Measuring reaction time with millisecond accuracy using the TRS-80 microcomputer

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A machine language subroutine is proposed for measuring reaction time with millisecond accuracy using the TRS-80 microcomputer. This timer is accurate to 1 msec in the first 30,000 msec and to 5 msec in the first 65,000 msec (1 part in 10,000).

The TRS-80 microcomputer is likely to become commonplace in information processing research because it is inexpensive, has wide marketing and servicing facilities, is portable, and does not require sophisticated programming (Durrett, 1978; Perera, 1978; Sidowski, 1978).

The TRS-80 can measure reaction time by means of an incrementing loop. For instance, this BASIC Level 2 loop,

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100 K=0
110 K=K+1
120 AS=INKEY$
130 IF AS="" THEN GOTO 110
140 PRINT "DELAY= ", K, "LOOPS"
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can be used to measure time for several thousand years with 12.5-msec resolution. The program cycles through Lines 110, 120, and 130, incrementing the counter, K, once with each cycle, until the subject responds by hitting a key. Control exits the loop; K contains the count of loops completed. Because the loop requires 12.5 msec to complete, reaction time in milliseconds can be calculated by multiplying 12.5 by variable K. This is not the fastest possible loop that can be written in BASIC, but simple instructions in BASIC function in the 3- to 10-msec range, and it takes several instructions to execute a loop that will test for an exit condition. The result is loop times in the 10- to 25-msec range.

A 12.5-msec timing loop does not provide adequate resolution for all purposes. Sternberg (1975) bases theoretical arguments on reaction time differences of 35 msec. Posner's name/physical match contrast yields a difference of about 70 msec (Posner & Rogers, 1978). Semantic marking appears as a 100-msec difference in reaction time (Chase, 1978). All of these effects are detectable using a 12.5-msec loop; however, only

imprecise parameter estimates can be made. Other effects may be undetectable using a 12.5-msec loop. For instance, Cavanaugh (1972) bases theoretical assertions on differences among scan rates for various types of materials. Words are scanned at a rate of 33 msec/item; colors, 38 msec; letters, 40 msec; and forms, 68 msec. Differences among these scan rates would not be detectable using a 12.5-msec loop. Radio Shack's expansion interface, with its real-time clock, provides only 25-msec resolution, precluding its usefulness in high-resolution timing measurements.

The machine language routine listed in Figure 1 is recommended for measuring reaction times because it provides millisecond accuracy. The user must perform three tasks. (1) Following power-up or reset, the machine asks, "MEMORY SIZE?" The user responds "32000" or according to the configuration table, Figure 2, in order to protect core memory from BASIC, in which the machine code will be safe to operate. (2) The timer is stored in the protected memory areas as shown in Figure 1, Lines 1-16. These statements may appear at any line number, providing that they are executed before the timer is called. (3) The timer is called as needed within a main program, as illustrated in Figure 1, Lines 100-190. Line 100 is the last line of the user's stimulus generator. Line 110 starts the timer. When the subject responds, the timer stops, and control returns to the main program at Line 120. Lines 130 and 140 retrieve the count of cycles completed. Line 150 combines the most significant byte and the least significant byte into the decimal equivalent of a 16-bit binary loop count. A correction factor of .9992 is applied because the crystal-controlled loop counter is not quite evenly divisible into millisecond increments. The offset of .6 is added so that rounding occurs when the integer value is taken. The variable RT contains the subject's reaction time. RT may be tested or stored by the user's BASIC program. Variable N contains a number representing the subject's response, which can be tested or stored or used to generate the string variable RESP\$, as shown. "%" is the type declaration character for an integer variable, defined as a 16-bit signed binary number with a range of +32,767 to -32,768. VARPTR is a function that finds the location in core memory

Reprints are available from the authors at P. O. Box 154, George Peabody College, Nashville, Tennessee 37203. A listing of the assembly language source code is available, as is a wiring diagram for linking the output ports of the TRS-80 to an external clock in order to verify the accuracy of measurement or to control external equipment. The authors thank Judy A. Hanna for her assistance in preparing this manuscript.

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(A)    PROTECT MEMORY
        TURN ON OR RESET MACHINE
        TRS=80 ASKS, "MEMORY SIZE?"
        USER REPLIES, "32000"
        OR AS PER CONFIGURATION TABLE

(B)    STORE TIMER
1   RAM%= 32000+1      : 'CHANGE AS PER CONFIGURATION TABLE
2   VR%=VARPTR(RAM%)   : POKE 16526, (PEEK(VR%))
3   POKE 16527, (PEEK(VR%+1)) : '2&3 FOR LEVEL II ONLY
4   'DEFUSR0=RAM%       : 'USE LINE 4 FOR DISK ONLY
5   FOR N=RAM% TO RAM%+79 : READ K : 'LOAD MACHINE
6   POKE N,K : NEXT N   : 'LANGUAGE CODE
7   DATA 243,205,127,10,84,93,24,08
8   DATA 00,00,00,00,00,00,00,00
9   DATA 01,01,00,120,33,03,56,221
10  DATA 33,214,255,253,33,03,00,24
11  DATA 10,221,09,48,06,253,09,221
12  DATA 33,218,255,134,40,243,00,00
13  DATA 253,229,221,229,213,221,225,221
14  DATA 119,08,209,221,115,10,221,114
15  DATA 11,209,221,115,12,221,114,13
16  DATA 111,96,211,00,00,195,154,10

(C)    USE TIMER
100 PRINT @ 540, "GO"      : 'PRESENT STIMULUS
110 N=USR(RAM%)           : 'FOR LEVEL II ONLY
110 'N=USR0(RAM%)         : 'FOR DISK ONLY
120 CLS                   : 'CONTROL RETURNS HERE
130 LSB=PEEK(RAM%+12)     : 'RETRIEVE COUNT
140 MSB=PEEK(RAM%+13)     : 'AND COMPUTE REACTION
150 RT=INT(.9992*(((MSB*256)+LSB)+.6)) : 'TIME
160 PRINT "REACTION TIME=", RT, "MILLISECONDS",
170 IF N=16 THEN RESP$="YES" : 'SUBJECT HIT D-KEY
180 IF N=8 THEN RESP$="NO"   : 'SUBJECT HIT K-KEY
190 PRINT RESP$ : 'RETURN   : 'TO CALLING PROGRAM

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Figure 1. Machine language routine. Note that the sixth entry in Statement 9 is "03." This number may be altered to cause particular sets of keys to be scanned.

that BASIC uses to store the value of the variable of interest.

As listed in Figure 1, the program will score a response on the "D" key as "yes" and a response on the "K" key as "no." This is not immutable. Any key, or an external switch, may be designated a response key. However, the sixth entry in Line 9 of Figure 1, "03," must be altered. Figure 3 provides the necessary information. For instance, to scan Keys 1 and 8, replace "03" with "48" (the sum of the two row designators). If the "1" key is hit, N will be 2; if the "8" key is hit, N will be 1. The "1" and "9" keys are indiscriminable using this procedure, as both return N = 2. Similarly,

the "0" and "8" keys both return N = 1. Note that the program in Figure 1 scores the "L" key (as well as the "D" key) as "yes" and the "C" key (as well as the "K" key) as "no."

The timer recycles at 65,536 msec. Hence, outcomes are ambiguous for reaction times in excess of 1 min. The timer loses 1 msec in the first 30,000 msec and 5 msec in the first 60,000 msec. This represents the best straight-line correction through a function that varies exponentially in a stepwise fashion. Verification was performed using a Systron-Donner 214 frequency counter with a crystal time base accurate to 10 parts/million. The timer was started immediately following stimulus presentation using the BASIC command OUT(0,1) and was stopped immediately after response using the machine language equivalent of the OUT(0,0) command. The second command remains in the program, so the user may verify the accuracy of the timer by inserting OUT(0,1) at Line 100 and decoding the signals on the TRS-80 interface connector. Data bus Bit 0 of Port 0 is thus latched and used to gate an external timing device.

CONFIGURATION TABLE			
SYSTEM		MEMORY SIZE?	RAM%=
4K	RAM=	20399	20400
16K	RAM=	32680	32681
32K	RAM=	49070	-16465
48K	RAM=	65450	-85

Figure 2. Configuration table.

		COLUMN DESIGNATOR							
		1	2	4	8	16	32	64	128
ROW DESIG- NATOR	01	@	A	B	C	D	E	F	G
	02	H	I	J	K	L	M	N	O
	04	P	Q	R	S	T	U	V	W
	08	X	Y	Z	EXT	EXT	EXT	EXT	EXT
	16	0	1	2	3	4	5	6	7
	32	8	9	:	;	,	-	.	/

Figure 3. Column and row designations. The row designator, when entered as the sixth element in Line 9 of Figure 1, will cause the set of keys in that row to be scanned. The column designator of the particular key hit will be returned as "N" in Line 110 of Figure 1. Two or more rows can be scanned by summing their row designators. An external switch can be arranged to register in one of the "EXT" locations.

Submillisecond accuracy may be achieved using this program. While timing, the IX counter, which is built into the machine hardware, increments from 65,498 to 65,536, increments the IY counter, and resets to 65,498. The IX counter may be indirectly addressed by $LSB = PEEK(RAM\%+10)$ and $MSB = PEEK(RAM\%+11)$. Then $M = ((MSB + 256 + LSB) - 65498) / 38$ will give the remainder, based on how far the IX counter advanced from 65,498 to 65,536. This is roughly 26.6-msec resolution.

An assembly language version of the program described

herein can be obtained from the authors. The assembly language source listing is easily transportable to machines other than the TRS-80.

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