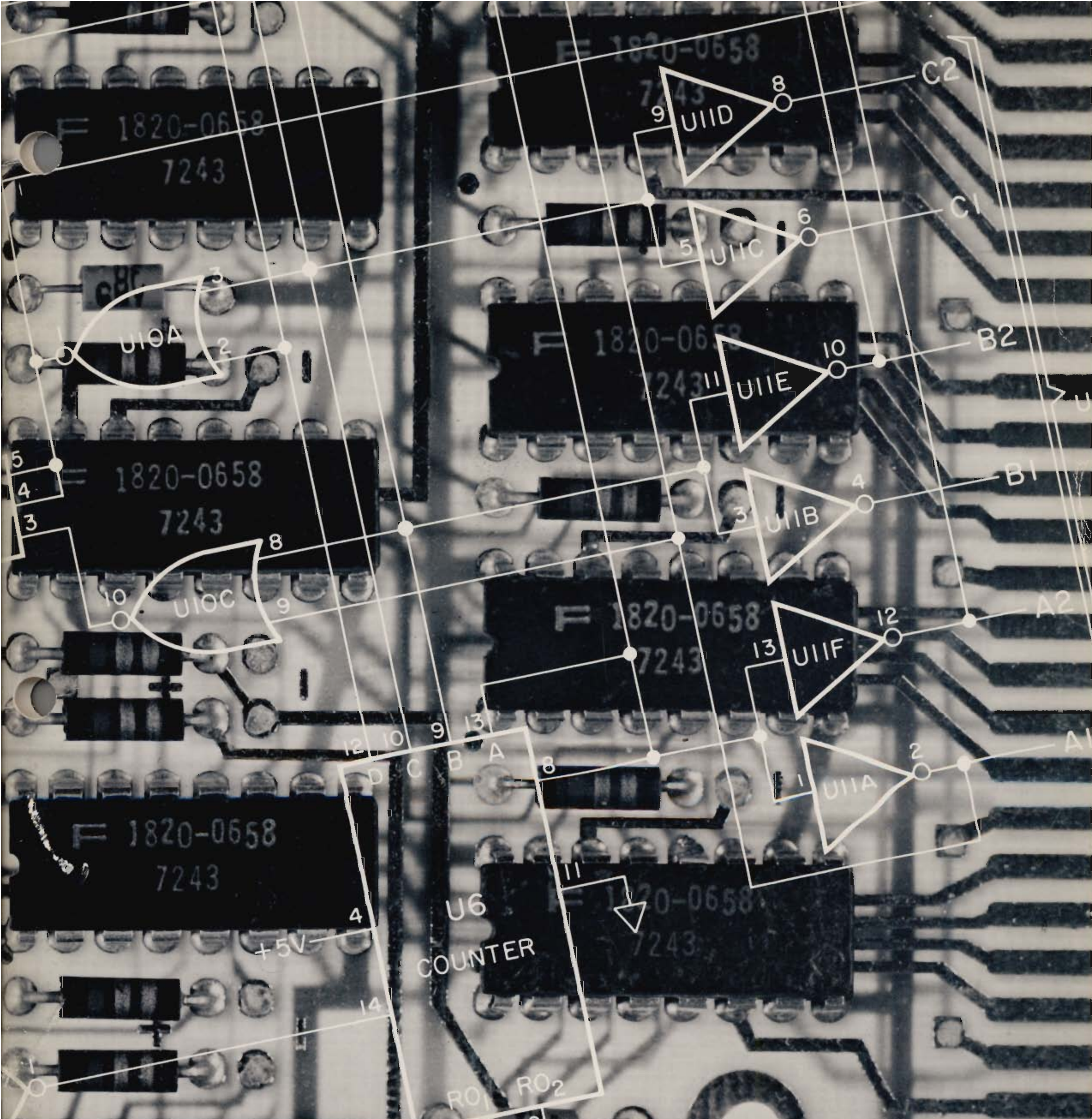


Selecting an HP Calculator Interface

HEWLETT PACKARD

Selecting an HP Calculator Interface

Hewlett-Packard Calculator Products Division

P.O. Box 301, Loveland, Colorado 80537, Tel (303) 667-5000

Here is a comparison of the available calculator interface hardware and I/O software. The page number in each column indicates where detailed information can be found.

I/O SOFTWARE AVAILABLE

Interface	9810A Calculator (p. 34)	9820A Calculator 9821A Calculator (p. 43)	9830A Calculator (p. 52)
11202A General I/O (8-Bit-Parallel ASCII) (p. 12)	11264A Peripheral Control Block: • 8-line ASCII input/output, • Output storage, • Output formatting, • Input/output programs, • High-speed data transfer. ——— 11252A PC2 Block: • Same I/O as above. • Binary input/output, • Input formatting, • Binary arithmetic & conversions, • Ready/busy status check.	11220A PC1 Block: • 7-line ASCII output/input, • Output storage, • Output formatting, • Data transfer. ——— 11224A PC2 Block: • Same I/O as above. • Binary input/output, • Input formatting, • Ready/busy status check.	Basic Calculator: • 8-line ASCII output, • 8-line binary output, • Output storage, • Output formatting, • Print/tab statements, • Output program listings. ——— 11272B Extended I/O ROM: • 8-line ASCII input, • 8-line binary input, • Code conversion for input and output, • Ready/busy status check.
11203A BCD Input (9-Line BCD) (p. 20)	11264A Peripheral Control Block: • 9-digit BCD input, • Function code (one digit), • Polarity, • Exponent (w/ sign). ——— 11252A PC2 Block: • Same I/O as above. • Single-bit binary input, • Ready/busy status check.	11220A PC Block: • 9-digit BCD input, • Function code (one digit), • Polarity, • Exponent (w/ sign). ——— 11224A PC2 Block: • Same I/O as above. • Single-bit binary input, • Ready/busy status check.	11272B Extended I/O ROM: • 9-digit BCD input, • Function code (one digit), • Polarity, • Exponent (w/ sign), • Ready/busy status check.
11205A Serial I/O (RS-232-C) (p. 26)	11264A Peripheral Control Block: • 10 or 11-bit ASCII I/O, • Adjustable Baud rate, • Output formatting, • Free-field input format. ——— 11252A PC2 Block: • Same I/O as above. • Input formatting, • Binary input/output, • Binary routines for code conversion.	11220A PC1 Block: • 10 or 11-bit ASCII I/O, • Adjustable Baud rate, • Output formatting, • Free-field input format. ——— 11224A PC2 Block: • Same I/O as above. • Input formatting, • Binary input/output.	Basic Calculator: • 10 or 11-bit ASCII output, • Adjustable Baud rate, • Print/tab statements, • Output program listings. ——— 11272B Extended I/O ROM: • Same I/O as above. • 10 or 11-bit ASCII input, • Code conversion for input and output.
11282A Digital Plotter (Incremental Plotter Control) (p. 31)			A complete set of 9830A plotter control statements are supplied on cassette with each interface (no additional ROM is needed.) • 6-line data output, • Plotter step sizes of 200-300 steps per min. (See page 61.)

Preface

This guide describes the general-purpose interfacing products currently available for HP 9800-Series Calculators. The guide is conveniently divided into three parts:

- **Chapter 1: THE CALCULATOR** – offers a brief comparison of each 9800-Series Calculator and an explanation of the calculator input/output scheme.

- **Chapter 2: THE HARDWARE INTERFACE** – describes the general-purpose interface cards and shows an application for each.

- **Chapters 3 & 4: PROGRAMMING** – Chapter 3 lists the general input/output commands for each calculator and describes typical programming techniques. Chapter 4 describes programming the HP Interface Bus.

Although some interfacing topics, such as 9830A Data Communications and controlling specific HP Calculator Peripherals, are not covered, the information in this guide is all that's needed to select the right interface for your special-purpose calculator system.

For more information on calculator interface products, please refer to the manuals listed in the Appendix or contact the nearest HP Sales and Service Office listed at the back of this guide.

Contents

Chapter 4: HP Interface Bus

Appendixes

Tables

Figures

Chapter 1
The Calculator

HP 9800-Series calculators provide both a wide range of computing power and a flexible interfacing system, within low-cost, attractive, desk-top packages. And a 9800-Series system is easy to set-up, with a variety of ready-to-use peripherals and plug-in interface cards. Even the I/O software is easy to load and use, since it's available in plug-in blocks to expand the calculator memory. From the key-per-function language of the 9810A, to the popular computer language (BASIC) of the 9830A, the 9800-Series offers a problem-solving calculator to fit almost every application.

The following table offers a brief comparison of each 9800-Series calculator. For complete information on any of these calculators, contact the nearest HP Sales and Service Office listed at the back of this guide.

Whichever model you choose, your calculator has the same versatile I/O structure that is compatible with a wide selection of HP calculator peripherals, standard computer peripherals, and interface products described in this guide.

Comparing 9800-Series Calculators

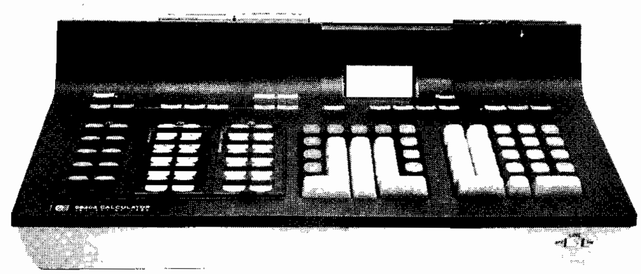
	HP9810A	HP9820A	HP9821A	HP9830A
Language	Reverse Polish[1]	Algebraic	Algebraic	BASIC
Keyboard	Key per function	Key per function	Key per function	Alphanumeric
ROM size (bytes)	5K to 11K	8K to 14K	8K to 14K	15K to 31K
RWM size Available to user	500 to 2036 keystrokes 51 or 111 data registers	1384 to 11624 bytes	1336 to 11624 bytes	3520 to 15808 bytes
User definable keys or functions	Optional-single key subroutine	Optional-single key subroutine or function with parameters	Optional-single key subroutine or function with parameters	Standard-subroutine or function with one parameter
Recording device	Magnetic Card (Cassette optional)	Magnetic Card (Cassette optional)	Cassette standard	Cassette standard (Disc memory optional)
Display	3-register numeric LED	16-character alphanumeric LED	16-character alphanumeric LED	32-character alphanumeric LED
Primary Printer	Optional 16-column alphanumeric	Standard 16-column alphanumeric	Standard 16-column alphanumeric	Optional 80-column alphanumeric

[1]Reverse Polish (Lukasiewicz) notation and an operational register stack provide the most-efficient way known to evaluate mathematical expressions.

HP9810A

The combination of one-key-per-function operation, Reverse Polish Notation (RPN) and a wide variety of software packages make the HP9810A an attractive, low-cost controller and processor. The HP9810A also offers the same input-output hardware structure and flexibility for special-purpose systems as the most sophisticated 9800-Series Calculator. There are four peripheral control ROM blocks available for the HP9810A; each is described in Chapter 3. Each of the blocks provides general I/O routines and formatted output capability. Two of the blocks even combine general I/O with routines for controlling specific calculator peripherals. The newest ROM block, the Peripheral Control 2 Block, has over 30 general I/O and advanced binary-arithmetic routines. These binary routines are ideally suited for numerical-control applications.

HP9820A



Its natural algebraic language and many programming and editing features, such as program flags and relative addressing, make the HP9820A ideal for users who do their own programming. And like the other 9800-Series Calculators, the HP9820A I/O software can be selected according to the user's needs. The basic Peripheral Control 1 Block provides general I/O statements and a complete set of plotter control statements. The Peripheral Control 2 Block has advanced binary I/O routines and a basic plot statement, in addition to the general I/O statements.

HP9830A

Its larger memory, array-variable capability, and disc-memory option make the HP9830A appealing to users with large program and data bases, such as structural engineers and investment analysts. The programming language (HP BASIC), alphanumeric keyboard, string-variable capability, and page-width printer appeal to users in fields outside the scientific, such as education and business. With an optional Terminal 1 ROM or Data Communications package, timeshare users can transform the HP9830A into a versatile (and very smart!) terminal with local or remote computation and storage capability.

HP9821A

The newest member of the 9800-Series family offers all of the programming, editing, and input-output features of the HP9820A. Even the same ROM blocks and peripherals can be used on the new HP9821A. In addition, the HP9821A has a built-in tape cassette for program and data storage as standard equipment. Typically, a cassette can hold up to 40, 167-register programs. Of course, data and programs can be stored on the same cassette. The built-in cassette means that the calculator can rapidly input and store large amounts of data automatically! And program linkage allows the use of any size program, since the calculator can load and run each segment as it's needed.

Read-Only Memories (ROMs)

9800-Series calculators are actually ROM-driven, general-purpose minicomputers. Each calculator model is hardware-structured around a 16-bit processor containing machine-language instructions stored in MOS ROM. The keyboard language which gives each model its unique features is also stored in ROM. In addition, each internal peripheral device (display, printer, magnetic cardreader or cassette, etc.) is controlled from software stored in ROM. Finally, the versatile I/O software for each calculator is stored in ROM which is available as plug-in blocks.

ROM Blocks

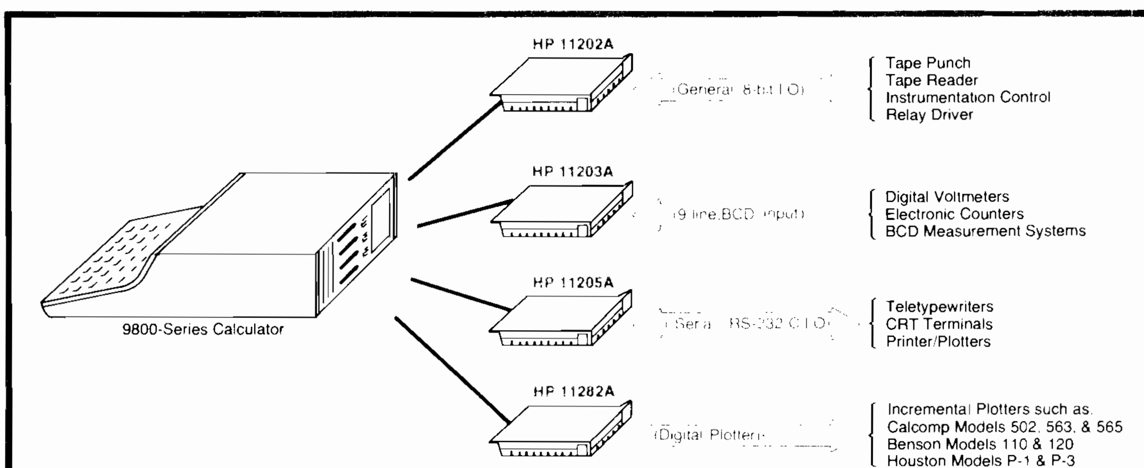
The software stored in each plug-in ROM block is added directly to the calculator memory by installing the block. In addition to the peripheral control blocks available for each calculator, there are a variety of special-purpose ROM blocks which add functions or statements to the calculator keyboard language.

- For the 9810A, three ROM blocks of up to 2048 bytes each may be added to the calculator. The first block is used to define and implement the functions of 15 keys on the keyboard. The second and third blocks are for control of internal and external peripherals.
- For the 9820A or 9821A, three blocks may be added, each controlling one of three sets of ten keys on the keyboard.
- For the 9830A, eight blocks may be added, and since the 9830A has an alphanumeric keyboard, no special keys are required.

A description of the I/O routines available with each peripheral control ROM block is in Chapter 3, Programming.

The Calculator I/O Scheme

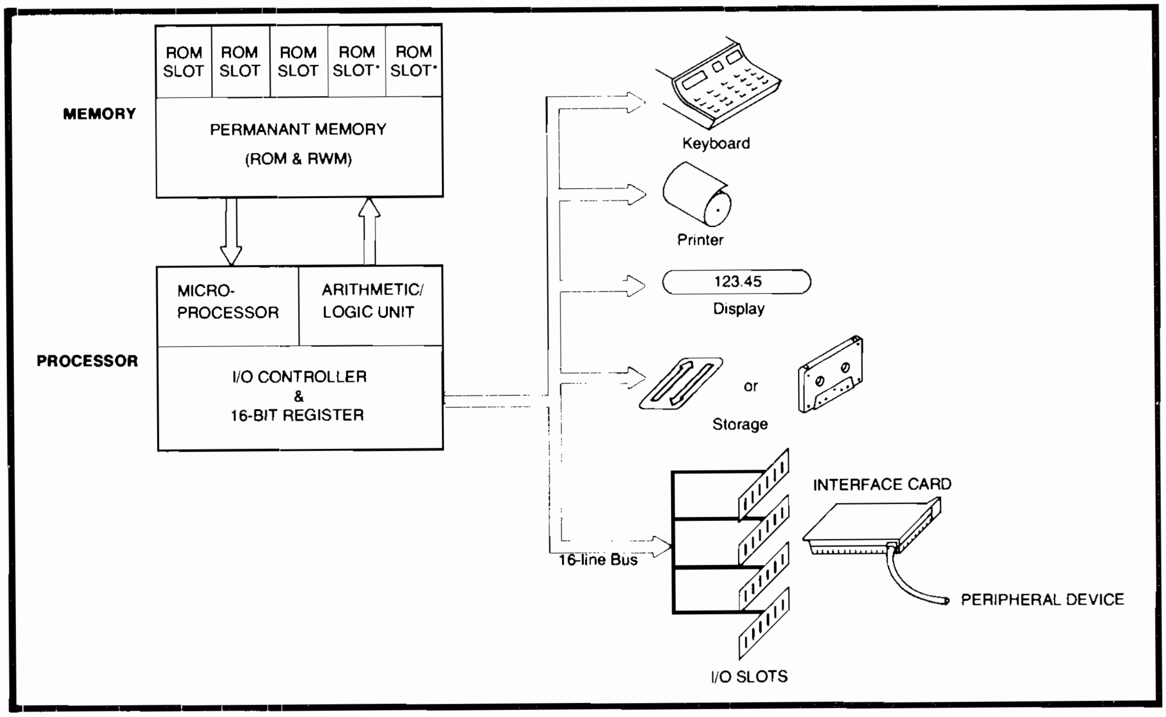
Interfacing any device to a 9800-Series calculator involves both hardware and software requirements. The hardware requirements are met by using one of the HP calculator interfaces described in Chapter 2. The software requirement is solved by installing a peripheral control ROM in the calculator. See Chapter 3 to select the right block.
Here are some general system configurations and the correct interface for each:



Typical Interface Applications

[1]The Digital Plotter Interface can be used with the HP9830A only.

The general I/O scheme for 9800-Series calculators is shown in the next figure. The I/O bus is used to transfer data between the calculator processor and peripheral devices. All data is transferred through the I/O Controller before it is stored in memory. The term "I/O" (Input/Output) is always with reference to the calculator.



The Calculator Input-Output Scheme

As shown in the figure, each external device must be connected to the calculator via an appropriate interface card and cable; the card plugs into any of the four I/O slots in the calculator's back-panel. Also note in the figure, that plug-in ROM blocks become a part of the calculator's executive memory. Each block adds up to 2048 bytes of ROM. Finally, notice that external devices share the same I/O register and bus used by internal peripheral devices (printer, display, etc.). The internal peripherals, however, do not respond to ROM I/O commands, but only to their specific commands (PRINT, DISPLAY, etc.).

Select Code

As described above, each external device is connected to the calculator via the same I/O bus. Since all external devices are "party-lined" on the same bus, each device is assigned a unique address, or select code, so that the correct device responds to each I/O operation.

For external peripherals[1], the select code is a one or two-digit number, which is specified in each I/O operation and decoded by the corresponding interface card. Each general-purpose interface card has a switch permitting the user to set one of nine different codes.

Input/Output Format

The I/O bus connecting processor with internal and external peripherals contains 16 lines. Data is transmitted in an 8-bit-parallel, character-serial fashion on half of the lines, while the other eight lines handle calculator and peripheral status codes.

In general, the I/O commands permit the calculator to send and receive data in standard 8-bit USASCII code. Some advanced ROM I/O commands, however, permit data transfer in other codes; for details see Chapter 3, Programming. The calculator generally sends and receives one 8-bit character at a time. If another character is to be sent or received, the calculator waits until the device is ready.

Peripheral Interrupt

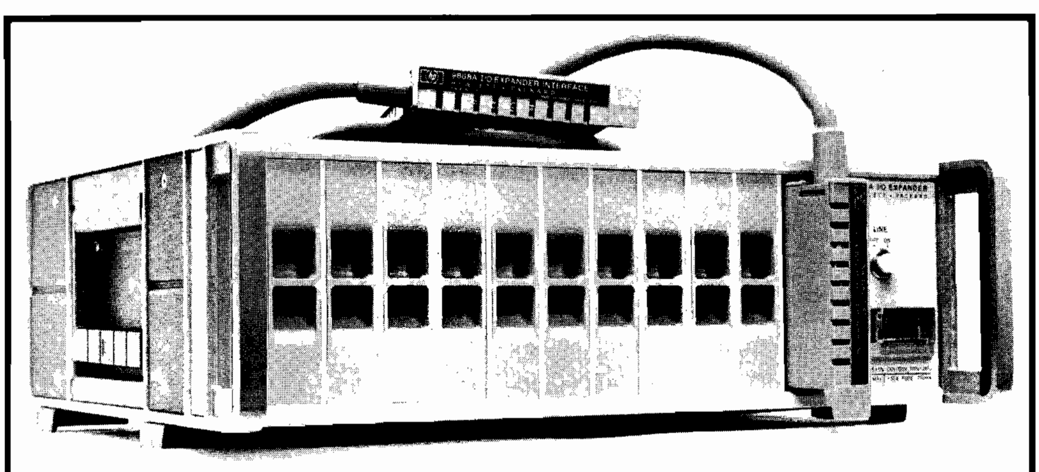
Because the calculator is the controlling device in most systems, there is no provision for peripheral interrupt operation, where a device can call for an I/O routine. The calculator must be in complete control of each device while that device is involved in data transfer.

Even though hard-wired interrupt capability is not available, a ''software interrupt'' method can be used. This method uses the READ STATUS or STAT function (available with a Peripheral Control 2 or Extended I/O ROM Block) to monitor the ready/busy status of the peripheral interface card.

Chapter 3 offers example program sequences showing software interrupt with each model calculator.

I/O Expander

If your system application requires more interface cards than can be plugged into the back of the calculator, the HP 9868A I/O Expander is available for adding up to nine extra interfaces.



The 9868A I/O Expander

The I/O Expander provides all power required for the additional interfaces, and also has a separately-fused block of eight power outlets on the back panel.Here is a brief list of specifications:

Available Power

+5V at 4A and ±12V at 350mA.
Most calculator interface cards use only +5V at about 100mA per card.

Power Requirements

100, 120, 220, or 240Vac (+5%, −10%), switch-selectable.
48 − 440 Hz, 80W at 60 Hz.

Dimensions

14cm (5½ inches) high × 42.5cm (16¾ inches) wide × 34.3cm (13½ inches) deep.

Weight

Shipping weight 8.64kg (19 lbs.).

Options

9868A Option AØ1 is a standard I/O Expander with a 4.6m (15 foot) interface cable. The standard I/O Expander has a 1.8m (6 foot) cable.

Service

In Warranty: An interface card or ROM block found defective will be quickly replaced by your local HP Sales and Service Office.

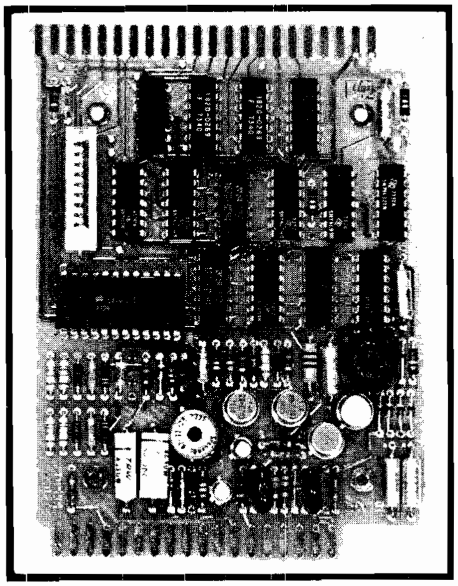
Out of Warranty: Each general-purpose interface card is supplied with complete service information, including a schematic diagram and troubleshooting procedure. HP can also repair or replace the card for a moderate charge. Since a defective ROM block can be repaired only at the factory, it must be replaced for the current exchange price.

NOTE
Calculator warranty does not cover damage caused by use of devices or interface hardware not supplied by HP.

For more information, contact your nearest HP Sales and Service Office listed at the back of this guide.

Notes

Chapter 2
The Hardware Interface



This chapter describes the HP general-purpose calculator interface cards currently available. The next few paragraphs offer some requirements which you should consider when selecting the right card for your application. See also the Software/Hardware Comparison Table at the front of this guide.

User Requirements

This guide assumes that the user wishes to interface a device which is not a standard calculator peripheral supplied by HP. To accomplish that, the same two objectives mentioned in Chapter 1 must be met: 1) one of the available interface cards must be plugged into the calculator and wired for the peripheral's I/O connector; and 2) I/O software must be available so that the calculator can control the peripheral. The I/O software is usually added by plugging in the correct peripheral control ROM block. (General WRITE and FORMAT statements are available without a ROM block with a 9830A Calculator.)

Here are some points to consider when selecting the interface card:

Functional Requirements:

- What data-transfer format is used? For example, if the device outputs data in eight-digit, binary-coded-decimal (BCD) form, consider the 11203A BCD Interface. But if the device outputs data in eight-line-parallel, character-serial fashion, consider the 11202A I/O Interface.
- What control logic is required? For instance, to interface to a digital voltmeter, only "sample data" and "ready" control logic are usually required (use an 11203A Interface). But to control the DVM range functions, another interface (11202A), is needed to output control characters.

Electrical Requirements:

- What data-logic and control-logic levels are required? If a CRT terminal to be interfaced meets RS-232-C specifications, an 11205A Serial I/O Interface can be used. But if the terminal meets all specifications except that the data lines require negative-true logic, then circuitry must be added between card and terminal to invert the signals.
- What data transfer rate is required? For applications using an 11202A I/O or 11203A BCD Interface, the data-transfer rate is not critical, since the peripheral is always under calculator control during I/O operations. (The actual data-transfer rate is determined by program execution time and peripheral response time.) When using an 11205A Serial I/O or 11282A Plotter Interface, however, the interface I/O rate must be closely matched to the peripheral I/O rate. Each of these latter interfaces can be set to various I/O rates; see the next table for more details.
- What power supplies are required? The calculator supplies power for each interface card. In a few cases interface lines can be used to source or sink power for peripheral circuits, **provided** that the interface's electrical limits are observed.

Mechanical Requirements:

- What type of interface cable connector is needed for the peripheral? Most cards are not supplied with connectors.
- What cable length is needed? The next table lists the cable length furnished with each interface.

Software Requirements:

- What I/O routines are needed to control the peripheral? See Chapter 3 for available I/O operations.
- What **other** peripheral control routines are required? For example, if you have a 9821A Calculator with a 9862A Plotter and a digital voltmeter, the PC1 Block provides more-flexible plotter capabilities than the PC2 Block.

User-Designed Interfaces

In some cases, one of the available calculator interface cards may not provide a complete hardware interface. If your application requires additional interface circuitry, be sure to utilize the most appropriate interface card(s) in your circuit design. You'll find electrical requirements listed with each calculator interface in this chapter.

Due to critical electrical and timing requirements, HP does not recommend replacing available interface cards with user-designed interface hardware. Please remember that HP warranties and supports only those items which are produced and quality-controlled by HP. The effectiveness of devices or programs created according to this guide is purely the responsibility of the user. The information herein is intended as a guide only.

The following table provides a quick comparison of each interface card. Refer to the remainder of this chapter for more details on each card.

Comparing General-Purpose Calculator Interfaces

CHARACTERISTIC	11202A General I/O	11203A BCD Input	11205A Serial I/O	11282A Digital Plotter
Data Direction	Input and output	Input only	Input and output	Output only
Number of Data Registers	One (8-bits)		One-(serial to parallel conversion)	
Data Lines	8 input 8 output	36 data and 12 function, polarity and exponent lines	One input One output	Four
Control Lines	Control out Flag in	Control out (2) Flag in	Clear To Send Data Set Ready Peripheral Busy	Pen up Pen down
Data Signals	"1" = <0.7V[1] "0" = >2.4V	"1" = <0.7V[1,2] "0" = >2.4V	"1" = 9V "0" = −9V	"1" = 5V "0" = 0V
Control Signals	"1" = <0.7V[1] "0" = >2.4V	"1" = <0.7V[1,2] "0" = >2.4V	"1" = 9V "0" = −9V	"1" = 5V "0" = 0V
Other Characteristics		Data input stability >500ns	Baud rates from 110-1200. 10 or 11 bit format.	Plotter speeds of 200/300 ips.
Other Items Supplied	Test connector (Part No. 11202-66592)	Test connector (Part No. 11203-66592)		I/O routines & Diagnostic supplied on Cassette
Cable Supplied	1.82m (6 feet) unterminated	1.82m (6 feet) unterminated	2.43m (8 feet)	1.82m (6 feet)
Connector Supplied	With options only; see p. 13	With options only; see p. 21	25-pin EIA connector	19-pin barrel connector

[1]Lines are TTL compatible.
[2]Lines can be wired for either "+" true or "−" true logic.

11202A I/O Interface

The HP 11202A I/O Interface is a general-purpose card which provides 8-bit data exchange between a 9800-Series calculator and a peripheral device. The interface transfers data in a "half-duplex" mode. That is, it can either input or output data, but not both at the same time. The interface provides storage of each input or output data character and also has a device control line and a device ready (flag) line. All data and control lines are compatible with standard TTL levels.

Technical Specifications

I/O Format

The interface sends and receives information in 8-bit-parallel, character-serial fashion. All ASCII-coded characters are listed in the Appendix.

Although the calculator handles only ASCII-coded information, the interface can transfer data in any 8-bit binary code.

Data Input Lines

Eight input lines are available. Each line has a low-power TTL load and a resistive divider.

Each data item placed on the interface input lines must be settled before the "data ready" signal ($\overline{\text{FLG}}$ line) is transmitted. Then the data must be held stable for at least 500ns.

Data Output Lines

Eight lines with open-collector SN7406 TTL inverters are available.

Control Lines

- Device Control ($\overline{\text{CTL}}$) – High-to-low transition indicates that the interface is ready to input data or has data to output.
- Device Ready ($\overline{\text{FLG}}$) – Peripheral device indicates "data accepted" or "data valid" by forcing the line low. The $\overline{\text{FLG}}$ signal must be greater than 500ns.
- I/O Status (I/O) – Tells device whether calculator has started an input operation (high) or an output operation (low).
- Stop ($\overline{\text{STP}}$) – $\overline{\text{STP}}$ is low whenever the calculator STOP key is held down.
- Enable Handshake ($\overline{\text{ECH}}$) – When $\overline{\text{ECH}}$ is connected to ground, the interface cannot drive $\overline{\text{CTL}}$ low until the peripheral device forces $\overline{\text{FLG}}$ high to indicate "ready". When $\overline{\text{ECH}}$ is left open, the interface does not check the $\overline{\text{FLG}}$ line before driving $\overline{\text{CTL}}$ low.

Signal Levels

All data and control lines use negative-true logic (i.e., <0.7V indicated logic "1" or "true", and >2.4V indicated logic "0" or "false"). A bar above each line name (e.g., $\overline{\text{CTL}}$ and $\overline{\text{FLG}}$) indicates that the line goes low to indicate logical 1. All other lines go high to indicate logical 1.

Select Code

The interface is set to respond to select code 1 when supplied. Any of eight other codes can be set by the user.

Options

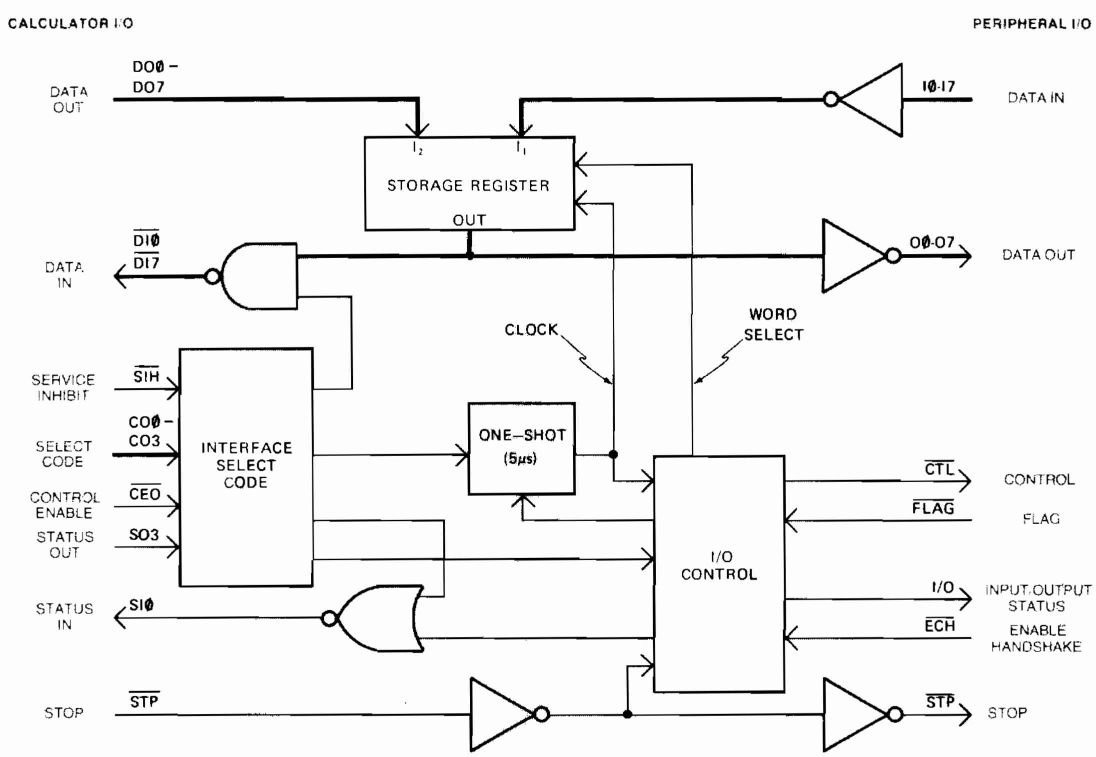
Here is a list of available 11202A Interface options. Except for options A10 and A11, each is prewired with a connector suitable for use with the listed HP instrument.

11202A Option:	Description:
A01	2748A/B Tape Reader
A02	2895A/B Tape Punch
A04	3482A or 3484A Plug-in for 3480 DVM
A05	3485A Scanner for 3480 DVM
A10	4.57m (15 foot) unterminated cable
A11	7.62m (25 foot) unterminated cable

Theory of Operation

In general, the 11202A is an 8-bit, bi-directional data buffer. Although the interface has separate input and output lines, it handles data in only one direction at a time. The SO3 signal determines whether the input or output mode is set.

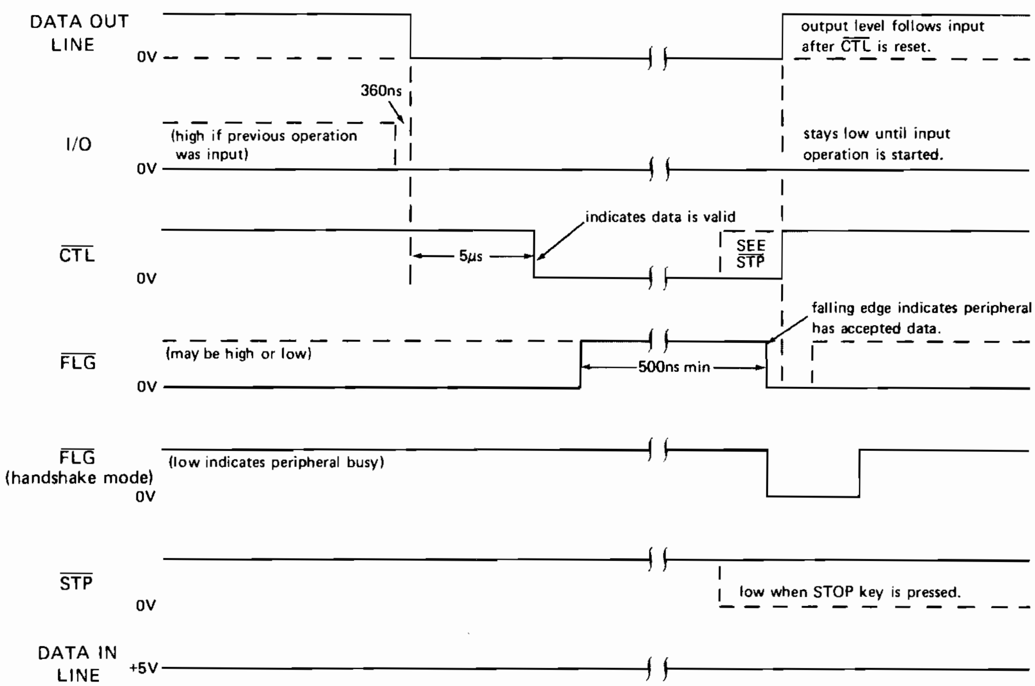
A simplified block diagram of the interface is shown below.



11202A Block Diagram

This sequence occurs for each output character:

1) After an appropriate OUTPUT command or WRITE statement is executed from the calculator, a Select Code signal is output.
2) The calculator checks interface status on the SIØ line. If the interface is not busy, data is held on the calculator output lines (DOØ-DO7) and an SO3 signal sets the I/O line low to indicate that a data-output operation has started.
3) A CEO and a Select Code signal are output. If the Select Code signal corresponds to the setting of S1, data is transferred to the interface output lines. 5μs later, the CTL line is forced low.
4) Data is held on the output lines until the peripheral device indicates "done" by forcing FLG low. Then data on the interface input lines is loaded into the storage register and onto the output lines.

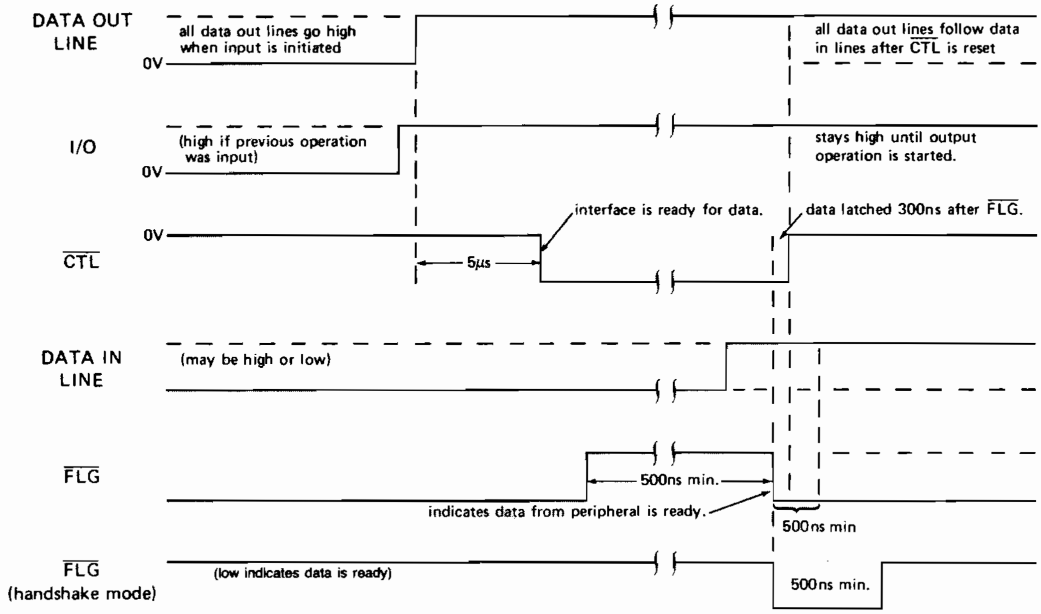


11202A Data-Output Timing Diagram

(Interface-peripheral lines are shown.)

This sequence occurs for each input character:

1) After an INPUT command or READ statement is executed from the calculator, a Select Code signal is output.
2) The calculator checks interface status on the SIØ line. If the interface is not busy, an SO3 signal sets the I/O line high to indicate that a data-input operation has started.
3) The calculator outputs CEO and Select Code signals. If the Select Code signal corresponds to the select code switch setting, the CTL line is forced low. Now the calculator monitors the SIØ line, waiting until the peripheral device has output data and indicated "done" by forcing the FLG line low. 300ns after FLG goes low, data is loaded into the interface and transferred to its output lines.
4) The interface then forces the SIØ line low and the calculator inputs the data on the next SIH pulse.



11202A Data-Input Timing Diagram

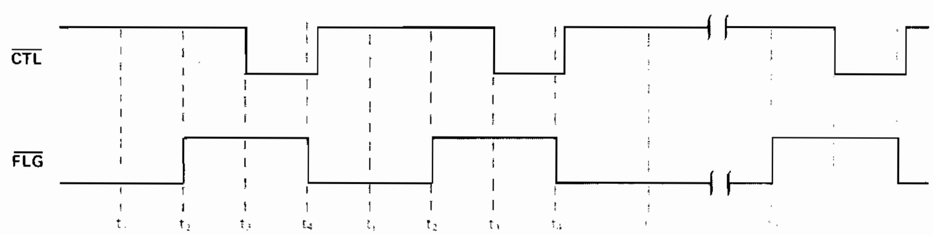
(Interface-peripheral lines are shown.)

Handshake Mode

As described in the previous sections, the interface normally interacts with a peripheral in a 'handshake' fashion – each device waits for the other to be ready before sending or receiving data. This section describes an alternate method of interface/peripheral control called the "Handshake Mode".[1]

Grounding the $\overline{\text{ECH}}$ line enables the interface to operate in the Handshake Mode. When the Handshake Mode is enabled, the interface checks for a high $\overline{\text{FLG}}$ line before continuing the I/O operation. Whenever $\overline{\text{FLG}}$ is found to be low, the interface stays in a busy state until the peripheral forces $\overline{\text{FLG}}$ high.

The "handshake" interaction between the $\overline{\text{CTL}}$ and $\overline{\text{FLG}}$ lines is shown here:



t_1 – peripheral holds interface 'busy' by holding $\overline{\text{FLG}}$ low.

t_2 – peripheral forces $\overline{\text{FLG}}$ high to continue I/O operation.

t_3 – interface forces $\overline{\text{CTL}}$ low to indicate 'ready to accept data' or 'output data is valid'.

t_4 – peripheral forces $\overline{\text{FLG}}$ low to indicate 'data ready' or 'data accepted'. Interface will again wait until $\overline{\text{FLG}}$ is returned high.

Handshake Mode Timing Diagram

Recommended Receiving Circuits

Each output signal from the interface is transmitted from an SN7406 TTL inverter, which has an open-collector output. The current-sinking capability of each inverter is 40mA and the breakdown voltage is 30V.

Here are typical specifications:

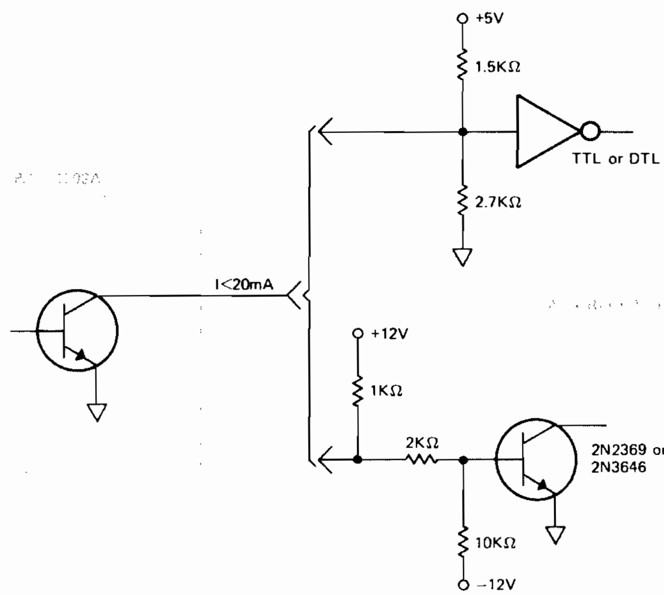
$$V_{ol}\begin{cases} @\ (I_{ol} = 16\text{ma}) = 0.4\text{V max.} \\ @\ (I_{ol} = 40\text{ma}) = 0.7\text{V max.} \end{cases}$$

V_{oh} (Open Collector) = 30V max.

I_{ol} = 40 mA max.

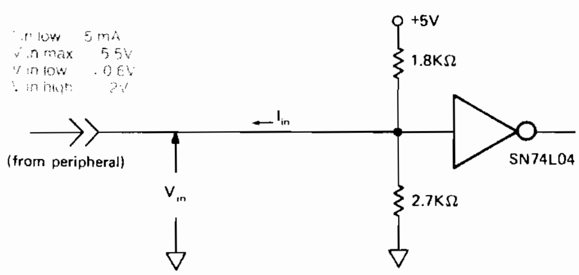
I_{oh} @ (V_{oh} max.) = 250 μA

Since each transmitter has an open collector, the peripheral receiving circuit must have a positive pull-up voltage not to exceed 30V and must be restricted to sourcing back to the transmitter less than 40mA. Recommended receiving circuits are shown on the right.



Recommended Peripheral Receiver Circuits

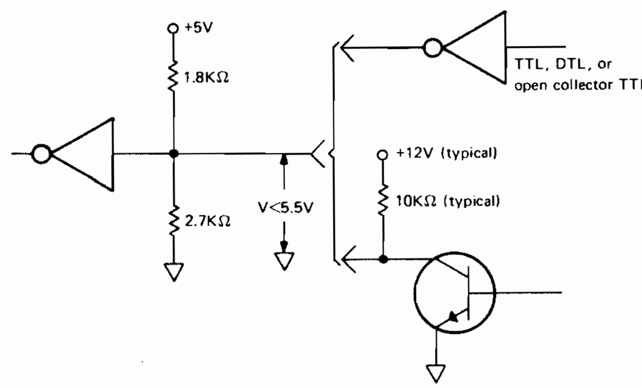
Recommended Transmitting Circuits



11202A Data Receiver Circuit

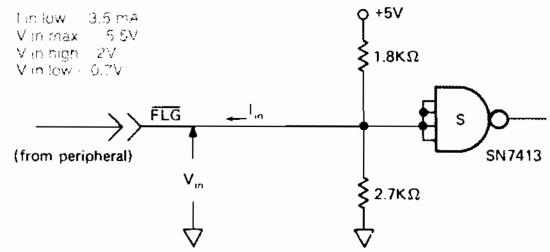
Each data input line on the interface (except $\overline{\text{FLG}}$) contains an SN74L04 low-power inverter. A resistive divider connected to each input line holds the voltage at about 3V when the cable is disconnected. The input voltage must not exceed 5.5V.

Recommended peripheral transmitting circuits are shown here. ➧



Recommended Transmitting Circuits

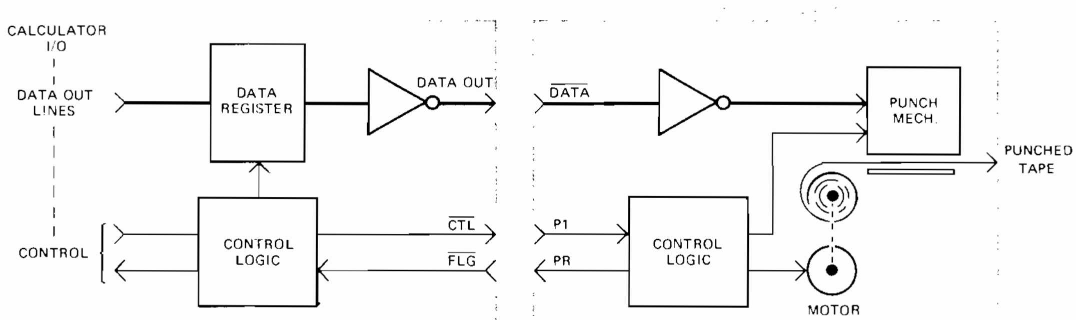
The device ready signal ($\overline{FLG}$) is received by an SN7413 Schmitt trigger circuit. This circuit accepts signals with slow rise and fall times, and provides good noise margins. Although the voltage on the $\overline{FLG}$ line must not exceed 5.5V, there is no restriction on the input rise and fall time. Either of the transmitting circuits shown above may also be used as a flag transmitter.



11202A Flag Receiver Circuit

Applications

A popular application for the 11202A is as an interface to the HP 2895B/8100A Option 004 Tape Punch. Here's a simplified functional diagram of the tape punch and the interface.



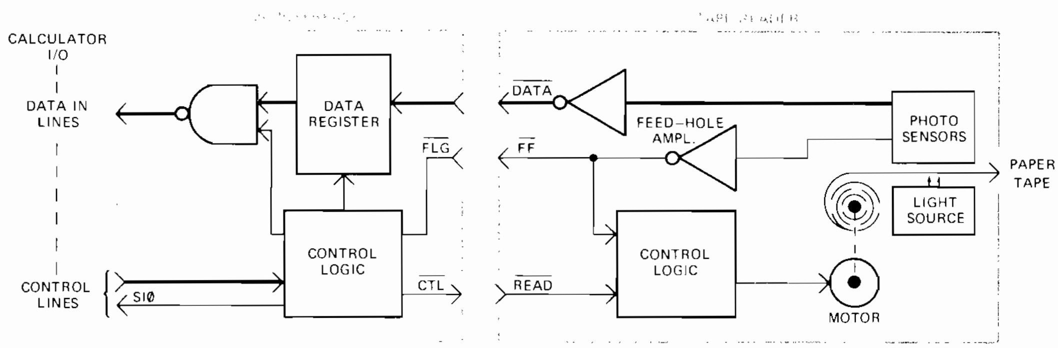
11202A/Tape Punch Interface

After the tape punch is readied with a blank tape, this sequence occurs to output and punch data:

1) A DATA OUTPUT or WRITE operation is executed from the calculator. The specified format determines how many characters are output with each data item.
2) After the calculator outputs the first character to the interface, the interface latches the data onto its output lines and sends a P1 ($\overline{CTL}$) signal to the tape punch. The P1 signal causes the tape punch to decode and punch that data. Then the motor advances the paper and the tape punch outputs a PR($\overline{FLG}$) signal, indicating that it is ready for more data.
3) The $\overline{FLG}$ signal returns the interface to its ready state and outputs an SI∅ signal to the calculator.
4) If the calculator has more characters to output, the sequence is repeated (see step 2).

Data Input

Another popular application for the 11202A is as an interface to a high-speed paper tape reader, such as the HP 2748B Tape Reader. A simplified functional diagram of that system is shown here:



11202A/Tape Reader Interface

After the tape reader has been readied with a tape, this sequence occurs to read the information:

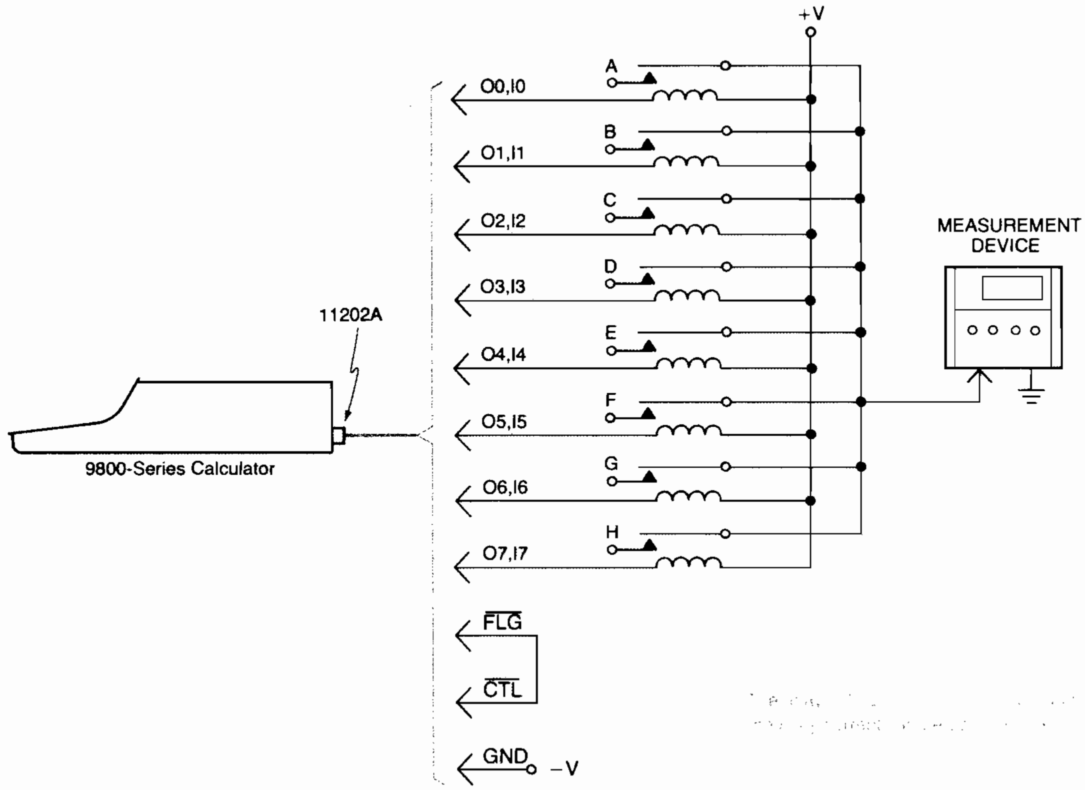
1) A DATA INPUT or READ operation is executed from the calculator. The specified format and the sequence of data on the paper tape determine how many characters are read during each operation.
2) The interface outputs a Read ($\overline{\text{CTL}}$) signal, which causes the tape reader motor to advance the tape. When a feed hole is detected on the tape, the motor stops and the data character is read. After the data is output on the Data lines, a FF($\overline{\text{FLG}}$) signal is output.
3) Upon receiving the $\overline{\text{FLG}}$ signal, the interface transfers the data character to the calculator.
4) After the calculator reads the data, it stores the data and then either requests more (return to step 2) or it terminates the input operation.

The next figure shows a scheme for using the 11202A Interface as a relay driver card. Up to eight relays can be controlled independently with any 9800-Series calculator.[1]

To select an input to the device, the calculator must output an ASCII character that causes all output lines to remain high except one – the low output causes current flow through the selected relay. Since the interface data-output lines are connected to the data-input lines, the output character will remain valid (holding the selected relay closed) until the next character is output.

See Chapter 3, Programming, for examples on how to output ASCII characters with each calculator.

[1] With a 9… [illegible]
PC… Block … [illegible]



11202A Relay-Control Application

Here is a list of usable ASCII output characters:

To select this input:	Output this ASCII character:	or WRITE BYTE:
A	SOH (00000001)	1
B	STX (00000010)	2
C	EOT (00000100)	4
D	FE$_0$ (00001000)	8
E	DC$_0$ (00010000)	16
F	space (00100000)	32
G	@ (01000000)	64
H	————	128
(no input)	NULL (00000000)	0

11203A BCD Interface

The HP 11203A BCD Interface provides a 9800-Series calculator with an interface to a variety of instruments having parallel binary-coded-decimal (''1248'' weighted BCD) outputs. The interface is normally connected to the ''Digital Recorder'' output of a BCD measurement device such as a digital voltmeter or frequency counter. When a Peripheral Control Block (9810A, 9820A, or 9821A) or Extended I/O ROM (9830A) is used, the interface can transfer up to nine BCD digits of data and also function, range, sign, and overload information to the calculator. For instruments that output more than 9 digits of data, the interface can be wired to input the nine most-significant digits.

Technical Specifications

Logic Levels

Levels are standard (control lines) or low power (data lines) TTL logic with logic ''1'' state high (>2.4V) and logic ''0'' state low (<0.7V) on all lines. The interface card can be easily wired for inverted levels on data and/or control lines.

Input Format

Each BCD data sample is serialized on the card into a sixteen-character sequence as follows: Function code, delimiter, mantissa sign, nine digits of data, exponent sign, overload, exponent and delimiter.

- The first delimiter (comma) separates function code and data into separate registers.
- The second delimiter (LF) terminates the entry sequence.
- Overload condition sets the most-significant exponent digit to eight and sets exponent sign positive (i.e., a large positive exponent is output).
- All unused data lines must be connected for zeros (grounded on the positive-true card).

Input Codes

Data – 9 bits, or digits, each with ''1248''binary-coded-decimal weighting. BCD codes 0 through 9 are entered as decimal numbers. BCD code 14 or 15 is accepted and entered as a decimal point, if it occurs in a data string.

NOTE

A 9820A or 9821A Calculator will halt program execution if a BCD 14 or 15 is received.

- Function and Exponent – ''1248'' BCD weighting: codes 0 through 9 decimal only.
- Mantissa Sign – One binary bit: ''0'' gives positive mantissa; ''1'' gives negative mantissa.
- Exponent Sign – One binary bit: ''0'' gives positive exponent; ''1'' gives negative exponent unless overload condition exists.
- Overload – One binary bit: ''1'' gives overload condition.

- Function and Exponent – ''1248'' BCD weighting: codes 0 through 9 decimal only.
- Mantissa Sign – One binary bit: ''0'' gives positive mantissa; ''1'' gives negative mantissa.
- Exponent Sign – One binary bit: ''0'' gives positive exponent; ''1'' gives negative exponent unless overload condition exists.
- Overload – One binary bit: ''1'' gives overload condition.

Control Lines

- Control 1 – Normal control line: leading edge initiates the data sample, and the trailing edge is triggered by a Flag returning low from the BCD source.
- Control 2 – A negative-going command from the interface signals the BCD source to initiate a data sample. Control 2 can be used if the BCD source returns Flag high to recognize control command.
- Flag – Returned low by the BCD source to signal that the data sample is complete and data is ready.

Select Code

The interface is set to respond to select code 3 when supplied. Any of eight other codes can be set by the user.

Maximum Data-Entry Rate

The maximum data-entry rate depends upon the calculator, the peripheral device, and the program execution time. Here is a list of maximum rates possible with current system configuration:

Data-Entry Rates with an 11203A

Calculator (ROM Block)	Maximum Rate (samples/sec.)
9810A (Any PC Block)	40
9820A (PC1)	4
9820A (PC2)	20
9821A (PC 1)	4
9821A (PC 2)	20
9830A (Extended I/O)	18

Stability of Input Data

Since the interface does not provide buffer-storage of input data, the BCD data must be held stable for the entire data-input sequence. The time needed for input data to remain stable depends upon the data-entry rate. For instance, if the system is sampling at 40 samples per second, the data must remain on the lines for a minimum of 25ms, whereas a sample rate of four samples per second requires that each data remain stable for not less than 250ms.

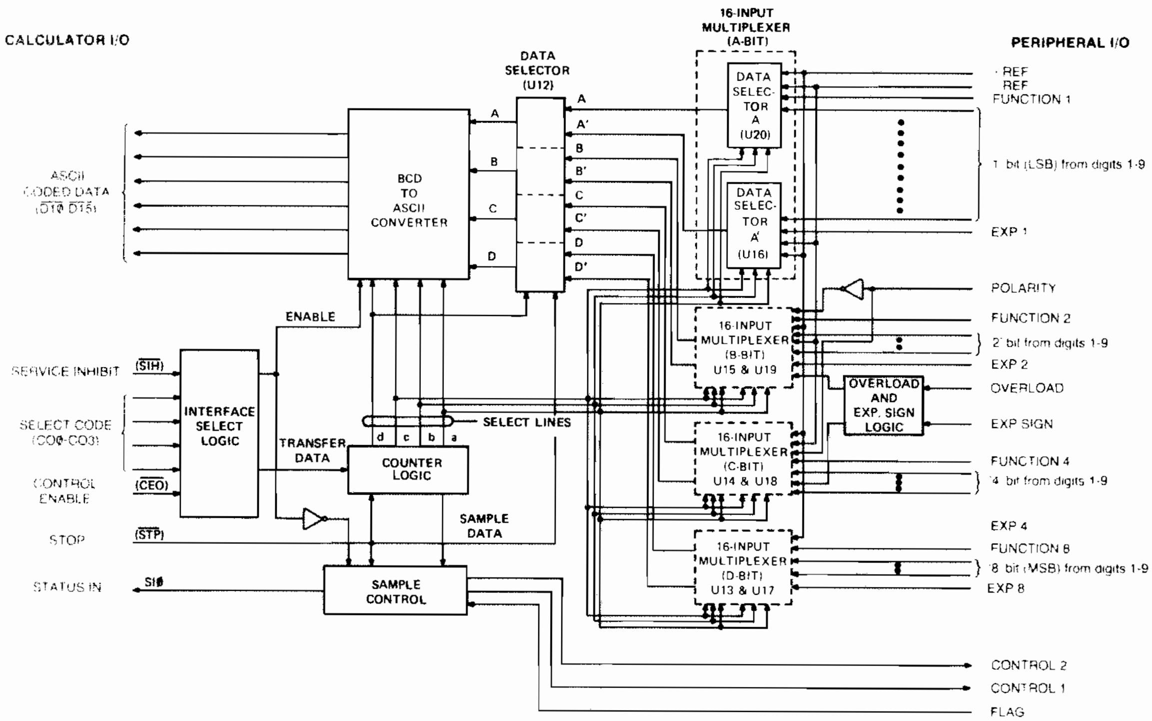
Options

Here is a list of interface options. Except for options A15 and A16, each is prewired with a connector suitable for use with the HP instrument listed:

11203A Option:	Connects to a:
A01	5326/5327 Counter
A02	5300A Counter System
A03	3480A/B DVM (3482A or 3482A Plug-in)
A04	3450A/B Multifunction Meter
A05	3575A Gain-Phase Meter
A06	3480A/B DVM (3485A Scanner Plug-in)
A07	3490A Multimeter
A08	3470A DVM System
A13	4270A Capacitance Bridge
A15	4.6m (15 foot) unterminated cable
A16	7.6m (25 foot) unterminated cable

Theory of Operation

The BCD Interface converts positive-true BCD-coded data to negative-true ASCII-coded data which is usable by the calculator. Here's a block diagram of the interface:



11203A Interface Block Diagram

Each data-input operation consists of a series of 16 identical calculator I/O signals. The instruction which tells the peripheral to take a data sample is initiated by the I/O signal. Then, after the peripheral has placed data on the BCD lines, the interface converts the first character (the function code) to ASCII and transmits it to the calculator. After accepting the first character, the calculator outputs the remaining 15 signals. Each of those signals causes the interface to send another ASCII-coded character.

The data input sequence is described in the table on the right.

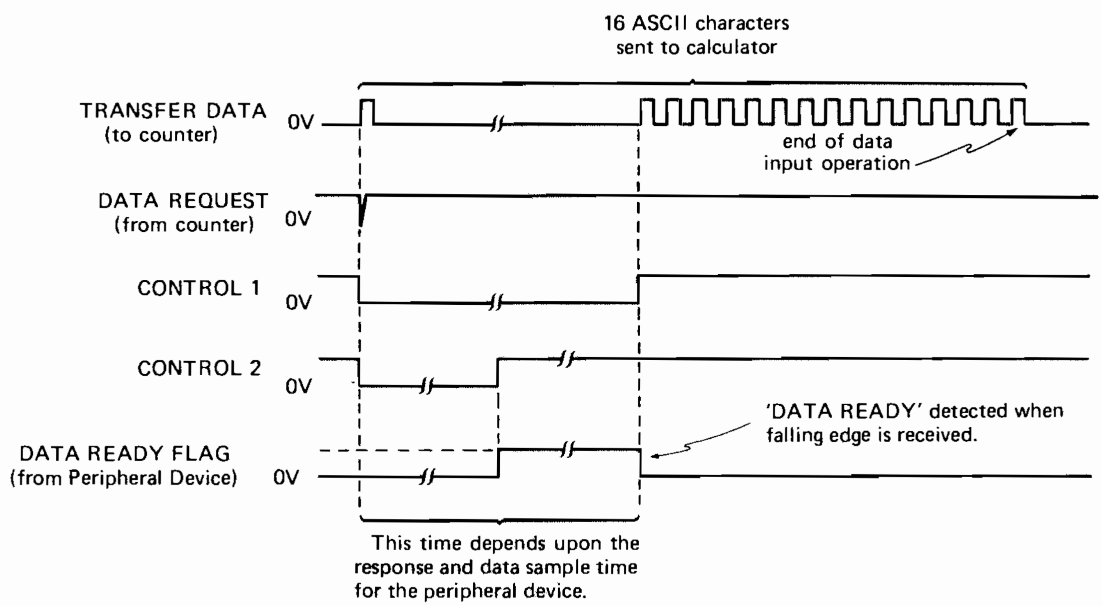
11203A Data-Input Sequence

Input Sequence	Data Item
1	Function Code
2	Comma*
3	Polarity
4	Digit 1 (MSD)
5	Digit 2
6	Digit 3
7	Digit 4
8	Digit 5
9	Digit 6
10	Digit 7
11	Digit 8
12	Digit 9
13	Exponent Sign
14	Overload
15	Exponent Digit
16	Delimiter*

*These characters are generated by the interface

The Data Request signal causes the Control 1 and Control 2 lines to go low, which instructs the peripheral to take a data sample. The Flag signal, which the peripheral transmits after it has placed BCD data on the interface input lines, resets Sample Control and causes an SIØ signal to be output (a low SIØ line indicates that the interface is not busy).

Either the Control 1 or the Control 2 line may be used to signal the peripheral device. As shown in the timing diagram, the Control 1 line remains low until a falling edge is seen on the Flag line; whereas, the Control 2 line remains low only until the Flag line goes high. Thus, the Control 1 line can be used when the peripheral device must maintain a low level during the entire data sampling period.Also, the Control 1 line **must** be used when the Flag line is held high during the entire data sample period.

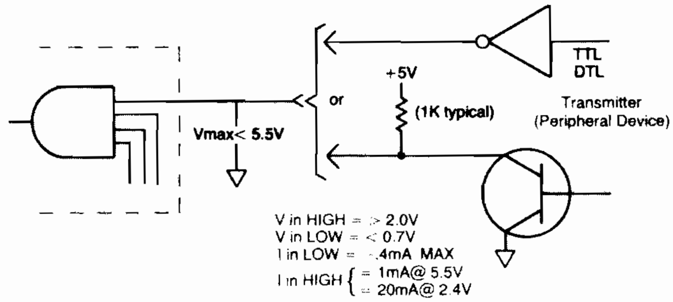


11203A Input-Timing Diagram

Recommended Input Circuts

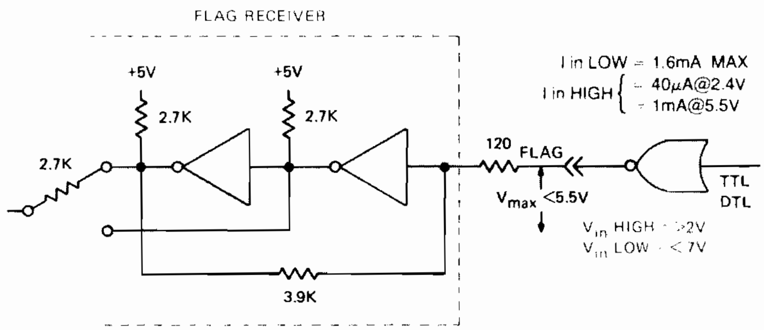
> **NOTE**
> All unused BCD input lines (e.g., data, function, polarity) must be wired for logic 0 (grounded for positive-true card).

Each data input line is connected to a TTL AND gate which is part of the data selector. To ensure proper operation, the transmitting circuit (on the peripheral end of the cable) must allow the receiver to source 0.4mA max. The input voltage must not exceed 5.5V. Typical data transmitter circuits are shown on the next page.



Typical 11203A Data Input Circuits

The flag receiver consists of two TTL inverters (TI 7405N). For proper operation the transmitting circuit must allow the receiver to source at least 3.2mA and the input voltage must not exceed 5.5V. A typical flag transmitter circuit is shown below:



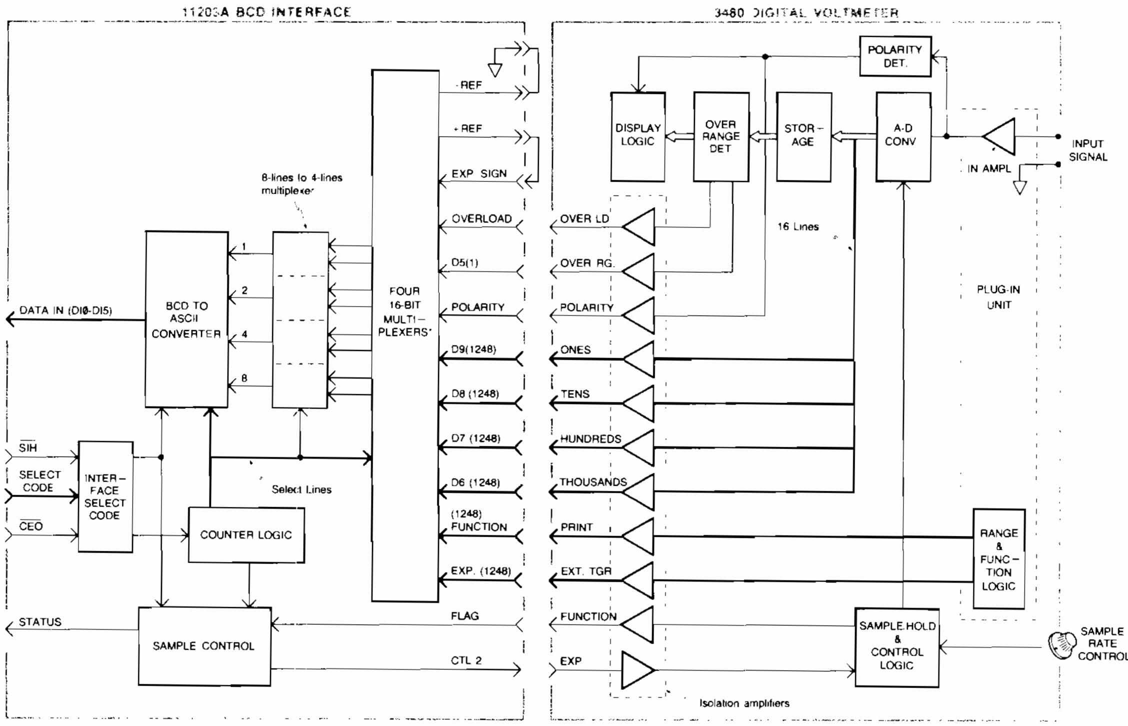
Typical Flag Circuit

Application

One of the most popular applications for the 11203A is as a calculator interface to a digital voltmeter. A simplified diagram of the HP3480 DVM and the BCD Interface is on the next page.

Referring to the diagram:

- Note that each I/O line is interfaced via an isolation amplifier.
- The four BCD data digits are wired to the four most-significant interface data digits. The "1" line of the fifth digit is wired to the DVM's Overrange line to generate a 1 when the DVM's halfdigit is lit. All unused data lines are wired for logic "0".
- Since the DVM has positive-true outputs, the interface −Ref. line is grounded. Notice that the +Ref. line is used to hold the Exp. Sign line high.
- The Control 2 line is used since the DVM responds to a negative-going external trigger pulse. The DVM resets the Control 2 high by forcing the Flag line high.



*All data input lines not shown are connected to logic [illegible] grounded

11203/DVM Interface

This sequence occurs each time an appropriate calculator data-input command is executed:

1) The interface requests a data sample by pulling the External Trigger (CTL2) line low. When the DVM begins its measurement cycle it forces the PRINT (Flag) line high to reset the Control 2 line.
2) When the measurement cycle is complete the DVM outputs BCD data and forces the PRINT (Flag) low; the data is held valid until the next External Trigger (CTL2) pulse is received.
3) Once Flag is forced low, this cycle occurs to input data to the calculator:

   a) The BCD function code is input as one ASCII digit.
   b) An ASCII ",," is generated and input to separate function and data characters.
   c) The polarity bit is input as an ASCII "+" or "−".
   d) Digits 1 − 9 are converted to ASCII and input one at a time.
   e) The exponent sign is input as an ASCII "+"or "−" (the diagram shows the Exponent Sign line hard-wired for "+").
   f) The Overload line is checked; if it is high, a large exponent value is input.
   g) The BCD exponent digit is converted and input; this digit reflects the decimal point position on the DVM.
   h) Finally, an ASCII "LF" is generated and input to terminate the input sequence.

Notice that two separate items are input during each sequence: a one-digit function code and a nine-digit (or less) data sample. Thus, each data-input operation **always** uses two calculator data registers. Program sequences used to control a DVM via the 11203A Interface are shown on page 39 (9810A) and page 49 (9820A or 9821A) and page 57 (9830A).

11205A Serial I/O Interface

The HP 11205A Serial I/O Interface provides an interface to a wide variety of peripheral equipment conforming to EIA specification RS-232-C. The 11205A is widely used when transmitting to teleprinters, but it can also be used with teletype replacement equipment, such as CRT terminals, page printers, and electrostatic printer/plotters.

The 11205A operates in ''half-duplex'', converting parallel calculator input/output data characters to an asynchronous, serial input/output data stream. The serial drivers and receivers meet the EIA RS-232-C voltage specification.

Technical Specifications

I/O Format

The interface sends and receives information in standard, 8-bit serial ASCII code. Since each 8-bit character is combined with one start bit and one or two stop bits, the I/O character format can be set to either 10- or 11-bit format.

Character Transfer Rate

Any one of these five asynchronous data rates can be selected:

110 Baud (10 char/sec when using 11-bit format)
150 Baud (15 char/sec when using 10-bit format)
300 Baud (30 char/sec when using 10-bit format)
600 Baud (60 char/sec when using 10-bit format)
1200 Baud (120 char/sec when using 10-bit format)

In addition, the interface will operate at any Baud rate from 110 to 1200 by changing two capacitors on the interface card.

Signal Lines

- Data Input – from terminal to calculator.
- Data Output – from calculator to terminal.
- Clear To Send signal – greater than +9V to hold terminal in ''ready-to-receive'' state.
- Signal Ground.
- Protective Ground.
- Peripheral Busy signal – line is not normally used but can be wired to signal the calculator when the terminal is ready to accept data:

  not ready signal $>+3V$:
  ready signal $<-3V$.

Select Code

The interface is set to respond to select code 15 when supplied. Any of nine other codes can be set by the user.

Output Delay

The interface provides an internal delay of about 200ms after transmitting any of these ASCII control characters ➧

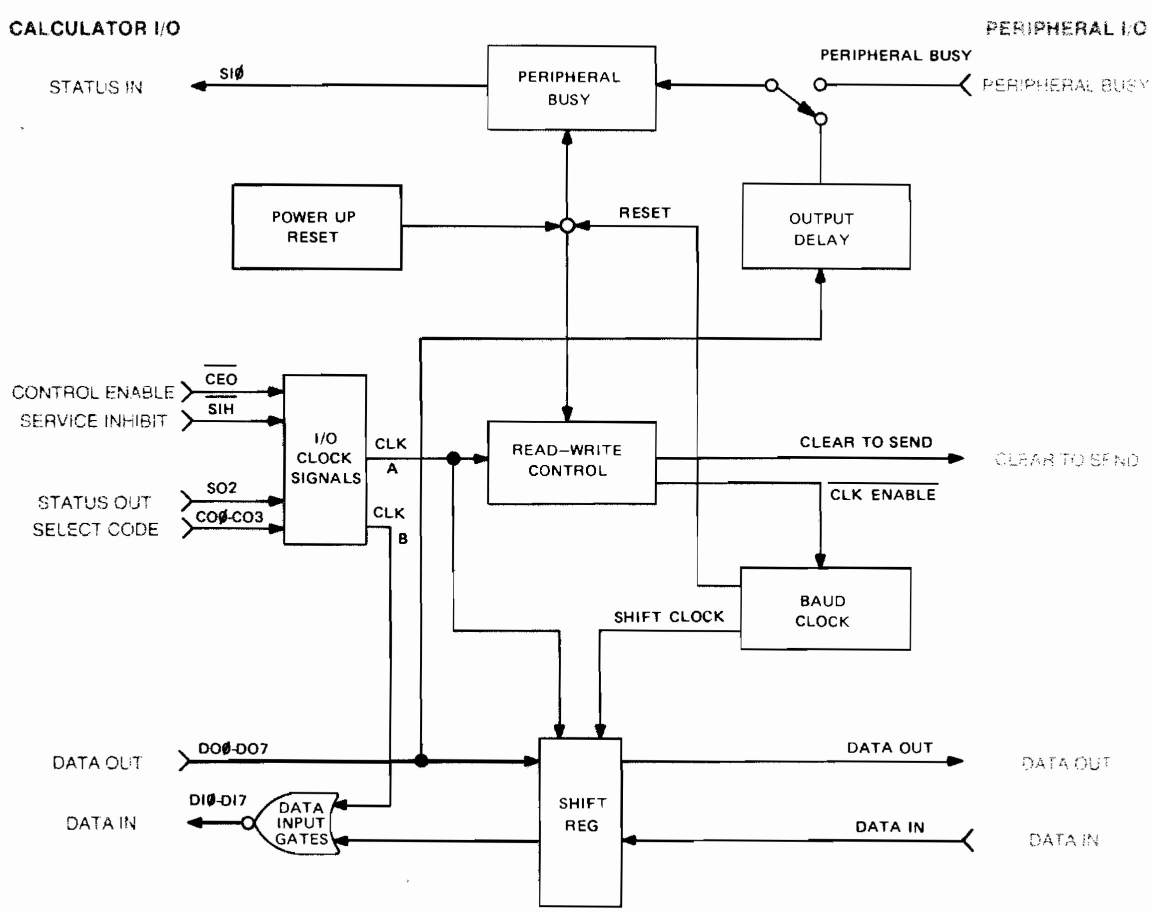
FEo (Format Effector)
Htab (Horiz. Tab)
LF (Line Feed)
Vtab (Vert. Tab)
FF (Form Feed)
CR (Carriage Return)

That delay is adequate to allow most terminals to respond to control characters. The delay may be disabled, if desired.

Theory of Operation

In general, the 11205A Interface is a serial-to-parallel data converter. When receiving data, it converts bit-serial, ASCII-coded data to bit-parallel, ASCII-coded data usable by the calculator. When sending data, it converts bit-parallel, ASCII-coded data to bit-serial ASCII code usable by terminal devices.

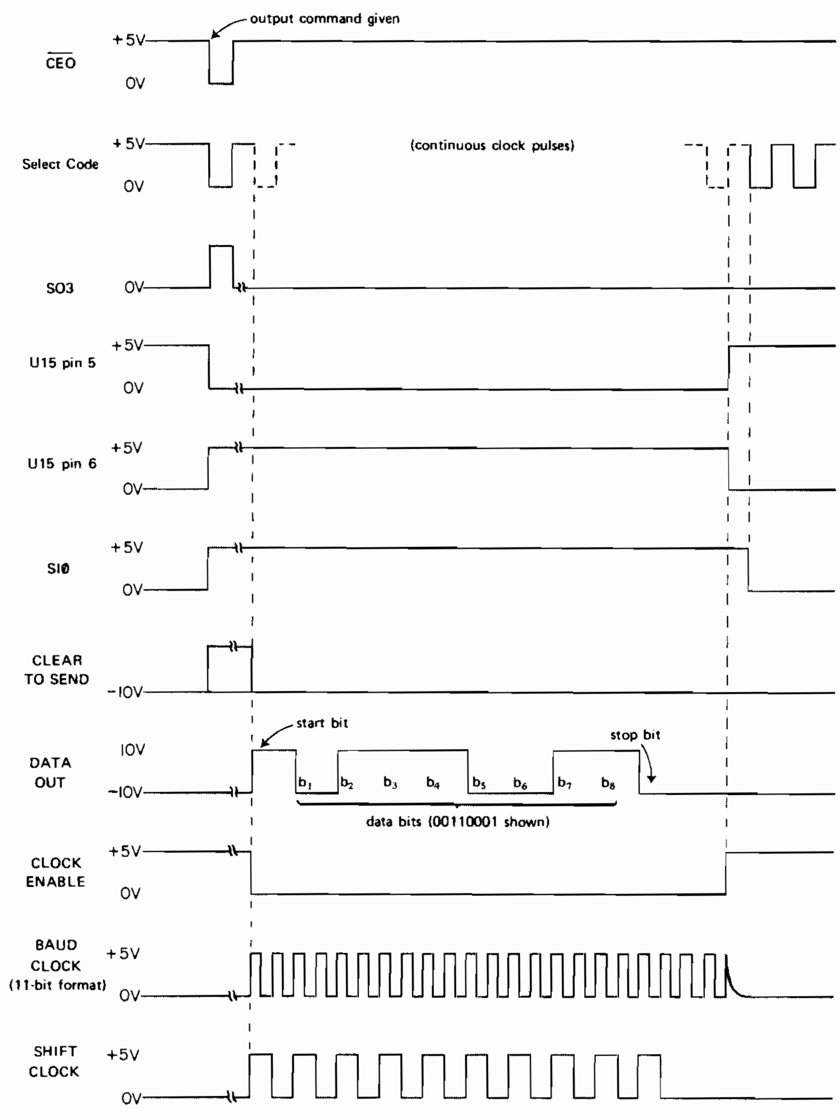
Here is a block diagram of the interface:



11205A Block Diagram

This sequence occurs for each character output:

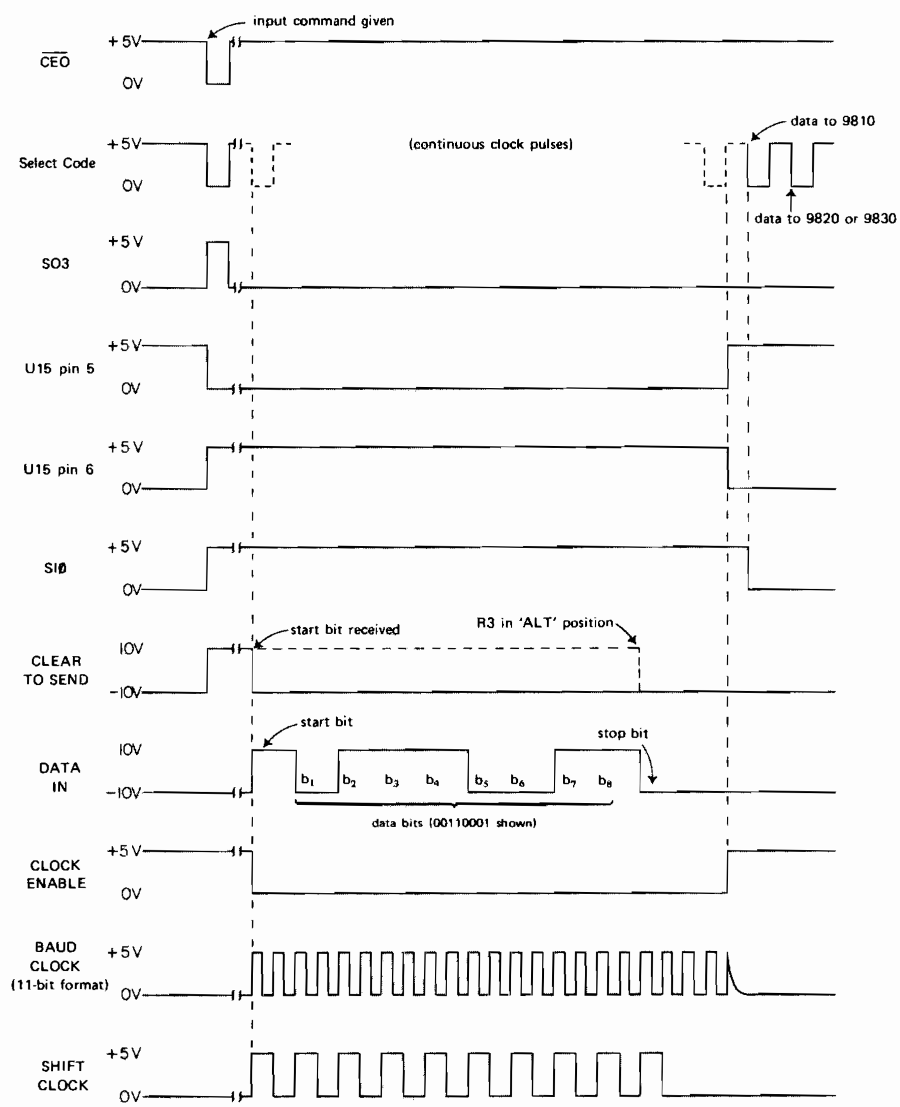
1) The $\overline{CEO}$ and Select Code signals are combined to provide I/O clock signals A and B. The Read-Write control circuit responds to the Clock A and holds the Clear To Send line low during the output operation.
2) After the data character is loaded into the Shift Register, the Baud clock is enabled for 10 or 11 counts (depending upon the setting of R2). Each time the Shift Register is clocked, one character bit is transferred to the terminal.
3) After the terminal receives the last bit(s) (one or two stop bits), it can signal the interface via the Peripheral Busy line. That line need not be used, however, since an internal delay is provided to delay output operation after certain control characters are sent.



11205A Output Timing Diagram

This sequence occurs for each character input:

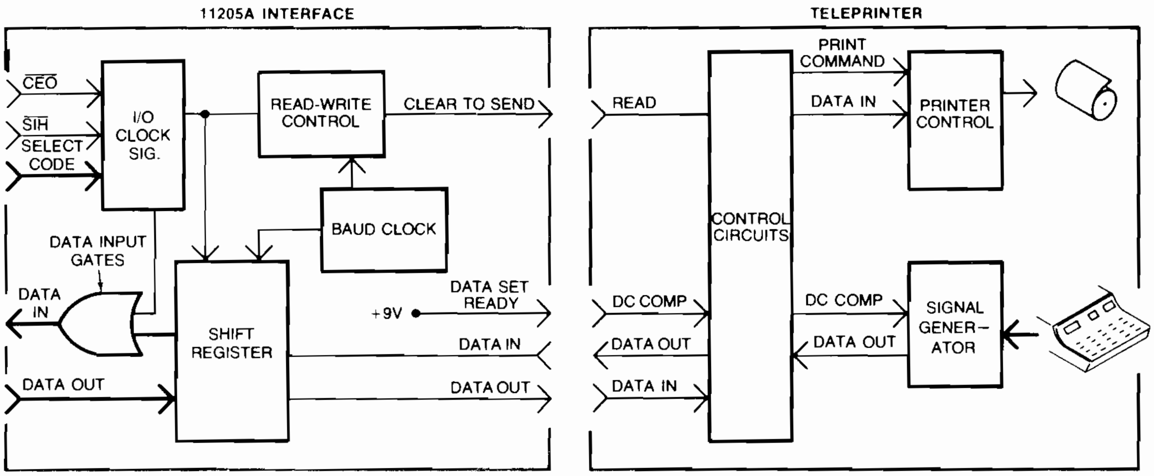
1) The $\overline{CEO}$ and Select Code signals provide a Clock A signal which is used to load the data from DOØ through DO7 into the Shift Register. The Read-Write Control circuit also responds to Clock A by forcing the Clear To Send line high, which signals the terminal to transmit a character. Also, SIØ goes high to indicate that the terminal is busy.
2) When the start bit is received, the Baud clock is enabled for 10 or 11 counts. Then the Shift Register loads one data bit with each clock pulse. If two stop bits are received, the second one is ignored.
3) The Baud clock is disabled after generating 10 or 11 pulses, depending upon the setting of R2. Then SIØ is forced low from either an Output Relay signal or a Peripheral Busy signal.
4) Finally, the Data Input gates are enabled and the character is transferred to the calculator.



11205A Input Timing Diagram

Application

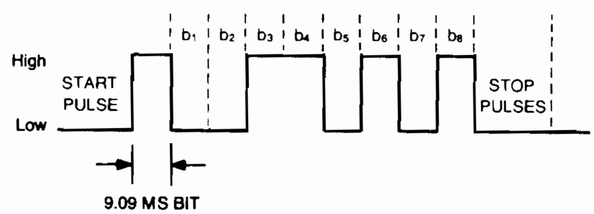
The next figure shows a simplified block diagram of an 11205A Interface with a teleprinter terminal. (The teleprinter tapereader and tape-punch functions are not shown.)



11205/Teleprinter Interface

Data Output

The terminal is held in a ready-to-receive state by the high DC COMP (Data-Set Ready) line. As the calculator outputs each character, the interface converts and outputs it as an 11-bit serial pulse sequence (see the timing diagram). Whenever the terminal is set for 'ON LINE' operation, it decodes each input character sequence and prints or responds to each character. Notice that the Read (Clear to Send) line is not used for output operation.



(110 Baud/11-bit format shown)

Transmission Sequence for ASCII 'S' (binary 01010011)

Data Input

The calculator begins each character-input sequence by causing the interface to force the Read (Clear to Send) line high. When the Read line is high, the terminal's signal generator converts the next keyboard operation to a sequence of 11 successive pulses which are output to the interface. The terminal also decodes the character and either prints it (or responds to it) as it is output.

As the interface receives the first pulse (start pulse), the Baud clock is started to shift-in the remaining 10 pulses. To prevent the terminal from sending another character, the Read (Clear to Send) line is pulled low as the start pulse is received. Once the character is loaded into the shift register, the Data Input gates are enabled to transfer the character (now in parallel-ASCII form) to the calculator. When the calculator is ready for another character, the Read (Clear to Send) line is again forced high.

Notice that for both input and output operation, each device responds to the start pulse and accepts each serially-coded character at the same timing rate (Baud rate) used by the sending device. This requires that both interface and terminal **must** be set to the same Baud rate. Remember that the 11205A can be set at any Baud rate from 110 to 1200 by either setting a switch or changing the value of two capacitors.

11282A Incremental Plotter Interface

The HP 11282A Incremental Plotter Interface allows a 9830A Calculator to control many digital plotters, including: Calcomp Models 502, 563, and 565, and Houston Models DP-1 and DP-3. The interface is supplied with a tape cassette containing a complete set of plotter-driver statements.

Technical Specifications

Speed

Nominal operating speed: 285 steps/sec.

Maximum operating speed: 300 steps/sec.

Interface can also be set for maximum speed of 200 steps/sec.

Plotter Step Size

The software provided can be used with plotters having either .01 inch, .005 inch, or .1 mm step sizes.

Signal Lines

- +X
- −X
- +Y
- −Y

} Coordinate data lines.

- Pen up
- Pen down

Output Specs.

- Output signals use positive-true logic.
- High or logic '1' $\geqslant$10V.
- Output rise time $<10\mu s$.
- Output pulse width $\geqslant 4\mu s$.
- Source impedance $\leqslant 500\Omega$.

Select Code

The interface is set to respond to select code 14 when supplied. Any one of nine other codes can be set by the user.

Options

Each optional interface is wired with an appropriate cable connector.

- Option 001 for Calcomp Models 502.
- Option 002 for Benson Models 110 and 120.

Plotter Control

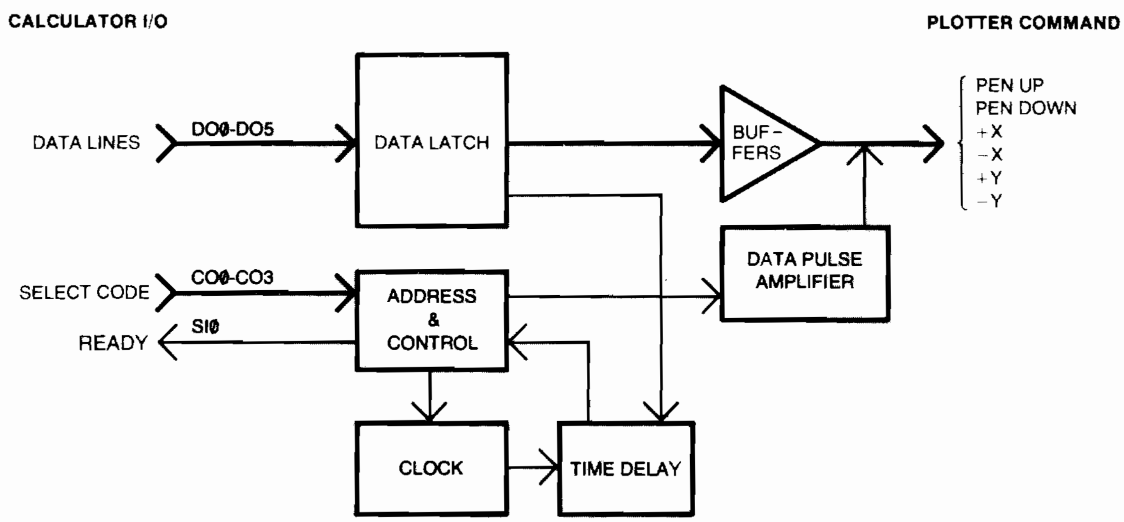
The binary tape cassette supplied with the interface provides these plotter-control operations:

- Set a scale for plotting.
- Draw X and Y axes of variable lengths, either with or without tic marks.
- Designate the select code setting for program output.
- Raise or lower the pen, either before or after plotting a point.
- Plot points with respect to the origin.
- Plot points with respect to the previously plotted point, rather than the origin.
- Reset the origin so that points may be plotted with respect to the new origin.
- Draw alphanumeric characters, while specifying the width, height and angle of rotation.
- Reference FORMAT statements for character output.

See page 61 for more information of these operations.

Theory of Operation

The interface card processes and outputs 6-bit commands from the 9830A to control the plotter functions. Here is a block diagram of the interface.



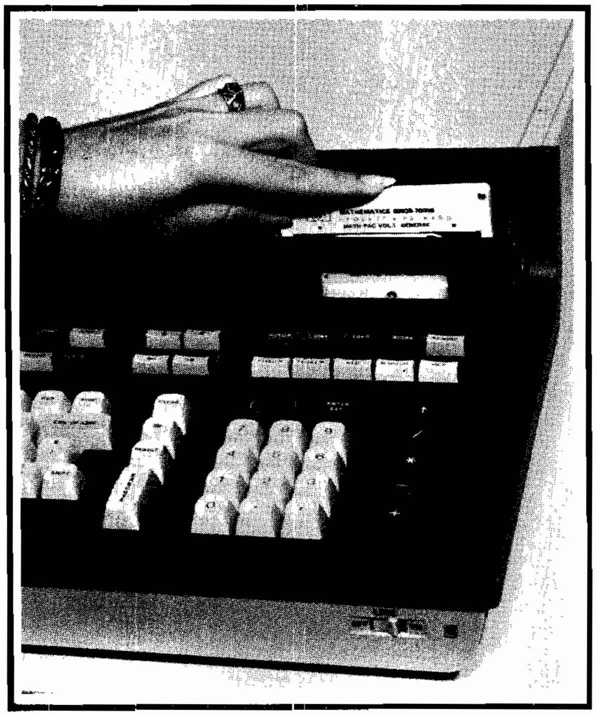
11282A Block Diagram

The interface Data Latch temporarily stores the 6-bit commands from the calculator. The delay circuit allows the plotter to respond to each command before a ready signal is sent to the calculator for the next command. Command signals to the plotter are held on the output lines for 12μs by the Data-Pulse Amplifier.

Three delay times are generated by the interface. A 3.3ms delay (before the interface indicates ready) allows the plotter to operate at about 300 steps/second. The delay may be increased to 5ms, allowing larger plotters to operate at about 200 steps/second. When a "pen up" or "pen down" command is received, a 60ms delay is generated to provide time for the pen to respond.

See page 61 for sample programs and plots using the 11282A Interface.

Chapter 3
Programming



Providing an interface between a calculator and a peripheral device requires the solution to two problems. The previous chapter described how to solve the first problem by selecting the correct interface card to meet the instrument's physical requirements. The second problem is to select and implement the correct software.

For 9800-Series calculators, the software interface is provided by I/O driver routines stored in MOS ROM and available as plug-in blocks. Except for the 9830A, each calculator requires a ROM block to add I/O routines to its keyboard language.

Each section of this chapter first lists the general I/O routines available for a calculator and then offers a more detailed description of the most-often-used routines.

For more information on the I/O routines for any given calculator, refer to the appropriate manual listed in the Appendix.

9810A Calculator I/O Routines

Here is a brief description of the routines available for the 9810A Calculator:

11264A PC Block I/O Routines[1]

COMMAND	DESCRIPTION
DATA OUTPUT	Output contents of X-register to specified device.
DATA INPUT	Request and input one data item to X-register.
OUTPUT FORMAT	Set character field-width and position decimal point for output data.
MESSAGE OUTPUT	Output any ASCII-coded character(s) to specified device.
PROGRAM OUTPUT PROGRAM INPUT	Transfer program steps, coded in octal keycodes, between program memory and a specified device.
SPECIAL OUTPUT SPECIAL INPUT	High-speed, 64-bit character transfer between X-register and specified device.

The PC2 Block provides all of the above routines and these advance routines:

11252A PC2 Block Advanced I/O Routines

COMMAND	DESCRIPTION
FORMATTED INPUT	Input data items of specified character length (overrides free-field format).
WRITE BYTE	Output any 8-bit ASCII-coded byte.
READ BYTE	Request and input any 8-bit ASCII-coded byte.
SPECIAL READ BYTE	Same as above but data-request signal is not output.
CEO OUTPUT	Output data-request signal.
STATUS CHECK	Check interface "busy" or "ready" status.
STORE DATA RECALL DATA	Permit data storage into, and recall from, program memory.
DECODE DATA ENCODE DATA	Permit storage and use of data transferred via Special I/O Routines (see previous table).
DECIMAL→BINARY CONV.	Replace integer in X with 8-bit binary-equivalent form.
BINARY→DECIMAL CONV.	Replace 8-bit binary number in X with decimal equivalent.
BINARY ARITHMETIC	Nine routines using binary numbers in X-and/or Y-registers.
CONDITIONAL BRANCHING	Branching instruction based on condition of interface Flag line.
REMOTE BRANCHING	Branching instruction based on data input from specified device.
KEY ENTRY	Program routine to convert each key entry to decimal number in X-register.

The following pages describe the most-often-used 9810A I/O routines. For detailed instructions on using the many other I/O routines available, see the Peripheral Control manual listed in the Appendix.

[1] These routines are also part of the 11262A PC Tape Cassette Block and the [illegible] PC Printer-Plotter Block.

General I/O Routines

The DATA OUTPUT Command

[FMT] [4] [(select code)] [PRINT SPACE]

This key sequence outputs the number in the X-register as a string of ASCII-coded numeric characters (i.e., digits, +, −, decimal point, and spaces) to the peripheral specified by the select code. The number is right-justified in a data-field width specified by using the following command. If the number is too large to be output in the specified field, "$" characters are output in place of the number.

Specifying Output Format

[FMT] [4] [•] [w] [•] [d]

This key sequence specifies the data-field width (**w**) and display format (**d**) for data output operations. The PC2 Block FORMATTED INPUT command also references **w** and **d**. **w** and **d** remain as specified until changed by the above command, although the display format can still be specified from the keyboard with the FIX or FLOAT keys. When the calculator is switched on, the data-field width is automatically set to 20.

For example, this program segment sets the output format and outputs the contents of registers 000 through 005 to an HP 2895B Tape Punch. The tape punch is connected to the 9810A via an 11202A Interface responding to select code 1.

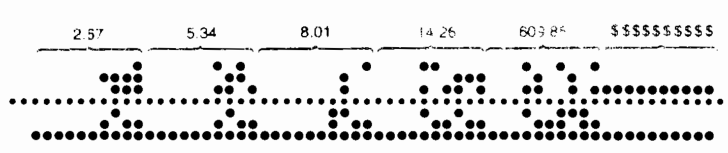
Notice that each number is output in a 10-character field (all leading characters are spaces) and that "$" characters fill the last field, since the large number cannot be output within the specified format.

```
0100--FMT---42  }
0101-- 4 ---04  }
0102-- . ---21  }
0103-- 1 ---01  } Set output format
0104-- 0 ---00  }
0105-- . ---21  }
0106-- 2 ---02  }
0107--CLR---20  }
0108--XFR---67  } Recall data register contents
0109--IND---31  }
0110-- a ---13  }
0111--PNT---45  }
0112--FMT---42  }
0113-- 4 ---04  } Output
0114-- 1 ---01  }
0115--PNT---45  }
0116-- 1 ---01  }
0117--XTO---23  }
0118-- + ---33  }
0119-- a ---13  }
0120-- 6 ---06  }
0121-- UP---27  } If a
0122-- a ---13  }
0123--X<Y---52  }
0124-- 0 ---00  }
0125-- 1 ---01  }
0126-- 0 ---00  }
0127-- 3 ---10  }
```

Sample Printout:

```
          2.67
          5.34
          8.01
        -14.26
        609.85
1.000000000 46
```

Sample Output:



The MESSAGE OUTPUT Command

FMT 4 (select code) FMT • • •

This sequence redefines the calculator keyboard as a general message-output keyboard. Pressing any of the keys shown in the ASCII table in the Appendix outputs that key's equivalent ASCII code. Also, when the output message mode is set:

↑ (SHF) Shifts the calculator to the opposite output mode (e.g., sets the shifted mode if the unshifted mode is set). The output characters available when the calculator is in the shifted output mode are colored light-blue in the table.

FMT Terminates the message-output sequence and returns the calculator to the run mode.

> **NOTE**
> The receiving peripheral must recognize and act on each ASCII code as it is sent from the calculator. Remember that the calculator must be in control of the peripheral during any I/O operation.

The following program, which prints a list of trigonometric values, shows typical data-output and message-output formats. The program requires the use of an HP 11210A Math Block. The printout was obtained using a Teletype Model ASR38, via an 11205A Interface responding to select code 8.

DEGREES	RADIANS	SIN	COS	TAN
0	0.00	0.000	1.000	0.000000000+00
10	0.17	0.174	0.985	1.763269807-01
20	0.35	0.342	0.940	3.639702343-01
30	0.52	0.500	0.866	5.773502692-01
40	0.70	0.643	0.766	8.390996312-01
50	0.87	0.766	0.643	1.191753593+00
60	1.05	0.866	0.500	1.732050808+00
70	1.22	0.940	0.342	2.747477419+00
80	1.40	0.985	0.174	5.671281820+00
90	1.57	1.000	0.000	9.999999999+98
100	1.75	0.985	-0.174	-5.671281820+00
110	1.92	0.940	-0.342	-2.747477420+00
120	2.09	0.866	-0.500	-1.732050808+00
130	2.27	0.766	-0.643	-1.191753593+00
140	2.44	0.643	-0.766	-8.390996312-01
150	2.62	0.500	-0.866	-5.773502692-01
160	2.79	0.342	-0.940	-3.639702343-01
170	2.97	0.174	-0.985	-1.763269807-01
180	3.14	0.000	-1.000	0.000000000+00
190	3.32	-0.174	-0.985	1.763269807-01
200	3.49	-0.342	-0.940	3.639702343-01
210	3.67	-0.500	-0.866	5.773502692-01
220	3.84	-0.643	-0.766	8.390996312-01
230	4.01	-0.766	-0.643	1.191753593+00
240	4.19	-0.866	-0.500	1.732050808+00
250	4.36	-0.940	-0.342	2.747477419+00
260	4.54	-0.985	-0.174	5.671281820+00
270	4.71	-1.000	0.000	9.999999999+98
280	4.89	-0.985	0.174	-5.671281820+00
290	5.06	-0.940	0.342	-2.747477420+00
300	5.24	-0.866	0.500	-1.732050808+00
310	5.41	-0.766	0.643	-1.191753593+00
320	5.59	-0.643	0.766	-8.390996312-01
330	5.76	-0.500	0.866	-5.773502692-01
340	5.93	-0.342	0.940	-3.639702343-01
350	6.11	-0.174	0.985	-1.763269807-01
360	6.28	0.000	1.000	0.000000000+00

Notice that blocks of spaces are output to position column headings, while specifying the correct output format (**w**) positions the data value under each heading.

```
0000--CLR---20
0001-- K ---55     Set Degrees
0002-- 1 ---01     mode
0003--FMT---42
0004-- 4 ---04
0005-- 8 ---10
0006--FMT---42
0007--SFL---54
0008--CLR---20
0009--CLR---20
0010--CLR---20
0011--CLR---20
0012--CNT---47
0013--CNT---47
0014--CNT---47
0015--CNT---47
0016--CNT---47
0017--CNT---47
0018-- D ---63
0019-- E ---60
0020-- G ---15
0021-- a ---13
0022-- E ---60
0023-- E ---60
0024--YTO---40
0025--CNT---47
0026--CNT---47
0027--CNT---47
0028--CNT---47
0029--CNT---47
0030--CNT---47
0031-- a ---13
0032-- A ---62
0033-- D ---63
0034-- I ---65     Output 5 line
0035-- A ---62     feeds
0036-- N ---73     Print table
0037--YTO---40     headings
0038--CNT---47
0039--CNT---47
0040--CNT---47
0041--CNT---47
0042--CNT---47
0043--CNT---47
0044--CNT---47
0045--CNT---47
0046--CNT---47
0047--CNT---47
0048--YTO---40
0049-- I ---65
0050-- N ---73
0051--CNT---47
0052--CNT---47
0053--CNT---47
0054--CNT---47
0055--CNT---47
0056--CNT---47
0057--CNT---47
0058--CNT---47
0059--CNT---47
0060--CNT---47
0061--CNT---47
0062--CNT---47
0063-- C ---61
0064-- O ---71
0065--YTO---40
0066--CNT---47
0067--CNT---47
0068--CNT---47
0069--CNT---47
0070--CNT---47
```

```
0071--CNT---47
0072--CNT---47
0073--CNT---47
0074--CNT---47
0075--CNT---47
0076--XTO---23
0077-- A ---62
0078-- N ---73
0079--SFL---54     Carriage return
0080--CLR---20     line feeds
0081--CLR---20
0082--FMT---42
0083--FMT---42
0084-- 4 ---04     Set output
0085-- . ---21     format
0086-- 1 ---01     w = 10 . 4 . 0
0087-- 0 ---00
0088-- . ---21
0089-- 0 ---00
0090-- a ---13
0091--FMT---42
0092-- 4 ---04     Output
0093-- 8 ---10     DEGREES
0094--FMT---42     data
0095--PNT---45
0096--FMT---42
0097-- UP---27
0098-- π ---56
0099-- X ---36
0100-- 1 ---01
0101-- 8 ---10
0102-- 0 ---00
0103--DIV---35
0104-- DN---25
0105--FMT---42
0106-- 4 ---04
0107-- . ---21
0108-- 1 ---01     Change format
0109-- 5 ---05     Output
0110-- . ---21     RADIANS
0111-- 2 ---02     data
0112--FMT---42
0113-- 4 ---04
0114-- 8 ---10
0115--FMT---42
0116--PNT---45
0117--FMT---42
0118-- a ---13     find sin a
0119-- M ---70
0120--FMT---42
0121-- 4 ---04
0122-- . ---21
0123-- 1 ---01
0124-- 5 ---05
0125-- . ---21     change format
0126-- 3 ---03     Output
0127--FMT---42     SIN data
0128-- 4 ---04
0129-- 8 ---10
0130--FMT---42
0131--PNT---45
0132--FMT---42
0133-- a ---13     find cos a
0134-- N ---73
0135--FMT---42
0136-- 4 ---04
0137-- 8 ---10     Output
0138--FMT---42     COS data
0139--PNT---45
0140--FMT---42
```

```
0141-- a ---13     find tan a
0142-- O ---71
0143--FMT---42
0144-- 4 ---04
0145-- . ---21
0146-- 1 ---01
0147-- 8 ---10
0148-- . ---21
0149-- . ---21     Change format
0150--FMT---42     Output TAN
0151-- 4 ---04     data
0152-- 8 ---10
0153--FMT---42
0154--PNT---45
0155--SFL---54     Carriage Returns
0156--SFL---54
0157--CLR---20     Line feed
0158--FMT---42
0159-- 3 ---03
0160-- 5 ---05
0161-- 0 ---00
0162-- UP---27
0163-- a ---13     End program
0164--X>Y---53     after a = 360
0165-- 0 ---00
0166-- 1 ---01
0167-- 9 ---11
0168-- 9 ---11
0169-- 1 ---01
0170-- 0 ---00
0171--XTO---23
0172-- + ---33
0173-- a ---13
0174-- 1 ---01
0175--XTO---23
0176-- + ---33
0177-- b ---14
0178-- 5 ---05
0179-- UP---27
0180-- b ---14
0181--X<Y---52
0182-- 0 ---00
0183-- 0 ---00     Output
0184-- 8 ---10     line feed
0185-- 3 ---03     after each
0186--FMT---42     5 lines
0187-- 4 ---04
0188-- 8 ---10
0189--FMT---42
0190--SFL---54
0191--CLR---20
0192--FMT---42
0193-- 0 ---00
0194--XTO---23
0195-- b ---14
0196--GTO---44
0197-- 8 ---10
0198-- 3 ---03
0199--FMT---42
0200-- 4 ---04
0201-- 8 ---10
0202--FMT---42     Output carriage
0203--SFL---54     return and
0204--CLR---20     5 line feeds.
0205--CLR---20
0206--CLR---20
0207--CLR---20
0208--CLR---20
0209--FMT---42
0210--END---[illegible]
```

The DATA INPUT Command

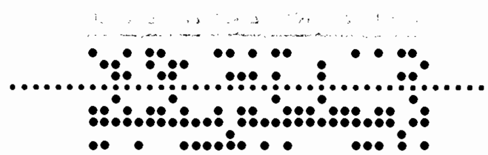
[FMT] [4] [(select code)] [.]

This sequence causes the calculator to accept a series of ASCII-coded characters (i.e., digits, +, −, decimal point, spaces and E). Each character but "E" is entered into the X-register as it is received. The "E" character causes the next two digits (and + or −, if present) to be entered as an exponent.

Any of these ASCII characters will begin a data-input operation: a digit, +, −, or a decimal point. The calculator ignores all other ASCII characters before accepting data.

Any ASCII character not listed above terminates a data-input operation. Also, a data-input operation is terminated if "E" is entered but not followed by a +, −, or digit. The comma and CR/LF characters are special terminating delimiters. The comma causes the calculator to do an ↑ operation and continue data input, and the CR/LF causes the calculator to do an $x \rightleftarrows y$ operation and terminate data input.

For example, the next program could be used to input and print the five ASCII-coded data items shown on this paper tape ➧



The tape reader is connected via an 11202A Interface set to select code 1.

```
0000--CLR---20
0001--FMT---42  )
0002-- 4  ---04 |
0003-- .  ---21 |
0004-- 0  ---00 } Set display format to FIX
0005-- .  ---21 |
0006-- 3  ---03 )
0007--FMT---42  )
0008-- 3  ---03 |
0009-- 1  ---01 } Input and print data items
0010-- .  ---21 |
0011--PNT---45  )
0012-- 1  ---01 )
0013--XTO---23  |
0014-- +  ---33 |
0015-- a  ---13 |
0016-- 5  ---05 } Repeat input
0017-- UP---27  |
0018-- a  ---13 |
0019--X<Y---52  |
0020--GTO---44  |
0021-- 7  ---07 )
0022--END---46
```

Here is a sample printout ➧

```
        12.500
        35.200
1.000000000 45
      -100.001
         0.100
```

Binary I/O Operation (PC2 Block Only)

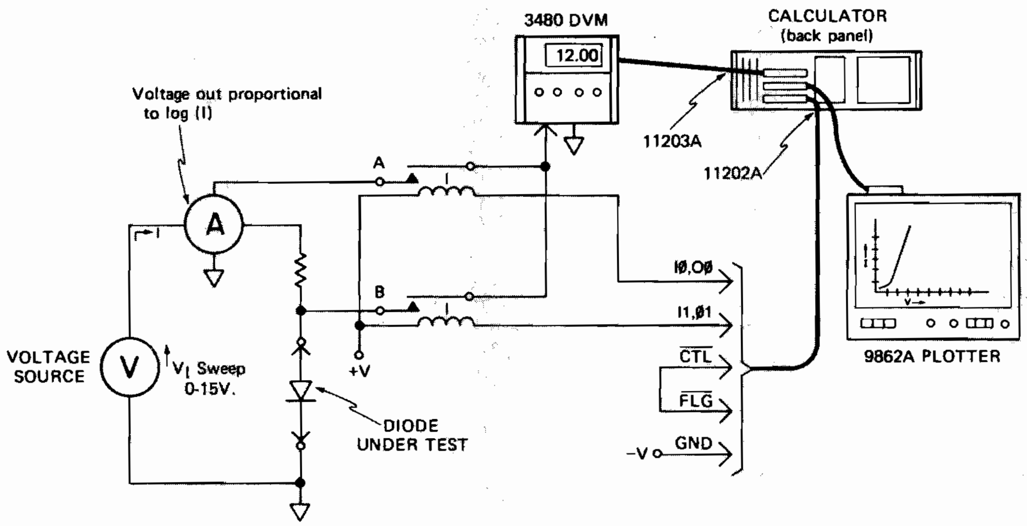
The WRITE BYTE and READ BYTE commands enable the calculator to exchange data in conventional binary form. As each 8-bit byte is sent or received, the calculator converts the binary information to or from its decimal-equivalent form.

The WRITE BYTE Command

FMT 6 (select code) x→( )

Converts the decimal number in X to its equivalent 8-bit binary-coded form and outputs the byte to the specified device. The number in X can be any integer within the range of from 0 to 255. A table of decimal and binary-equivalent numbers is in the Appendix.

An application of the relay controller scheme described on page 19 is shown below. The system is used to measure and plot diode V-I characteristics.



To operate the system, a program is used to alternately close relays A and B and then take readings from the DVM's BCD output using an 11203A BCD Interface. The program could either plot sets of V-I readings as they are taken or store a series of readings and plot them later. The plotting method used depends upon the voltage sweep time, the program execution time, and the number of V-I reading (sample density) required.

The following program segment shows how to control the relays using WRITE BYTE commands. Notice that the 11202A is set to select code 1 and the 11203A is set to select code 2.

```
0150-- 1 ---01  }
0151--FMT---42  }
0152-- 6 ---06  } Output binary "00000001" to close relay A
0153-- 1 ---01  }
0154--XTO---23  }
0155--FMT---42  }
0156-- 3 ---03  }
0157-- 2 ---02  } Input DVM function code in Y and first data reading
0158-- . ---21  } (I) in X. Then store reading in reg. a.
0159--XTO---23  }
0160-- a ---15  }
0161-- 2 ---02  }
0162--FMT---42  }
0163-- 6 ---06  } Output binary "00000010" to close relay B
0164-- 1 ---01  }
0165--XTO---23  }
0166--FMT---42  }
0167-- 3 ---03  }
0168-- 2 ---02  } Input function code in Y and second data reading
0169-- . ---21  } (V) in X. Then store reading in reg. b.
0170--XTO---23  }
0171-- b ---14  }
```

Here is an alternate method to control the relays using the MESSAGE OUTPUT command available with each peripheral control block.

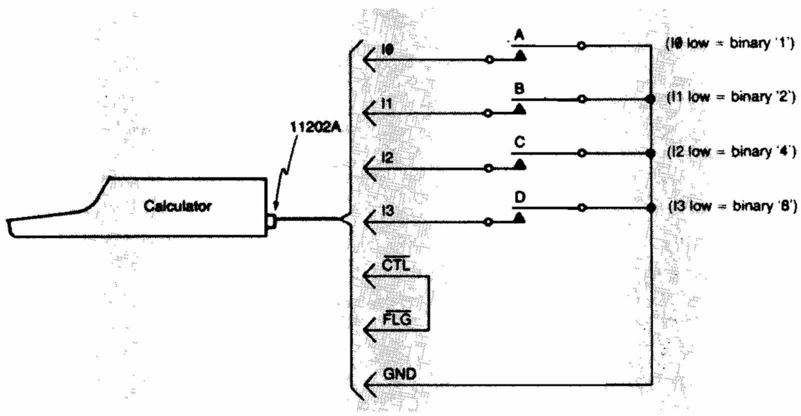
```
0150--FMT---42  }
0151-- 4 ---04  }
0152-- 1 ---01  } Output ASCII "A" (binary "01000001")
0153--FMT---42  } to close relay A
0154-- A ---62  }
0155--FMT---42  }
0156--FMT---42  }
0157-- 3 ---03  }
0158-- 2 ---02  } Input and store first data reading (I)
0159-- . ---21  }
0160--XTO---23  }
0161-- a ---13  }
0162--FMT---42  }
0163-- 4 ---04  }
0164-- 1 ---01  } Output ASCII "B" (binary "01000010")
0165--FMT---42  } to close relay B
0166-- B ---66  }
0167--FMT---42  }
0168--FMT---42  }
0169-- 3 ---03  }
0170-- 2 ---02  } Input and store second data reading (V)
0171-- . ---21  }
0172--XTO---23  }
0173-- b ---14  }
```

The READ BYTE Command

FMT 6 (select code) X→( )

Inputs an 8-bit byte from the specified device, converts the byte to its decimal-equivalent number, and stores the number in X.

A typical use for READ BYTE is shown in this application, which is part of a numerically-controlled drill system. The circuitry shown consists of an 11202A Interface and four limit-switches which monitor the position of the drill platen (working surface). Each switch closes when the platen reaches one of its four lateral boundaries.



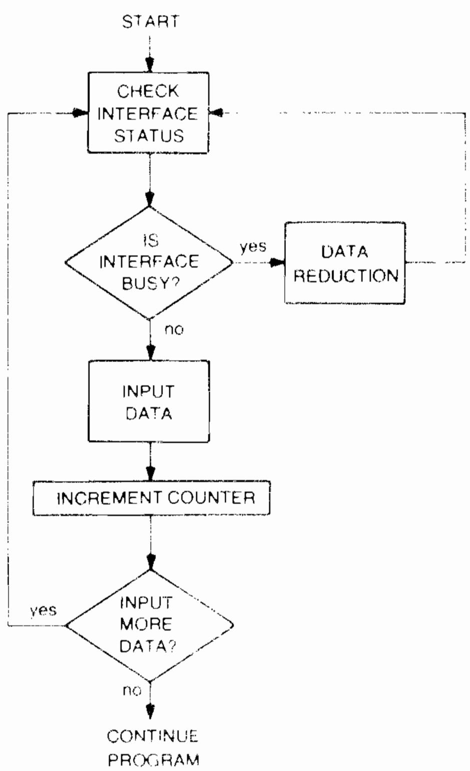
This program sequence can be used to monitor the switches and branch to an appropriate routine when the platen has reached one of its boundaries ➧

Up to eight switches, or other circuitry which forces an input-line low, could be monitored by using all of the 11202A data-input lines.

```
0200--FMT---42   }
0201-- 6 ---06   } Input one byte
0202-- 1 ---01   }
0203--XFR---67   }
0204-- UP---27
0205-- 1 ---01   }
0206--X=Y---50   }
0207--GTO---44   } If switch A is closed,
0208--LBL---51   } go to Label A
0209-- A ---62   }
0210--CNT---47   }
0211-- 2 ---02   }
0212--X=Y---50   }
0213--GTO---44   } If switch B is closed,
0214--LBL---51   } go the Label B
0215-- B ---66   }
0216--CNT---47   }
0217-- 4 ---04   }
0218--X=Y---50   }
0219--GTO---44   } If switch C is closed,
0220--LBL---51   } go to Label C.
0221-- C ---61   }
0222--CNT---47   }
0223-- 8 ---10   }
0224--X=Y---50   }
0225--GTO---44   } If switch D is closed,
0226--LBL---51   } go to Label D.
0227-- D ---63   }
0228--CNT---47   }
```

Peripheral Interrupt

Although there is no provision for hard-wired peripheral interrupt operation, the following flowchart and program show one method to provide ''software interrupt'' capability. In this program, the calculator monitors an 11203A BCD Interface connected to a measurement device. When the interface is found busy, the calculator performs time-consuming data reduction. When the interface is ready, however, the calculator branches to a data-input routine. This method uses the READ STATUS command, available only with the PC2 Block.




```
0100--LBL---51
0101-- C ---61
0102--FMT---42
0103-- 6 ---06
0104-- 1 ---01
0105--GTO---41
0106-- UP---27
0107-- 0 ---00
0108--X=Y---50
0109--GTO---44
0110--LBL---51
0111-- D ---63
0112--CNT---47
0113--FMT---42
0114-- 3 ---03
0115-- 1 ---01
0116-- . ---21
0117--XTO---23
0118-- a ---13
0119-- 1 ---01
0120--XTO---23
0121-- + ---33
0122-- b ---14
0123-- 2 ---02
0124-- 0 ---00
0125-- UP---27
0126-- b ---14
0127--X>Y---53
0128--GTO---44
0129--LBL---51
0130-- C ---61
0131--CNT---47
0132--GTO---44
0133--LBL---51
0134-- E ---60
0135--LBL---51
0136-- D ---63
   •
   •
   •
0250--GTO---44
0251--LBL---51
0252-- C ---61
0253--CNT---47
0254--LBL---51
0255-- E ---60
```

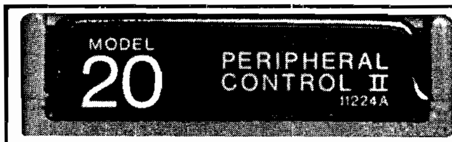
- 0102–0112: Check interface status. If interface is busy, go to data reduction routine.
- 0113–0122: Input data. Increment data counter.
- 0123–0131: When 20 data items have been input, exit routine.
- 0135–•••: Data reduction routine.
- 0250–0252: Return to check interface status again.

9820A and 9821A Calculator I/O Routines

Here is a brief description of the I/O routines available for the 9820A and 9821A Calculators:

11220A PC1 Block I/O Routines

STATEMENT	DESCRIPTION
FORMAT	Specify conversion specs and edit specs for data output.
WRITE	Output data or ASCII-coded character strings to specified device.
READ	Request and input data (free-field input format).
TRANSFER	High-speed data transfer between two specified devices.
PLOT SCALE AXIS LETTER PEN	Five statements used to control an HP 9862A Plotter.



11224A PC2 Block I/O Routines

STATEMENT	DESCRIPTION
FORMAT	Specify conversion specs and edit specs for both input and output data.
WRITE	Output data or ASCII-coded character strings to specified device.
READ	Request and input data and character strings.
TRANSFER	High-speed data transfer between two specified devices.
WRITE BYTE	Output any 8-bit ASCII-coded byte.
READ BYTE	Request and input any 8-bit ASCII-coded byte.
BUS COMMAND	Control instruments connected via an HP Interface Bus (see Chapter 4).
READ STATUS	Check interface "busy" or "ready" status.
PLOT	Output X-Y coordinates to an HP 9862A Plotter.

The following pages describe the most-often-used I/O routines. For detailed instructions on using other I/O routines, refer to the appropriate peripheral control operating manual listed in the Appendix.

General I/O Routines

The WRITE Statement

WRT select code [. format] , data list

WRITE statements are used to output data and character strings to the device specified by the select code. Data is output in a "free-field" format, or in the form indicated by a FORMAT statement. When a PC2 Block is used, the format parameter may be used to reference any of ten FORMAT statements by their line numbers.

Free-Field Formatting

The free-field format is automatically set when the calculator is switched on, and causes each data item to be output, right justified, in an 18-character field. A carriage-return line-feed (CR/LF) instruction is automatically output after four data items are output and at the end of the statement. Examples of free-field formatted output to a Teletype ASR38 are shown below.

Lines Ø & 1: Each item is output in an 18-character field. The current display format specifies the output form (integer precision).

Line 2: Provides a delay for the teletype carriage to return.

Line 3: Outputs a CR/LF instruction.

Lines 4 - 7: CR/LF is output after each four items. Notice that the FLOAT format is automatically set when data overflows the currently set format. Also notice that a CR/LF is automatically output after each WRITE statement.

```
0:
FXD 0⊢
1:
WRT 15,1,2,3,4⊢
2:
DSP ⊢
3:
WRT 15⊢
4:
FXD 4;1→A⊢
5:
WRT 15,A,√A,AAAA
AAA,1/A⊢
6:
DSP ⊢
7:
A+1→A;JMP -2⊢
```

1	2	3	4
1.0000	1.0000	1.0000	1.0000
2.0000	1.4142	128.0000	.5000
3.0000	1.7321	2187.0000	.3333
4.0000	2.0000	16384.0000	.2500
5.0000	2.2361	78125.0000	.2000
6.0000	2.4495	279936.0000	.1667
7.0000	2.6458	823543.0000	.1429
8.0000	2.8284	2.09715200pE 06	.1250
9.0000	3.0000	4.782969000E 06	.1111
10.0000	3.1623	1.000000000E 07	.1000

FORMAT Statements

The formatting of numbers and the spacing between successive items is easily controlled with the FORMAT and WRITE statements. When expressions, variables, and constants are specified in a WRITE statement, their values can be output according to either of the following FORMAT statement specifications:

FMT [r] FXD **w . d**	FXD indicates fixed-point format.
FMT [r] FLT **w . d**	FLT indicates exponential format (often called floating-point or scientific notation).
	w indicates total field width (in character spaces).
	d indicates the number of digits to the right of the decimal point.

Other available format statement specifications are:

FMT [r] X	Outputs a blank character space.
FMT [r] /	Outputs a CR/LF for a printer.
FMT [r] " text "	Outputs a quote field (see the list of output characters in the Appendix).
FMT Z	Suppresses the automatic CR/LF output after each WRITE statement (see the example on page 49).
FMT *	Specifies free-field I/O format with the PC2 Block.

Any combination of specifications can appear in the same FORMAT statement when each item is separated by a comma.Most of the specifications can be duplicated a specific number of times when a repeat factor (r) is specified. For example:

```
FMT 2FXD 6.2, 4X, FXD 10.1⊢
```

causes the first fixed-point field to appear twice, followed by four character spaces, and then another fixed-point field.

Here are more examples:

Lines 0 & 1: Each data item is output according to its corresponding format specification.

Lines 2 & 3: Notice that the `2/` spec. causes two line feeds and that the text within quotes is output between data items. Since the last data item was larger than the specified field, "$" characters filled the field.

```
0:
FMT FXD 6.1,FXD
10.2,FLT 12.5⊢
1:
WRT 15,7.5,-25.8
,2.6E95⊢
2:
FMT 2/,2FXD 20.3
,"SUM=",FLT 5.0⊢
3:
WRT 15,126.005,3
.123,123456⊢
```

```
 w = 6     w = 10        w = 12
   7.5    -25.80 2.60000E 95

        w = 20                  w = 20              w = 5
             126.005                3.123SUM=$$$$$
```

Here is a sample program which uses many formatting features. The program requires an HP 11221A Math Block. The printout was obtained on a Teletype Model ASR38, via an 11205A Interface set to select code 8 .

```
0:
TBL 1;SFG 14⊢          set degrees
1:
0→A→X⊢
2:
FMT 5/,6X,"DEGRE
ES",6X,"RADIANS"
,10X,"SIN",12X,"       Output 5 CR/LF.
COS",10X,"TAN",/       Output column headings
⊢                      Output CR/LF.
3:
WRT 8⊢
4:
FMT FXD 10.0,5X,
FXD 10.2,5X,FXD        Format specifications for line 5.
10.3,5X,FXD 10.3
,5X,FLT 10.2⊢
5:
WRT 8,X,πX/180,
SIN X,COS X,TAN        Output and print one line of data.
X⊢
6:
IF (A+1→A)=5;0→A       If five lines have been printed,
;WRT 8⊢                do an extra CR/LF
7:
IF X<350;X+10→X;       If 36 lines have been printed, exit printout routine
JMP -2⊢
8:
FMT 5/;WRT 8⊢          Output 5 CR/LF.
9:
END ⊢
```

DEGREES	RADIANS	SIN	COS	TAN
0	0.00	0.000	1.000	0.00E 00
10	.17	.174	.985	1.76E-01
20	.35	.342	.940	3.64E-01
30	.52	.500	.866	5.77E-01
40	.70	.643	.766	8.39E-01
50	.87	.766	.643	1.19E 00
60	1.05	.866	.500	1.73E 00
70	1.22	.940	.342	2.75E 00
80	1.40	.985	.174	5.67E 00
90	1.57	1.000	0.000	9.99E 99
100	1.75	.985	-.174	-5.67E 00
110	1.92	.940	-.342	-2.75E 00
120	2.09	.866	-.500	-1.73E 00
130	2.27	.766	-.643	-1.19E 00
140	2.44	.643	-.766	-8.39E-01
150	2.62	.500	-.866	-5.77E-01
160	2.79	.342	-.940	-3.64E-01
170	2.97	.174	-.985	-1.76E-01
180	3.14	0.000	-1.000	0.00E 00
190	3.32	-.174	-.985	1.76E-01
200	3.49	-.342	-.940	3.64E-01
210	3.67	-.500	-.866	5.77E-01
220	3.84	-.643	-.766	8.39E-01
230	4.01	-.766	-.643	1.19E 00
240	4.19	-.866	-.500	1.73E 00
250	4.36	-.940	-.342	2.75E 00
260	4.54	-.985	-.174	5.67E 00
270	4.71	-1.000	0.000	9.99E 99
280	4.89	-.985	.174	-5.67E 00
290	5.06	-.940	.342	-2.75E 00
300	5.24	-.866	.500	-1.73E 00
310	5.41	-.766	.643	-1.19E 00
320	5.59	-.643	.766	-8.39E-01
330	5.76	-.500	.866	-5.77E-01
340	5.93	-.342	.940	-3.64E-01
350	6.11	-.174	.985	-1.76E-01
360	6.28	0.000	1.000	0.00E 00

The READ Statement

RED select code [, format] , data register list

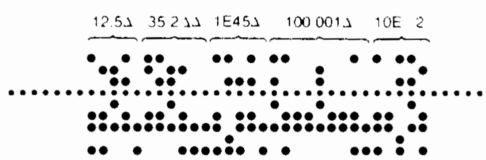
READ statements are used to request and input data from a specified device. The number of register names in the list determines how many data items are input and stored.

The calculator generally assumes a free-field input format. When a PC2 Block is used, however, FORMAT statements can be referenced by line number. Here are general rules for free-field input formatting:

- Any non-numeric characters (except "E") in a data item are ignored.
- An initial comma causes the first register name to be skipped. Two consecutive commas indicate that no data item is supplied for the corresponding register name in the list.
- The "E" character, when part of a data item, causes the data to be raised by the power of 10 indicated. For example, any of the following data items will be read as the number "1234" (note that the "E" is missing from the last two data items):

1.234E3
1.234E∆3
1.234E+3
1.234+3
1.234+Ø3

For example, the following program can be used to input and print the five data items on this ASCII-coded paper tape ➧



The program assumes that the tape reader interface is set to select code 1.

```
[illegible]
RED [illegible] A,B,C,X,Y
[illegible]
[illegible]
PRT A,B,C,X,Y
[illegible]
END [illegible]
```

Here is a sample printout ➧

[illegible]

Binary I/O Routines

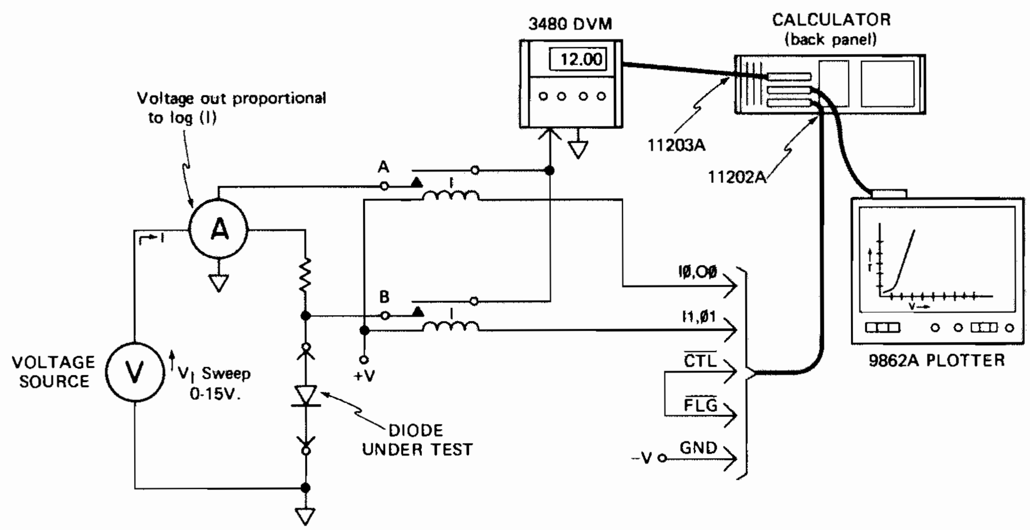
The binary input and output routines available with the PC2 Block permit data exchange in apparent-binary form. As each 8-bit byte is received or sent, the calculator converts it to or from its decimal equivalent value.

The WRITE BYTE Statement

WTB select code , decimal number

WRITE BYTE outputs the 8-bit binary-equivalent form of any decimal integer from 0 to 255.

The following diagram, which is based on the relay control scheme described on page 19, shows a typical application for the WRITE BYTE statement. The system is used to measure and plot diode V-I characteristics.



To operate the system, a program is used to alternately close relays A and B and then take readings from the DVM's BCD output using an 11203A BCD Interface. The program could either plot sets of V-I readings as they are taken or store a series of readings and plot them later. The plotting method used depends upon the voltage sweep time, the program execution, and the number of V-I readings (sample density) required.

These program lines could be used to control the relays with WRITE BYTE statements. Note that the 11202A is set to select code 1 and the 11203A is set to select code 2.

`9: WTB 1,1⊢`	Output binary "00000001" to close relay A.
`10: FMT *;RED 2,A,Y⊢`	Input DVM function code in A and first data reading (I) in Y.
`11: WTB 1,2⊢`	Output binary "00000010" to close relay B.
`12: FMT *;RED 2,A,X⊢`	Input function code in A and second data reading (V) in X.

Here is an alternate method to control the relays using FORMAT and WRITE statements available with either the PC1 or the PC2 Block. Note that the 'Z' specification is referenced to suppress the CR / LF automatically output after each WRITE statement.

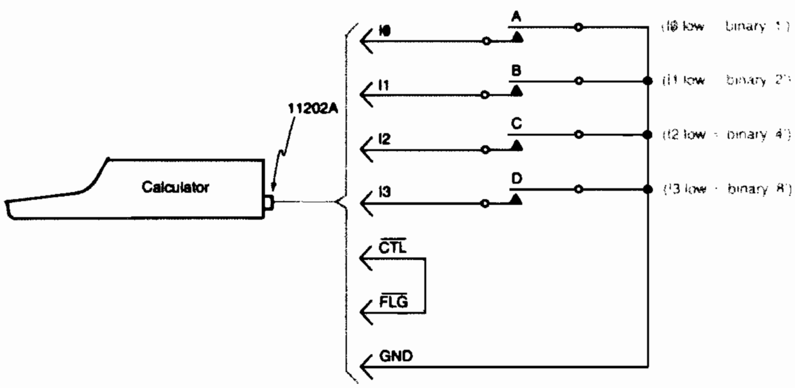
`9: FMT "A",Z;WRT 1⊢`	Output ASCII "A" (binary "01000001") to close relay A.
`10: FMT *;RED 2,A,Y⊢`	
`11: FMT "B",Z;WRT 1⊢`	
`12: FMT *;RED 2,A,X⊢`	Output ASCII "B" (binary "01000010") to close relay B.

The READ BYTE Function

RDB select code

READ BYTE inputs one 8-bit byte and stores its decimal-equivalent value.

A typical use for READ BYTE is shown in the following application, which is part of a numerically-controlled drill system. The circuitry shown consists of an 11202A Interface and four limit-switches which monitor the position of the drill platen (working surface). Each switch closes when the platen reaches one of its four lateral boundaries.



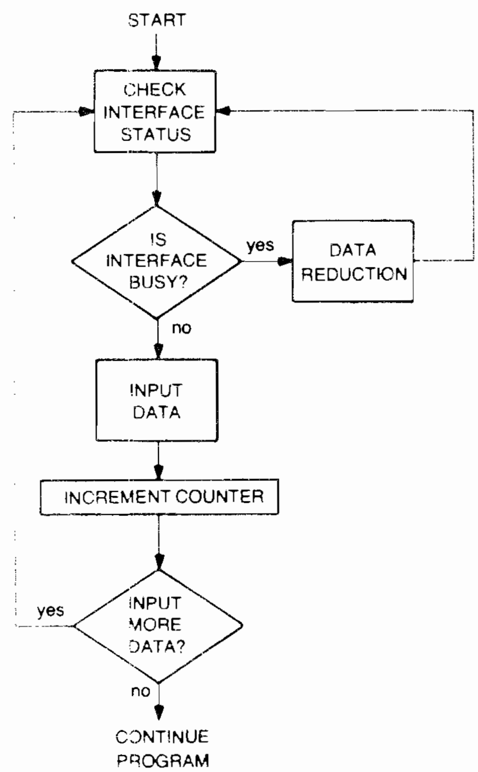
This program sequence can be used to monitor the switches and branch to an appropriate routine when the platen has reached one of its boundaries ➧

Up to eight switches, or other circuitry which forces an input line low, could be monitored by using all of the 11202A data-input lines.

```
8:
IF RDB 1=1;JMP 5
⊢
9:
IF RDB 1=2;JMP 6
⊢
10:
IF RDB 1=4;JMP 7
⊢
11:
IF RDB 1=8;JMP 8
⊢
```

Peripheral Interrupt

Although there is no provision for hard-wired interrupt operation, the following flowchart and program show a method to provide a "software interrupt" capability. This method uses the READ STATUS function, which is available only with the PC2 Block.



Here is a brief summary of the program:

- Line 7: Check status of interface set to select code 1. If the interface is busy (Ø), go to data reduction routine.
- Line 8: Input next data item; increment data counter.
- Lines 9 – 13: Data reduction routine.
- Line 14: If interface was busy, return to line 7.
- Line 15: If more data is needed (C≤20), return to line 7.

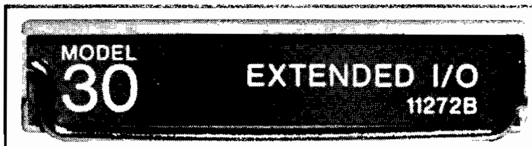
Using this technique permits the calculator to input data as fast as possible and still perform another task (data reduction in this case) while the peripheral is busy.

```
7:
IF RDS 1=0;GTO 9
⊢
8:
RED 1,A,B;C+1→C;
GTO 15⊢
9:
  •
  • data reduction routine
  •
14:
GTO 7⊢
15:
IF C≤20;GTO 7⊢
```

9830A Calculator I/O Routines

Here is a brief description of each I/O routine available for the 9830A:

9830A Basic Output Routines	
STATEMENT or FUNCTION	**DESCRIPTION**
FORMAT	Specify format of data output using WRITE Statements.
WRITE	Output data and character strings to specified device.
PRINT	Output data and text to primary calculator printer. A free-field output format is provided.



11272B Extended I/O ROM Routines	
STATEMENT or FUNCTION	**DESCRIPTION**
ENTER	Request and input data or character strings from specified device.
OUTPUT	Similar to WRITE statement, except that code-conversion parameters are possible.
WRITE BYTE	Output any 8-bit binary byte.
READ BYTE	Request and input one byte from specified device.
COMMAND	Control instruments using an HP Interface Bus (see Chapter 4).
STAT	Check "busy" or "ready" status of specified interface.
ROTATE	Perform binary rotation on specified expression.
INCLUSIVE OR	Combine two expressions in an 'inclusive or' logic operation.
BINARY AND	Combine two expressions in an 'and' logic operation.
SPACE	Output specified number of space characters.
LINE FEED	Output specified number of line-feed characters.

The following pages describe the most-often-used 9830A I/O routines. For more detailed instructions on using these and the other I/O routines, refer to the manuals listed in the Appendix.

General I/O Routines

The WRITE and FORMAT statements are available with the basic 9830A Calculator to provide Fortran-like output capability.

The WRITE Statement

WRITE (select code , format) list

WRITE statements are used to output data and character strings, just like 9830A PRINT statements. In addition, the device select code and an output format are specified in each WRITE statement. (The PRINT statement automatically assumes select code 15 and a free-field format). As an example, either of these lines can be used to output the constants 1, 2, and 3 to the calculator primary printer (select code 15):

```
10 PRINT 1,2,3
20 WRITE (15,*)1,2,3
```

Notice that a * is used in place of a format reference to specify the free-field format. Here are more examples (the output device is an HP 9866A Printer):

```
10 X=4
20 WRITE (15,*)1,2,3,X,X+1
30 WRITE (15,*)1;2;3;X;X+1
40 WRITE (15,*)X"SQARED ="X↑2;
50 WRITE (15,*)X"CUBED ="X↑3
```

Lines 20 & 30: When commas are used to separate each item (line 20), each is output in a 15-character field:

```
1              2              3              4              5
```

But when semicolons are used (line 30), the values are ''packed'' together in 6-character fields:

```
1     2     3     4     5
```

Lines 40 & 50: A variable, a quote field, and an expression are in each of these statements. Ending the first of two statements with a semicolon supresses a CR/LF, causing both printouts to appear on the same line:

```
4     SQUARED = 16     4     CUBED = 64
```

A comma could be used instead of the semicolon, but then the printout would be:


```
4     SQUARED =16                4     CUBED =64
```

Without any punctuation at the end of line 40, the printout would be:

```
4     SQUARED =16
4     CUBED=64
```

Notice that a CR/LF is automatically output after the last WRITE statement when using free-field format. For more examples using WRITE statements without FORMAT statements, please refer to the ''WRITE'' and ''PRINT'' sections of the 9830A Operating and Programming Manual.

Formatting

The formatting of numbers and the spacing between successive items is easily controlled with the FORMAT and WRITE statements. The WRITE statement references a format by specifying the line number of the corresponding FORMAT statement (see the next examples).

When expressions, variables, and constants are specified in a WRITE statement, their values can be output according to either of the following FORMAT statement specifications:

F **w . d**	where:	F indicates fixed-point format; **w** indicates total field width (in character spaces); **d** indicates the number of digits to the right of the decimal point.
E **w . d**	where:	E indicates exponential format (often called floating-point or scientific notation); **w** indicates total field width (in character spaces); **d** indicates the number of digits to the right of the decimal point.

The other available FORMAT statement specifications are:

- X — which indicates a blank character space.
- / — which indicates a carriage return-line feed for the printer.
- " text " — which indicates a quote field.
- B — which allows separate 8-bit ASCII-coded characters, without the automatic CR/LF (see the examples on pages 57 and 59).

Any combination of specifications can appear in the same FORMAT statement, provided that each item is separated by a comma. Also, any of the specifications can be duplicated a specific number of times when a repeat factor is specified. For example:

```
10 FORMAT 2F6.2,4X,F6.2
```

causes the first fixed-point field to appear twice, followed by four character spaces, and then another fixed-point field.

Here are more examples:

```
10 FORMAT F6.1,F10.2,E12.5
20 WRITE (15,10)7.5,-25.8,2.6E+95
30 FORMAT 2F20.3,F5.0
40 WRITE (15,30)126.005,3.123,"SUM="789432
```

Lines 10 & 20: The three values are output according to the ''F'' and ''E''specifications. Here is the output:

```
   7.5    -25.80 2.60000E+95
```

Lines 30 & 40: The first two values are output according to the first specification. The text is output character-by-character between values. $'s are output in place of the last value since the specified field width is too small.

```
             126.005               3.123SUM=$$$$$
```

Here is an example program using many formatting specifications. The printout (see the next page) was obtained using a Teletype Model ASR38, via an 11205A Interface set to select code 8 .

```
10 DEG
20 FORMAT 5/,6X,"DEGREES",6X,"RADIANS",10X,"SIN",12X,"COS",10X,"TAN",/
30 WRITE (8,20)
35 WAIT 200
40 FORMAT F10.0,5X,F10.2,5X,F10.3,5X,F10.3,5X,E10.3
50 X=0
60 FOR I=1 TO 5
70 WRITE (8,40)X,PI*X/180,SIN(X),COS(X),TAN(X)
75 WAIT 200
80 IF X>350 THEN 130
90 X=X+10
100 NEXT I
110 WRITE (8,*)
120 GOTO 60
130 FORMAT 5/
140 WRITE (8,130)
150 END
```

Lines 20 & 30: Output five carriage-return line-feeds. Then output column headings between blocks of spaces, and an extra LF .

Line 40: Format specifications for line 70.

Lines 60–100: Output five lines of data. Increment X by 10 for each line.

Lines 110 & 120: Output an extra CR/LF after each five lines.

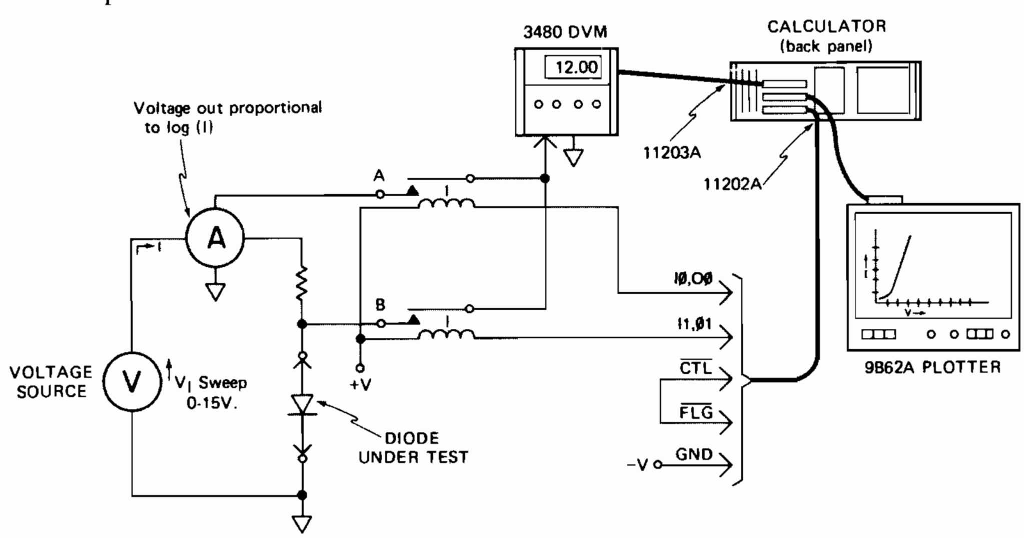
Lines 130 & 140: Output five CR/LFs.

Lines 35 & 75: Provide a delay for the teletype carriage to return.

DEGREES	RADIANS	SIN	COS	TAN
0	0.00	0.000	1.000	0.00E 00
10	.17	.174	.985	1.76E-01
20	.35	.342	.940	3.64E-01
30	.52	.500	.866	5.77E-01
40	.70	.643	.766	8.39E-01
50	.87	.766	.643	1.19E 00
60	1.05	.866	.500	1.73E 00
70	1.22	.940	.342	2.75E 00
80	1.40	.985	.174	5.67E 00
90	1.57	1.000	0.000	9.99E 99
100	1.75	.985	-.174	-5.67E 00
110	1.92	.940	-.342	-2.75E 00
120	2.09	.866	-.500	-1.73E 00
130	2.27	.766	-.643	-1.19E 00
140	2.44	.643	-.766	-8.39E-01
150	2.62	.500	-.866	-5.77E-01
160	2.79	.342	-.940	-3.64E-01
170	2.97	.174	-.985	-1.76E-01
180	3.14	0.000	-1.000	0.00E 00
190	3.32	-.174	-.985	1.76E-01
200	3.49	-.342	-.940	3.64E-01
210	3.67	-.500	-.866	5.77E-01
220	3.84	-.643	-.766	8.39E-01
230	4.01	-.766	-.643	1.19E 00
240	4.19	-.866	-.500	1.73E 00
250	4.36	-.940	-.342	2.75E 00
260	4.54	-.985	-.174	5.67E 00
270	4.71	-1.000	0.000	9.99E 99
280	4.89	-.985	.q74	-5.67E 00
290	5.06	-.940	.342	-2.75E 00
300	5.24	-.866	.500	-1.73E 00
310	5.41	-.766	.643	-1.19E 00
320	5.59	-.643	.766	-8.39E-01
330	5.76	-.5p0	.866	-5.77E-01
340	5.93	-.342	.940	-3.64E-01
350	6.11	-.174	.985	-1.76E-01
360	6.28	0.000	1.000	0.00E 00

To output single characters without automatic carriage-return line feeds, FORMAT B specifications are referenced.

The following diagram and program sequence show a typical use for FORMAT B. The diagram shows a system based on the relay control scheme described on page 19. The system is used to measure and plot diode V-I characteristics.



To operate the system, a program is used to alternately close relays A and B and then take readings from the DVM's BCD output using an 11203A BCD Interface. The program could either plot sets of V-I readings as they are taken, or store a series of readings and plot them later. The plotting method used depends upon the voltage sweep time, the program execution time, and the number of V-I readings (sample density) required.

The following program sequence controls the relays and inputs data readings from the DVM. Notice that the 11202A responds to select code 1 and the 11203A responds to select code 2.

```
10 FORMAT B
20 WRITE (1,10)"A";       Output ASCII "A" (binary "01000001") to close relay A.
30 ENTER (2,*)A,Y         Input DVM function code in A and complete data sample (I) in Y.¹
40 WRITE (1,10)"B";       Output ASCII "B" (binary "01000010") to close relay B.
50 ENTER (2,*)A,X         Input function code in A and complete data sample (V) in X.¹
```

Notice in lines 20 and 40 that single characters are output without CR/LFs by referencing FORMAT B and ending each line with a semicolon.

The following routines are available with the HP 11272B Extended I/O ROM.

```
OUTPUT ( select code , format [ , conversion table] ) list
```

OUTPUT is a general-purpose statement for transmitting data and coded commands. In addition, when the external device requires non-ASCII code, conversion from ASCII to that code can be performed by referencing a conversion table. Here are some examples:

```
10 OUTPUT (15,*)A,B,C
20 OUTPUT (15,*,A)A,B,C
30 OUTPUT (9,35,T)"ABCDEF",1,2,3
40 WRITE (1,30)"B";
50 ENTER (2,*)A,X
```

Line 10: The A, B, and C values are output to the device responding to select code 15. The * specifies the free-field PRINT format.

Line 20: The values corresponding to conversion table A elements A(A), A(B), and A(C) are output.

Line 30: After ASCII-coded ''ABCDEF'' is output, the values corresponding to conversion table 'T' elements T(1), T(2), and T(3) are output.

To set up a conversion table, an integer array is used. The decimal equivalents of the ASCII characters are stored as array elements. The decimal equivalents of the foreign code characters correspond to the array subscripts.

[1] A complete description of the 11203A data-input sequence is listed on page 22.

For example, suppose you wish to punch data on a paper-tape reader using EIA[1] code, rather than ASCII code. After writing a table that compares the ASCII-coded and EIA-coded characters to be punched (see below), this integer array and conversion table can be programmed:

```
10 DIM A[128]
20 A[32]=48
30 A[1]=49
40 A[2]=50
50 A[19]=51
60 A[4]=52
70 A[21]=53
80 A[22]=54
90 A[7]=55
100 A[8]=56
110 A[25]=57
120 A[59]=44
130 A[107]=46
140 A[128]=10
```

Character	ASCII Decimal Equivalent	EIA Decimal Equivalent
0	48	32
1	49	1
2	50	2
3	51	19
4	52	4
5	53	21
6	54	22
7	55	7
8	56	8
9	57	25
,	44	59
.	46	107
LF	10	128

Once the conversion table is programmed, executing this statement:

```
10 OUTPUT (3,*,A)A,B,C
```

outputs each value in EIA code rather than ASCII code.

If EIA-coded data were to be input (using ENTER statements), this same conversion table could be referenced to automatically convert each value from EIA to ASCII.

The ENTER Statement

ENTER (select code , format [, conversion table]) variable list [, FOR parameter]

The ENTER statement enables the calculator to receive data from an external device. If the incoming data is not in ASCII code, conversion to ASCII code may be automatically performed by referencing a conversion table (see the preceeding section). Also, FOR parameters may be used to input multiple data items using the same statement.

Here are some examples:

```
10 ENTER (7,*)A,B,C
20 DIM C[5]
30 ENTER (3,*)A,B,C[1],C[2],C[3],C[4],C[5]
40 ENTER (3,*)A,B,(FORI=1TO5,C[I])
50 ENTER (7,*,A)A,B
```

Line 10: Three data items are input and stored from the device set to select code 7. When the free-field format is specified (*) each data item must be separated by a comma or other non-numeric character, and the last item must be followed by a line feed (LF) character.

Lines 20 – 40: Line 20 defines a one-dimensional, five-element array to be filled by line 30 or 40. Lines 30 and 40 perform the same operations: Input seven data items, and store the last five items in array C.

Line 50: Two data items are input. By referencing conversion table A, each item is converted from another code to ASCII as it is input.

If a standard ASCII "←" character is input, a backspacing operation is simulated. For example, if the input characters are 12←34, the resulting data values would be 134. If an escape (ESC) or an alternate mode (ALT) control character is input, a search is made for a LF (end of data). When a LF is found, all data from ESC or ALT to the LF is ignored, and since the ENTER statement has not been terminated, the next data item is accepted.

Binary I/O Routines

The WRITE BYTE Function

WBYTE decimal integer

The WRITE BYTE function outputs the 8-bit apparent binary-equivalent of the specified decimal integer. See the table in the Appendix for ASCII output characters and decimal-equivalent forms.

Here is an alternate method to control the system described on page 56.

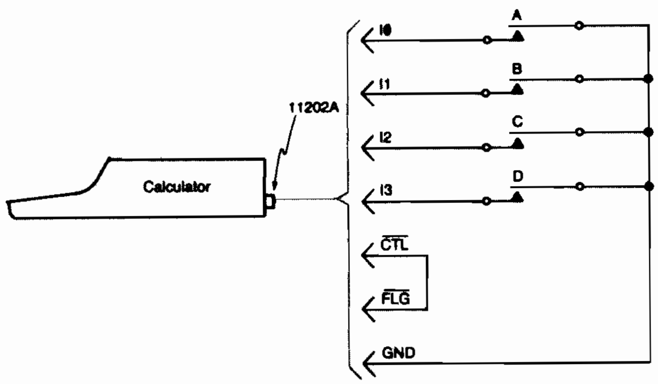
```
10 FORMAT B
20 WRITE (1,10)WBYTE1;   Output binary "00000001" to close relay A.
30 ENTER (2,*)A,Y
40 WRITE (1,10)WBYTE2;   Output binary "00000010" to close relay B.
50 ENTER (2,*)A,X
```

The READ BYTE Function

RBYTE select code

READ BYTE inputs one 8-bit apparent-binary byte of data and converts it to its decimal-integer form.

A typical use for READ BYTE is shown in this application, which is part of a numerically-controlled drill system. The circuitry shown at the right consists of an 11202A Interface and four limit-switches which monitor the position of the drill platen (working surface). Each switch closes when the platen reaches one of its four lateral boundaries.



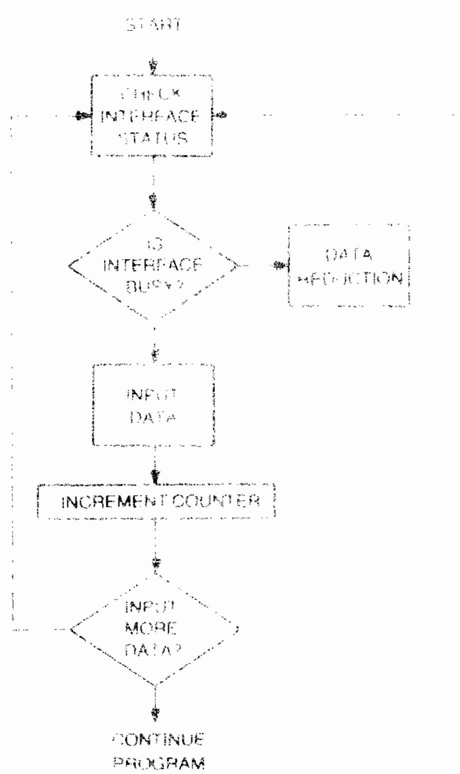
This program sequence can be used to monitor the switches and branch to an appropriate control routine when the platen reaches a boundary:

```
130 IF RBYTE1=1 THEN 200
140 IF RBYTE1=2 THEN 210
150 IF RBYTE1=4 THEN 220
160 IF RBYTE1=8 THEN 230
```

Up to eight switches, or other circuitry which forces an input line low, could be monitored by using all of the 11202A data-input lines.

Peripheral Interrupt

Although there is no provision for hard-wired peripheral interrupt operation, this flowchart and program show one method to provide 'software interrupt' capability. In this program, the calculator monitors an 11203A BCD Interface connected to a measurement device. When the interface is found to be busy, the calculator performs some time-consuming data reduction. When the interface is ready, however, the calculator branches to a data-input routine.

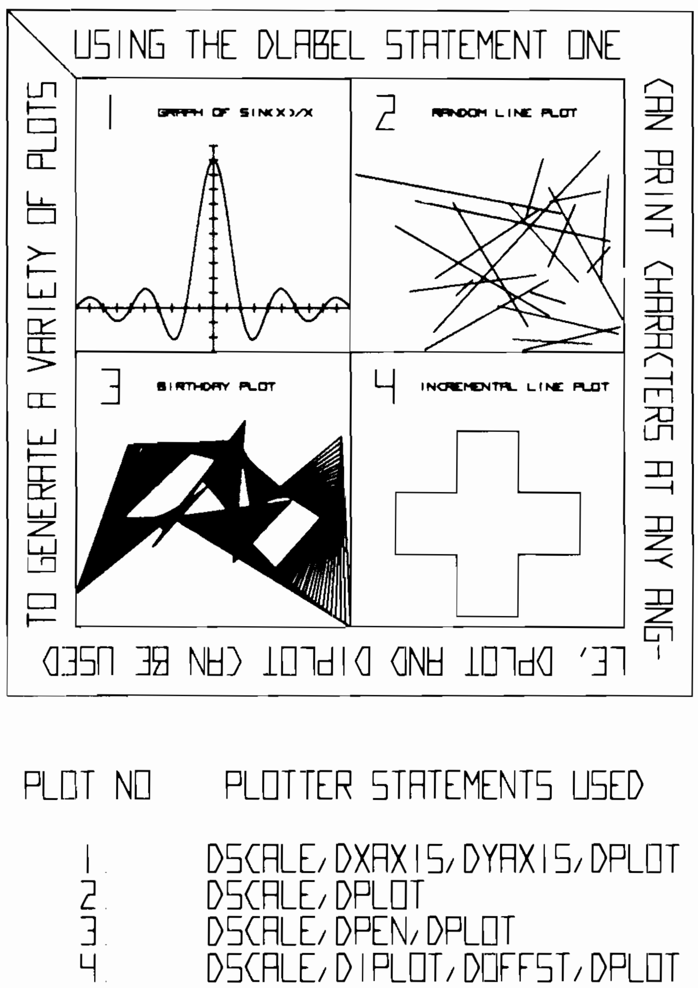



```
110 FOR I=1 TO 20
120 IF STAT1=0 THEN 150
130 ENTER (1,*)A,B
140 NEXT I
 *
 *
 *
260 GOTO 120
```

Incremental Plotter Control

The binary cassette (HP Part No. 11282-90001) supplied with the 11282A Interface contains the following four programs:

- A 1424 word program, for 0.01 inch (0.1mm)step-size plotters, which has the complete set of plotter control commands listed below on the next page.
- A 1424 word program for 0.005 inch step-size plotters which also has all commands.
- A 411 word program for 0.01 inch (0.1mm) step-size plotters allowing use of the DSCALE, DPLOT, and DIPLOT commands. By proper use of DSCALE, this driver program can be used for any step-size plotter.
- A diagnostic program which shows many plotting formats.



11282A Diagnostic Program

Plotter Control Commands

Command	Remarks
DSCALE Xmin, Xmax, Ymin, Ymax, DX, DY	Establishes relationship between user units and inches (cms.). Sets the present pen position to (Xmin, Ymin).
DOFFST X, Y	Moves origin to point (X, Y).
DXAXIS Y-offset [, Tic, 1st [, Start Point, End Point]]	Draws X axis along the line Y = Y-offset from X = Start Point to X= End Point, with tic marks at Tic intervals - in user's units. The first tic will be drawn 1st user units from the beginning of the axis.
DYAXIS X-offset [, Tic, 1st [, Start Point, End Point]	Draws Y axis. Parameters are analogous to those of DXAXIS.
DPLOT X, Y [, Control Pen]	Moves the plotter pen to point (X, Y) measured from origin. Control Pen parameter raises or lowers pen.
DIPLOT X, Y [, Control Pen]	Similar to DPLOT except that the point (X, Y) is measured from the current pen position rather than origin.
DPEN P	Raises or lowers pen.
DLABEL (LN or * [, CW, CH, θ]) [LIST]	Draws alphanumeric characters specified in the LIST parameter either in free format (*) or according to the FORMAT at line number LN. CW (character width), CH (character height), and θ (angle along which characters are drawn) specify the characters' appearance.
DSCODE C	Adjusts the software to output at select code C.

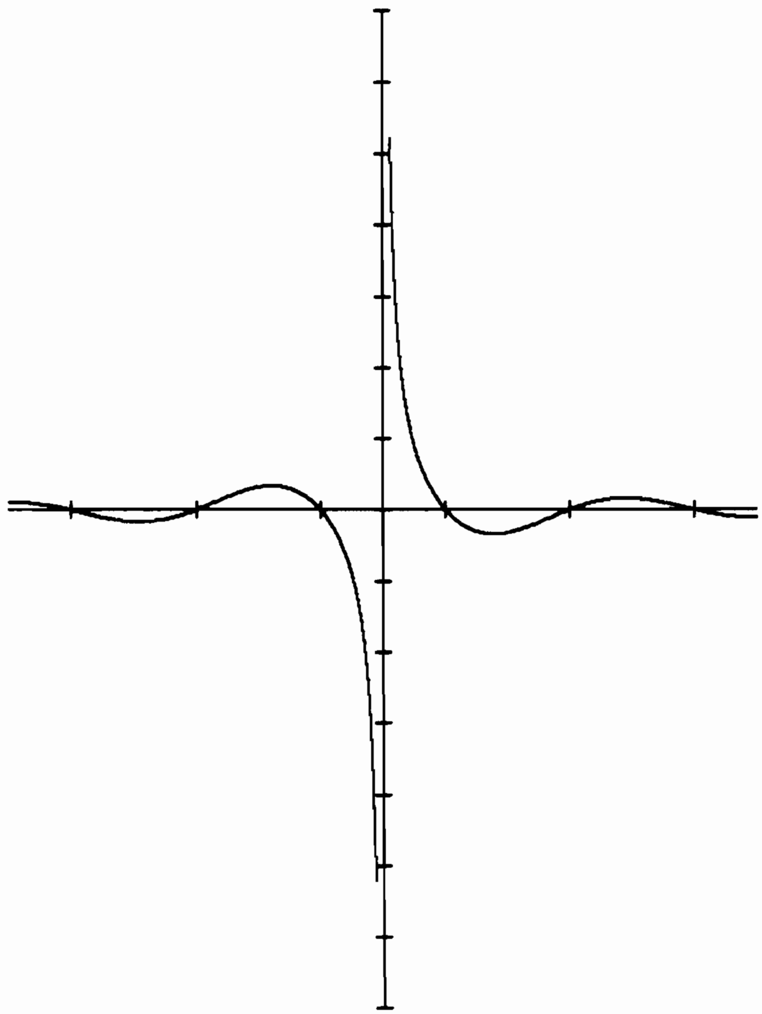
The following programs and plots show the control flexibility available with the 11282A Interface.

Example 1:

This program illustrates the use of the DPLOT, DXAXIS and DYAXIS statements to make a simple graph. It plots the graph of Y = (Cos X)/X.

```
10 DSCALE -3*PI,3*PI,[illegible]
20 DXAXIS 0,PI,PI/2
30 DYAXIS 0,1,0
40 FOR X=-3*PI TO 3*PI STEP PI/50
50 IF X=0 THEN 80
60 IF ABS(COS(X)/X)>=[illegible] THEN 1[illegible]0
70 DPLOT X,COS(X)/X
80 NEXT X
90 GOTO 120
100 DPEN 1
110 GOTO 80
120 DPEN 1
130 END
```

Notice that line 50 is included to prevent division by zero; also that line 60 is used to keep the plotter pen within the limits set by the DSCALE statement and thus prevent plotting errors when the value of (Cos X)/X becomes very large or very small.



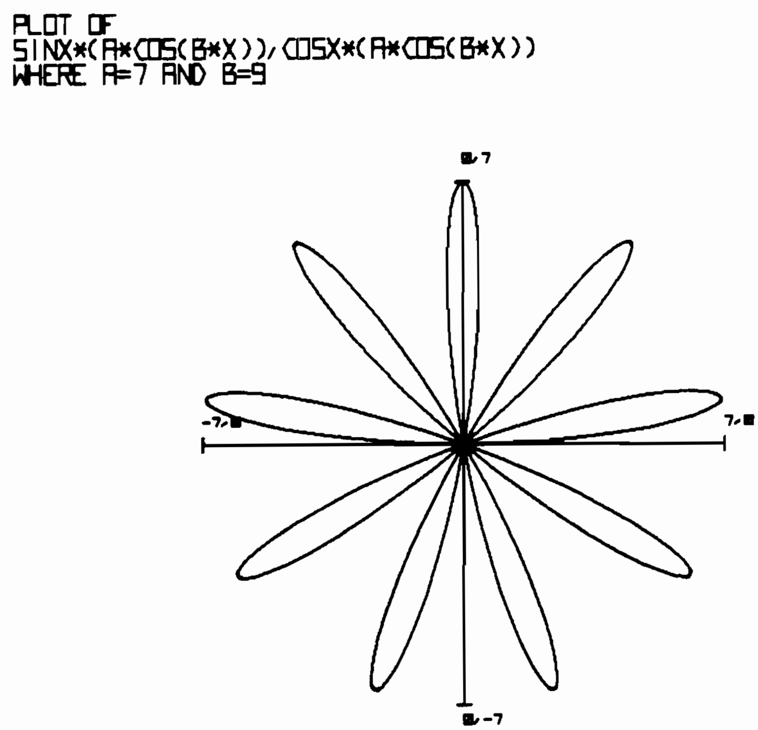
Example Plot #1

Example 2:

This program illustrates how to label axes and title the graph.

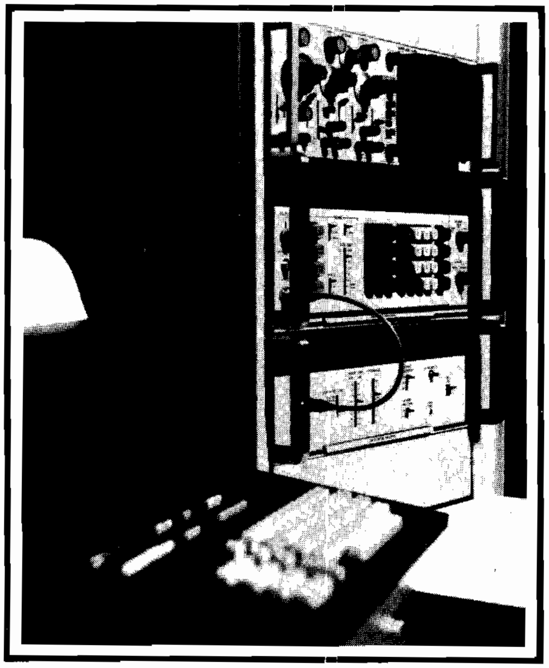
```
10 DSCALE -12,12,-13,11[illegible]
20 DEG
30 DXAXIS 0,7,0,-7,7
40 DYAXIS 0,7,0,-7,7
50 DLABEL (*,0.2,0.25,3)
60 DPLOT 0,7.5,1
70 DLABEL (*)"0,7";
80 DPLOT 7,0.5,1
90 DLABEL (*)"7,0";
100 DPLOT 0,-7.5,1
110 DLABEL (*)"0,-7";
120 DPLOT -7,0.5,1
130 DLABEL (*)"-7,0";
140 FOR I=0 TO 180 STEP [illegible]
150 A=7
160 B=9
170 DPLOT SINI*(A*COS(B*I)),COSI*(A*COS(B*I[illegible]
180 NEXT I
190 DPEN [illegible]
200 DPLOT -12,11,1
210 DLABEL (*,0.3,0.5,0)"PLOT OF"
220 DLABEL (*)"SINX*(A*COS(B*X)),COSX*(A*COS(B*X))"
230 DLABEL (*)"WHERE A=7 AND B=9";
240 DPEN 1
250 END
```

Notice that tic marks have been placed at the end of the axes and at the origin so that they may serve to give emphasis to the coordinate values which are drawn. Also note that the plotted values are offset a bit from the actual end of the axes so that the numbers may be read more easily (lines 60 – 130).



Example Plot #2

Chapter 4
HP Interface Bus



Introduction

The HP Interface Bus (HP-IB) is an easy-to-use hardware and software interface for a wide variety of programmable instrumentation. Up to 15 instruments which have HP-IB capability built-in can be interconnected at the same time via a simple one-cable system. And since bus capability is designed into each instrument, data and control instructions are easily exchanged with or without the use of a central control device.

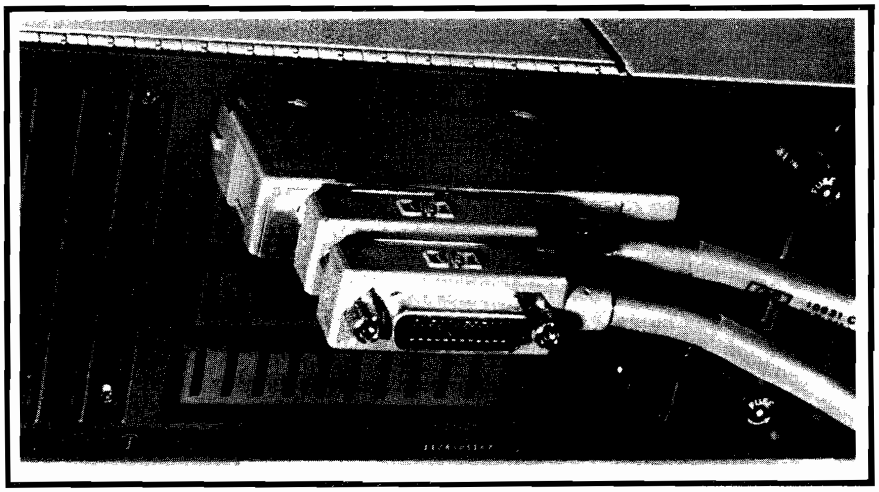
Many of the latest HP measurement instruments are available with HP-IB capability, including digital voltmeter and counter systems, network analyzers, and frequency synthesizers. Your nearest HP Sales and Service Office can describe the many instruments with bus capability.

This chapter offers a brief description of the bus hardware and software structure. Also included are examples showing how to control an instrument with a 9820A, 9821A, or 9830A Calculator.

For more-detailed information on the HP-IB either refer to the Interface Bus User's Guides listed in the Appendix, or contact the nearest HP Sales and Service Office. You'll find office locations listed in the Appendix.

Hardware for the HP-IB

Each instrument on the HP-IB is connected through a 15-wire cable with a piggy-back connector on each end (see photo below). Cables are available in 3, 6, and 12 foot lengths. Total cable length for a system can be up to 51 feet.



HP-IB Connectors

The HP-IB control and data-transfer logic must be designed into each instrument. Many HP instruments are offered with bus capability as optional equipment.

The HP 59405A Interface provides HP-IB capability for the 9820A, 9821A, and 9830A Calculators. The interface card buffers all data and control instructions between the calculator and instruments on the bus. An appropriate ROM block provides HP-IB driver commands for each calculator:

- 9820A or 9821A requires an 11224A PC2 Block.
- 9830A requires an 11272B Extended I/O ROM.

Instrument Functions

Each instrument on the HP-IB performs one or more of these functions:

- A TALKER is any device which can be addressed to transmit data.
- A LISTENER is any device which can be addressed to receive data.
- A CONTROLLER is any device which can be a talker or listener and send instructions to other instruments.
- The SYSTEM CONTROLLER is a device which can do all of the above functions, and also can initialize the bus and control other instruments on the bus. Since the calculator generally assumes this most-flexible function, the 59405A Interface can be prewired to assign the calculator as system controller.

Operating Modes

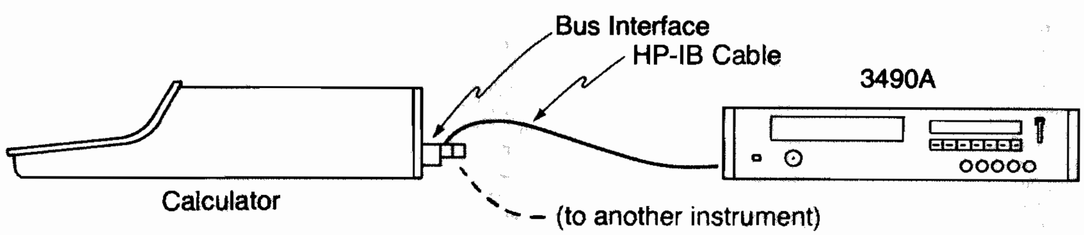
The HP-IB alternates between two modes: ADDRESS mode and INSTRUCTION mode. Executing each calculator Bus Command automatically sets the bus in the appropriate mode.

When the address mode is set, ASCII characters are used to specify which instruments are to be the talker and listener for subsequent instructions. The bus interface is set at the factory to recognize ASCII "5" as the calculator listener address and ASCII "U" as the calculator talker address.

During the instruction mode, ASCII characters are used to send instructions from the assigned talker to the assigned listener. For instruments addressed to talk, the instruction characters represent measurement data taken by the instrument.

Examples

The following examples describe how to control an HP 3490A Multimeter via the HP-IB. The system interconnections are shown below. Although these instructions are tailored to the 3490A, the same general operating sequences apply when controlling other instruments via the bus.



The following tables list the address characters and instruction characters assigned to the 3490A and the calculator. The tables also show the DVM's remote-control capability available via the bus.

This Character:	Specify this Address*:
U	Calculator talker
5	Calculator listener
V	3490A talker
6	3490A listener

*These addresses are prewired. Each device can be set for 30 other talker-listener address sets.

3490A Remote Instruction Characters

Characters	Instruction
R 1	10,000kΩ; Test 7
R 2	1,000kΩ; Test 6
R 3	100kΩ; 100V; Test 5
R 4	10kΩ; 10V; Test 4
R 5	1kΩ; 1V; Test 3
R 6	.1kΩ; .1V; Test 2
R 7	Autorange; Test 1
F 0	DC Volts
F 1	K Ohms
F 2	AC Volts
F 3	Test
S 0	Sample/Hold Off
S 1	Sample/Hold Off
S 2	Track/Hold
S 3	Acquire/Hold
T 0	Internal Sample Rate
T 1	Immediate Internal
T 2	Next External Trigger
T 3	None
M 0	Addressed Multi with No Output
M 1	Addressed Multi with Output
M 2	Addressed Single with No Output
M 3	Addressed Single with Output
M 4	Interrupt Multi with No Output
M 5	Interrupt Multi with Output
M 6	Interrupt Single with No Output
E	Execute Mode of Operation

Here is the general sequence used to send instructions to the 3490A and input data readings:

1) Set the 3490A to the Remote mode.
2) Use BUS COMMAND to output talker-listener addresses and instructions.
3) Use READ (9820A or 9821A) or ENTER (9830A) statement to input data.
4) Repeat steps 2 & 3 for each data reading.
5) When finished, set the 3490A back to the Local mode.

In addition, the READ STATUS or STAT function, available with a PC2 Block or Extended I/O ROM, permits the calculator to monitor service requests from other instruments on the bus. When a service request is detected, the calculator can poll the bus to determine which instrument is requesting service and then take appropriate action.

Bus Control with the 9820A or 9821A

The BUS COMMAND, READ, WRITE, and FORMAT statements are used to control instruments via the HP-IB. Those statements are available with the PC2 Block. Here's the general BUS COMMAND syntax:

CMD "? ⟨addresses⟩ "[, " ⟨instructions⟩ "] , ...

The "?" character at the beginning of each address field clears previous bus addresses. Multiple address/instruction sequences can be output by separating each quote field with a comma.

Before the 3490A can be controlled via the bus, the DVM must be set to Remote by executing this line:

```
FMT Y3,Z;WRT 13⊢
```

To return control to the 3490A front panel after data readings are transferred, execute this line:

```
FMT Y4,Z;WRT 13⊢
```

The following program shows how to first set the 3490A range, function, trigger, and sample controls and then input and print 10 data readings.

Program Summary

Line 1: Referencing FMT Y3 (Z suppresses output of CR/LF) in a WRITE statement outputs BCD 768 to set the 3490A to Remote. Note that the bus interface responds to select code 13.

Line 2: This BUS COMMAND statement clears previous addresses (?), specifies calculator as talker (6), specifies 3490A as listener (U), and sends instructions.

Line 3: This BUS COMMAND statement changes calculator addresses to allow data transfer from 3490A to calculator. Lines 2 and 3 could be condensed into this one statement:

```
2:
CMD "?6U","F0R4T
1M3E","?5V"⊢
```

Line 4 & 5: Input and print data reading.

Line 6: Return to line 2 (repeat bus operations) until 10 readings have been taken.

Line 7: Output BCD 1024 to set the 3490A to Local.

```
0:
0→A→B⊢
1:
FMT Y3,Z;WRT 13⊢
2:
CMD "?6U","F0R4T
1M3E"⊢
3:
CMD "?5V"⊢
4:
FMT 1;RED 13,A⊢
5:
FXD 5;PRT A⊢
6:
B+1→B;IF B<9;
GTO 2⊢
7:
FMT Y4,Z;WRT 13⊢
8:
END ⊢
```

Bus Control with the 9830A

The COMMAND, ENTER, and WRITE/WRITE BYTE statements available with the Extended I/O ROM are used to control instruments via the HP-IB. Here's the general COMMAND syntax:

CMD "? addresses " [, " instructions "] , . . .

The "?" in each address field clears bus addresses previously set. If desired, multiple address-instruction sets may be sent by separating each quote field with a comma.

Before controlling the 3490A via the bus, the DVM must be set to Remote by write byting BCD 768 and specifying the 3490A listener address. After data readings are transferred, write byting BCD 1024 resets the 3490A to Local control.

The following program shows how to first set 3490A function, range, trigger, and sample controls, and then input and print 10 data readings.

```
5 FORMAT B
10 WRITE (13,5)WBYTE768;
20 FOR I=1 TO 10
30 CMD "?6U","F0R4T1M3E","?5V"
40 FORMAT 4X,F10.0
50 ENTER (13,40)A
60 PRINT A
70 NEXT I
80 WRITE (13,5)WBYTE1024;
90 END
```

Program Summary

Line 5: FORMAT B is referenced to permit single character output, without a CR/LF.

Line 10: Outputs BCD 768 to set the 3490A to Remote. Note that the bus interface responds to select code 13.

Line 20 & 70: Repeat the control statements 10 times.

Line 30: This COMMAND statement clears all previous addresses (?), specifies the calculator as talker (6), specifies the 3490A as listener (U), and sends instructions. In the last quote field, the addresses are reassigned to permit data transfer from the 3490A to the calculator.

Lines 40 - 50: Input and print one data reading. the input format (line 40) instructs the calculator to ignore the first four characters input from the 3490A.

Line 80: After 10 data readings are taken, BCD 1024 is output to set the 3490A to Local.

Other Calculator Manuals

For the 9810A:

	HP Part No.
• Operating and Programming	09810-90000
• Peripheral Control	09810-90010

For the 9820A:

• Operating and Programming	09820-90001
• Peripheral Control 1 • Peripheral Control 2	09820-90026

For the 9821A:

• Operating and Programming	09821-90001
• Peripheral Control 1 • Peripheral Control 2	09820-90026

For the 9830A:

• Operating and Programming	09830-90001
• Extended I/O ROM	09830-90029
• Data Communications Interface	11285-90000

Calculator Interfaces:

• 11202A I/O Interface	11202-90000
• 11203A Serial Interface	11203-90000
• 11205A Serial I/O Interface	11205-90000
• 11282A Digital Plotter Interface (9830A only)	11282-90000

HP Interface Bus:

• HP-IB Users Guide (9820A & 9821A)	59300-90001
• HP-IB Users Guide (9830A)	59300-90002
• ASCII-Programmable Modules	Applications Note AN-174

I/O CHARACTERS AND EQUIVALENT ASCII FORMS

ASCII Char.	EQUIVALENT FORMS Binary	Octal	Dec [2]	CALCULATOR KEY [1] 9810A	9820A/9821A	9830A
NULL	00000000	000	0	CONTINUE	SPACE	— —
SOH	00000001	001	1	IF FLAG	STOP	— —
STX	00000010	002	2	IF x<y	PC2 [4]	— —
ETX	00000011	003	3	IF x=y	≠	— —
EOT	00000100	004	4	IF x>y	$	— —
ENQ	00000101	005	5	GO TO	LOAD	— —
ACK	00000110	006	6	PAUSE	&	— —
BELL	00000111	007	7	↓		— —
BS	00001000	010	8	x⇄y	(	— —
HTAB	00001001	011	9	x⇄y	)	— —
LF	00001010	012	10	CLEAR	✱	— —
VTAB	00001011	013	11	CLEAR	+	— —
FF	00001100	014	12	SET FLAG		— —
CR	00001101	015	13	SET FLAG	−	— —
SO	00001110	016	14	— —	.	— —
SI	00001111	017	15	— —	/	— —
DLE	00010000	020	16	0	NORMAL	— —
DC_1	00010001	021	17	IF FLAG	TRACE	— —
DC_2	00010010	022	18	IF x<y	FIXED N	— —
DC_3	00010011	023	19	IF x=y	FLOAT N	— —
DC_4	00010100	024	20	IF x>y	ENTER	— —
NAK	00010101	025	21	GO TO	— —	— —
SYNC	00010110	026	22	PAUSE	SPACE N	— —
ETB	00010111	027	23	↓	PRINT	— —
CAN	00011000	030	24	— —	RECORD	— —
EM	00011001	031	25	— —	JUMP	— —
SUB	00011010	032	26	— —	END	— —
ESC	00011011	033	27	— —	RETURN	— —
FS	00011100	034	28	— —	IF	— —
GS	00011101	035	29	— —	GO TO SUB	— —
RS	00011110	036	30	— —	FLAG N	— —
US	00011111	037	31	— —	SET CLEAR FLAG N	— —

ASCII Char.	EQUIVALENT FORMS Binary	Octal	Dec [2]	CALCULATOR KEY [1] 9810A	9820A/9821A	9830A
space	00100000	040	32	CONTINUE	SPACE	Space Bar
!	00100001	041	33	1	STOP	SHIFT ! 1
"	00100010	042	34	2	1 PC2 [4]	— —
#	00100011	043	35	3	≠	SHIFT # 3
$	00100100	044	36	4	$	SHIFT $ 4
%	00100101	045	37	5	%	SHIFT % 5
&	00100110	046	38	6	&	SHIFT & 6
'	00100111	047	39	7	'	SHIFT ' 7
(	00101000	050	40	8	(	(
)	00101001	051	41	9	)	)
*	00101010	052	42	×	✱	✱
+	00101011	053	43	+	+	+
,	00101100	054	44	CLEAR x	,	,
−	00101101	055	45	−	−	−
.	00101110	056	46	•	•	.
/	00101111	057	47	÷	/	/
∅	00110000	060	48	0	0	0
1	00110001	061	49	1	1	1
2	00110010	062	50	2	2	2
3	00110011	063	51	3	3	3
4	00110100	064	52	4	4	4
5	00110101	065	53	5	5	5
6	00110110	066	54	6	6	6
7	00110111	067	55	7	7	7
8	00111000	070	56	8	8	8
9	00111001	071	57	9	9	9
:	00111010	072	58	×	R( )	* :
;	00111011	073	59	+	2 PC2 [4]	+ ;
<	00111100	074	60	[illegible]	≤	SHIFT < ,
=	00111101	075	61	−	=	=
>	00111110	076	62	•	>	SHIFT > .
?	00111111	077	63	÷	?	SHIFT ? /

I/O CHARACTERS AND EQUIVALENT ASCII FORMS

ASCII Char.	EQUIVALENT FORMS Binary	Octal	Dec [2]	CALCULATOR KEY [1] 9810A	9820A/9821A	9830A
@	01000000	100	64	↑ ROLL	GO TO	SHIFT RESULT
A	01000001	101	65	A	A	A
B	01000010	102	66	B	B	B
C	01000011	103	67	C	C	C
D	01000100	104	68	D	D	D
E	01000101	105	69	E	E	E
F	01000110	106	70	F	F	F
G	01000111	107	71	G	G	G
H	01001000	110	72	H	H	H
I	01001001	111	73	I	I	I
J	01001010	112	74	J	J	J
K	01001011	113	75	K	K	K
L	01001100	114	76	L	L	L
M	01001101	115	77	M	M	M
N	01001110	116	78	N	N	N
O	01001111	117	79	O	O	O
P	01010000	120	80	π	P	P
Q	01010001	121	81	b	Q	Q
R	01010010	122	82	a	R	R
S	01010011	123	83	y→( )	S	S
T	01010100	124	84	x→( )	T	T
U	01010101	125	85	1/x	U	U
V	01010110	126	86	int x	V	V
W	01010111	127	87	INDIRECT	W	W
X	01011000	130	88	y←( )	X	X
Y	01011001	131	89	x←( )	Y	Y
Z	01011010	132	90	x^2	Z	Z
[	01011011	133	91	√x	3 PC2 [4]	—
\	01011100	134	92	LABEL	√	—
]	01011101	135	93	CHG SIGN	4 PC2 [4]	—
^	01011110	136	94	ENTER EXP	ENTER EXP	↑
_	01011111	137	95	SUB RETURN	→	—

ASCII Char.	EQUIVALENT FORMS Binary	Octal	Dec [2]	CALCULATOR KEY [1] 9810A	9820A/9821A	9830A
`	01100000	140	96	↑ ROLL	GO TO	—
a	01100001	141	97	A	A	SHIFT A
b	01100010	142	98	B	B	SHIFT B
c	01100011	143	99	C	C	SHIFT C
d	01100100	144	100	D	D	SHIFT D
e	01100101	145	101	E	E	SHIFT E
f	01100110	146	102	F	F	SHIFT F
g	01100111	147	103	G	G	SHIFT G
h	01101000	150	104	H	H	SHIFT H
i	01101001	151	105	I	I	SHIFT I
j	01101010	152	106	J	J	SHIFT J
k	01101011	153	107	K	K	SHIFT K
l	01101100	154	108	L	L	SHIFT L
m	01101101	155	109	M	M	SHIFT M
n	01101110	156	110	N	N	SHIFT N
o	01101111	157	111	O	O	SHIFT O
p	01110000	160	112	π	P	SHIFT P
q	01110001	161	113	b	Q	SHIFT Q
r	01110010	162	114	a	R	SHIFT R
s	01110011	163	115	y→( )	S	SHIFT S
t	01110100	164	116	x→( )	T	SHIFT T
u	01110101	165	117	1/x	U	SHIFT U
v	01110110	166	118	int x	V	SHIFT V
w	01110111	167	119	INDIRECT	W	SHIFT W
x	01111000	170	120	y←( )	X	SHIFT X
y	01111001	171	121	x←( )	Y	SHIFT Y
z	01111010	172	122	x^2	Z	SHIFT Z
{	01111011	173	123	√x	3 PC2 [4]	—
¦	01111100	174	124	LABEL	√	—
}	01111101	175	125	CHG SIGN	4 PC2 [4]	—
~	01111110	176	126	ENTER EXP	ENTER EXP	—
DEL	01111111	177	127	SUB RETURN	→	—

11202A-C-50673 T-0001

[1] When SHIFT is shown, the SHIFT key is held down while the following key is pressed. Where a key is not shown in the 9830A column, use a WRITE (FORMAT B) statement to output the decimal-equivalent number.

[2] Decimal numbers are used with PC2 READ BYTE, WRITE BYTE, and 9830A WRITE (FORMAT B) statements.

[3] The keys colored blue correspond to the shifted output mode; refer to the appropriate PC Block Operating Manual for instructions.

[4] These are the blank keys and are numbered from top to bottom as on the 9820A or the 9821A keyboard. The characters can be output with the indicated PC Block.

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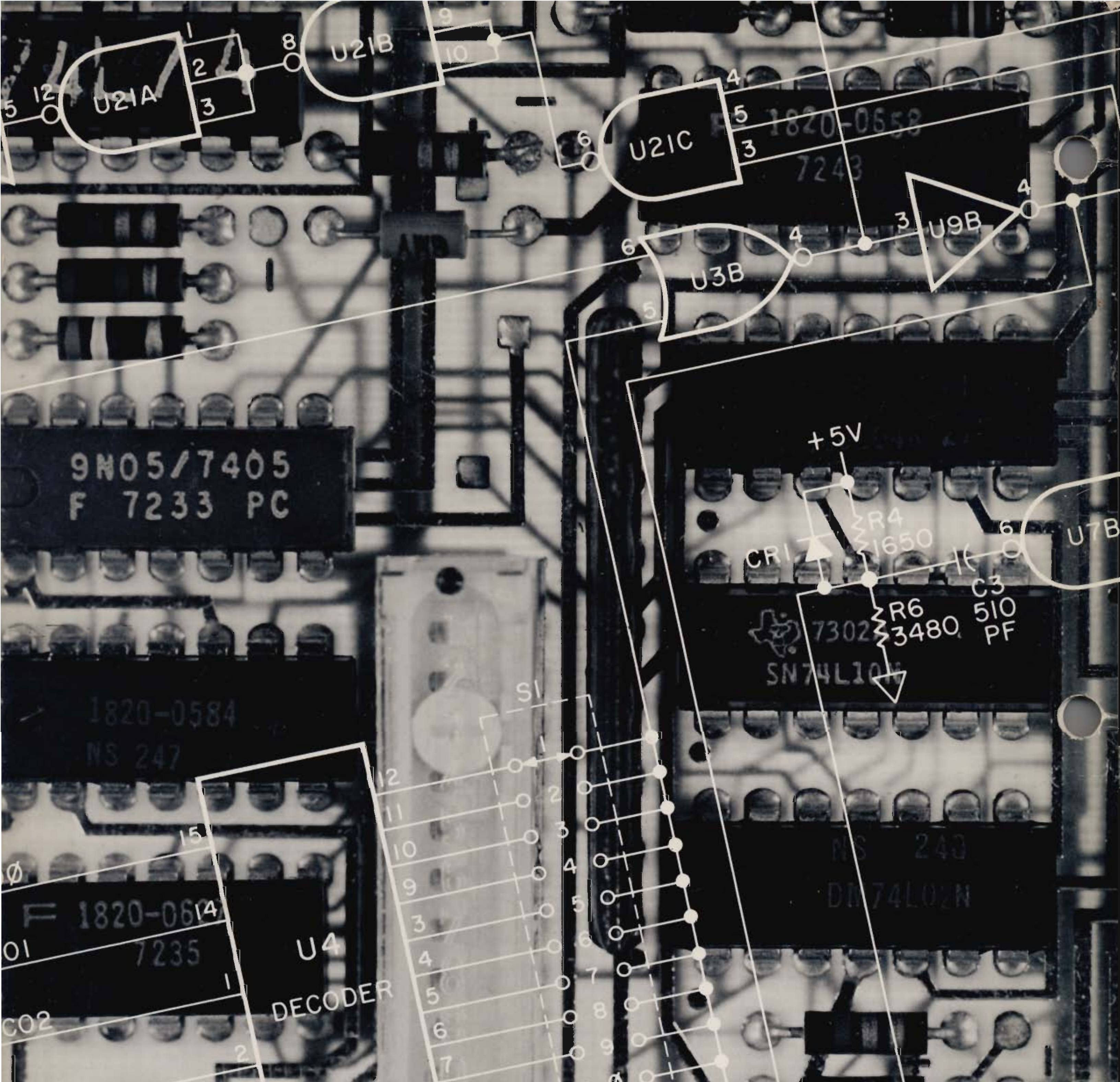

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