,67,232
490 DATA 169,255,141,72,232,173,217,3
500 DATA 24,109,218,3,168,174,218,3
510 DATA 173,75,232,41,95,9,64,141,75
520 DATA 232,169,26,141,68,232,165,143
530 DATA 197,143,240,252,169,65,141,69
540 DATA 232,189,218,3,41,191,16,4,41
550 DATA 127,9,64,153,223,129,136,202
560 DATA 208,238,169,255,141,73,232
570 DATA 173,74,232,201,255,208,65,173
580 DATA 77,232,141,77,232,168,41,32
590 DATA 240,9,174,73,232,142,73,232
600 DATA 238,213,3,152,41,64,240,224
610 DATA 206,216,3,208,219,162,40,189
620 DATA 32,157,223,129,202,208,250
630 DATA 173,74,232,201,255,208,13,173
640 DATA 77,232,41,32,240,242,174,73
650 DATA 232,142,73,232,238,213,3,208
660 DATA 231,173,73,232,140,214,3,141
670 DATA 215,3,96
```

Figure 2. A BASIC program that implements PET Flasher.

Table 1
Screen Memory Addresses for Each Screen Line

	Address		Byte	
Line	Hexadecimal	Decimal	Low	High
01	7FFF	32767	255	127
02	8027	32807	039	128
03	804F	32847	079	128
04	8077	32887	119	128
05	809F	32927	159	128
06	80C7	32967	199	128
07	80EF	33007	239	128
08	8117	33047	023	129
09	813F	33087	063	129
10	8167	33127	103	129
11	818F	33167	143	129
12	81B7	33207	183	129
13	81DF	33247	223	129
14	8207	33287	007	130
15	822F	33327	047	130
16	8257	33367	087	130
17	827F	33407	127	130
18	82A7	33447	167	130
19	82CF	33487	207	130
20	82F7	33527	247	130
21	831F	33567	031	131
22	8347	33607	071	131
23	836F	33647	111	131
24	8397	33687	151	131
25	83BF	33727	191	131

in BASIC by PEEKing Location 59471. When no switch is closed, the decimal code at Location 59471 is 255. Switch debouncing is not necessary.

PET Flasher has been tested against an external time base. We have verified that displays are presented for the specified number of CRT sweeps and that reaction times from display onset are accurate within ±1 msec. However, when PET Flasher presents a stimulus display at the center of the CRT screen (Line 13), as is done by the version described in this article, there is a constant 8-msec discrepancy between the reaction times measured by PET Flasher and the same reaction times measured by an external timer. This occurs because PET Flasher times from the beginning of the screen sweep, whereas an external timer cannot be activated until the sweep reaches the center of the CRT screen and the stimulus display is presented. This constant error is easily corrected by subtracting 8 msec from the calculated reaction times.

With one rather straightforward change, PET Flasher can be modified to present the one-line display at any screen location. All that is required are new values in the locations used by PET Flasher to select a particular line in screen memory. These values are shown in Table 1, which gives the high and low byte-decimal equivalents corresponding to each of the 25 screen lines. Since PET Flasher stores the low byte values in Locations 888 and 941 and stores the high byte values in Locations 889 and 942, display location can be changed by simply POKEing the appropriate low and high byte values into these locations prior to calling the subroutine. For example, to present a display at Line 6 on the screen, Line 270 in the BASIC program requires the following statement sequence: POKE 888, 199: POKE 889, 128: POKE, 941, 199: POKE 942, 128. If these or similar POKE statements are not included in the BASIC program, then PET Flasher, by default, presents the display on Line 13 of the screen.

The fixation point can also be located anywhere on the screen, since any screen location (32768 to 33767) may be specified in the POKE statement on Line 300 of the BASIC program in Figure 2. In addition, any character in the PET/CBM character set may be used for fixation by POKEing the location specified in Line 300 with the PET/CBM decimal code for the selected character.

PET Flasher meets our need to use PET/CBM microcomputers to measure reaction times to visual displays with millisecond accuracy. In addition, since PET Flasher is easily incorporated within any BASIC program, it has proved useful in a variety of experimental contexts requiring accurately timed stimulus displays and reaction times to these displays.

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NOTE

1. In Revision 2 ROMs, the jiffy clock is located on Page 2 rather than Page 0. As a result, two additional instructions must be added to the subroutine, and the high and low byte counters must be relocated. These modifications are available upon request.

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