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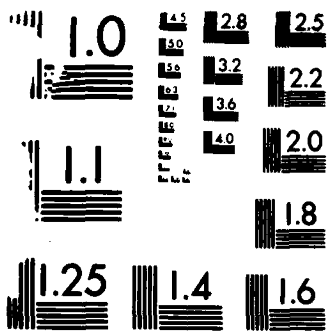

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Many technological advances produced the field-portable dark adaptometer. The LED light source provides an inexpensive, rugged and entirely portable alternative to conventional illumination sources. Microcomputer technology facilitated dark adaptometry data acquisition and analysis. Further refinements in the microcomputer industry have produced smaller, truly portable, and relatively inexpensive computers with the IEEE-488 communications interface standard. The IEEE-488 interface, in turn, is a powerful tool for streamlining the clinical dark adaptometer. Its power and utility come from its inherent ability to

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Abstract cont.

maintain communications among many devices concurrently and from the wide availability of IEEE-488 support products.

These technologies are integrated in this dark adaptometer to produce a unit that is a compact and rugged alternative to laboratory and clinical visual function test equipment, and brings new sophistication to visual function diagnosis in field work.

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LABORATORY NOTE NO. 85-55

A PORTABLE SOLID STATE DARK ADAPTOMETER

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and
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DIVISION OF OCULAR HAZARDS

OCTOBER 1985

LETTERMAN ARMY INSTITUTE OF RESEARCH
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A Portable Solid State Dark Adaptometer--Wheeler and Zwick

Edwin S. Beatrice 29 Oct 85

(Signature and date)

A PORTABLE SOLID STATE DARK ADAPTOMETER

Present ground and air combat poses a constantly growing threat to the visual health of today's soldier, due in part to the increased use of laser targeters and rangefinders. At the same time, the soldier must use increasingly complex weaponry where unimpaired visual acuity is a critical requirement. This paradox raises the urgent need for comprehensive measurement of the soldier's visual function. One measurement is dark adaptometry, which indicates the increase in visual sensitivity that occurs with time in darkness after exposure to a standard bright light. This test is relatively simple to administer and is extremely sensitive to various environmental and pathological conditions that might affect a soldier's visual performance (1).

Conventional dark adaptometers often use complex incandescent tungsten light sources in conjunction with a variable optical density wedge to measure dark adaptation. While these adaptometers measure dark adaptation over a range of frequencies, they have the disadvantages of being complex and expensive, and of requiring time-consuming manual data processing. The solid state dark adaptometer utilizes LED sources, which eliminates the need for complex tungsten optical systems.

A microcomputer controls the various functions of the solid state dark adaptometer. The computer provides control flexibility and processing capability important to visual function testing. Since the computer is responsible for data acquisition and manipulation, we have been able to develop a highly efficient dark adaptation protocol for use in our laboratory. The computer provides a complete set of the patient's dark adaptometry data after 25 minutes of testing. Also, readily modifiable software directs dark adaptometer control. As such the dark adaptometer has test protocol extensibility, and flexibility in data storage format and data analysis. Dedicated integrated circuit (IC) chip timers allow microcomputer control of the apparent intensity of the appropriate LED display source by varying the LED duty cycle (Fig. 1). This scheme allows the computer to adjust the intensity of the LEDs to the patient's threshold, as defined by the patient's response through an input line to the computer. Since this threshold decreases as a function of increasing dark adaptation time, a plot of LED intensity over time gives a characteristic curve for patients with normally functioning photoreceptor cells (Fig. 2). The

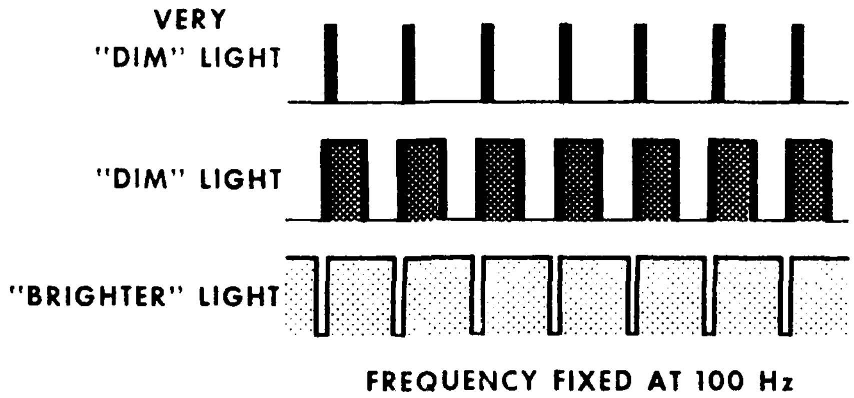

Figure 1. LED intensity with varying duty cycle.

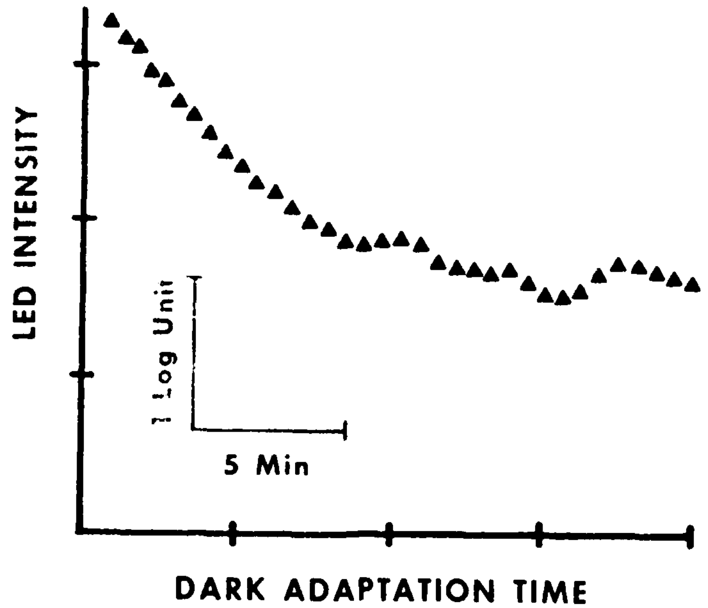

Figure 2. Threshold response of normal patient during dark adaptation.

computer also has the option of testing photoreceptor function at either 8 or 16 degrees of arc on the transverse foveal plane of the retina, both in the paramacular region.

The solid state dark adaptometer design presently used in our laboratory employs an H-8 computer, dual floppy disk drive chassis, H-19 monitor, as well as a 36-inch (91.44 cm) hemisphere used to light adapt the patient and to house visual sensitivity measurement boards (dark adaptation). This system represents a cumbersome complex of equipment when field portability is required.

Straightforward, rapid visual function testing is needed. While our laboratory's dark adaptometer is sufficient as a standard clinical unit, visual function testing also is needed on the battlefield, where a soldier's visual integrity determines success or failure during a mission or training exercise. In the present paper we describe the use of modern electro-optical and computer technology to design a field portable visual function test apparatus for measurement of dark adaptation. This design yielded a portable dark adaptometer that meets those characteristics essential to field equipment.

PORTABLE DARK ADAPTOMETER CRITERIA

Many criteria must be considered in the design of field equipment. Reliability and portability are essential characteristics. The LED threshold detectors, chosen for their simplicity and ease of being computer controlled, offer the added advantage of being extremely rugged light sources. Then the major criterion in the redesign challenge for making the laboratory dark adaptometer suitible for field use is portability.

The first step to reducing the size of the solid state dark adaptometer was to redesign the visual display unit. The light adaptation hemisphere was sized down to 12 inches (30.48 cm) in diameter and mounted pronated to the top of the visual display unit. This facilitated the use of a much smaller LED display board enclosure (Fig. 3).

The major obstacle to full portability of the dark adaptometer, however, was the bulky computer equipment normally required to support the device. Advances in computer technology offer a number of alternatives. Inexpensive single-board 8-bit computers in combination with programable read-only memory chips (proms) have been used in our laboratory to run fixed-protocol dark adaptometry. While such computers provide adequate portability, they are limited in data storage as well as program modifiability. Inexpensive portable computers complete with two disk drives and multiple external device control offer portability along with increased memory capacity and programing capability. Such machines generally have 8- or 16-bit data

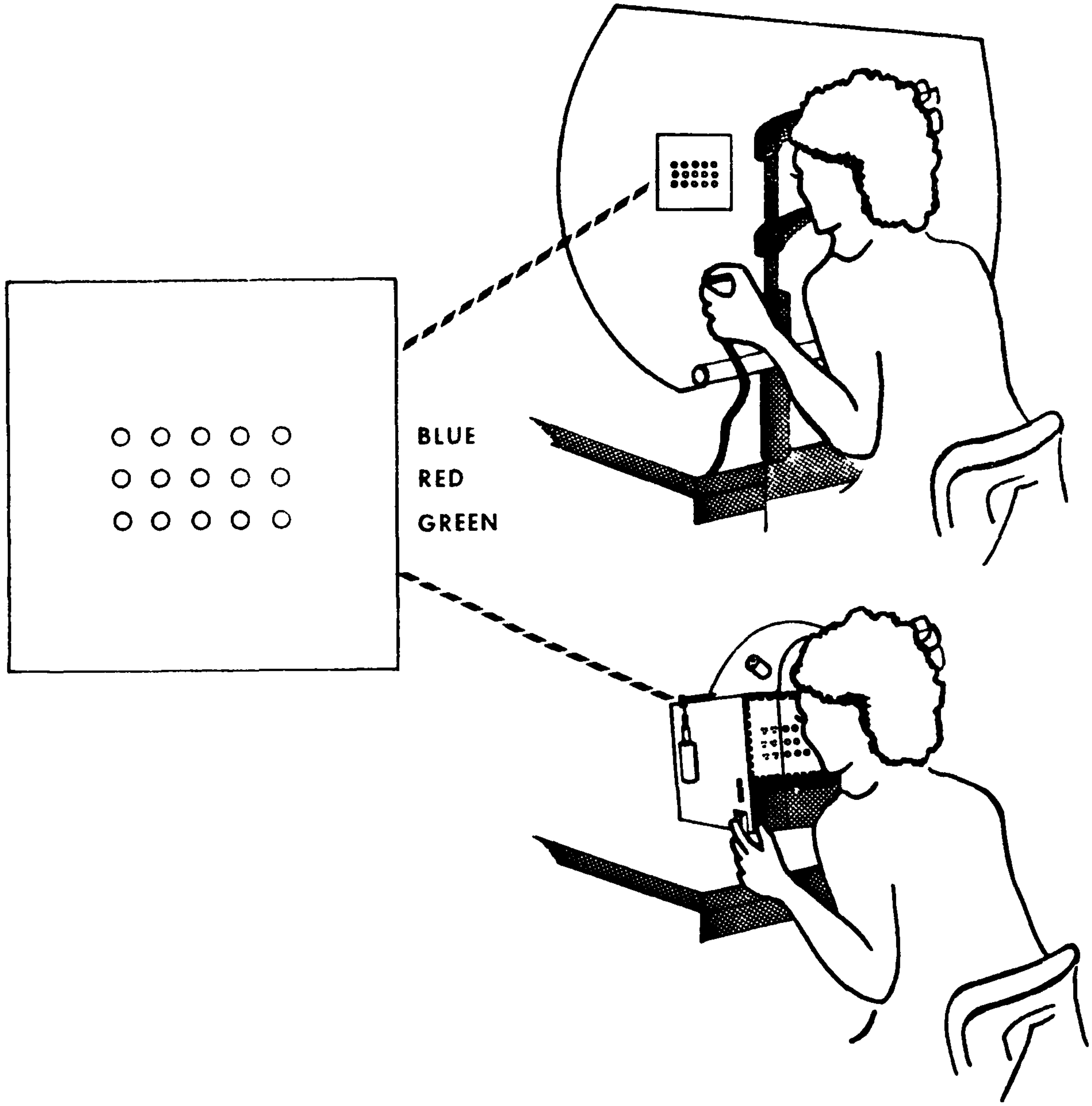

Figure 3. Laboratory and field dark adaptometer visual displays.

words, at least 64K Random Access Memory (RAM), and come equipped with a standard communications bus for control of external devices. Many of the units are now available at costs of less than 600 dollars.

A critical design requirement for portability is controlling various functions with a portable microcomputer. Although there are a number of ways to accomplish this, we chose an Osborne 1 portable computer in conjunction with its IEEE-488 interface. The IEEE-488 interface is vitally important in implementing the dark adaptometer control functions.

THE IEEE-488 INTERFACE

The IEEE-488 (Institute of Electrical and Electronics Engineers - 488) interface standard is the heart of the system's control. This standard, developed by an IEEE committee in 1975, offers compatibility among equipment adhering to the standard which has widespread support by manufacturers. It also features straightforward handshaking and a liberal (one megabyte/second with tristate buffers) maximum data transfer rate. ("Interface" is defined here as a means of communication among different devices. As such, an "IEEE-488 interface" means the IEEE-488 standard, the lines on which the standard is used, or the electronic circuitry that implements the standard.)

In an IEEE-488 system, any of four different devices may use the interface concurrently: the controller, devices that talk, devices that listen, and devices that both talk and listen.

Although more than one controller per system is possible, our system has only one, an Osborne 1 microcomputer. Talkers are devices that put data on the data bus (e.g. a digital voltmeter or other measurement device). Listeners take data from the data bus (e.g. printers, plotters). A digital multimeter is an example of both a talker (gives measurement data) and listener (listens for functions and range settings). Concurrently, up to fifteen devices can use the interface.

The IEEE-488 interface has an 8-bit-parallel byte-serial data transfer format with additional lines dedicated to interface management and control. The lines used in the Osborne interface are described in Table 1.

TABLE 1

IEEE-488 lines used in Osborne 1 dark adaptometer interface

Group	Line used	Line function
Interface Management Lines	Attention (ATN)	Used by controller to signal impending interface information. It is set low (true) to signal to devices that the data contains address or control bytes.
Transfer Control Lines	Data Valid (DAV)	Set low (true) by a talker after it has put a byte of data on the data bus. This tells all listeners that the data bus information is valid.
	Not Data Accepted (NDAC)	Set low (true) by listener when it is acquiring data from the data lines.
	Not Ready for Data (NRFD)	Set low (true) by any listener not ready to receive data from the data lines.
Data Lines	DIO-7	IEEE-488 data bus. These lines carry information between the devices

The parallel data are carried on an 8-bit bidirectional data bus. The handshaking lines, collectively known as the Transfer Control Bus, consist of the Data Valid (DAV) line, the Not Ready for Data (NRFD) line, and the Not Data Accepted (NDAC) line. One line of the Interface Management Bus, the Attention (ATN) line is used in the Osborne interface. All lines are active low to make certain hardware simplifications (page 15).

The DAV line is used by the talker to verify to listeners that data are on the data bus. The NRFD and NDAC lines are used by all active listeners. The listeners allow NRFD to go high (inactive) when they are ready to receive each byte of data. They let NDAC go high when they have accepted each byte.

Data Transfer

Communication between devices in parallel format requires some method of verification of data transfer, known as handshaking. When sending parallel data to a single device, a printer for instance, the designer may develop a very simple handshaking scheme. An example of such a scheme is the Centronics printer interface standard. Data are sent on a parallel data bus along with a signal on a STROBE line which indicates that the data are present. The printer confirms that it has accepted the data by returning a signal on the ACKNOWLEDGE line. Such a straightforward handshake is fine for communications with a single device, but when several devices may be using the interface concurrently, some "on-line," some "off-line," all with potentially different information processing speeds and capabilities, a more sophisticated handshake is necessary. The IEEE-488 accommodates these different interface requirements.

There are two modes of data transfer on the IEEE-488 bus in this system configuration: one, the controller (Osborne 1) is a talker, and two, it is a listener. The handshake associated with each is unique.

Controller as talker handshake

Figure 4 shows a timing diagram of the controller talker handshake as well as a flowchart of the software the controller uses to perform the handshake. The controller sets the ATN line low (logic level 1 or "true" due to active low logic) to indicate that it is changing the interface status of a device (whether it is a talker, or listener, or on standby). In this case the data sent to the device are called an interface message. If the ATN line is left false, the information sent over the data bus is device data, and constitutes a device message. Step one of the controller talker handshake is to condition this line.

In their quiescent state, all listening devices on the IEEE-488 interface have a NRFD status false which indicates readiness to receive data, and a NDAC status true which indicates none have yet accepted the data to be put on the data bus. Step two is the verification of these signals. A lack of either signal means that no IEEE-488 devices are on the interface. If this occurs, the software returns an error message (no devices are present). After verifying that devices are on the interface, the controller puts a byte of data on the data bus (Step 3). The controller makes a final check that the NRFD line is false (Step 4) and indicates that the data are available by setting DAV true (Step 5). The talker enters a timed loop (Step 6) where it waits for all devices to respond as having accepted the data by setting the NDAC line false (Step 7). The duration of this loop is determined by the slowest anticipated device on the interface. If

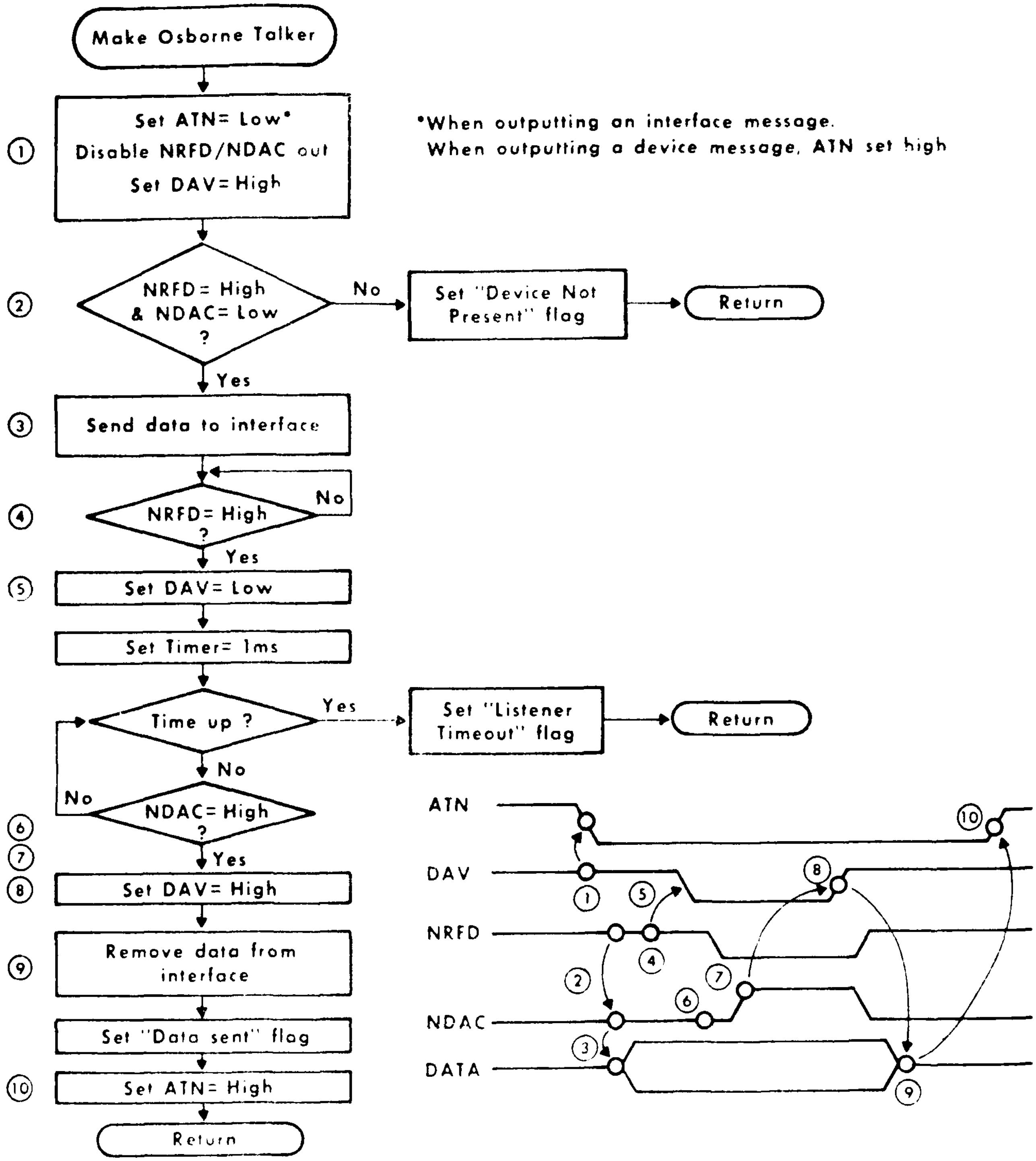

Figure 4. Flowchart and timing diagram for Osborne 1 as controller/talker.

this "timeout" occurs, there must be a problem with a device on the interface, and the software returns an error.

If the NDAC line is set false, which indicates that all the devices have accepted the data, the talker pulls the data off the interface by first setting DAV false (the data are no longer valid) (Step 8), and then removing the data from the data bus (Step 9). Finally, in an interface message transfer, the ATN line is set high to denote interface message termination (Step 10).

Controller as listener handshake

The handshake for the Osborne as the contoller listener is similar to the controller talker handshake, except, since it is a listener, it must condition the NRFD and NDAC lines, and monitor the DAV line. The flowchart and timing diagram for this configuration are summarized in Figure 5.

As a listener, the Osborne sets the NRFD line false (ready for data), and sets the NDAC line true (it has not accepted the data) (Step 1). Then a timer is set according to the same considerations as discussed in the previous subsection. The Osborne checks to see that the DAV line is set true, which means data are available on the data lines (Step 2). If this timer "times out" before a DAV true condition, the software returns a "talker timout" error flag.

When the Osborne detects that the DAV line is true, it reads the data on the data bus (Step 3). It then signals the talker that is has accepted the data by setting the NDAC line false and that it is no longer ready for data during this byte transfer handshake by setting the NRFD line true (Step 4). The Osborne then waits for the talker to pull its data off the line and set the DAV false (Step 5). When this has occurred, it sets the NDAC true to conclude the handshake (Step 6). The software then returns a "data received" flag.

Handshake comments

The IEEE-488 handshaking scheme may appear to be somewhat cumbersome and unnecessarily complicated. To some extent, this is accurate. However, this design provides flexibility necessary for the dark adapatometer which is unavailable from simpler handshake schemes. First, implicit error-checking is integral to the IEEE-488 handshake software. Secondly, there is redundancy in the lines used by listeners to acknowledge the receipt of data - both NDAC and NRFD are used in the handshake. These two characteristics provide reliable data transfer critical to physiological test equipment. The IEEE-488 communications standard has provisions for communication among more than two devices. This is crucial when there are several functions

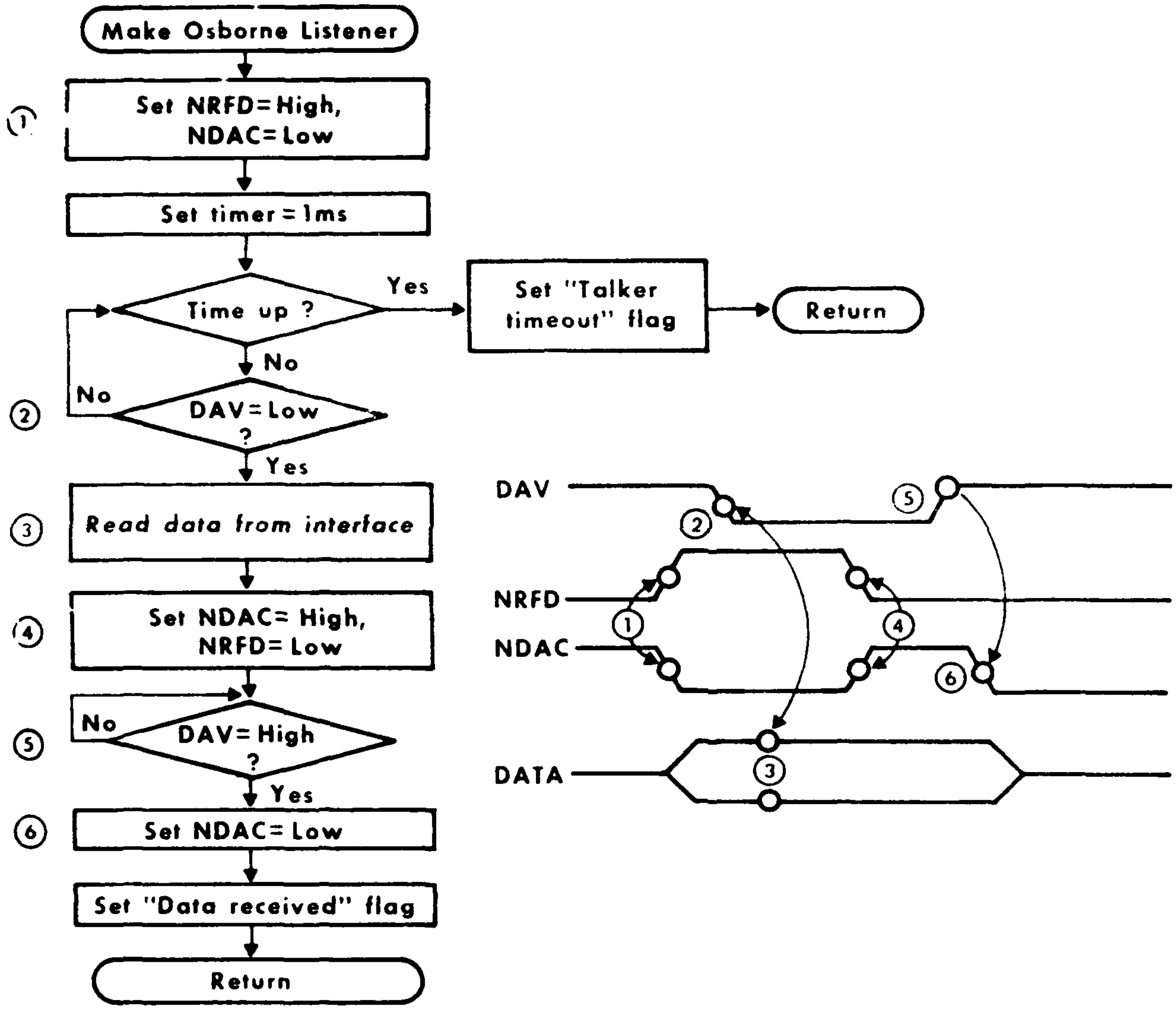

Figure 5. Flowchart and timing diagram for Osborne as controller/listener.

that need controlling such as in the dark adaptometer and other physiological test equipment.

The IEEE-488 interface is a standard communications interface. This means that the dark adaptometer interface is compatible with any computer that has an IEEE-488 interface. This computer transportability is another important feature of this IEEE-488 interface.

Handshake software

The Osborne as talker and listener handshakes are implemented by Assembly Language (AL) program subroutines, which are called from BASIC programs. These AL routines are included as Listing 1 (Appendix). Input-output (I/O) ports in the Osborne provide hardware support for the IEEE-488 interface. Individual I/O port lines correspond to the IEEE-488 handshake lines (e.g., ATN, NRFD, NDAC, etc.). These I/O ports are memory mapped, meaning that the AL software may treat them as though they were actually memory locations, the bits of which correspond to IEEE-488 lines. This makes controlling the handshake lines the relatively straightforward task of conditioning I/O memory locations. The Osborne has the added complication of having the I/O memory locations in an alternative memory "bank", which serves to add virtual memory to the system. Listing 1 outlines the method needed for alternate memory bank addressing.

BASIC language programs use the AL talk and listen routines through USR function commands. The BASIC program must first DEFine the address of the AL routine to be used. Then the command D = USR (A) executes the AL routine at the defined address. In the Output Interface Message and Output Device Message routines, the USR argument, A, is sent to the IEEE interface as data. D returns with the AL routines' error status. In the Input Device Message routine, the argument, A, is arbitrary, and D returns with both the routine's error status and with data from the interface.

In the Osborne, there is a software quirk where the USR function does not properly send its argument to the assembly language routine. In lieu of this, BASIC POKE statements are used to place desired output data in a pre-defined memory location for access by the AL routines.

IEEE-488 Interface Hardware

A number of considerations determined the framework for the hardware design to implement the dark adpatometer interface functions. These are:

* Compatibility. The design must be compatible with the IEEE-488 interface bus.

* Power consumption. The dark adaptometer is designed to be a portable unit. As such, battery operation is desirable. This makes low power devices a priority.

* Drive capability. The interface is required to run signals through several feet of cable to the dark adaptometer and to the Osborne. It must therefore have the capability to drive such signals.

* Availability. "Down-time" due to chip failure can be costly in weeks or months lost clinical time. A design with readily available chips is a valuable asset in the event of a failed device.

Transistor-Transistor Logic (TTL) was chosen as the device family with the optimum combination of these considerations. Where possible, Low-Power Schottky (LS) devices were used to minimize power consumption.

Figure 6a shows a block diagram of the Osborne IEEE-488 interface circuitry. The interface circuitry has two main functions: first, to interpret and manage incoming interface messages, device messages, and data output, and second, to provide the signals necessary to support the dark adaptometer visual display unit. Boolean logic gates decode the incoming Osborne IEEE-488 handshaking lines: NDAC, NRFD, DAV, and ATN. When these lines indicate the Osborne is sending an interface message, the data lines, DIO-7, are loaded into the first 8-bit latch and decoded into select lines for the timer, buffer, and latch chips of the dark adaptometer control circuitry. If the handshaking lines indicate an incoming device message, the latch is not accessed; rather, the lines are decoded into a device enable line which loads the data on the data lines into the device previously selected by the interface message. Finally, if the handshake lines indicate that the Osborne is configured as a listener, then whichever talker was enabled by the most recent interface message loads data onto the data bus. This is a general description of how data are transferred between the Osborne and the interface circuitry. A detailed explanation of how data are input to and output from the interface will now be presented.

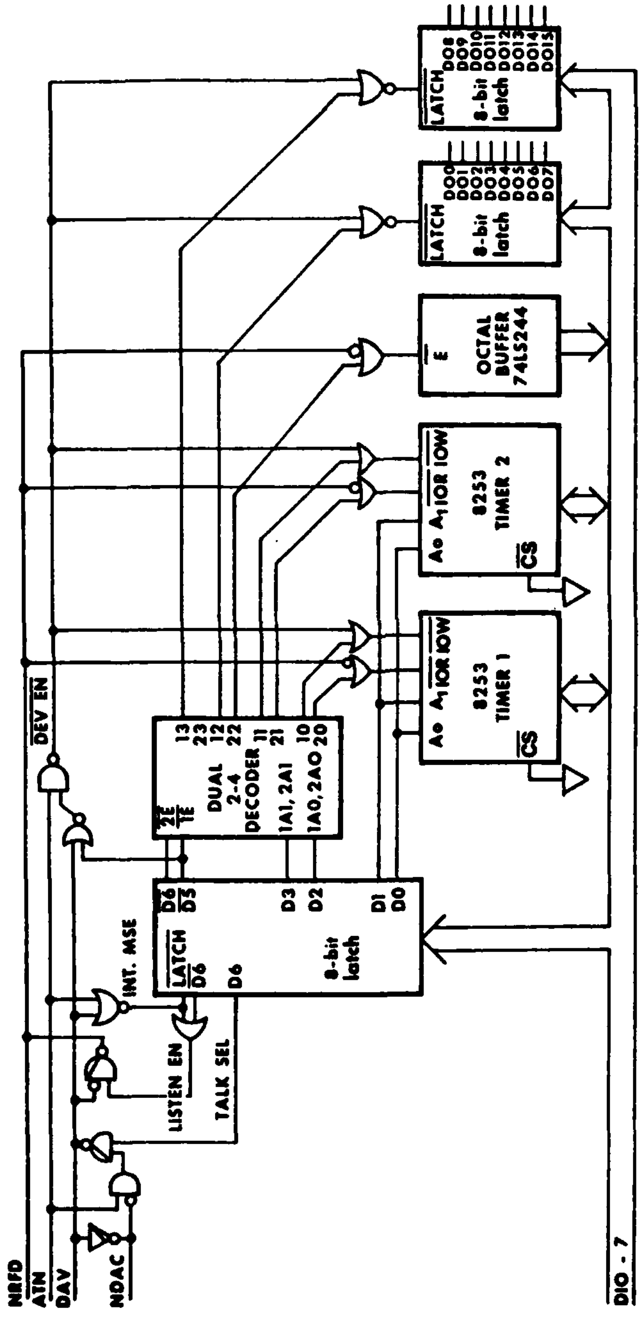

Figure 6a. Osborne 1/ Dark Adaptometer IEEE-488 interface block diagram.

Interface input select logic

Figure 6b shows the part of the IEEE-488 interface that comprises the input select logic. The explanation of the select logic assumes a basic knowledge of digital Boolean logic gates.

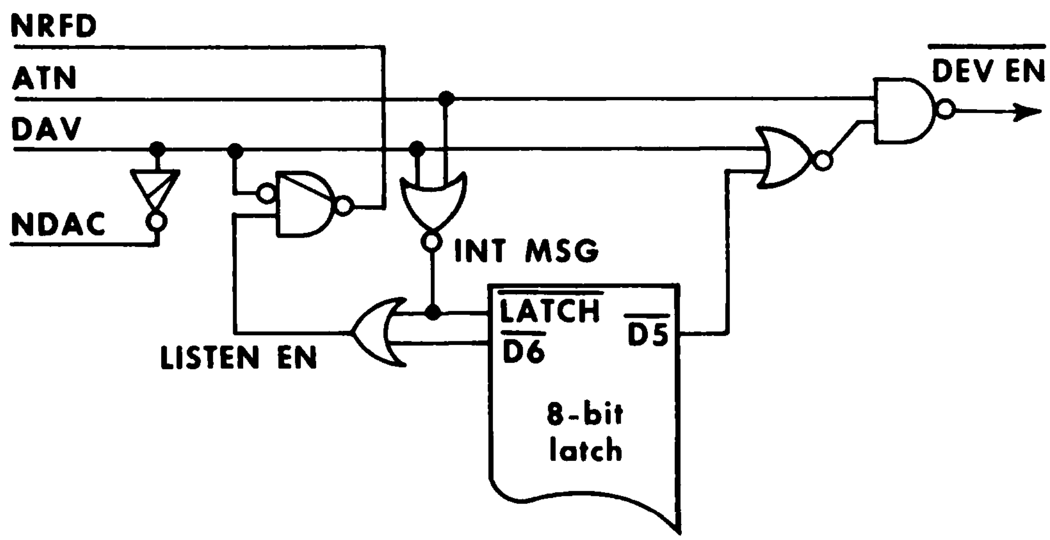

Figure 6b. Interface input select logic.

The handshake diagram of Figure 4 provides the basis for understanding the input select logic of the interface. As seen in Figure 4, the first step in the handshake is to set the ATN line to indicate an interface message or a device message. If the data comprise an interface message, an 8-bit "active device" latch stores the device number indicated on the data lines. The enable for the latch (NOT LATCH) depends on the status of both the ATN and DAV lines. A NOR gate decodes these two lines and provides the NOT LATCH enable line for the device latch. The decoding works as follows. When the Osborne sends an interface message, it brings the ATN line low [(Step 1) Fig. 4]. It then puts the interface data on the data bus [(Step 3) Fig. 4] and pulls the DAV line low to indicate the data is valid [(Step 5) Fig. 4]. At this point in the handshake, both the ATN and DAV lines are low. The NOR gate output now goes high, unlatching the device latch and allowing the data on the data bus to enter the latch. When the Osborne sets the DAV high [(Step 8) Fig. 4], the NOR output goes low, latching the new data into the latch. Since there is only one device latch, there may be only one active device accessed by the interface at a given time. This does not take advantage of the full potential of the IEEE-488 interface standard, but is quite adequate for this application.

Interface messages define not only which devices are active on the interface at any given time, but also whether they are talkers or listeners. A talker enabling interface message has bit 6 set to 1; a listener enabling message has bit 5 set to 1.

With a device message, the Osborne may output data to any device that it has previously activated with an interface message. In a device message, the ATN line is left high (which precludes unlatching the active device latch). The ATN line, along with the DAV and bit 5 of the device latch (listener enable) are decoded as a device enable line that enables various dark adaptometer support chips on the interface.

In addition to decoding the handshaking lines mentioned, the input select circuitry must also condition the NDAC and NRFD lines appropriately. These lines were provided on the IEEE-488 interface primarily to accommodate devices of different data acquisition and assimilation rates. Since TTL circuitry gate delays are on the order of nanoseconds and the processor speed of the Osborne is several hundred nanoseconds, this provision is unnecessary in this application, and inverters are added from DAV to both NDAC and NRFD to conform to the handshaking standard. These inverters are open collector gates, whose outputs go low when their input is high, but whose outputs "float" or go "open" when their input is low. This allows many devices to access the NDAC and NRFD lines. Either line will stay low until the open-collector gate output of the slowest device on the line releases it high. This is why these handshake lines are low level true.

<u>Interface output select logic</u>

When the Osborne activates a talker, the Osborne sets itself as a listener and performs the handshake (Fig. 5). Figure 6c shows the interface circuitry specifically responsible for output to the Osborne in this handshake. In the handshake, the Osborne signals its readiness for data by setting NRFD high and NDAC low. If bit 6 of the device latch indicates that a talker is active, and if the ATN line is high, then the NDAC line is encoded onto the DAV line [(Step 2) Fig. 5]. NRFD is used as a Not Device Enable line for the dark adaptometer support chips. After receiving data from the data bus, the Osborne sets the NDAC high [(Step 4) Fig. 5]. The interface output circuitry then sets DAV high accordingly and completes its portion of the handshake.

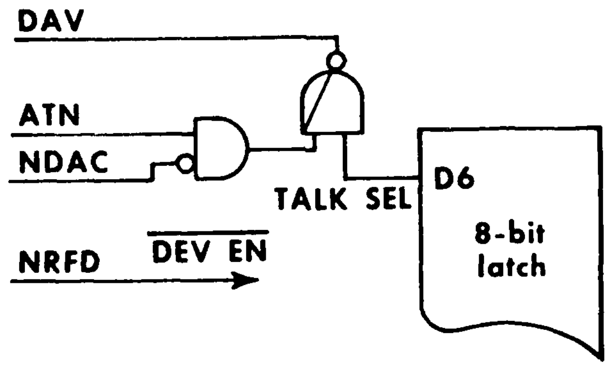

Figure 6c. Interface output select logic.

Dark Adaptometer Support Circuitry Overview

A dual 2 line - 4 line decoder (74LS139) decodes the device latch data into select lines for the devices which support the dark adaptometer. Two 8253 programmable interval timers control the elapsed time of the dark adaptometer runs (timer 1) and the duty cycle of the LEDs in the dark adaptometer (timer 2). Two 8-bit latches select various LED display options and control timer gates on the 8253s. Finally, an octal buffer relates patient response and timer status back to the Osborne.

Although the interface is configured for dark adaptometer control, the interface is quite flexible for configuration to other clinical and research control applications. With little modification, the output latches could just as well drive lights, buzzers, solenoids, shutter releases, and many other stimuli and mechanical devices. Likewise the buffer can be configured to receive multiple inputs from various monitoring devices, as well as the patient's own responses. In this way, this IEEE-488 interface may be adapted to many clinical and research uses that until now may have been restricted to larger, less flexible, and more expensive computer/controllers.

Alternative Computer Controllers

This interface circuit is described as one for the Osborne 1 IEEE-488 bus. One should note, though, that the IEEE-488 standard is just that - a standard. As such this interface is compatible with any computer with an IEEE-488 bus. Many computers have an IEEE-488 bus or an option for one. These include the Hewlett-Packard line, any using the S-100 bus, the Commodore Pet, the IBM PC, DEC, and Apple. This list is not comprehensive, but it serves to illustrate the computing power available for the IEEE-488 interface standard.

CONCLUSION

Many technological advances produced the field-portable dark adaptometer. The LED light source provides an inexpensive, rugged and entirely portable alternative to conventional illumination sources. Microcomputer technology facilitated dark adaptometry data acquisition and analysis. Further refinements in the microcomputer industry have produced smaller, truly portable, and relatively inexpensive computers with the IEEE-488 communications interface standard. The IEEE-488 interface, in turn, is a powerful tool for streamlining the clinical dark adaptometer. Its power and utility come from its inherent ability to maintain communications among many devices concurrently and from the wide availibility of IEEE-488 support products.

These technologies are integrated in this dark adaptometer to produce a unit that is a compact and rugged alternative to laboratory and clinical visual funtion test equipment, and brings new sophistication to visual function diagnosis in field work.

RECOMMENDATIONS

Computer technology advances will inevitably produce increasingly smaller computers with greater processing capability. As miniaturization is crucial to greater portability, we recommend that the portable dark adaptometer design utilize smaller, more powerful microcomputers as they become available.

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APPENDIX

Listing 1.

```
                ;***********************************************
                ; Assembly language drivers for Osborne 1
                ; IEEE-488 interface.
                ; Written 6/85 by Gary A. Wheeler
                ;
                ;
                ;***********************************************
                ;
                ; Transfer routine to high memory       850605
                ;
C000 =          destin    equ 0c000h
                ;
0100                org  100h
                ;
                    ;Transfer routine
                    ;
0100 010601         lxi  b, finish-begin+1   ;no of bytes to move
0103 111401         lxi  d, begin            ;where they come from
0106 2100C0         lxi  h, destin           ;where they're going
0109 1A         movm ldax d                  ;get byte
010A 13             inx  d                   ;increment pointer
010B 77             mov  m, a                ;store byte
010C 23             inx  h                   ;increment pointer
010D 0B             dcx  b                   ;decrement count
010E 78             mov  a, b                ;both B and C must be 0
010F B1             ora  c                   ;so OR them to see
0110 C20901         jnz  movm                ;otherwise not done
0113 C9             ret                      ;return to CP/M
                    ;
0114 =              begin equ $
                    ;
BEEC =              offset equ destin-begin
                    ;
                ; Variables
2900 =                  porta     equ  2900h
2901 =                  cporta    equ  2901h
2902 =                  portb     equ  2902h
2903 =                  cportb    equ  2903h
EF08 =                  flagpos   equ  0ef08h
                ;
                ;
                ; Output Interface Message (OIM) routine         850604
                ;
                ;
C000 =          oim      equ     $+offset
                ;
                  ;
                  ; Make Osborne Talker (MOT) routine      850603
                  ;
```

```
                                ; Set:                    To direction reg. value:
                                ; PIA0-7  DATA0-7                 1 (output)
                                ; PB0     ENABLE DATA OUT         1
                                ; PB1     ENABLE NDAC/NRFD        1
                                ; PB2     ENABLE EOI/DAV          1
                                ; PB3     EOI                     1
                                ; PB4     ATN                     1
                                ; PB5     DAV                     1
                                ; PB6     NDAC                    0 (input)
                                ; PB7     NRFD                    0
                                ;
                                ;
                                ;make osborne talker

0114 00                         nop
0115 F3                         di                  ;disable interrupts
0116 D300                       out     00h         ;switch to memory bank 2
0118 3E00                       mvi     a, 0h
011A 3208EF                     sta     flagpos
011D 320129                     sta     cporta      ;make per/dir porta dir
0120 320329                     sta     cportb      ;make per/dir portb dir
0123 3EFF                       mvi     a, 0ffh
0125 320029                     sta     porta       ;make dir port a output
0128 3E3F                       mvi     a, 00111111b
012A 320229                     sta     portb       ;make dir port b 0011 1111
012D 3E04                       mvi     a, 04h
012F 320129                     sta     cporta      ;make per/dir port a per
0132 320329                     sta     cportb      ;make per/dir port b per
                         ;
                         ;Output Interface Message        850604
                         ;
                                ;returns error status to FAC
                                ;
0135 3E12                       mvi     a, 00010010b
0137 320229                     sta     portb       ;make ATN=low, disable NDAC/NRFD out
013A 0E10                       mvi     c, 00010000b ;ATN mask
013C CD5CC0                     call    bout        ;output interface message
013F 3E02                       mvi     a, 00000010b
0141 320229                     sta     portb       ;make ATN=hi, disable NDAC/NRFD out
0144 D301                       out     01h         ;switch to memory bank 1
0146 3E01                       mvi     a, 01h
0148 3208EF                     sta     flagpos
014B 72                         mov     m, d        ;return status to FAC
014C 23                         inx     h
014D 3600                       mvi     m, 00h
014F FB                         ei                  ;enable interrupts
0150 C9                         ret
                         ;

                         ;Output Device Message (ODM) routine    850604
```

```
                    ;
                            ;Output Device Message
                            ;returns error status to FAC
                            ;
C03D =              odm     equ     $+offset
0151 F3                     di                  ;disable interrupts
0152 D300                   out     00h         ;mem bank 2
0154 3E00                   mvi     a, 00h
0156 3208EF                 sta     flagpos
0159 3E02                   mvi     a, 00000010b ;en data out, dis NDAC/NRFD out
015B 320229                 sta     portb       ;clear DAV,EOI,ATN
015E 0E00                   mvi     c, 00h
0160 CD5CC0                 call    bout        ;output device message
0163 D301                   out     01h         ;mem bank 1
0165 3E01                   mvi     a, 01h
0167 3208EF                 sta     flagpos
016A 72                     mov     m, d        ;store status in FAC
016B 23                     inx     h
016C 3600                   mvi     m, 00h
016E FB                     ei                  ;enable interrupts
016F C9                     ret
                    ;
                    ;                                           850604
                    ;
                    ;Byte OUTput (BOUT) to IEEE-488 bus routine
                    ;
                    ;
                            ;Proper data direction assumed from MOT routine
                            ;memory addressing to bank 2 assumed set up
                            ;uses value in mem #C000 as device data
                            ;returns error status in reg D
                            ;Reg C carries ATN mask
                            ;
C05C =              bout    equ     $+offset
0170 3A0229                 lda     portb       ;get device status
0173 E680                   ani     10000000b ;NRFD = HI?
0175 C26FC0                 jnz     nod         ;no, jmp "no device"
0178 3A0229                 lda     portb       ;get device status
017B E640                   ani     01000000b ;NRFD = HI?
017D CA6FC0                 jz      nod         ;yes, jmp "no device"
0180 C372C0                 jmp     sd          ;device on-line - send data
C06F =              nod     equ     $+offset
0183 1601                   mvi     d, 01h      ;no, set status "device not present"
0185 C9                     ret
C072 =              sd      equ     $+offset ;send data to interface
0186 3A00C0                 lda     0c000h
0189 2F                     cma
018A 320029                 sta     porta
C079 =              dchk    equ     $+offset
018D 3A0229                 lda     portb       ;get device status
```

```
0190 E680            ani     10000000b ;NRFD = HI?
0192 C279C0          jnz     dchk      ;no, loop
0195 3E22            mvi     a, 00100010b
0197 B1              ora     c
0198 320229          sta     portb     ;set DAV = LO
019B 060A            mvi     b, 0Ah    ;set timer = 1 ms
C089 =          dac  equ     $+offset
019D 05              dcr     b         ;decriment timer
019E C290C0          jnz     tst       ;if not time up, test for NDAC
01A1 1602            mvi     d, 02h    ;yes, set status "listener timeout"
01A3 C9              ret
C090 =          tst  equ     $+offset
01A4 3A0229          lda     portb     ;get device status
01A7 E640            ani     01000000b ;NDAC = HI?
01A9 C289C0          jnz     dac       ;no, loop
01AC 3E02            mvi     a, 00000010b
01AE B1              ora     c
01AF 320229          sta     portb     ;clear DAV
01B2 3EFF            mvi     a, 0ffh
01B4 320029          sta     porta     ;remove data from I/O bus
01B7 1600            mvi     d, 00     ;set status "data sent"
01B9 C9              ret
                ;
                ;
                ; Input Device Message (IDM) routine        850604
                ;
                     ;Input Device Message
                     ;
C0A6 =          idm  equ  $+offset
01BA F3              di                    ;disable interrupts
01BB D300            out  00h              ;mem bank 2
01BD 3E00            mvi  a, 00h
01BF 3208EF          sta  flagpos
                ;
                ;
                ; Make Osborne Listener (MOL) routine       850604
                ;
                ;    Set:                          To dir reg value:
                ;    PIA0-7     DATA0-7               0 (input)
                ;    PB0        ENABLE DATA OUT       1 (output)
                ;    PB1        ENABLE NDAC/DRFD      1
                ;    PB2        ENABLE EOI/DAV        1
                ;    PB3        EOI                   0
                ;    PB4        ATN                   1
                ;    PB5        DAV                   0
                ;    PB6        NDAC                  1
                ;    PB7        NRFD                  1
                ;
                     ;Make Osborne Listener
                     ;
```

```
01C2 3E00           mvi  a, 00h
01C4 320129         sta  cporta          ;make per/dir port a dir
01C7 320329         sta  cportb          ;make per/dir port b dir
01CA 320029         sta  porta           ;make port a input
01CD 3ED7           mvi  a, 11010111b    ;make port b 1101 0111
01CF 320229         sta  portb
01D2 3E04           mvi  a, 04h
01D4 320129         sta  cporta          ;make per/dir port a per
01D7 320329         sta  cportb          ;make per/dir port b per
                                                                  ;
                ; Byte input routine (BIN) from IEEE-488 bus routine   850604
                ;
                    ;Proper data direction assumed from MOL routine
                    ;memory addressing to bank 2 assumed set up
                    ;returns device data in FAC lo byte
                    ;returns error status in FAC hi byte
                    ;
01DA 3E45           mvi  a, 01000101b
01DC 320229         sta  portb                ;clear NRFD, set NDAC lo
01DF 060A           mvi  b, 0Ah               ;set timer = 1 ms
COCD =          tmr equ  $+offset
01E1 05             dcr  b                    ;decriment timer
01E2 C2D8C0         jnz  tdav                 ;if not time up, test DAV
01E5 1602           mvi  d, 02h               ;yes, set status "talker timeout"
01E7 1E00           mvi  e, 00h               ;clear data
01E9 C3F9C0         jmp  rmem
COD8 =         tdav equ  $+offset
01EC 3A0229         lda  portb                ;DAV=lo?
01EF E610           ani  0010000b
01F1 C2CDC0         jnz  tmr                  ;no, loop
01F4 3A0029         lda  porta                ;read data
01F7 2F             cma
01F8 5F             mov  e, a
01F9 3E85           mvi  a, 10000101b
01FB 320229         sta  portb                ;clear NDAC, set NRFD
COEA =         tsdv equ  $+offset
01FE 3A0229         lda  portb                ;DAV=hi?
0201 E61C           ani  0010000b
0203 C2EAC0         jnz  tsdv                 ;no, loop
0206 3EC5           mvi  a, 11000101b
0208 320229         sta  portb                ;yes, set NDAC=lo
020B 1600           mvi  d, 00h               ;clear error flag
               ;
COF9 =         rmem equ  $+offset
020D D301           out  01h             ;mem bank 1
020F 3E01           mvi  a, 01h
0211 3208EF         sta  flagpos
0214 73             mov  m, e            ;put data in FAC lo
0215 23             inx  h
0216 72             mov  m, d            ;put status in FAC hi
```

```
0217 FB             ei                        ;enable interrupts
0218 C9             ret


0219 =               finish    equ  $
0219                 end       100h
```

DTIC

END

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