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BRL

A COMPUTER-AIDED SYSTEM FOR MEASURING AND RECORDING SHORT TIME INTERVALS

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JANUARY 1992

U.S. ARMY LABORATORY COMMAND

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ABERDEEN PROVING GROUND, MARYLAND

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An inexpensive computer-aided system has been developed for the measurement and storage of short time interval data. The use of interchangeable time base oscillators, an open-ended, modular counting architecture, signal processing of user-supplied handshaking signals and regulation of power supply voltage allow this system to be adapted to a wide variety of applications. Construction and assembly of this system is simplified by the use of commercially available PC digital interface boards. Schematic diagrams, complete descriptions of circuit functions, and sample software are included.

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1. INTRODUCTION

The ability to accurately measure time intervals is a common requirement for many laboratory and applied systems. As computers become increasingly widespread in these environments, they serve as a convenient medium in which to store a wide variety of data. Thus, a system that can rapidly measure short time intervals and transfer this information to computer memory is of general interest to the research and development community. This report offers a detailed description of an integrated hardware/software system which has been developed to make and record such measurements.

This system was initially developed to interface with a rotating reticle infrared tracking system (Thomson 1991). Trackers of this type operate by spinning a chopper wheel in the field of view and an infrared detector. For a constant chopper wheel angular velocity, the position of the infrared emitting object is determined from the time required for the wheel to rotate from a predetermined orientation to a position which obturates the image projected on the infrared detector. Thus, the position measurement reduces to a time interval measurement.

This time measurement and recording system was built to be flexible and easy to utilize, in spite of the fact that it was designed to match the specific requirements of the infrared tracker. To this end, the oscillator which serves as the time base for these measurements can be easily changed to match a wide range of resolution and maximum time interval requirements. High resolution measurements of longer time intervals may require a larger number of bits than are available in the counting circuitry. To accommodate these circumstances, the counting circuitry utilizes a modular, open-ended architecture which can be readily expanded. Handshaking signals for event and measurement synchronization are also provided. Schematics and timing diagrams are included for all the electronic circuits. Appendix A includes a listing of all required components.

Measured time intervals are transferred to computer memory storage using a commercially available, digital I/O interface board. Once in memory, this data is available for long-term disk storage, plotting, decision making, and system control. Documented examples of computer routines for data acquisition, storage, and plotting are described and listed in Appendix B.

The hardware/software system described in this report offers a convenient and inexpensive method for measuring and recording time interval data. All associated electronics and programming utilize conventional techniques which can be readily duplicated and adapted to serve a wide variety of needs. Most of the "bugs" which inevitably appear when integrating multiple components have been exterminated. Therefore, the included information should serve as a complete guide for the cloning and application of such systems. Toward this end, it is assumed that the reader is interested in all the details which are relevant to developing and applying such a system. Consequently, a minimal amount of effort has been expended on sanitizing this report to protect the reader from technical jargon and details.

2. DESCRIPTION OF SYSTEM HARDWARE

2.1 Hardware Overview. The major components of this time interval measurement system and their interconnections are illustrated in Figure 1. It is assumed that the generic measurement apparatus assesses and converts a parameter of the event into a time interval which is related to the magnitude of the parameter of interest. The boundaries of this time interval are designated by a *START* pulse and a *STOP* pulse which are routed to the time interval measurement board (TIMB). Upon acquisition of the *START* pulse, the counter on the TIMB is reset to zero before beginning to count clock pulses from a fixed frequency time base oscillator. This counting continues until the *STOP* pulse is acquired. Thus, the value of the counter at the time the *STOP* pulse is received is proportional to the time interval between the *START* and *STOP* pulses. Arrival of the *STOP* pulse also initiates other activities on the TIMB. At this time handshaking lines are activated by the TIMB and the counter values are routed to the digital interface board (DIB) via the parallel *DATA* lines. Two complementary handshaking *READY* signals are provided to the DIB to satisfy the sense requirements of both the on-board hardware and driving software. That is, these handshake signals trigger the latching of the counter data by the DIB and also notify the computer that new data is available to be read from the DIB. When the computer is not busy, this new data is read into memory through the bus that connects the DIB to the computer.

The *TRIGGER* lines are used to synchronize the data acquisition process for noncontinuous events. It is assumed that these synchronizing lines are activated when the event is initiated. Thus, this signal could be provided by the pulse which precipitates the

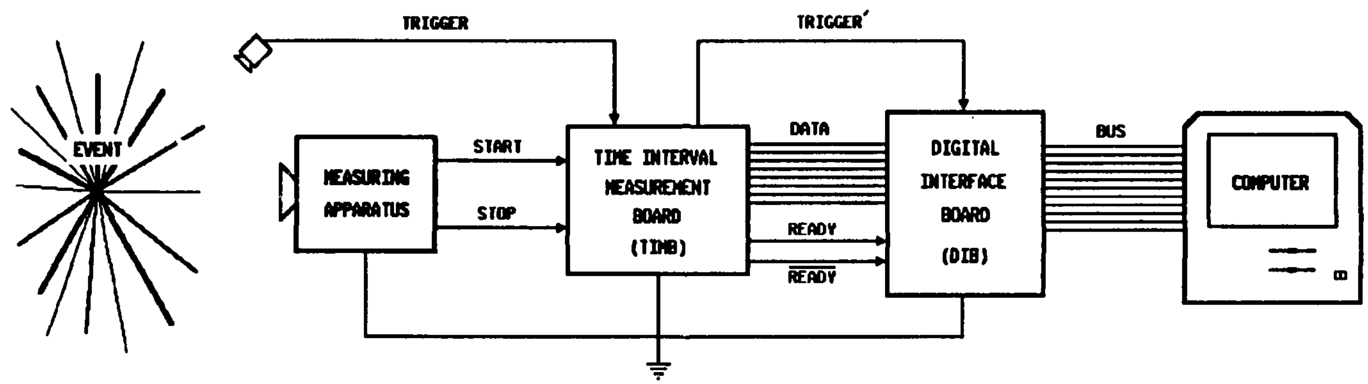


Figure 1. Major Components of Time Interval Measurement System.

event, a threshold indicator in the measuring apparatus or a separate sensor. Because the *TRIGGER* signal could come from such a wide variety of sources, it is conditioned by the TIMB to yield the *TRIGGER'* signal which has well-defined voltage thresholds and limits. This signal is then fed to the computer via the DIB to initiate data acquisition.

The ground connections between these components are explicitly illustrated for two reasons. First, they serve as a reminder that a common reference potential is required for successful communications between subcomponents. This is an obvious observation which, nevertheless, is occasionally overlooked and can cause unnecessary grief. Secondly, as will be discussed later, these common ground connections can serve as pathways by which noise is transferred between components.

2.2 Electronic Timing Circuitry. Time intervals are measured by counting the number of pulses output by a fixed frequency oscillator between a *START* and a *STOP* pulse. These control signals are routed to the TIMB along separate input lines. Each time measurement cycle can be divided into four distinct operations.

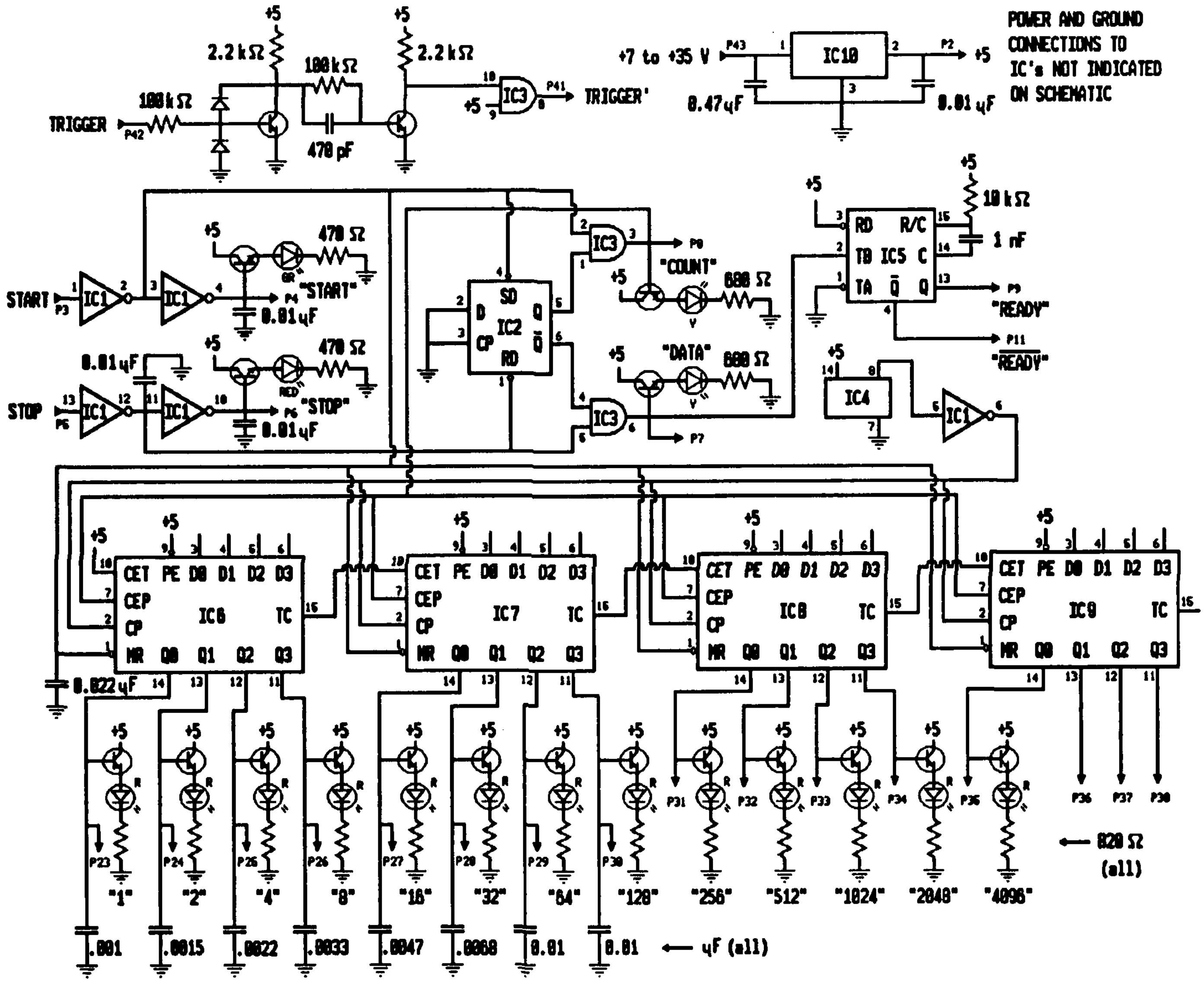
START: When the *START* line goes high, the counters are reset to zero for the ensuing count period.

COUNT: When the *START* line drops back down, the counters are enabled which begin totalling the pulses from the fixed frequency oscillator.

STOP: When the *STOP* line goes high, the counters are disabled which terminates the incrementing of the counters.

DATA: When the *STOP* line drops back down, handshaking signals are output to the DIB which latches the new counter value.

A schematic diagram of the TIMB electronics is illustrated in Figure 2. All the TIMB circuitry was wired on a single printed circuit board which included a 44-pin edge connector. Edge connector pin numbers are denoted by the prefix P. Integrated circuits (IC) are designated by the prefix IC with pin numbers on individual ICs labelled without any prefix. For clarity, the IC power and ground connections are not illustrated. A timing diagram which corresponds to the operations enumerated above is displayed in Figure 3. Signal names are listed on the left while signal locations are listed on the right.



IC1: 74HC04 IC2: 74HC74 IC3: 74HC08 IC4: ECS-100AC IC5: 74HC221 IC6-IC9: 74HC161 IC10: LM340-5.0

ALL TRANSISTORS ARE 2N3904 (npn) OR EQUIVALENT. ALL DIODES ARE 1N4003 OR EQUIVALENT.

Figure 2. Schematic Diagram of Timing Electronics.

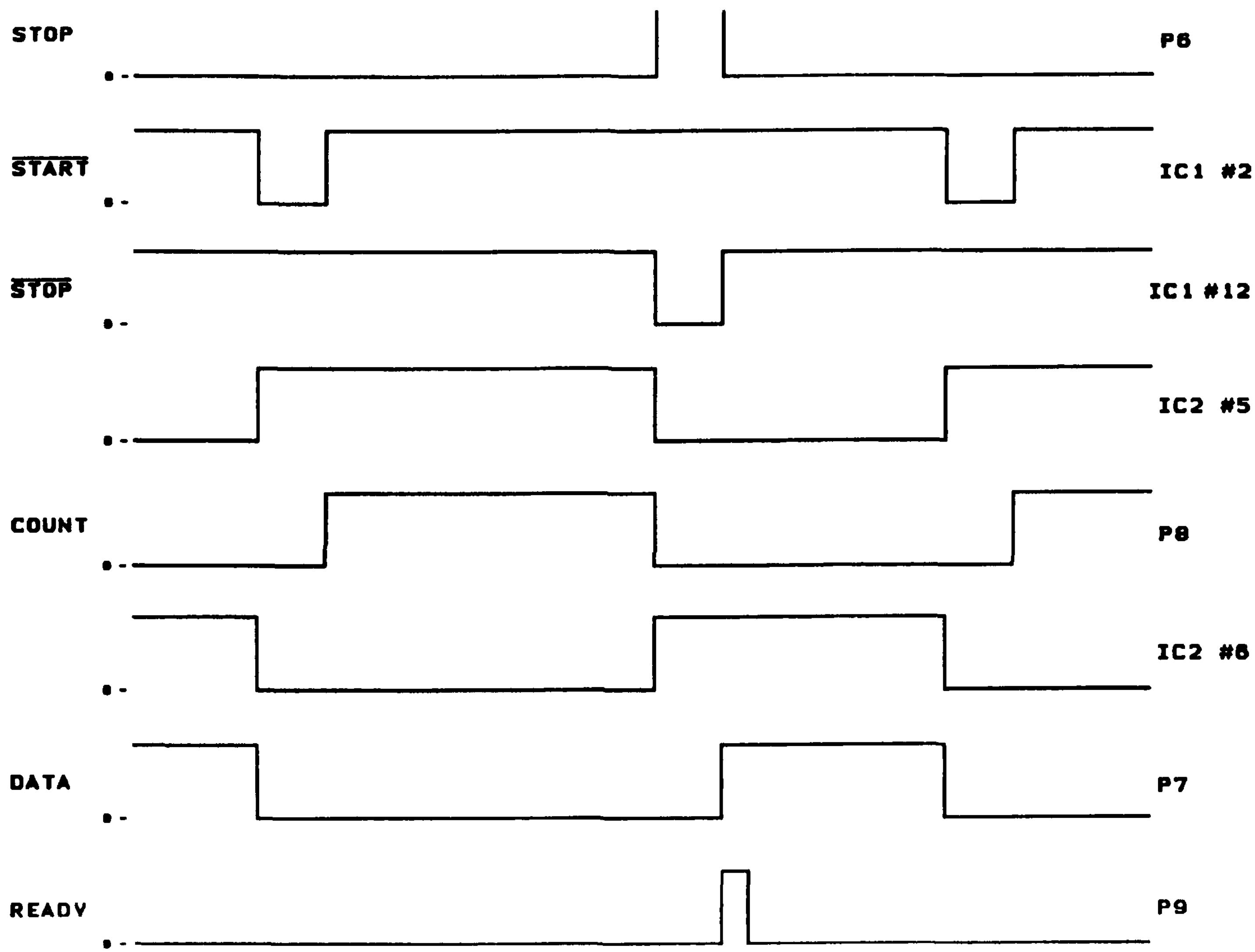


Figure 3. Timing Diagram of Timing Electronics.

The *START* and *STOP* signals, which are input through pins P3 and P5, must be positive pulses with a duration that is short compared to the time between these pulses. The arrival of the *START* pulse initiates a number of events. First, after double buffering, a green "START" light emitting diode (LED) is illuminated. Indicators of this type are provided for each step of the time measuring cycle and are particularly useful during debugging operations. This double buffered signal is also output on pin P4 to serve as a synchronization pulse for other equipment such as oscilloscopes, etc. After being inverted, the *START* pulse also clears the 74HC161 presettable synchronous 4-bit binary counter chips (IC6 through IC9) by pulling down their active-low master reset (MR) inputs. Finally, the inverted *START* pulse sets half of the 74HC74 dual D type flip-flop (IC2) which drives the Q bar output low. This low signal causes the associated AND gate to also output a low signal which turns the "DATA" LED indicator off. This "DATA" indicator will be discussed in greater detail later. When the positive *START* pulse ends, a similar series of events are initiated. Now the double buffered *START* signal turns off the "START" LED indicator. The inverted *START* signal terminates the clearing of the counters by pulling high the MR lines of the counter chips and causes the connected AND gate to output a high level. This high gate output on pin 3 of IC3 pulls the count enable pins (CEP) on the counter chips high to allow pulse counting and illuminates the yellow "COUNT" LED indicator. The "COUNT" signal is available on pin P8.

Counting of the oscillator pulses continues until the *STOP* line goes high. At this time the double buffered *STOP* signal turns the "STOP" indicator on. The inverted *STOP* signal resets the flip-flop in IC2 which drives output Q low. This low signal is routed through an AND gate to turn the "COUNT" indicator off and terminate oscillator pulse counting by pulling the counter CEP lines low. When the inverted *STOP* signal reset the flip-flop, the Q bar output was pulled high. Therefore, when the *STOP* signal drops back down, the inverted *STOP* signal and Q bar output are both high. These signals cause the output of the associated AND gate to go high which illuminates the "DATA" LED indicator. The AND gate output is also routed to the positive edge trigger input (TB) of the 74HC221 nonretriggerable monostable multivibrator (IC5) which triggers complementary "READY" handshaking pulses on the Q and Q bar outputs. The 10-kΩ and 1-nF RC circuit components on the monostable set the duration of these handshaking pulses to approximately 10 µs. These "READY" signals are routed to the DIB and serve to initiate latching of the new data and transfer to computer memory. Finally, the double buffered *STOP* signal turns off the "STOP" indicator. With the arrival of the next *START* pulse, the four-step time measurement process is started once again.

During the "COUNT" phase of a time interval measurement, the array of binary counting chips (IC6-IC9) tally pulses from a fixed frequency clock. The oscillator which serves as the time base for these measurements (IC4) determines both the resolution and the longest time interval which can be measured. For flexibility, modular plug-in TTL oscillators are used which can be obtained with clocking frequencies from 1 MHz to over 50 MHz. Thus, high-frequency time bases can be used in applications with stringent resolution requirements while slower time bases can be utilized where resolution is not a critical factor and longer time intervals need to be evaluated. The ability to measure longer time intervals with higher resolution is limited by the number of bits of the counting circuitry. If the time interval is sufficiently long, and the clocking frequency is sufficiently high to allow the counter array to exceed its largest recordable number, the counter will "roll over" to zero and the time information will be lost. The cascading modular arrangement of the binary counting chips allows extra bits of counting capability to be added with a minimum of effort. All counting chips are fed the same clock pulses (CP), count enable pulses (CEP), and master reset (MR) pulses. Additional counting chips must also be supplied with a count enable carry (CET) pulse from the terminal count (TC) output of the preceding counter. This "look-ahead" carry scheme enables the more significant counter to increment only when the less significant counter rolls over and registers a carry. The presetting capability of these counters is not utilized and, thus, the active-low parallel enable (PE) inputs are pulled high.

As an example of selecting a clock frequency and determining the required number of counting bits, consider the case of the IR tracker. The design specifications for this instrument called for reliable data acquisition at a rate of 2,000 Hz with maximum resolution. Typical maximum clocking frequencies for the 74HC161 binary counters are reported to be 44 MHz (Signetics 1988). However, temperature and source voltage variations can degrade this maximum frequency by more than a factor of two. Therefore, a clock frequency of 10 MHz was chosen to allow reliable operation in all anticipated ambient conditions. The 2,000 Hz data acquisition rate translates to a maximum counting interval of 0.5 ms. Counting a 10-MHz clock for this maximum time interval would yield a maximum count of 5,000. Thirteen binary counting bits must be available to record this number of clock cycles. The

74HC161 binary counting chips come 4 bits to a package, so 16 bits of binary counting capacity were installed on the TIMB. All 16 of the binary counter outputs are routed to the edge connector with the 13 least significant bits also directed to LED indicators.

The supply voltage range for the 74HC family of integrated devices is 2–6 V. In order to increase the flexibility of this time measurement apparatus, an LM340-5.0 voltage regulator (IC10) is included on the TIMB. With sufficient heat sinking capability, this 5-V regulator can be powered by a 7- to 35-V supply connected to pin P43. The regulated 5-V supply output is available on pin P2 to power external low current circuitry.

The *TRIGGER* signal can be used to initiate the acquisition of time interval data. This active-high handshaking signal could be supplied from a variety of sources operating at dissimilar voltages. If these signals are supplied by long cables routed through noisy environments, they may also include assorted voltage spikes and "ringing." Feeding such poorly defined signals directly into a computer system can cause problems. Therefore, circuitry is included on the TIMB to clean up the *TRIGGER* signal and output a corresponding *TRIGGER'* signal with well-defined voltage thresholds and levels. In operation, the diode-clamped *TRIGGER* signal turns on a transistor which outputs its signal to another high-speed inverting transistor. This inverted signal drives an AND gate configured as a buffer which produces the *TRIGGER'* signal. During prototype testing, the *TRIGGER'* signal was activating even while the *TRIGGER* input was grounded. The source of this problem was found to be power line noise which was generated by output current switching and parasitic capacitance on the TIMB. The addition of 0.1 μF despiking capacitors on each IC package did not correct the problem. Eventually, the problem was corrected through the addition of small bypass capacitors to selected outputs as illustrated in the schematic of Figure 2. Ground connections between the various system components can also serve as pathways for the transfer of noise. The high operating frequencies of these components requires that all ground connections be low impedance pathways in addition to low resistance.

The TIMB circuitry was assembled on a single 4-in by 4.5-in printed circuit board. The straight-forward nature of this circuitry allows standard layout and wiring techniques to be utilized. A complete listing of all the TIMB components is included in Appendix A along with the part numbers and prices quoted by a major electronics supplier.*

2.3 Computer Interfacing. The binary time interval data from the TIMB is transferred to computer memory using a commercially available digital interface board. A National Instruments** model number PC-DIO-24 was utilized for the IR tracker work, however, interface boards of this type are produced by many manufacturers. Details of this board and the associated connecting hardware are included in Appendix A along with part numbers and prices.

A major chore in utilizing this interface board is to correctly connect the necessary outputs from the TIMB to the terminal strip of the DIB. To simplify this task, a wiring diagram is provided in Figure 4. For completeness, all the input and output connections of the TIMB edge connector are indicated instead of just the connections required by the DIB.

Before a DIB is installed in a personal computer, the board must be configured for an acceptable I/O base address. On the PC-DIO-24 this is accomplished by setting a series of dual inline parallel (DIP) switches on the board. Most PC-compatible computers provide usable I/O addresses in the range from hex 200 through 3FF. A commonly used I/O address for the PC-DIO-24 is hex 210 because this is the value that the board is configured to when originally purchased. This base address and an offset value ranging from 0 to 3, are used to access the various features, or registers, of the DIB. Additional information on accessing the PC-DIO-24 registers is included in the manufacturer's user manual (National Instruments 1990) and specific examples are included in the sample software listing of Appendix B.

The heart of the PC-DIO-24 is an 8255*** programmable peripheral interface integrated circuit. This device contains a total of 24 bits of digital I/O arranged in three groups, or bytes, of 8 bits each designated as ports *A*, *B*, and *C*. The 13 data bits from the TIMB are fed into port *A* and the lower significant bits of port *B*. Thus, data transfer from the TIMB to the DIB is

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* Digi-Key Corporation, P.O. Box 677, Thief River Flls, MN 56701.
** National Instruments, 6504 Bridge Point Parkway, Austin, TX 78730.
*** Advanced Micro Devices, Inc.

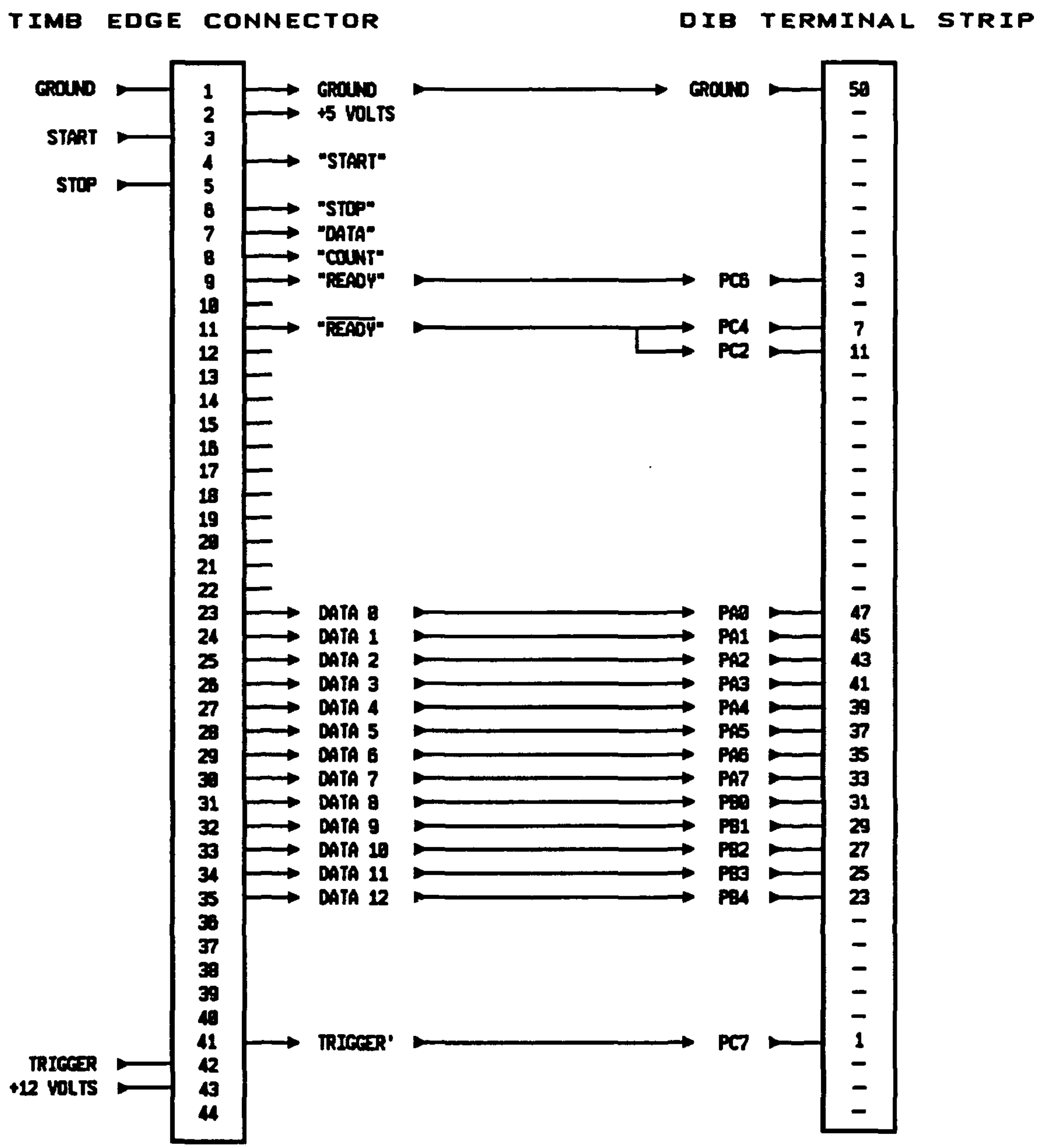

Figure 4. Data Interface Board Wiring Diagram.

a two-step process involving the transfer of two data bytes which must then be combined. Port *C* is used for transferring handshake signals. The 8255 supports three different modes of operation for basic, strobed, and bidirectional I/O. Since the TIMB is a WRITE ONLY device with respect to the DIB and supplies all required handshaking signals, the strobed mode of operation can be utilized. The mode of the 8255 is set by writing a control word to the configuration register which is addressed by the base address plus an offset of three. This control word sets the mode of operation and the direction of data transfer for the three I/O data ports. The manufacturer's user manual and the sample software listing of Appendix B also include additional information on setting the configuration register.

Handshaking signals are transferred from the TIMB to the DIB through I/O port *C*. As data becomes available, the "READY" BAR signal from the TIMB momentarily pulls bits 2 and 4 of I/O port *C* low. This action causes the hardware of the DIB to latch the available data into I/O ports *A* and *B*. The complementary "READY" signal is routed to bit 6 of I/O port *C* to notify the controlling software that latched data is available for transfer to computer memory. Similarly, the *TRIGGER'* line from the TIMB is routed to bit 7 of I/O port *C* to notify the controlling software when to initialize data acquisition.

3. SUMMARY

This report provides a detailed description for the assembly and utilization of an inexpensive integrated hardware/software system which measures and records short time intervals. The use of interchangeable time base oscillators and an open-ended, modular counting architecture allow this system to be adapted to a wide variety of applications. Signal processing of user-supplied handshaking signals and regulation of power supply voltage further enhance the overall flexibility. Schematic diagrams and complete descriptions of circuit functions are included for the fabrication of the required electronic modules.

The use of commercially available digital interface boards for the transfer of timing data to computer memory further simplifies the construction and assembly of this system. Wiring diagrams and sample software are included to aid in the interfacing of the time measurement electronics to PC computers.

4. REFERENCES

National Instruments PC-DIO-24 User Manual, Part No. 320288-01, National Instruments, Austin, TX, October 1990.

Signetics High-Speed CMOS Data Manual, 1988.

Thomson, G. M. "Passive IR Tracking of Incoming Kinetic Energy Munitions." Proceedings of the 1991 BRL Technical Symposium: Emerging Technology for the Future Battlefield, November 1991.

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APPENDIX A:

TIMING SYSTEM PARTS LIST

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Table A-1. Time Interval Measurement Board Parts List

Description	Part No.*	Quantity	Price/ Unit	Total Price
printed circuit board	K260-ND	1	12.05	12.05
edge board connector (soldier tail)	C1-22	1	4.19	4.19
IC socket 14 pin	A9414	4	0.71	2.84
IC socket 16 pin	A9416	4	0.82	3.28
74HC04 hex invertor	MM74HC04N	1	0.28	0.28
74HC74 dual D flip-flop	MM74HC74AN	1	0.40	0.40
74HC08 quad 2-input AND gate	MM74HCO8N	1	0.28	0.28
10-MHz TTL oscillator (ECS-100AC)	X114	1	3.71	3.71
74HC221 dual non-retrig. monostable	MM74HC221N	1	1.00	1.00
74HC161 synch. binary counter	MM74HC161N	4	0.50	2.00
LM340-5.0 5-V, 1.5-A reg.	LM340KC-5	1	2.82	2.82
2N3904 npn transistor	2N3904	19	0.23	4.37
red LED	P367	14	0.17	2.38
yellow LED	P369	2	0.25	0.50
green LED	P368	1	0.25	0.25
IN4003 diode	1N4003G1	2	0.11	0.22
470-Ω resistor 1/8 watt	470E	2	0.06	0.12
680-Ω resistor 1/8 watt	680E	2	0.06	0.12
820-Ω resistor 1/8 watt	820E	13	0.06	0.78
2.2-kΩ resistor 1/8 watt	2.2KE	2	0.06	0.12
10-kΩ resistor 1/8 watt	10KE	1	0.06	0.06
100-kΩ resistor 1/8 watt	100KE	2	0.06	0.12
470-pF capacitor	P4032	1	0.09	0.09
1-nF capacitor	P4036	2	0.12	0.24
0.0015-μF capacitor	P4187	1	0.08	0.08
0.0022-μF capacitor	P4189	1	0.09	0.09
0.0033-μF capacitor	P4191	1	0.09	0.09
0.0047-μF capacitor	P4193	1	0.12	0.12
0.0068-μF capacitor	P4195	1	0.17	0.17
0.01-μF capacitor	P4147	6	0.12	0.72
0.022-μF capacitor	P4149	1	0.13	0.13
0.1-μF capacitor	P4164	6	0.12	0.72
0.47-μF capacitor	P6385	1	0.21	0.21
				44.65

* Part numbers are from Digi-Key catalog #913, May–June 1991. Address: P. O. Box 677, Thief River Falls, MN 56701. Phone: (800) 344-4539.

Table A-2. Digital Interface Board Parts List

Description	Part No.*	Quantity	Price/Unit	Total Price
Digital I/O Board, PC-DIO-24	776-247-01	1	195.00	195.00
I/O Connector Block	776-164-02	1	150.00	150.00
				345.00

* Part numbers are from National Instruments catalog, "IEEE-488 and VXIbus Control, Data Acquisition and Analysis," 1991. Address: 6504 Bridge Point Parkway, Austin, TX 78730-5039. Phone: (512) 794-0100.

APPENDIX B:

SAMPLE SOFTWARE

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```
'#############################################################################
'
' PROGRAMMING ENVIRONMENT: Microsoft QuickBASIC VERSION 4.5
' THIS PROGRAM IS DESIGNED TO DRIVE THE DIGITAL INTERFACE BOARD (DIB) FOR
' THE ACQUISITION OF TIME INTERVAL MEASUREMENTS.
' IF YOU HAVE ANY QUESTIONS PLEASE CONTACT TOM KOTTKE AT:
'                       ATTN: SLCBR-TB-EP
'                       BALLISTIC RESEARCH LABORATORY
'                       ABERDEEN PROVING GROUND, MD 21005
'                       (410) 278-2557
'
'#############################################################################
'
' REQUIRED CONNECTIONS BETWEEN THE NATIONAL INSTRUMENTS PC-DIO-24 I/O
' BOARD AND THE EDGE CONNECTOR OF THE TIME INTERVAL MEASUREMENT BOARD.

' DIGITAL I/O BOARD TERMINAL STRIP # 1 CONNECTS TO EDGE PIN #41
' DIGITAL I/O BOARD TERMINAL STRIP # 3 CONNECTS TO EDGE PIN # 9
' DIGITAL I/O BOARD TERMINAL STRIP # 7 CONNECTS TO EDGE PIN #11
' DIGITAL I/O BOARD TERMINAL STRIP #11 CONNECTS TO EDGE PIN #11
' DIGITAL I/O BOARD TERMINAL STRIP #23 CONNECTS TO EDGE PIN #35
' DIGITAL I/O BOARD TERMINAL STRIP #25 CONNECTS TO EDGE PIN #34
' DIGITAL I/O BOARD TERMINAL STRIP #27 CONNECTS TO EDGE PIN #33
' DIGITAL I/O BOARD TERMINAL STRIP #29 CONNECTS TO EDGE PIN #32
' DIGITAL I/O BOARD TERMINAL STRIP #31 CONNECTS TO EDGE PIN #31
' DIGITAL I/O BOARD TERMINAL STRIP #33 CONNECTS TO EDGE PIN #30
' DIGITAL I/O BOARD TERMINAL STRIP #35 CONNECTS TO EDGE PIN #29
' DIGITAL I/O BOARD TERMINAL STRIP #37 CONNECTS TO EDGE PIN #28
' DIGITAL I/O BOARD TERMINAL STRIP #39 CONNECTS TO EDGE PIN #27
' DIGITAL I/O BOARD TERMINAL STRIP #41 CONNECTS TO EDGE PIN #26
' DIGITAL I/O BOARD TERMINAL STRIP #43 CONNECTS TO EDGE PIN #25
' DIGITAL I/O BOARD TERMINAL STRIP #45 CONNECTS TO EDGE PIN #24
' DIGITAL I/O BOARD TERMINAL STRIP #47 CONNECTS TO EDGE PIN #23
' DIGITAL I/O BOARD TERMINAL STRIP #50 CONNECTS TO EDGE PIN # 1

'#############################################################################
'
'  INTRODUCTORY REMARKS
'
'#############################################################################
SCREEN 12
100 CLS 0
COLOR 11
```

```
PRINT "                         Program:"
LOCATE 1, 32
COLOR 14
PRINT "TIMER.BAS "
COLOR 11
PRINT : PRINT
PRINT "  This program is designed to acquire new time interval data or"
PRINT : PRINT
PRINT "  display previously saved data from a disk file."
PRINT : PRINT
PRINT "  The user has the option of determining how many time interval"
PRINT : PRINT
PRINT "  data points will be recorded, how the data will be plotted"
PRINT : PRINT
PRINT "  and whether the data will be saved in a disk file."
PRINT : PRINT : PRINT : PRINT : PRINT
COLOR 3
PRINT " Do you wish to recall data which has previously "
INPUT " been saved in a disk file? (Y or N)"; Ans$
PRINT : PRINT
COLOR 10
'
'###########################################################################
'
' DEFINE THE BASE ADDRESS OF THE I/O DATA ACQUISITION BOARD TO 210 HEX
'
'###########################################################################

BaseAddress% = 2 * 256 + 1 * 16 + 0

'###########################################################################
'
' DEFINE THE BYTE WHICH IS USED TO CONFIGURE THE DIGITAL I/O BOARD
'
'###########################################################################

D7 = 1'    #### PLACES THE BOARD IN A MODE SETTING STATUS ###################
D6 = 0'    #### TOGETHER WITH D5 SELECTS MODE 1 OPERATION ###################
D5 = 1'    #### TOGETHER WITH D6 SELECTS MODE 1 OPERATION ###################
D4 = 1'    #### SETS UP PORT A FOR DATA INPUT ###############################
D3 = 1'    #### SETS UP HIGH NIBBLE OF PORT C FOR INPUT #####################
D2 = 1'    #### SELECTS MODE 1 OPERATION FOR PORT B #########################
D1 = 1'    #### SETS UP PORT B FOR DATA INPUT ###############################
```

```
D0 = 1'    #### DOES NOT MATTER ##############################################

'############################################################################
'
' DETERMINE DECIMAL EQUIVALENT OF CONFIGURATION BYTE
'
'############################################################################

CNFG = D0 + D1 * 2 + D2 * 4 + D3 * 8 + D4 * 16 + D5 * 32 + D6 * 64 + D7 * 128

'############################################################################
'
' OUTPUT CONFIGURATION BYTE
'
'############################################################################

OUT BaseAddress% + 3, CNFG

'############################################################################
'
' DETERMINE THE TOTAL NUMBER OF DATA POINTS
'
'############################################################################

IF ((Ans$ = "Y") OR (Ans$ = "y")) THEN
    COLOR 3
    INPUT " Enter the name of the existing data file: "; File$
    PRINT : PRINT
    OPEN File$ FOR INPUT AS #1
    INPUT #1, NumSamples%
    ELSE
    LOCATE 26, 1
    INPUT " Enter number of new data points to be recorded:  "; NumSamples%
    PRINT : PRINT
    END IF

'############################################################################
'
' DIMENSION REQUIRED VARIABLES
'
'############################################################################

REDIM DataYB%(NumSamples%), DataYA%(NumSamples%), DataY%(NumSamples%)
```

```
'################################################################################
'
' OBTAIN DATA VALUES
'
'################################################################################

IF ((Ans$ = "Y") OR (Ans$ = "y")) THEN 'READING DATA FROM EXISTING FILE

    FOR I% = 1 TO NumSamples%
        INPUT #1, DataY%(I%)
        NEXT I%

    CLOSE #1

    ELSE                                        'OBTAIN NEW DATA

'################################################################################
'
' INITIALIZE THE COUNTING VARIABLE
'
'################################################################################

Count% = 0

'################################################################################
'
' SUSPEND DATA ACQUISITION UNTIL A HIGH SIGNAL IS RECEIVED ON PC7 WHICH
' IS PIN #1 ON THE DIGITAL I/O BOARD TERMINAL STRIP CONNECTOR. THIS SIGNAL
' WILL BE SUPPLIED BY THE TRIGGER' OUTPUT WHICH IS PIN #41 OF THE TIME
' INTERVAL MEASUREMENT BOARD EDGE CONNECTOR.
'
'################################################################################
BEEP
CLS 0
LOCATE 4, 10
PRINT "DATA ACQUISITION SUSPENDED -- AWAITING TRIGGER PULSE "

WAIT BaseAddress% + 2, 128 'SOFTWARE DELAYS UNTIL BIT 7 OF I/O PORT C GOES
HIGH

'###################  BEGINNING OF THE DATA ACQUISITION LOOP  ##############
```

```
DO

    Count% = Count% + 1                   '### INCREMENT COUNTER VARIABLE ###

    WAIT BaseAddress% + 2, 64             '### WAIT UNTIL HIGH LEVEL DATA READY
                                          '### SIGNAL IS RECEIVED ON PC6 WHICH
                                          '### IS TERMINAL STRIP PIN NUMBER 3.
                                          '### THIS SIGNAL COMES FROM PIN 9 OF
                                          '### THE TIME INTERVAL MEASURE BOARD.

    DataYA%(Count%) = INP(BaseAddress% + 0)     '### INPUT LOWER BYTE OF DATA
                                                '### FROM I/O PORT A
    DataYB%(Count%) = INP(BaseAddress% + 1)     '### INPUT UPPER BYTE OF DATA
                                                '### FROM I/O PORT B

    LOOP UNTIL Count% = NumSamples%

BEEP

'############################################################################
'
' COMBINE THE LOW AND HIGH DATA BYTES INTO A SINGLE DECIMAL NUMBER
'
'############################################################################

FOR I% = 1 TO NumSamples%
    DataY%(I%) = 256 * DataYB%(I%) + DataYA%(I%)
    NEXT I%

    END IF

'############################################################################
'
' PRINT ACQUIRED DATA TO SCREEN
'
'############################################################################
CLS 0
COLOR 14
LOCATE 1, 25
PRINT "ACQUIRED TIME INTERVAL DATA"
PRINT : PRINT
COLOR 10
NumLines% = NumSamples% \ 10
```

```
FOR I% = 1 TO NumLines%
    PRINT USING "####"; 1 + 10 * (I% - 1);
    PRINT USING "\  \"; "  ";

    FOR J% = 1 TO 9
        PRINT USING "####"; DataY%(J% + 10 * (I% - 1));
        PRINT USING "\ \"; "  ";
        NEXT J%

    PRINT USING "####"; DataY%(10 + 10 * (I% - 1))

    NEXT I%

    LOCATE 29, 1
    INPUT "Enter a carriage control to continue: "; a$

'############################################################################
'
' DATA GRAPHING ROUTINE
'
'############################################################################

SCREEN 12                                                  ' #### GRAPH LABELING
CLS 0
COLOR 10
LOCATE 28, 1
PRINT "OPTIONS:      (I)ncrease Scale       (D)ecrease Scale       (F)inished
Graphing"
COLOR 14
LOCATE 8, 1
PRINT "   T"
PRINT "   i"
PRINT "   m"
PRINT "   e"
PRINT
PRINT "   I"
PRINT "   n"
PRINT "   t"
PRINT "   e"
PRINT "   r"
PRINT "   v"
PRINT "   a"
```

```
PRINT "   1"
LOCATE 26, 4
PRINT "0                                  C o u n t   N u m b e r"
NS = 80 - LEN(STR$(NumSamples%))
LOCATE 26, NS
PRINT NumSamples%
VIEW (50, 0)-(638, 395), 3, 1                 ' #### DECLARES GRAPHICS WINDOW
WINDOW (1, 0)-(NumSamples%, 8092)
YGraphMax% = 8192

500                                            ' #### GRAPH MANIPULATION
DO

    LOCATE 1, 1
    PRINT "        "
    LOCATE 1, 1
    PRINT YGraphMax%

    VIEW (50, 0)-(638, 395), 3, 1             ' #### REDECLARES GRAPHICS WINDOW

    WINDOW (1, 0)-(NumSamples%, YGraphMax%)
    FOR I% = 1 TO NumSamples%
        CIRCLE (I%, DataY%(I%)), .5, 4
        PAINT (I%, DataY%(I%)), 4, 4
        NEXT I%
    LOCATE 28, 9
    Option$ = INPUT$(1)

    IF Option$ = "D" OR Option$ = "d" THEN
        YGraphMax% = YGraphMax% / 2
        GOTO 500
    END IF

    IF Option$ = "I" OR Option$ = "i" THEN
        YGraphMax% = YGraphMax% * 2
        GOTO 500
    END IF

    IF Option$ = "F" OR Option$ = "f" THEN
        GOTO 1000
    END IF

    GOTO 500
```

```
LOOP

1000

'############################################################################
'
' OBTAIN OUTPUT FILE INFORMATION
'
'############################################################################

CLS 2                                           ' CLEARS TEXT
COLOR 14
INPUT "  Do you wish to dump this data to a disk file? (Y or N):  "; Dump$
PRINT : PRINT
IF (Dump$ = "Y") OR (Dump$ = "y") THEN
    INPUT "  Enter data filename:  "; Name$
    OPEN Name$ FOR OUTPUT AS #1
    LOCATE 10, 10
    PRINT "Please wait..."
    WRITE #1, NumSamples%
    FOR I% = 1 TO NumSamples%
        WRITE #1, DataY%(I%)
    NEXT I%
    LOCATE 20, 1
    COLOR 14
    PRINT "Data dump to "; Name$; " is complete."
    CLOSE #1
    GOTO 2000
END IF

IF Dump$ = "N" OR Dump$ = "n" THEN
    GOTO 2000
END IF

GOTO 1000

'############################################################################
'
' PROGRAM FINISHED
'
'############################################################################
```

```
2000 LOCATE 25, 1
INPUT "Do you wish to (R)estart or (Q)uit?  "; Done$
IF Done$ = "Q" OR Done$ = "q" THEN
    LOCATE 28, 1
    PRINT "Goodbye."
    END
END IF

IF Done$ = "R" OR Done$ = "r" THEN
    GOTO 100
END IF

GOTO 2000
```

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