HP 2240A Measurement and Control Processor

HEWLETT hp PACKARD

An intelligent analog/digital subsystem
to simplify product test and equipment control

Technical Data

Introduction

The HP 2240A Measurement and Control Processor is an intelligent analog/digital subsystem that simplifies product test and equipment control in manufacturing and engineering applications. Using advanced microprocessor technology, the HP 2240A offers a new concept in measurement and control—computer-independent task execution. Together with associated products and accessories, the HP 2240A processor comprise a powerful subsystem that gives you a complete set of tools for easy, low-cost automation for your measurement and control application.

The HP 2240A Measurement and Control Processor includes the mainframe with a microprocessor-based control card and internal power supply. The HP 2240A product line also offers associated products and accessories, including a flexible mix of function cards and separate signal conditioning products, that will enable you to get all the capabilities needed to solve your measurement and control problems.

Content and organization of this data book

This document describes the HP 2240A and its associated products. The data book is organized into sections that include the HP 2240A product overview, programming information, data sheets on the 2240A hardware and associated products and accessories, extended performance option description, benchmark performance data of the 2240A using various computing controllers and with/without extended performance option, and product support information.

For fast, easy location of a particular section of 2240A product line information in this book, use the Quick Reference Index on the facing page (B). A Technical Data Index is provided on page (C) for reference to coverage of specific products by model number.

Other related publications

The following additional publications provide supplementary technical data, pricing and configuration information, and application notes.

HP 2240A Measurement and Control Processor Configuration Guide. This document provides configuring information for the HP 2240A, associated products and accessories, including:

- Signal conditioning and field wiring connections
- Application configuring worksheet
- Mounting alternatives
- Computers and accessories checklist
- Ordering information

HP 2240A Application Note 224-1. This document provides applications information on the HP 2240A, including

- Programming information
- Measurement and control application examples

HP 2240A Application Note 224-2. This document provides information on how to use the HP 22914A Breadboard Card for signal conditioning to the HP 2240A, including

- Suggested design procedure for special conditioning
- Signal conditioning circuit layout examples

HP 1000 Computer Systems Measurement and Conrol Specifier. This document provides recommendations for use of various HP measurement and control subsystems, including the HP 2240A, with the HP 1000 Computer System. Your application's test characteristics form the basis for recommended selections.

HP 1000 Computer Systems Technical Data. This document provides technical information and data sheets on the HP 1000 computer family, including

- HP 1000 concept and systems
- Computers, memory systems, and accessories
- System consoles
- System disc memories
- Product support information
- Site planning information

HP 1000 Computer Systems Configuration and Site Preparation Guide. This document provides configuration, price, prerequisite, and site preparation information for HP Computer Systems, options, accessories, and support services.

HP 9825A Desktop Computing System Technical Data. This document provides technical information on the HP 9825A Desktop Computer, including

- Specifications
- Read-only memories (ROMs)
- 9825A interfaces
- Ordering information

HP 9835A and HP 9845A Desktop Computing Systems Technical Data. HP 9835A and 9845A Desktop Computers technical data documents are available from your local HP Sales and Service Offices.

HP Computer Museum
www.hpmuseum.net

For research and education purposes only.

Quick Reference Index

HP 2240A product overview

HP 2240 Programming: HP-MCL

HP 2240A mainframe and function cards data sheets

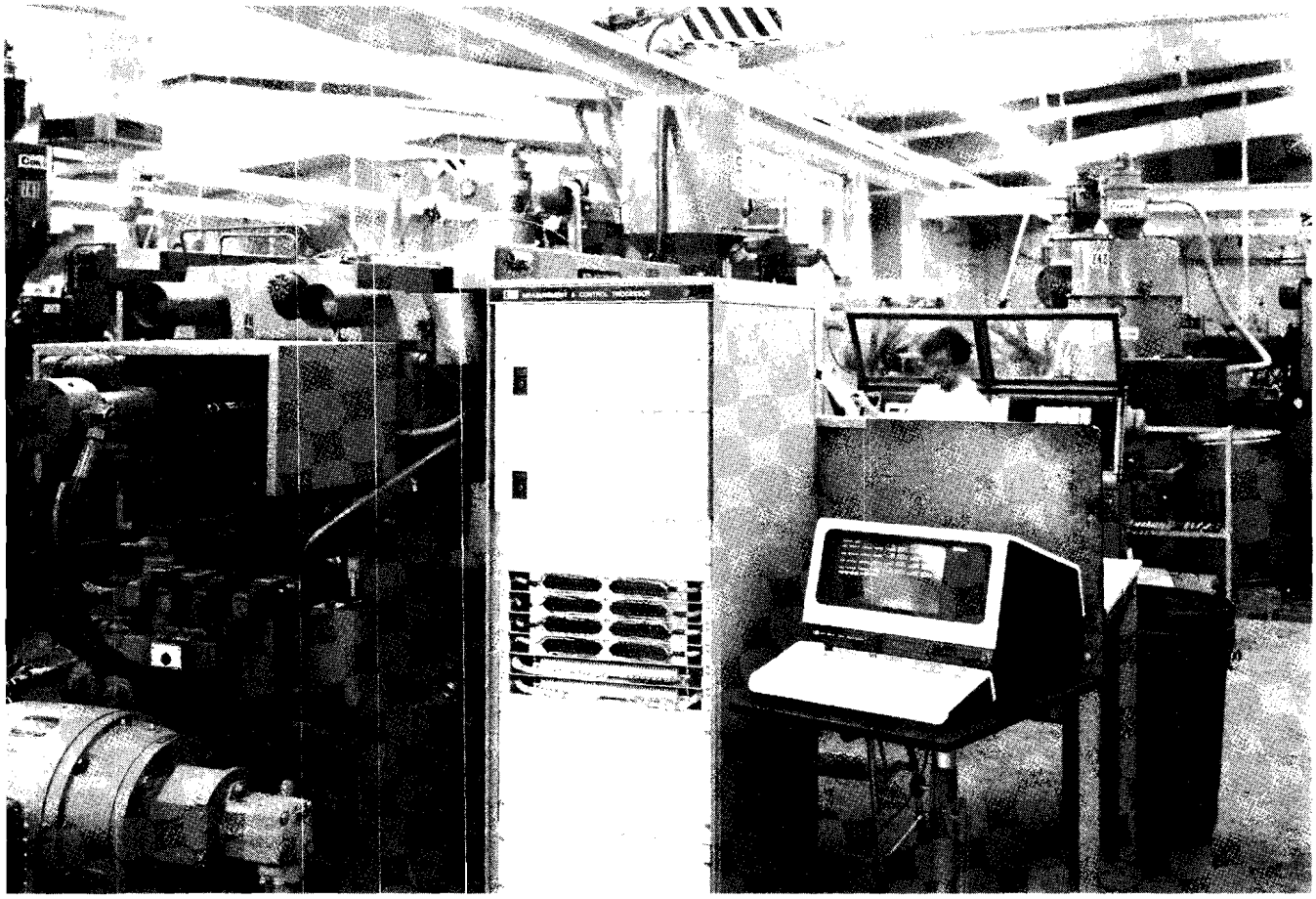
HP 2240A signal conditioning products data sheets

HP 2240A accessory products

HP 2240A extended performance option

HP 2240A performance briefs

HP 2240A Measurement and Control Products, technical data index



The HP 2240A Concept: automated measurement and control capabilities at an affordable price

A flexible mix of analog and digital capability

The HP 2240A Measurement and Control Processor and associated products, together with a computing controller, form a powerful automated system that gives you all the capabilities needed to solve your measurement and control problems. The basic HP 2240A mainframe controls 128 analog/digital I/O channels that are expandable to 256 channels with the addition of an HP 2241A Extender. It takes measurements at burst rates up to 20,000 readings/second, stores the measurements, and transmits results to your computer at speeds up to 200,000 bytes/second. The HP 2240A product line includes a flexible mix of measurement and control function cards and signal conditioning cards that you select from to get both analog and digital functions in one subsystem.

Measurement Function Cards

- **Analog Input Card (22900A).** 32 single-ended or 16 differential channels, ±10V, 12 bits including sign, 20 kHz sample/scan rate. Auto correction for gain and offset temperature drift. Diode overvoltage protection
- **Digital Input Card (22902A).** 32 channels, TTL or CMOS levels.
- **Common Interrupt (Event Sense) Card (22903A).** 16 channels. TTL or CMOS levels, individual channel enable and transition direction, interrupt test.
- **Counter/Stepper Motor Card (22905A).** 4 channels individually configured for event counting, frequency measurement, period measurement or stepper drive output. Internal self-test clock, TTL compatible.

Control Function Cards

- **Analog Output Card (22901A).** 4 channels, 0 to 10V, or −10 to +10V output, 10 bits with dual level storage. Auto readback from first level. 4-lead remote sense (Kelvin) connections.
- **Analog Output Card (22901B).** 4 channels, 0 to 10V, −10 to +10V, or 4 to 20 mA outputs, 12 bits with dual level storage. Auto readback from first level. 4-lead remote sense (Kelvin) connections.
- **Digital Output Card (22904A).** 32 channels, TTL or CMOS, open-collector output, dual level storage, auto readback, level or pulse outputs.

Signal Conditioning Cards

- **Relay Output Card (22912A).** 16 channels, 2 Amps, 250 VAC/DC, 60 VA rating, Form C (SPDT) hermetically sealed relays.
- **Isolated Digital Input Card (22913A).** 16 channels, DC (5 to 120V) and AC (16 to 230V) with selectable response times and overload fuses. Pin separation (spacing) has been successfully tested against UL's dielectric strength (breakdown) requirements.

- **General Purpose Breadboard Card (22914A).** 16 channels for analog or digital, input or output user signal conditioning. Pad layouts for standard instrumentation amplifiers, relays, filters, fuses, resistors, and voltage regulators.

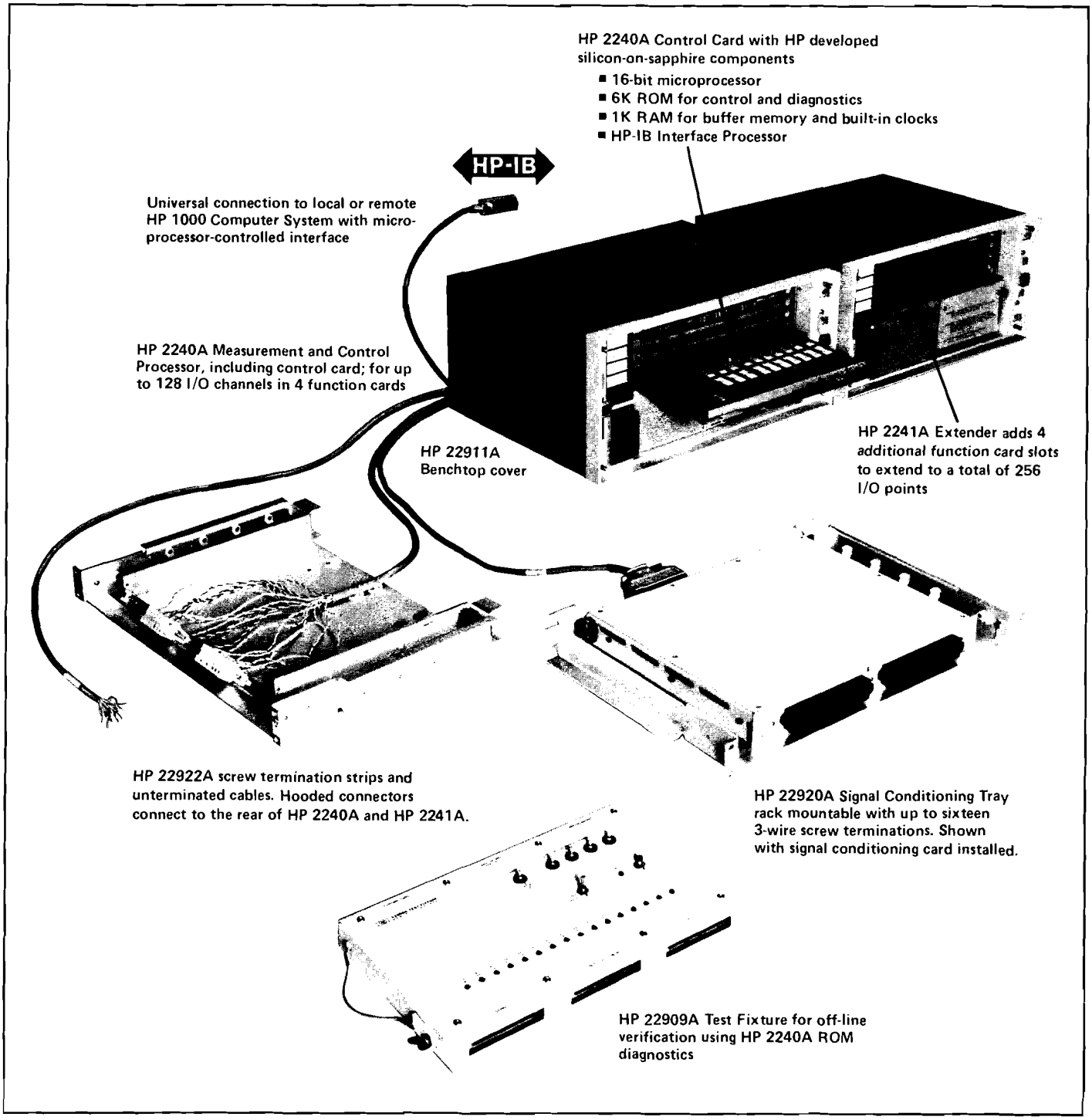
- **Low Level Analog Input Card (22915A).** 16 low-level analog input channels, jumper-selectable gains ±20 mV, ±50 mV, ±100 mV, ±500 mV and ±10V.

- **Low Level Analog Input Card (22915B).** 16 low-level analog input channels, jumper-selectable gains ±20 mV, ±50 mV, ±1.25V, ±5V and ±10V.

- **Screw Terminations (22922A).** 28 screw terminations on each connector. Two connectors (56 screw terminals) for field wiring (14-22 AWG) connections which connect to the signal conditioning cards.

A HP 22909B Verification Kit is available for off-line verification of the HP 2240A, troubleshooting down to the board level, and can be used as an I/O simulator for program development.

The figure shown below illustrates typically how the HP 2240A products can be simply interconnected to form an intelligent measurement and control subsystem for your HP-IB computing controller.



Typical 2240A Measurement and Control Subsystem

An intelligent approach to processing measurement and control signals

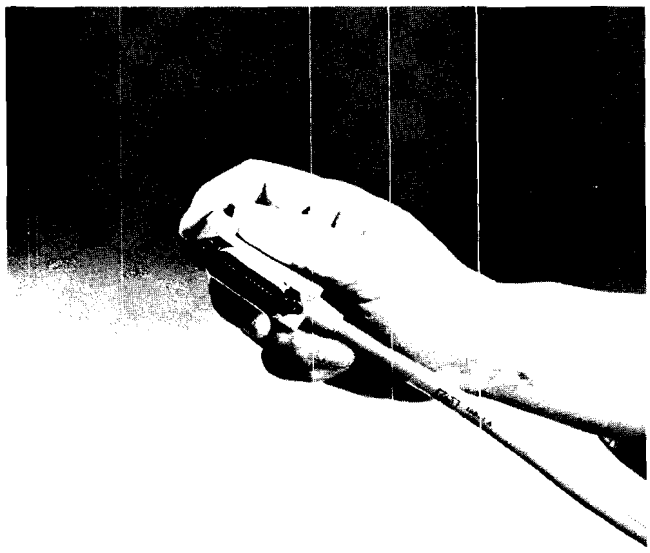
The HP 2240A Measurement and Control Processor contains built-in microprocessor intelligence that gives you a new approach to processing measurement and control signals. Real-Time measurement and control tasks previously handled by a computing controller can now be delegated to the HP 2240A. All timing, scanning, buffering, formatting and interrupt handling functions are also decoupled from the computer and handled independently by the HP 2240A, enabling more predictable and repeatable task performance. Decoupling these tasks from the computer allows your controller to perform other tasks, resulting in higher total system throughput.

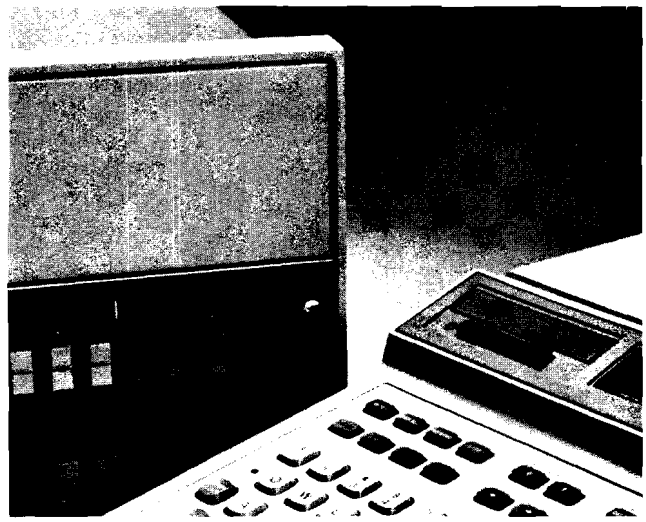
A powerful command set is included in the HP 2240A firmware so that you can easily program tasks on HP computing controllers in common high-level languages such a FORTRAN, BASIC, HP Assembly and HPL. Because of this programming ease, the HP 2240A is a logical way to help reduce applications software costs.

Standardized interface to easy-to-use computers

The HP 2240A is designed to operate with computers that are compatible with the Hewlett-Packard Interface Bus (HP-IB), our implementation of IEEE Standard 488-1978 "Digital Interface for Programmable Instrumentation", and identical ANSI Standard MC 1.1. A single cable connection is all that is required to link your computing controller to the 2240A and its associated products, creating the nucleus of a high-performance measurement and control system.

Hewlett-Packard offers a wide variety of computers – from desktop models to larger models for higher computational and control applications. Using the standard HP-IB interface you can easily plug together the measurement and control setup that fits your application, including local and remote connection capability to your computing controller, without the need for special hardware or software design or support. And with the HP 12050A Fiber Optic HP-IB Link, you can locate your 2240A measurement and control station up to





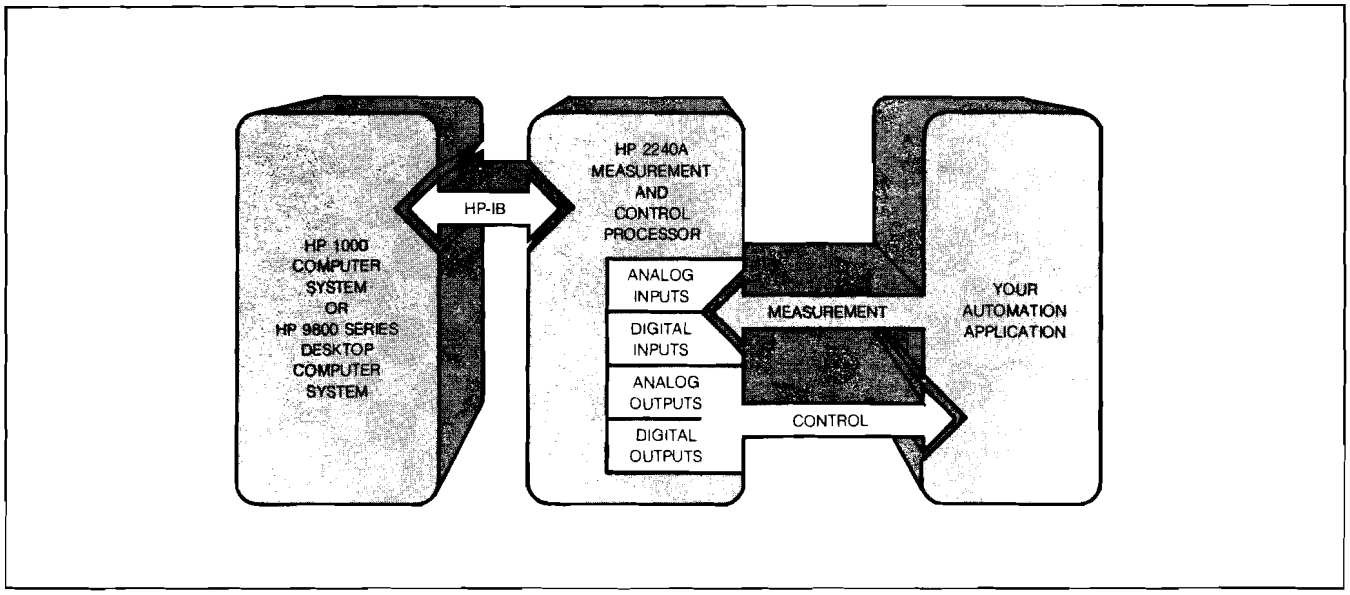
100 metres from your computing controller. The fiber optic transmission medium provides excellent electromagnetic noise immunity and electrical isolation between computing controller and instrumentation, which is ideal for industrial measurement and control applications in severe environments.

Adapts to your growing measurement and control needs

The HP 2240A approach adapts to your growing measurement and control requirements. HP's Real-Time Executive (RTE) operating system on HP 1000 computers enables real-time scheduling of multiple programs by priority, event, time clock, or by another program. This "multiple programming" capability allows you to add more HP 2240A measurement and control stations, either on the same HP-IB cable or with additional HP-IB cables. Multiple HP 2240A's and their display terminals share the resources of the one HP 1000 computer automatically under the control of the HP 1000's RTE software.

Additional HP 2240A stations can be locally or remotely connected. The HP 12050A Fiber Optic HP-IB link extends your HP-IB capability to 100 metres. With a HP 37201A HP-IB Extender you can connect a 2240A station up to 1000 meters over a single twisted pair of wires. For extremely remote locations you can use the HP 37201A and industry standard modems to delegate tasks over phone lines, thus saving you the expense of an additional computing controller at the remote site.

Your measurement and control may grow to the point where you have multiple computing controllers with their 2240A stations. With off-the-shelf distributed processing software for the HP 1000 Computer Systems, you can tie together your measurement and control automation areas into a computer-to-computer network. This allows you to share expensive line printers for reports and disc memories for common programs and test data. You can pass automatically-collected work station data to central manufacturing for standards and variance analysis. You can even share computing needs with other computers in your network, allowing you to reduce the computing power (and cost) required at remote test stands.



HP 2240A Operation: easy steps to automation

You can understand and use the HP 2240A in just a few hours and start to implement your measurement and control solutions. The diagram shows the simplicity of the 2240A approach. The computer controller is connected to the 2240A via a single HP-IB interface cable, and connection of the 2240A to your application is via common industrial sensors and devices. For more versatility required by your application, you may add other HP-IB compatible instruments to your 2240A station in a test or control cluster, all controlled by a common HP-IB connection to the computing controller.

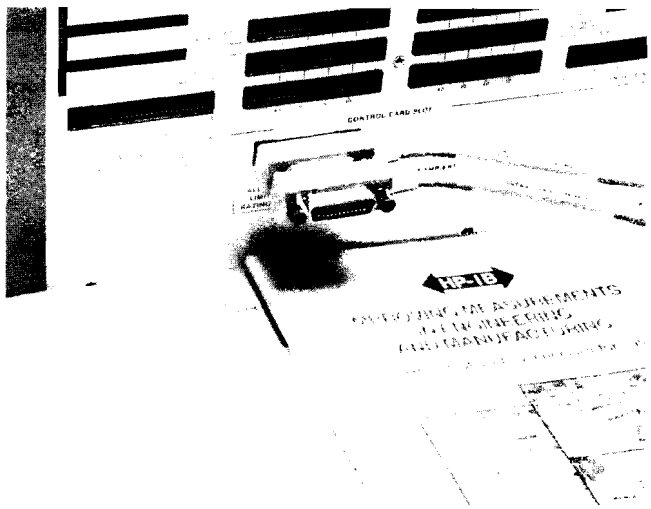
A self-teaching user's manual with numerous measurement and control examples is delivered with every 2240A. Getting started takes a matter of hours, and does not require specialized training courses away from your facility. In addition, straightforward instructions in the HP 2240A installation and service manual, along with the use of the HP 22909B Verification Kit, make installation without special training a reality. Installation planning and field wiring diagrams simplify sensor and control point connections for both the electrician and the programmer.

Connect the HP 2240A and HP computer

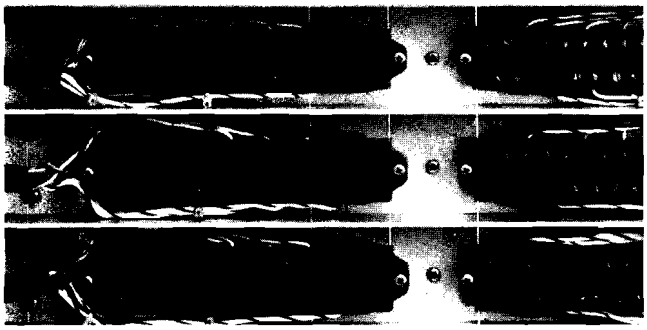
Select the HP computer with the computational power and memory that meets your measurement and control requirements and connect it to your HP 2240A via the single HP-IB cable. The HP-IB/IEEE 488-1978 interface standard eliminates the need for special design of computer-to-instrument interface logic and cables. By using the industry standard interface and putting more of the interface control software into the 2240A's microprocessor, HP frees you from the programming details of timing and interface control. And if your application requires local and remote installations of several 2240As, there are no complications to your operations because with the use of standard HP-IB interface message protocol, local or remote programming is identical.

Connect the HP 2240A to your application

The HP 2240A connects to your measurement and control application via common industrial sensors or control points. A single 2240A mainframe accepts both analog and digital inputs and outputs, and several interrupt-driven inputs, to make it easier for you to interface to real-time processes. You can add special signal conditioning with simple screw terminal connections in a separate structure so that your



2240A is isolated from any electrical noise or interference emanating from your measurement points. The HP 2240A has a full range of measurement and control functions, and you can add special purpose instrumentation via the HP-IB without any special hardware or software interface design.



Delegate tasks to the HP 2240A

The HP 2240A has a high level of intelligence that allows you to delegate real-time tasks from the computer controller. A single program statement can delegate a complete measurement/control task to the 2240A. Without further interaction with the computer, the 2240A holds the delegated task instructions in its memory and executes them in sequence. A complete task can include synchronizing 2240A operation with an external event, periodically acquiring a group of measurements, starting a control sequence at a specified time, or repeating an entire series of commands. Buffering of measurement and control outputs is handled by the 2240A microprocessor and its fast read and write memory. Results are automatically formatted by the 2240A for transmission to the controller, further reducing computer overhead.

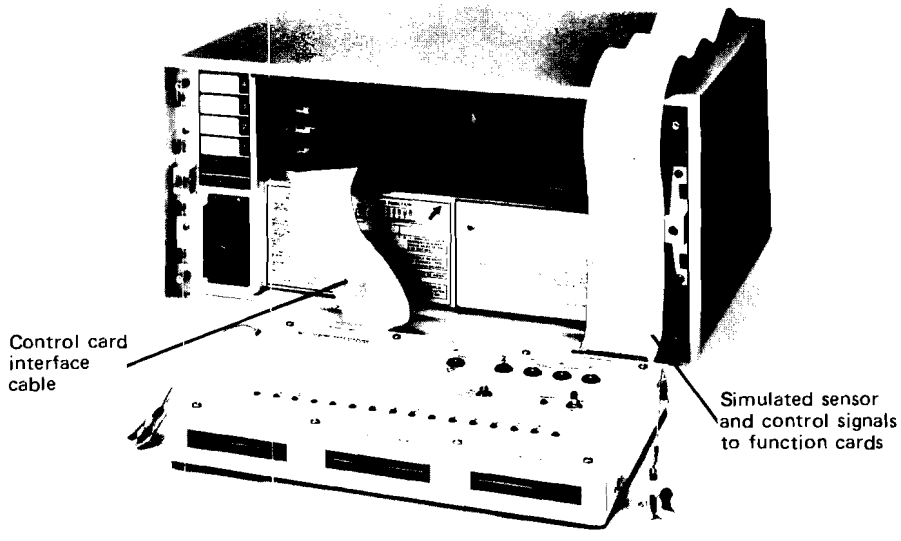
The powerful command set in the HP 2240A is easy to understand and use. The high level statements of the command set make system programming easier, while the task delegation capability frees the computer for other uses and reduces program timing constraints.

Easy self-testing and servicing

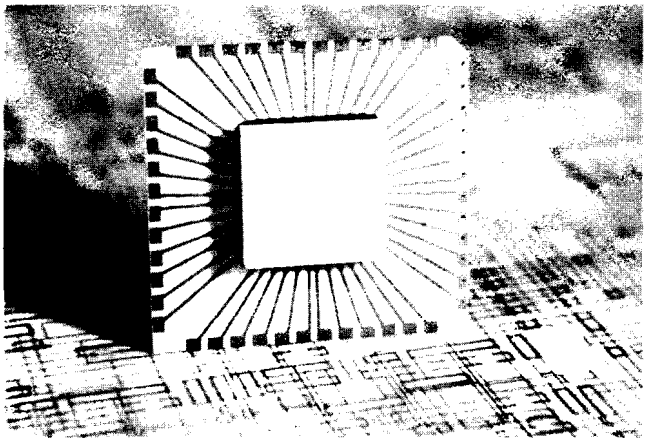
A significant advance in self-testing capability has been designed into the HP 2240A that allows you to test your measurement and control interface independent of the computer system. Remote measurement stations no longer need a separate terminal link back to the computer to run computer-based diagnostics. Over 2K words of diagnostics in the 2240A firmware, combined with the capabilities of the HP 22909A Test Fixture, makes testing and servicing of the HP 2240A easy and reduces downtime and maintenance costs.

- **Power on self test.** The HP 2240A runs self tests to verify control circuit operation every time power is applied to the unit. It tests the microprocessor, RAM and ROM memory patterns, HP-IB interface chip, and 2240A backplane circuits.
- **Subsystem configuration check.** A single command checks the configuration of all function cards in the HP 2240A mainframe/HP 2241A extender. Commands to the analog input function card quickly check the ADC for 0V and 10V full scale operation.
- **Input/Output signal simulation.** The HP 22909A Test Fixture can be used to simulate your signal inputs and test 2240A control outputs before you connect up to your application's test stand or process.

The test fixture, ROM memories and service manual allow you to quickly isolate failures to the HP 2240A function card level. You can then replace the board and take advantage of HP's fast and effective worldwide board exchange program.



HP 22909A test fixture and cables allow complete verification of all HP 2240A and HP 2241A analog and digital function cards, independent of the computer controller.



HP 2240A Programming Simplicity . . . with HP-MCL

Programming the HP 2240A Measurement and Control Processor is easy because of its powerful, built-in microprocessor and the flexible IEEE 488-1975 interface bus. The microprocessor provides the HP 2240A with an easy-to-learn command set, called HP-MCL (Hewlett-Packard's Measurement and Control Language), that is tailored to product test and equipment control applications. The IEEE 488-1975 (HP-IB) interface bus allows you to program the HP 2240A from any computing controller with the standard interface.

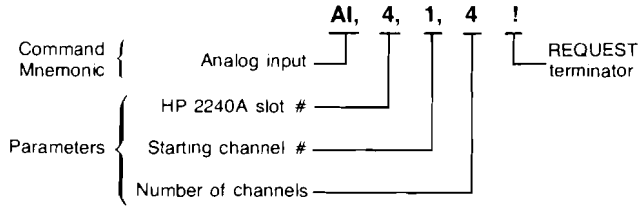
With the power of HP-MCL and flexibility of HP-IB, a computing controller can now delegate complex measurement and control operations to the HP 2240A, which frees the controller (and programmer) from detailed tasks it previously had to control. The delegated operations can be one or more HP-MCL commands to gather analog and digital data, wait for digital triggers, pace readings, or control events via analog or digital outputs, make decisions, and manage repeated execution of measurement tasks.

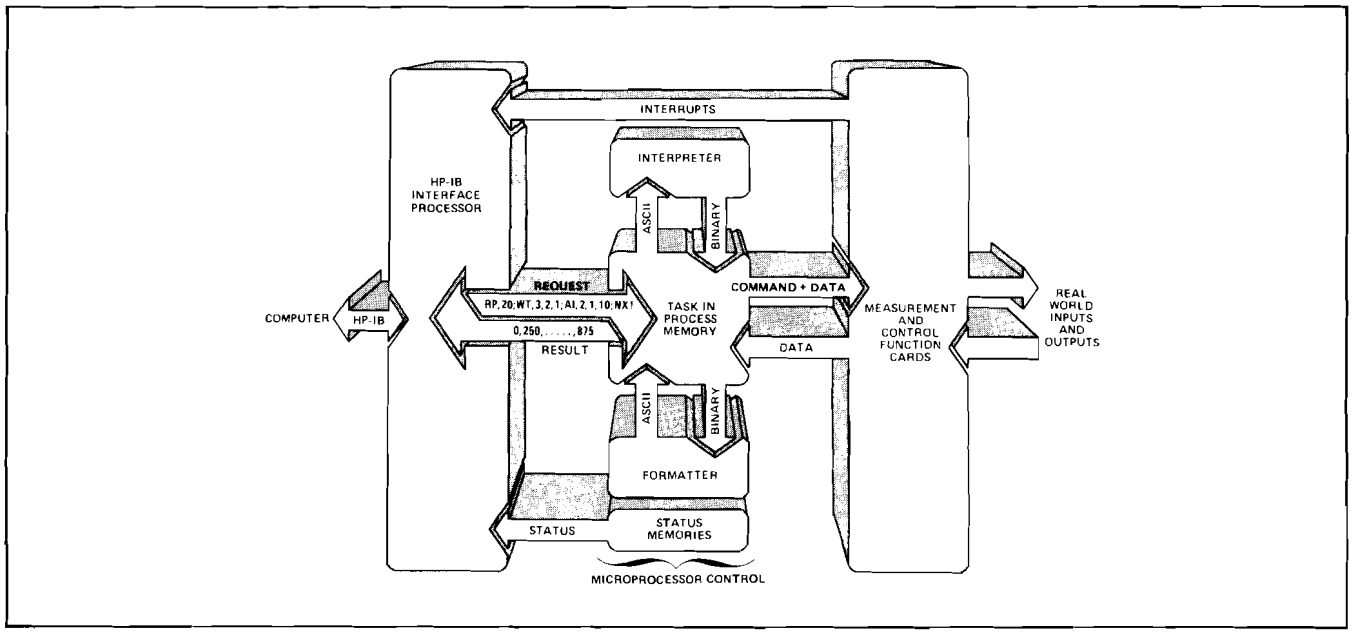
Communications between the computing controller and the HP 2240A is achieved through simple HP-IB data messages. The messages convey requests, results, status information and control signals, such as the interrupts shown on the simplified HP 2240A Measurement and Control Processor block diagram shown below. Programming the HP 2240A therefore is via the use of REQUEST and RESULT data messages. A REQUEST message is one or more commands to the HP 2240A grouped together. A RESULT message is the data returned by the HP 2240A.

HP-MCL . . . Requests that get results

The HP-MCL command set built into the HP 2240A consists of easily recognized mnemonics that can be grouped together in many combinations into an alphanumeric REQUEST message and sent to the HP 2240A with a simple HP BASIC, FORTRAN, or HPL statement used by HP computing controllers. The HP 2240A memory interprets the REQUEST message and executes the commands in sequence with no further interaction with the computer, then formats a RESULT message in ASCII for the computer to read. The computer reads the RESULT message, again, via a simple HP BASIC, FORTRAN, or HPL statement.

The HP-MCL command set for the 2240A is summarized in the table on page 2-1. The commands are grouped into types and each command is marked as to its compatability with the measurement and control function cards available for the HP 2240A. Note that most commands require other parameters to be specified with the command mnemonic, as shown in the simple example REQUEST message shown below:





HP 2240A Measurement and Control Processor Block Diagram

• Analog and Digital I/O Commands

For use with the 22900A Analog Input and 22915A/B Low Level Analog Input Cards

- AI — Sequential Analog Input (across a number of channels)
- AU — Sequential Analog Input (Uncorrected for temperature drift)
- RI — Repeated Analog Inout (on one channel)
- RU — Repeated Analog Inout (Uncorrected for temperature drift)

For use with the 22901A/B Analog Output Cards

- AO — Analog Unipolar Output
- AB — Analog Bipolar Output
- RO — Repeated Analog Unipolar Output
- RB — Repeated Analog Bipolar Output

For use with the 22902A Digital Input and 22903A Common Interrupt Card

- DI — Digital (point) Input
- FI — Field Input (16 digital points/field)

For use with the 22903A Common Interrupt Card

- MI — Mask Register Status Input (Read)
- MO — Mask Register Output (Set)
- SI — Sense Register Status Input (Read)
- SO — Sense Register Output (Set)

For use with the 22904A Digital Output Card

- DO — Digital (point) Output
- FO — Field Output (16 digital points/field)

For use with the 22905A Counter/Stepper Card

- RC — Read Count
- CR — Counter Reset
- ST — Start Totalize
- SF — Start Frequency or Period
- SS — Start Stepper

• Synchronizing, Timing, and Pacing Commands

- WB — Wait Before Each Data Transfer (specified time)
- WN — Wait Now (specified time)
- WR* — Wait and Reset Internal Timer (specified time)
- WT — Wait for Trigger (from Digital Input or Common Interrupt Card)
- TP — Timer Preset (to specified time)
- TE — Read Time Elapsed
- WU — Wait Until Elapsed Time (specified)
- TI — Interrupt Computer after specified Time Interval

• Task Supervision Commands

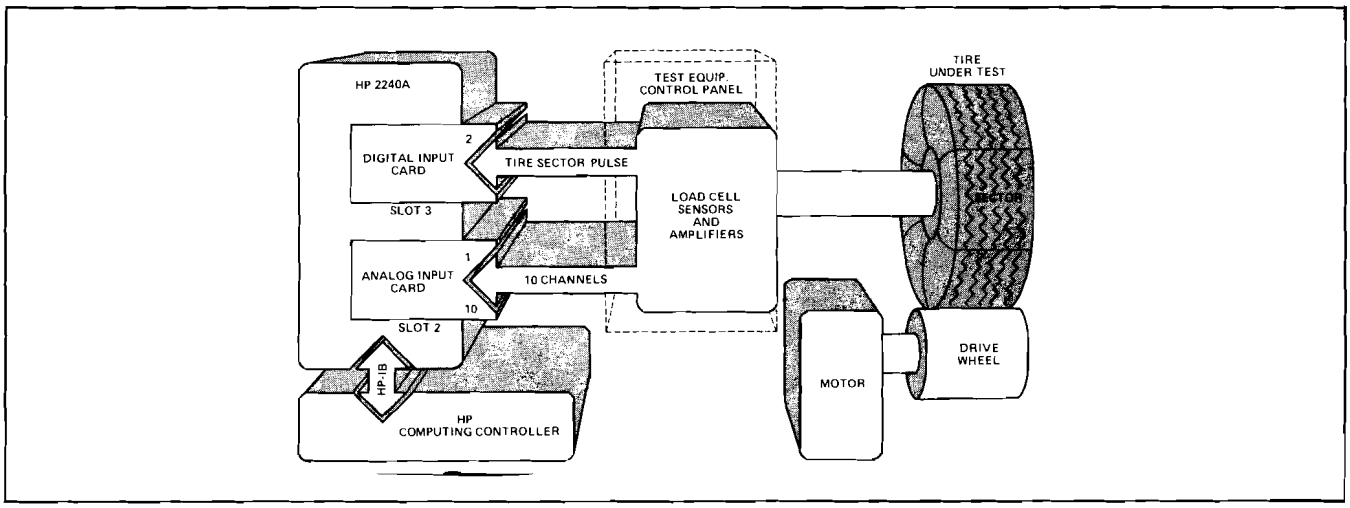
- RP-NX — Repeat — Next (looping capability)
- IF-EI* — IF-End IF (decision making capability)
- IC — Interrupt Computer upon Task Completion
- IN — Interrupt Computer Now
- IE* — Interrupt Computer upon Error
- SN — System Normalize (Reset 2240 and all Cards to Normal State)
- PM — Processor Mask (Selectively disable internal 2240A interrupts)
- SM — Set Require Service Mask (set which 2240A conditions issue a computer interrupt)
- BK — Block Current Result (Transmit current result as multiple data messages)
- BD — Block Default (Transmit all future results as multiple data messages)
- MB* — Mark Bin (Subdivide 2240A Buffer into user defined "bins")
- CB* — Close Bin (Seal current bin and continue to next bin)
- EX* — Exit a specified level of RP-NX loops (or terminate request)

• Test and Verification Commands

- AC — Analog Calibration
- AE — Analog Autocalibration Enable
- AD — Analog Autocalibration Disable
- CT — Counter Test
- VE — Verification Echo (for HP-IB communications testing)
- OT — Offline Test (for 2240A control card testing)
- SC — Read System Configuration

* Available with Extended Performance Option (see section 6).

For specific function card programming examples, consult the data sheets in section 3.

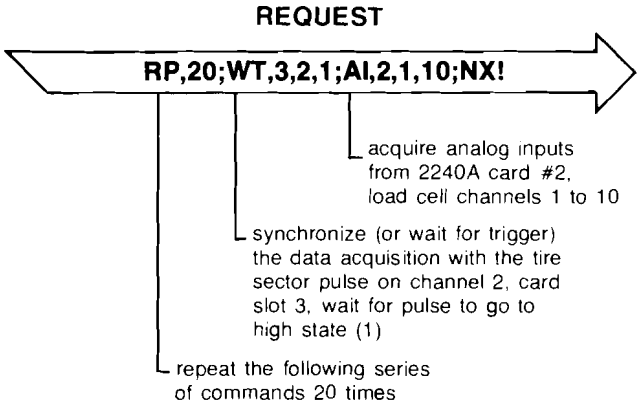


Tire Equipment Measurement and Control Example

Simplified Programming Example

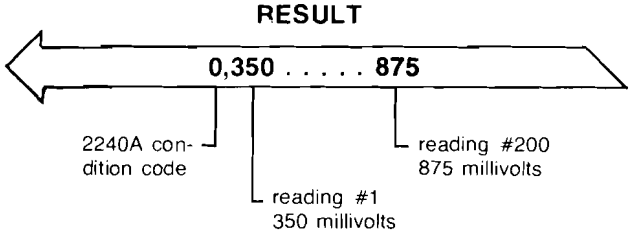
A tire equipment measurement and control application will demonstrate the simplicity of programming the HP 2240A. In this application the HP 1000 computing controller delegates HP-MCL to the HP 2240A to measure out-of-round forces on a rotating tire (see test setup diagram). This is done simply with two HP FORTRAN statements:

```
    WRITE(12,101)
101 FORMAT("RP,20;WT,3,2,1;AI,2,1,10;NX!")
```



The RP,20 . . . NX loop decouples the 2240A from the HP controller for 20 tire sector scans of 10 readings each. The 2240A buffers all 200 readings, formats the data and waits for HP controller to read the result with the single FORTRAN statement:

```
READ(12,*) CODE,MVOLT
```

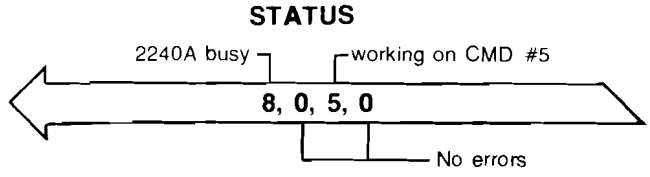


Result data is returned in the same order as it was requested by the commands, with a *condition code* as a message header. In the FORTRAN READ statement, 12 is the HP-IB device number and CODE is the HP-IB condition code (0 = no errors in executing task). The 200 analog readings are read in "free-field:: format (*), stored in an integer array MVOLT, and are immediately available for processing.

HP 2240A Immediate Status

The HP 2240A uses HP-IB secondary addresses or special character sequences to differentiate status reads from normal requests. Your program can ask for HP 2240A status at any time, even interrupting the transmission of a long request or result message. The HP FORTRAN statements are shown below.

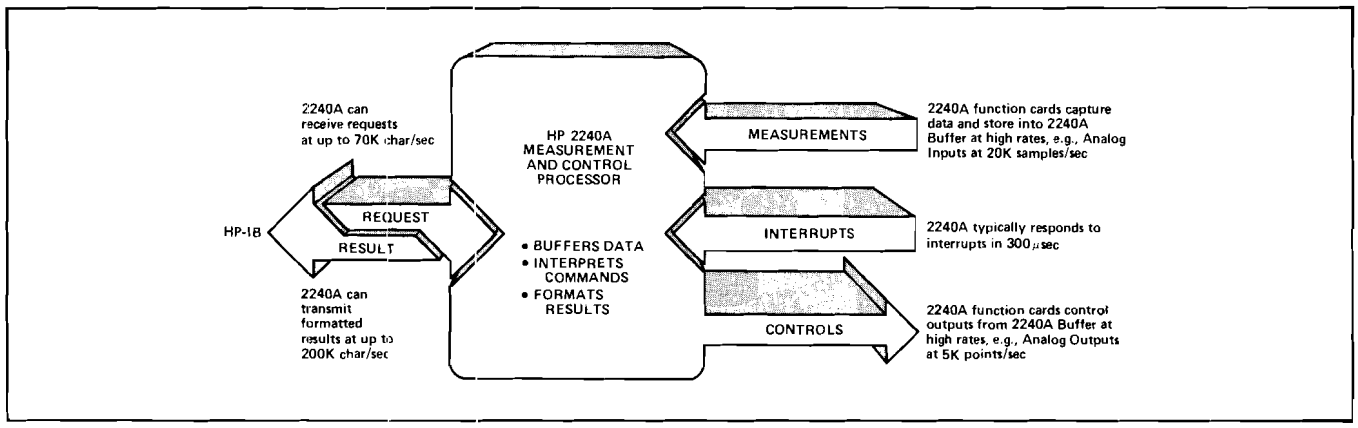
```
    WRITE(12,102)
102 FORMAT("$T2")
    READ(12,*)SUMRY,ERROR,NUMBR,MISC
```



The HP 2240A immediate status addresses are summarized in the table below.

HP 2240A IMMEDIATE STATUS

TYPE	SECONDARY ADDRESS (SPECIAL CHARACTERS)	INFORMATION
Summary	1 ($T1)	2240A summary status (busy, result, ready, error, etc.)
Extended	2 ($T2)	More details on 2240A status (error type, command being processed, etc.)
Interrupt	3 ($T3)	Why the 2240A interrupted. One status READ captures all pending interrupts from processor and function cards, down to the single channel level.



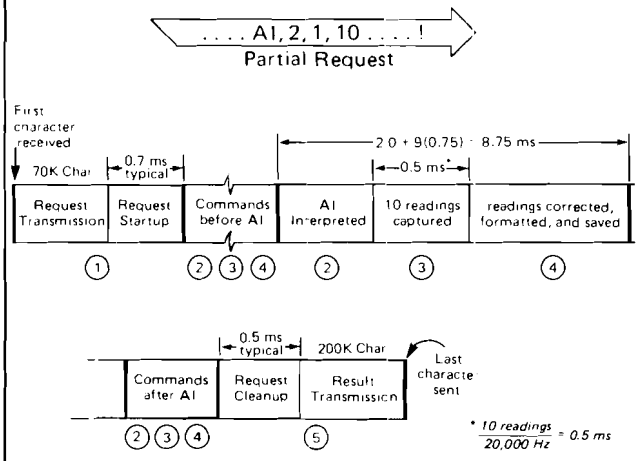
Typical HP 2240A Decoupled Data Rates

HP 2240A Performance: decoupled operation allows better performance prediction

With decoupled HP-MCL task operation your HP 2240A is relieved from computer software uncertainties, allowing better prediction of the performance of the measurement and control portion of your application. Typical HP 2240A decoupled data rates are shown on the simplified 2240A processor diagram.

Using known execution times of the 2240A processor, the delegated HP-MCL task becomes more self-contained and its performance more predictable. The task timing can be computed by adding up the elements of request execution time, as summarized at the left.

Timing Elements of an HP-MCL Request



You can add up the timing elements of any request to predict its worst case execution time.

(1) **Request Transmission or Startup**

After receiving a request at up to 70,000 characters/sec and 0.7 ms for Startup, the 2240A begins executing commands. It works left-to-right, processing each command and its data entirely before going on to the next.

Command Execution

The 2240A processes all commands similarly whether they capture data, control outputs, synchronize, or supervise.

(2) It interprets the command and prepares any output data.

(3) It rapidly captures all data for a measurement command, or updates all output channels for a control command.

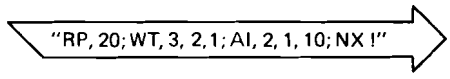
(4) It corrects (analog), formats, and saves in the buffer any captured data.

(5) **Cleanup and Result Transmission**

After the last command is executed plus 0.5 ms for cleanup, the 2240A is ready to begin transmitting the result at up to 200,000 characters/sec.

Sample computation of performance

Taking the tire equipment measurement and control application example given previously in page 2-2, the measurement of ten load cell sensors is triggered by the rotating tire sector pulses. The computation of sampling time for each sector and for the complete request is shown below. The task is defined by the single request statement:



HP-MCL COMMAND	EXECUTION TIME IN MILLISECONDS
Request receipt and startup	$\frac{26 \text{ bytes}}{70\text{K char/sec}} + .7 = 1.1$ ms
RP, 20	.55 ms
WT, 3, 2, 1,	.9 ms
AI, 2, 1, 10	2.0 + 9(.75) = 8.75 ms
NX	.35 ms
Request cleanup and result transmission	$.5 + \frac{200 \times 6 \text{ bytes}}{200\text{K bytes/sec}} = 6.5$ ms

The predicted execution time for this inner measurement loop is
.9 + 8.75 + .35 = 10.0 ms
or
the maximum number of loop executions per second
$\frac{1}{10.0 \text{ ms}}$ = 100 loops per second

The total execution time for the 2240A Request/Result is
1.1 + .55 + 20(10.0) + 6.5 = 208 ms
or
the maximum number of such tasks per second
$\frac{1}{208}$ = 4.8 tasks per second

This computation gives a good estimate of worst case performance. Transmission rates may be limited by your controller. Interrupts may delay execution about 300 μsec per interrupt. Where timing is critical, a command can be used to shut off interrupt sources during the remainder of the request.

The following table gives performance in a simple-to-use form for several commands. Use those numbers as we have in the sample at the left to predict 2240A performance in your application.

PERFORMANCE OF SELECTED HP-MCL COMMANDS

2240A Command	EXECUTION TIME IN MILLISECONDS: First Channel or Field (ms)	EXECUTION TIME IN MILLISECONDS: Each Add'l. Channel or Field (ms)	Keyed Comments*
MEASUREMENT			
AI	2.0	.75	A
RI	2.0	.75	A
DI	1.2	.25	B
FI	1.5	.65	C
RC	1.5	.65	D
CONTROL & STIMULUS			
AO	1.6	.75	E
DO	1.6	.6	F
FO	1.5	.65	G
SS	1.5	—	H
SYNCHRONIZATION AND TIMING			
WT	.9	—	
WB	.5	—	
TI	.9	—	I
TE	1.2	—	I
TASK SUPERVISION			
RP	.55	—	
NX	.35	—	
IC	.4	—	
TEST AND VERIFICATION			
VE	1.5	.9	J
OT	3 seconds		K
IMMEDIATE STATUS			

Execution Times are worst case ignoring delays due to interrupts. Note that the times shown for additional channels include the time for correction and formatting and do not indicate the rate at which channels are actually scanned or updated. See the comments below keyed to each command for typical rates.

A Maximum 20 kHz scan rate into buffer across channels, or 20 kHz sample rate on one channel for 250 - 300 sample buffer load. This rate can be guaranteed using a special command which inhibits interrupts. An additional 0 - 50 μsec is required when crossing a card boundary.

B Sequential digital points are gathered into HP 2240A buffer at a rate of 90 μsec per point (11,000 points/sec).

C 16-bit fields of digital points are gathered into 2240A buffer at a rate of 70 μsec per field (14,000 field/sec).

D Totalizer counts at 500 kHz maximum. Frequency counter at 500 kHz maximum. Period counter at 100 kHz maximum.

E Maximum analog output update rate from 2240A buffer is 200 μsec per point (5,000 points/sec).

F Sequential digital output points are updated from 2240A buffer at a rate of 450 μsec per point (2,200 points/sec).

G Sequential 16-bit fields of digital outputs can be updated from 2240A buffer at a rate of 250 μsec per field (4,000 fields/sec).

H Adjustable stepper pulse output rates to 500 pulses/sec.

I Interval Timer (TI) and elapsed time counter (TE) are updated every 10 milliseconds.

J Time for each ASCII integer to be echoed on HP-IB.

K Allow 3 seconds for Offline Verification Test before initiating further commands.

** Data gathering and update rates are typical.*

Type	Execution Time
Summary status	1.0 ms
Extended status	1.3 ms
Interrupt status	2.2 ms + 0.4 ms per interrupting card

Complete Command Timing for all 48 commands is available in the HP 2240A Users Manual (02240-93001). Contact your local HP Systems Engineer for performance predictions tailored to your application.

HEWLETT hp PACKARD

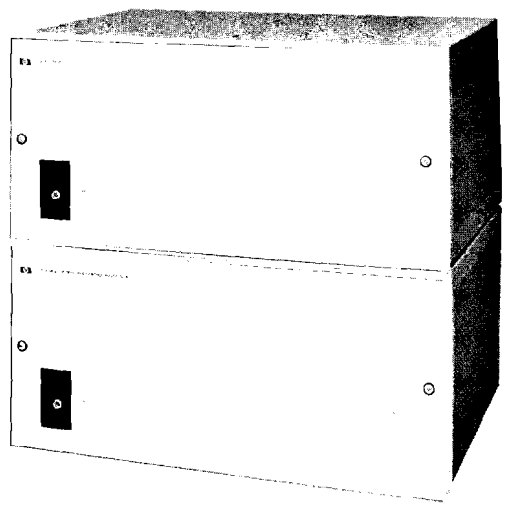
Measurement and control processor

Measurement and control processor extender

models
2240A
2241A

Features

- Microprocessor control of measurement and control cards
- Combined digital and analog I/O capability
- Easy to understand operation
- Powerful high level HP-MCL programming
- HP-IB* compatibility gives flexibility of choice of computing controllers
- Adaptive drift correction for analog input
- Verification without need for computer controller
- Submitted for UL listing



Description

HP 2240A MEASUREMENT AND CONTROL PROCESSOR MAINFRAME

The 2240A Measurement and Control Processor consists of a bench top or rack mountable mainframe with self-contained power supply, printed circuit backplane, and a control card. The control card (see functional block diagram below) contains the microprocessor, HP-IB interface, firmware routines (6K x 16-bit ROM's) for execution of measurement and control functions and verification tests in conection with an available test fixture, and 2K bytes of RAM memory for command and data storage.

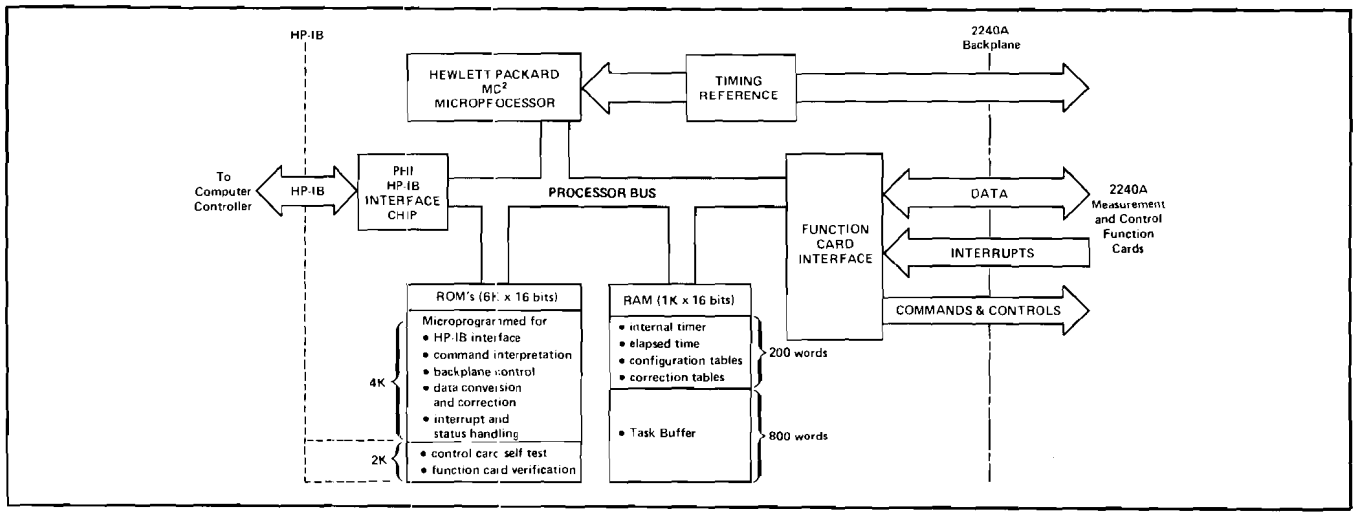
The 2240A holds four optional measurement or control function cards which can provide a mix of up to 128 analog and/or digital I/O points. A 2241A Extender holds an additional four optional function cards which are addressed through the 2240A for a total capacity of 256 analog and/or digital I/O points.

The 2240A mainframe has a ready lamp which shows the 2240A has passed a self-test which is administered by the microprocessor at power on or under program control. With the front cover removed, the 2240A has an additional 5 indicator lights that provide error information during the microprocessor controlled self test and a summary of activity during normal operation. This same activity information is available as summary status under program control.

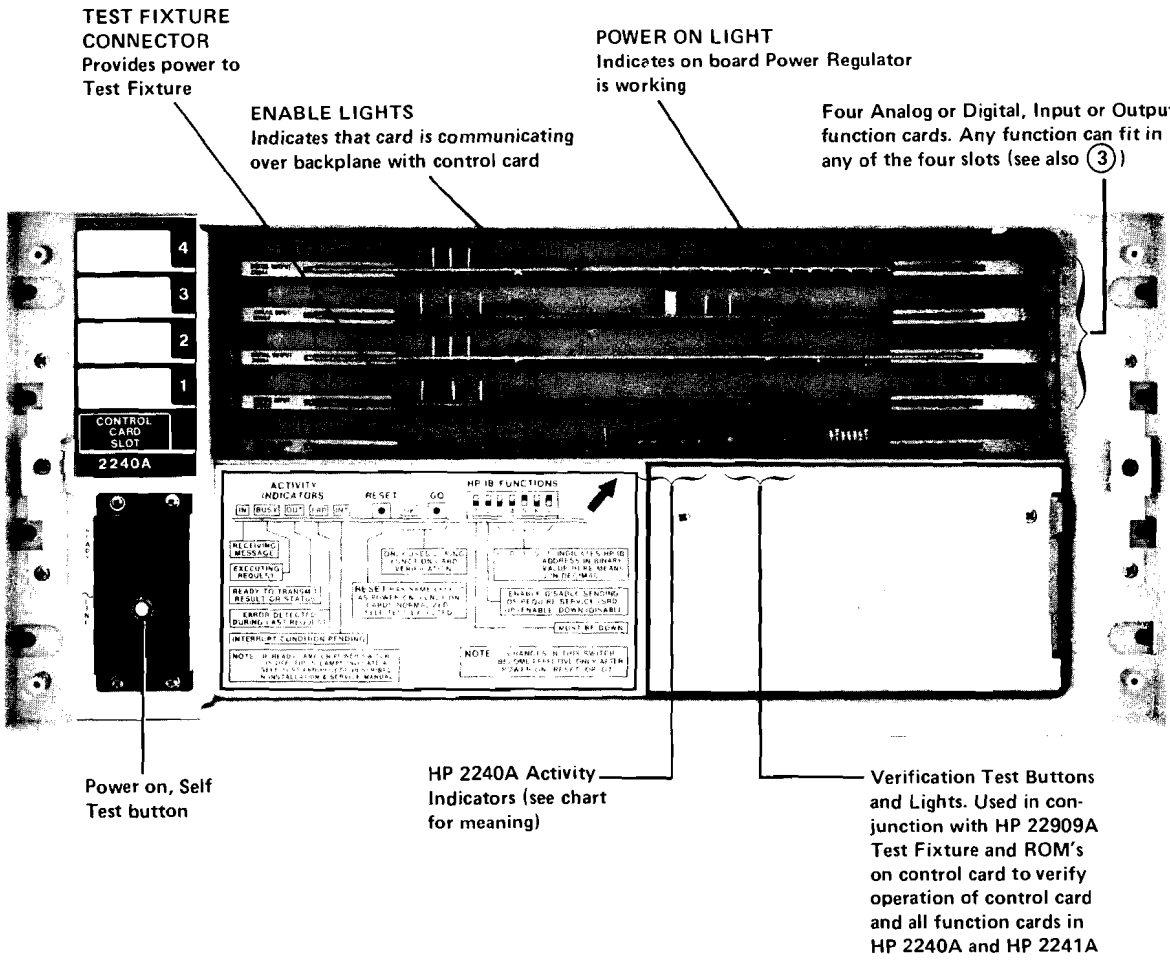
HP 2241A MEASUREMENT AND CONTROL PROCESSOR EXTENDER

The 2241A Extender is identical to the 2240A mainframe minus the microprogrammed HP-IB control card. Interconnecting cables to the 2240A are supplied with the 2241A.

HP's implementation of IEEE Standard 488 and ANSI Standard MC1.1 "Digital Interface for Programmable Instrumentation."



HP 2240A Control Card Functional Block Diagram



FRONT VIEW OF HP 2240A
(with front panel cover removed)

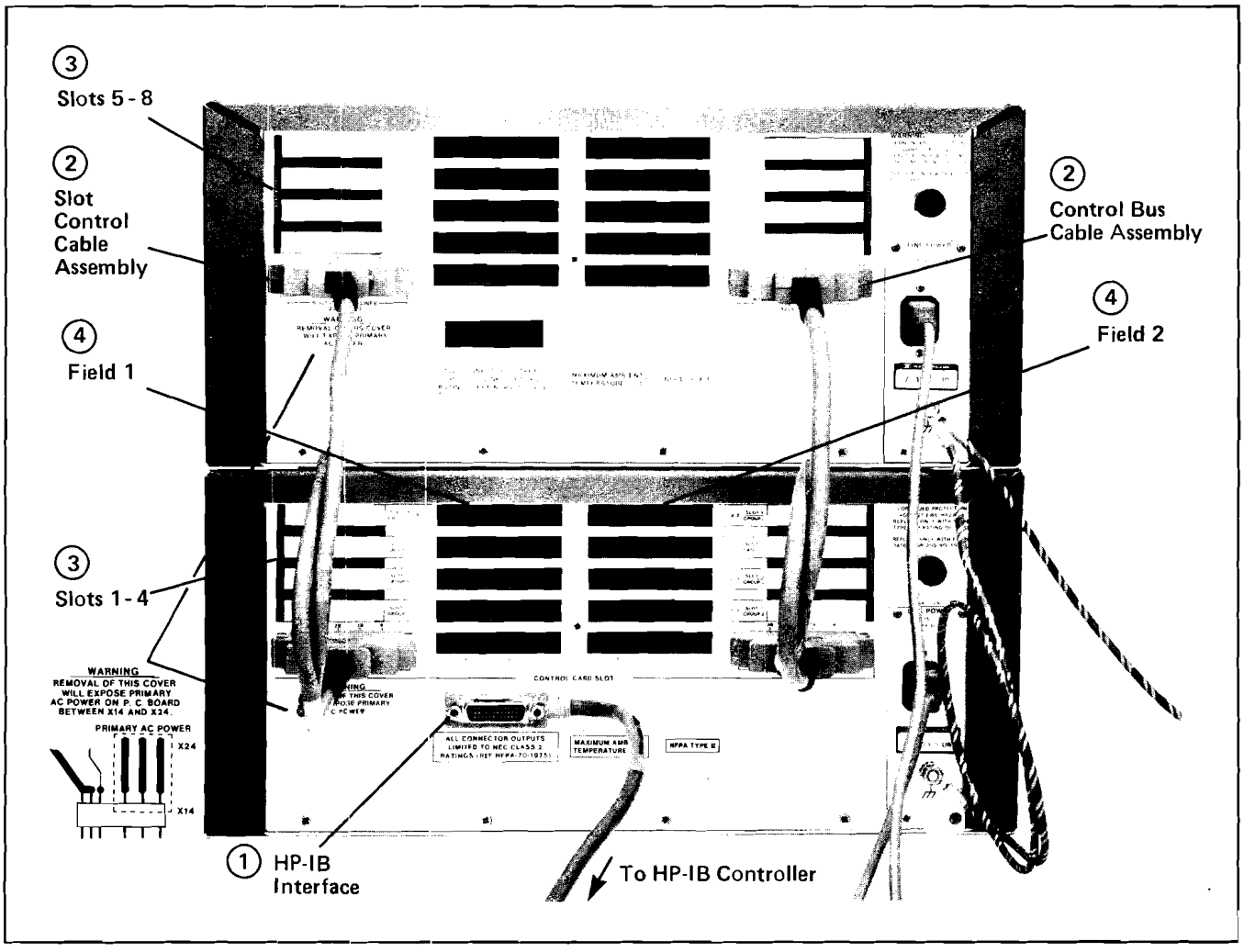
HP 2240A/2241A INTERCONNECTION (see photo below)

(1) **HP-IB Interface** – The HP-IB cable from the HP-IB controller hooks easily to the 2240A. Up to 14 total 2240A/2241A sets can be connected to one HP-IB port giving up to 3584 analog and/or digital I/O points.

(2) **Simple 2240A/2241A Interconnection** – The 2240A is easily connected to the 2241A via 2 cable assemblies. The slot control cable assembly allows the 2240A to specify which slot is addressed in the 2241A and provides for the communication of interrupts (Require Service) from the card in the 2241A. The control bus cable assembly provides for data and command flow between the 2240A and 2241A.

(3) **Plug-in Cards** – Up to 8 I/O cards can be controlled by each 2240A. A total of 112 I/O cards with multiple 2240A's is possible on one HP-IB interface. These cards can be mixed in any order and type within mainframes or extenders.

(4) **Flexible Addressing via Single Channel or Multiple Channel Commands** – Each of the slots in the 2240A and 2241A is separated into 2 groups of 16 channels each called a field. With the appropriate card in the slot, each of the fields may be addressed on a single channel basis or as a 16 channel field.



Rear View of HP 2240A/HP 2241A Interconnection

PROGRAMMING STRUCTURE

There are 48 HP-MCL commands that are associated with the 2240A/2241A and the function cards. These commands use the Request/Result protocol described earlier for communication between the controller and the 2240A/2241A. Tables 1 through 3 show 24 of these commands in functional groups that pertain to the 2240A/2241A as a subsystem or that apply to multiple cards. The remaining 24 HP-MCL commands using Request/Result appear with the specific function card to which they apply. In addition, a special protocol allows the user to determine at any time the internal condition of the 2240A, including pending interrupts. This is shown in Table 4.

Test and Verification Commands

Testing of the 2240A off-line, establishing the system configuration, verifying the operation of the HP-IB interface and checking the operation of the ADC and common interrupt card are accomplished by this set of commands. In addition, these functions can also be done under program control. Additional off-line testing of function cards is accomplished by using the 22909A Test Fixture.

Table 1

COMMAND	FUNCTION
OT	OFFLINE TEST: Abandon current request, go offline from HP-IB, run self test, and re-initialize the 2240A. (Also occurs at power-on.)
SC	SYSTEM CONFIGURATION: Return card types and number of channels for all 8 possible slots. This information is gathered and saved only at initial power-on and following execution of the OT command.
SW	SEQUENTIALLY WRITE SIMULATED INTERRUPTS: Allows simulation of inputs to common interrupt card to test for the proper operation of the sense and mask registers in generating interrupts.
RR	REPETITIVELY READ ADC 10 OR 0 V REFERENCE: Verifies proper operation of majority of ADC card without disconnection.
VE	VERIFICATION ECHO: Echo the specified parameters back to controller to verify the HP-IB operation or to simulate data input.

Synchronization Timing, and Pacing Commands

These commands enable the 2240A Measurement and Control Processor to synchronize the inputs and outputs of function cards and to utilize an 8-hour clock for time interval interrupt capability and elapsed time monitoring. Basic timing is derived from a 0.01% crystal reference. For a complete discussion on timing and the effect of interrupts on accuracy, see the HP 2240A User's Manual.

Table 2

COMMAND	FUNCTION
WB*	WAIT BEFORE EACH CARD I/O: Wait the specified time before all subsequent inputs or outputs to cards in the current request. (1 ms resolution.)
WN*	WAIT NOW: Wait the specified time before proceeding with request processing. (1 ms resolution.)
WT*	WAIT FOR TRIGGER: Wait until specified logic level occurs on a digital input or common interrupt channel.
WU	WAIT UNTIL: Wait until elapsed time is equal to or greater than the time specified in the command. (1 ms resolution.)
TE	READ TIME ELAPSED: Read time ins sec and msec from elapsed time counter. (10 ms resolution.)
TI	TIME INTERVAL PRESET: Preset the interval timer to interrupt the controller (Require Service) after the specified time delay.
TP	ELAPSED TIME PRESET: Preset elapsed time clock. Count will roll over to 0 at time of 28800 seconds (8 hours). (10 ms resolution.)

* *Interrupts may be disabled for best timing/triggering accuracy.*

Task Supervision Commands

This set of commands provides the 2240A Measurement and Control Processor with the capability to request service from a controller at an appropriate time during a test or process, set up loops within its own requests, block data into the optimum format, and normalize to a known ready state.

Table 3

COMMAND	FUNCTION
IC	INTERRUPT ON COMPLETION: Interrupt controller (Require Service) upon completion of the current request.
IN	INTERRUPT NOW: Interrupt controller (Require Service) when command is encountered, and then proceed to process any other commands in the current request.
RP	REPEAT: Repeat the following series of commands, between the RP and the NX command, for the specified number of times.
NX	NEXT: End of the repeat series initiated by the last RP command.
SN	SYSTEM NORMALIZE: Resets cards, internal timer, interrupts, blocking, and interrupt (Require Service) mask; re-enables ADC auto-calibration.
PM	PROCESSOR MASK: Select which internal functions are permitted to interrupt processing of the current request.
SM	SET REQUIRE SERVICE MASK: Select which conditions can cause a controller interrupt (Require Service). Power ON default values determined by switch on front of control card.
BK	BLOCK CURRENT RESULT: Transmit current result as multiple data messages. Set maximum number of free-field data items for each message.
BD	BLOCK DEFAULT: Transmit current and future results as multiple data messages. Set maximum number of free-field data items for each message.

Immediate Status

The 2240A uses HP-IB secondary addresses or character sequences (e.g., $T1) to differentiate status reads from normal requests. A program can ask for status at any time, even interrupting the transmission of a long request or result.

Table 4

Type	Secondary Address (special characters)	Information
Summary	1 ($T1)	Current activity of 2240A: Request being received, busy executing, result ready, error in last request, or interrupt pending.
Extended	2 ($T2)	More details: which command is being executed, type of error, if any.
Interrupt	3 ($T3)	Why the 2240A interrupted: pending interrupts from processor and function cards down to the single channel level. Clears pending interrupts.

Interface Specifications:

The 2240A requires an electric and mechanical interface compatible with IEEE Standard 488-1978. In addition, the programming interface must be capable of handling 5 *messages* sent or received on the HP-IB. These five are: *Data* message, *Require Service* message, *Status Byte* message, a *Clear* message, and an *ABort* message. Details on these messages can be found in HP 2240A Measurement and Control Processor User's Manual (02240-93001).

Physical Dimensions (width x height x depth):

2240A: 48.26 cm (19 inches) x 22.23 cm (8-3/4 inches) x 35.56 cm (14 inches); Net Weight: 13.8 kg (30.4 lb.)

2241A: 48.26 cm (19 inches) x 22.23 cm (8-3/4 inches) x 35.56 cm (14 inches); Net Weight: 13.1 kg (28.8 lb.)

(Net weight of 2240A/2241A does not include function cards.)

Environmental:

Temperature:

Operating: 0 to 55° C (2240A air intake ambient)

Non-operating: -40° C to 75° C

Humidity: 10 to 95% relative humidity non-condensing @ 40° C

Power Requirements:

Voltage (AC single-phase): 120V +6%, -28%; 240V +6%, -28%

Current: 1.4A maximum @ 127 VAC, 0.7A maximum @ 253 VAC, including worst-case cards.

Power: 130 watts maximum (including function cards)

Frequency: 48 - 66 Hz

Product Safety: The HP 2240A/2241A has been submitted to Underwriters Laboratories for listing (bench top version only) and recognition (rack mounted version) under the Process Control Standard 1092, with complimentary listing and recognition under Data Processing Equipment (UL478) and Office Appliances (UL114).

In addition, the signal conditioning cards (22912A, 22913A, 22914A), the signal conditioning tray (22920A) and the general purpose screw termination tray (22922A), are in the process of being submitted to Underwriters Laboratories for recognition under the same categories.

Prerequisites

2240A: HP-IB Interface and cable and one 22909A Test Fixture (pg. 24) per facility for installation

2241A: 2240A (one 2241A per 2240A)

Hardware Supplied

HP 2240A Measurement and Control Processor including AC power cable, and microprocessor-based control card with HP-IB interface. It includes ROM's (firmware) which implements the following request/result protocol, all commands to all function cards, immediate status, self test, and function card verification.

HP 2241A Measurement and Control Processor Extender including AC power cable, slot control line cable (02241-60002), and control bus cable (02241-60003).

Input/output cables from the function cards in the 2240A or 2241A to signal conditioning cards in the 22920A and to termination strips (22922A) *are not* provided with the 2240A or 2241A. See the Cable Assemblies data sheet (Models 22906A, 22907A, and 22908A) for ordering information.

Software Supplied

2240A: None required. User program communicates directly with 2240A firmware via READ and WRITE statements or equivalent.

2241A: None required.

Documentation Furnished

2240A: HP 2240A Installation and Service Manual (02240-93003), HP 2240A Measurement and Control Processor User's Manual (02240-93001), and HP 2240A Quick Reference Guide (02240-93005).

2241A: All information on the 2241A function cards, signal conditioning and accessories are also included in the manuals supplied with the 2240A.

Accessories

22909B: The 22909B consists of a test fixture, a function card extender board, and control and function card cables that allow calibration and maintenance adjustments. Complete maintenance of the 2240A require spare boards and parts in addition to test equipment specified in the 2240A Installation and Service Manual.

22910B: The 22910B consists of a power supply extender that allows withdrawal of the internal 2240A/2241A power supply for dynamic testing.

22911A: Bench top cover for the 2240A/2241A. Required for bench top applications (not used in rack mounted applications). Physical dimensions (width x height x depth): 48.26 cm (19 inches) x 22.23 cm (8.75 inches) x 33.66 cm (13.25 inches); Net Weight: 144 kg (3.25 lb.)

Ordering Information

For the entire 2240A family, the products are ordered as the product number with the appropriate option number if required. Field upgrades use the same product numbers.

Installation

The 2240A/2241A mainframe, function cards, signal conditioning, and accessories are customer installed products. A test fixture (22909A) is required per customer facility for operational checks of the function cards. Complete instructions for installation are contained in the HP 2240A Installation and Service Manual. Hewlett-Packard will provide installation services on a time and material basis. Customers desiring this installation service should contact their local Hewlett-Packard sales office.

Warranty

All Hewlett-Packard software products, computers, components, and systems are covered by warranty for a minimum of 30 days or a maximum of 90 days, depending upon the type of product and the conditions of purchase. For specific information, contact your Hewlett-Packard Sales Representative.

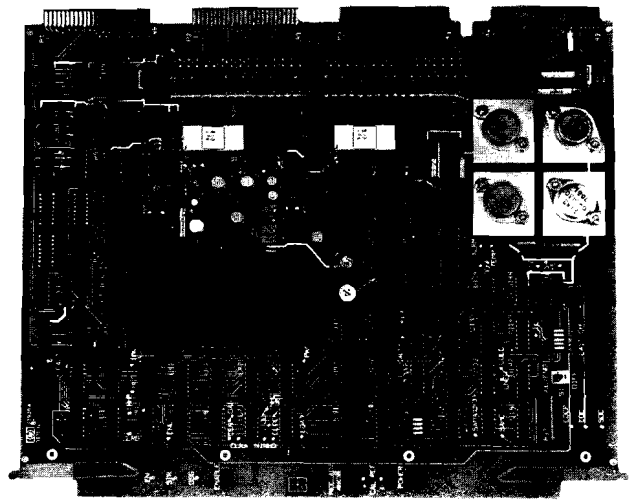
HEWLETT hp PACKARD

16/32 Channel analog input

model 22900A

Features

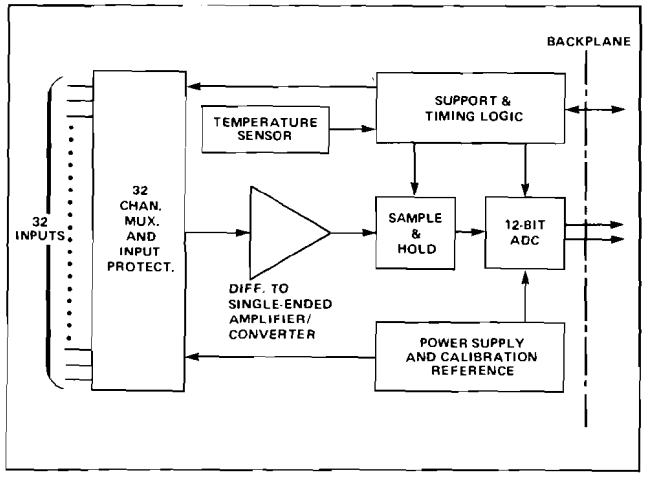
- **16 non-isolated differential or 32 non-isolated, single-ended, solid state multiplexed channels (jumper-selectable)**
- **CMOS Multiplexer with 12-bit, 20 kHz successive approximation ADC and sample and hold**
- **Operates in 3 modes — random, sequential, and repetitive (single-channel sampling)**
- **±10V inputs, overvoltage protection**
- **Adaptive temperature drift correction**



Description

The 22900A A/D Converter and Multiplexer card provides the capability of converting 32 single-ended or 16 differential analog voltage inputs to digital form. Each card is dedicated for either differential or single-ended inputs.

A unique feature of this card is a self-check and adaptive drift correction feature using a highly stable reference supply and a temperature sensing circuit. The adaptive drift correction is performed automatically or it can be requested under program control.



HP 22900A Functional Block Diagram

Specifications

Resolution: 12 bits including sign; LSB = 5 mV
Input Channel Span: 20 volts
Input Channel Range: -10 to +10 volts
Common Mode Rejection (CMR): ⩾ 80 db DC to 100 Hz

Sample and Hold:
- Aperture Time: < 250 ns
- Delay: < 220 ns

Crosstalk (differential mode):
- Common Mode Crosstalk: 80 db DC to 100 Hz
- DC Crosstalk: 80 db

Input Overload Crosstalk: Readings on other channels in specification with a maximum of ±15V on any one channel.

Input Overload Protection: Diode resistor clamping
- Steady State: Up to ±15V on any one input line to ground or to another input.
- Transient: ±42V for 500 ms without damage.

Effective Input Impedance:
- Power Off: 1KΩ (±10%) to ground, 2KΩ (±20%) to any other channel.
- Power On: ⩾ 5MΩ
- Source Impedance: Up to 1KΩ
- Source Imbalance: Up to 1KΩ
- Common Mode Return: Up to 10KΩ maximum

Accuracy:*
- With Drift Correction:
  - Accuracy at 0 - 55°C ambient: ±0.05% of input channel span ±½ LSB (after 5-minute warmup).
- No Drift Correction:
  - Accuracy at 25°C: ±0.037% of input channel span ±½ LSB (after 5-minute warmup), ±0.02%/30 days of input channel span.
  - Temperature Coefficient: ±0.002%/°C of input channel span.
- Maximum Voltage for Rated Accuracy:
  - Differential Input: Differential ⩽ ±10V; common mode voltage ⩽ ±10V; sum ⩽ ±10V.
  - Single-Ended Input: Between input and common ⩽ ±10V.

Repeatability: ±0.025% input channel span

Throughput to 2240A Buffer: Up to 200 - 300 samples (depending on the magnitude) at 20 kHz rate with microprocessor interrupts disabled. (See HP 2240A/HP 1000 System Performance, pages 16 - 17.)

Physical Characteristics:
- PC Board: 34.80 cm (13.7 inches) long; 28.91 cm (11.38 inches) wide.
- Net Weight: 0.7 kg (1.6 lb.)

Power Required: 8 watts

Environmental: Same as 2240A Measurement and Control Processor.

**With respect to the voltage standard used as the reference during user calibration. Accuracy includes linearity, offsets, gain calibration transfer and dynamic response errors, ±10% line voltage variation. It includes multiplexer, sample and hold, amplifier and ADC.*

Prerequisite

2240A or 2241A (1 slot)

Hardware Supplied

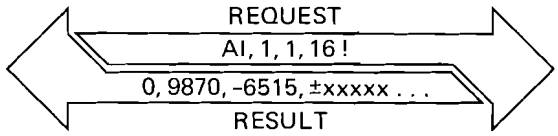
22900A 20 kHz 12-bit ADC

Software Supplied

None required

Programming Example

Scan 16 analog channels from 22900A in slot 1 and return the data in corrected millivolts.



Where:

AI = READ Sequential ADC channels and return readings as corrected millivolts.
1 = Start at slot 1
1 = Start at channel 1
16 = Scan 16 channels

0 = Condition code, 0 or 1
0 = no errors
9870 = 9870 mV = 9.870V (Channel 1)
-6515 = -6515 mV = -6.515V (Channel 2)
±xxxxx = General format of returned data, -10000 to +10000 mV, step size 5 mV.

TABLE OF 22900A HP-MCL COMMANDS

COMMAND	FUNCTION
AC	ANALOG CALIBRATE: Perform a temperature calibration on an analog input card, to update drift correction factors.
AD	ANALOG AUTOCAL DISABLE: Inhibits Auto Calibration cycle, which prevents automatic update of drift correction factors.
AE	ANALOG AUTOCAL ENABLE: Allows automatic updating of drift correction factors when temperature changes.
AI	ANALOG INPUT: Reads sequential analog input channels and corrects for temperature drift.
AU	ANALOG UNCORRECTED INPUT: Reads sequential analog input channels uncorrected for temperature drift.
RI	REPEATED ANALOG INPUT: Repeatedly reads analog inputs from a single channel and corrects for temperature drift.
RU	REPEATED ANALOG UNCORRECTED INPUT: Repeatedly reads analog inputs from a single channel which are uncorrected for temperature drift.

Note: For more details on 22900A commands, see HP 2240A User's Manual (02240-93001).

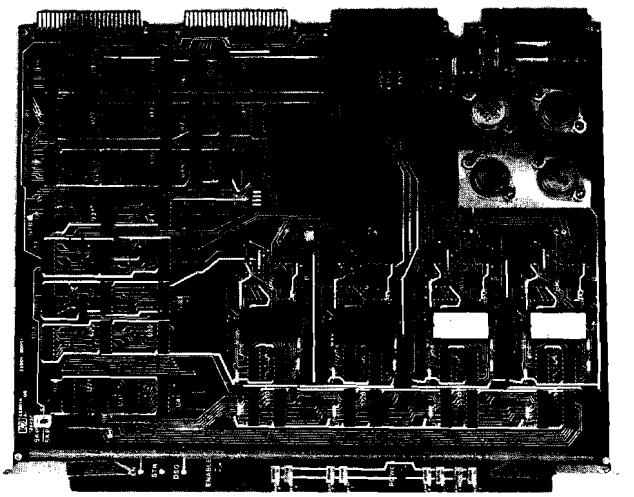
HEWLETT hp PACKARD

4-Channel digital-to-analog voltage converter

model 22901A

Features

- **4 independent channels**
- **10-bit non-isolated voltage D/A converters**
- **Bipolar or unipolar operation (jumper selectable)**
- **Kelvin connection per channel to maintain accuracy at load**
- **Automatic readback before output on first level storage for error checking**



Description

The 22901A D/A Voltage Converter card provides 4 independent digital-to-analog converter channels. Each channel is jumper selectable for bipolar or unipolar operation. Kelvin connections per channel compensate for line resistance giving more accurate outputs. Dual level storage for error checking (switch selectable) is also provided.

Specifications

Analog Output: 10-bit voltage output, non-isolated.
  Unipolar: 0 - 10.23 VDC @ 5 ma
  Bipolar: -10.24 to +10.22 VDC @ 5 ma
  Resolution: Unipolar 10 mv
    Bipolar 20 mv

Accuracy: ±0.1% full span @ 25°C
  Temperature Coefficient (0 - 55°C ambient):
    Offset: ±0.003% full span/°C
    Gain: ±0.010% full span/°C

Ripple and Output Noise: 5.0 mv P-P maximum, DC to 500 kHz

Settling Time: 100 μs to 0.1% of final value

Maximum Analog Output Update Rate From 2240A Buffer: 200 μs per point (5000 pts./sec). (See HP 2240A/HP 1000 System Performance, pages 16 - 17.)

Output Protection: can withstand indefinite short circuits.

Data Output Format: ± Millivolts

Physical Characteristics:
  PC Board: 34.80 cm (13.7 inches) long; 28.91 cm (11.38 inches) wide

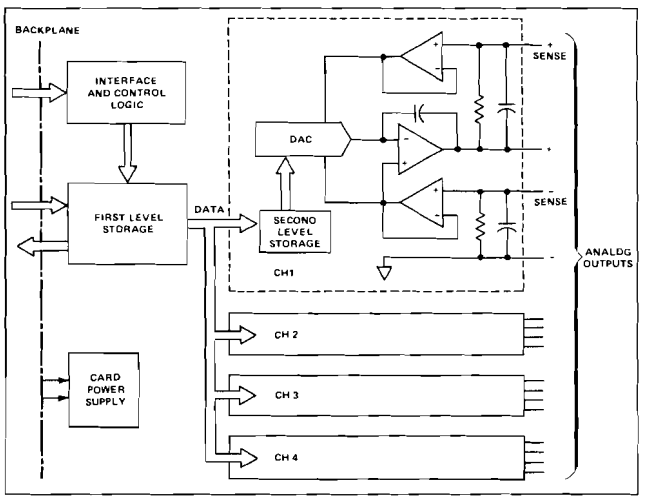
Net Weight: 0.6 kg (1.3 lb.)

Power Required: 9.3 watts

Environmental: Same as 2240A Measurement and Control Processor.

Prerequisite

2240A or 2241A (1 slot)



HP 22901A Functional Block Diagram

Hardware Supplied

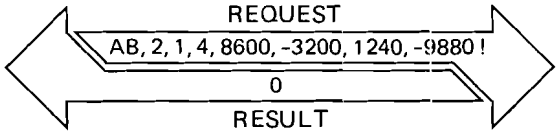
22901A 4-channel DAC

Software Supplied

None required

Programming Example

Output 8.6V, -3.2V, 1.24V, and -9.88V from 4 bipolar channels on DAC card in slot 2 of 2240A.



Where:

AB = analog bipolar output
2 = Start at slot 2
1 = start at channel 1
4 = Output 4 channels
8600 = output value in millivolts channel 1
-3200 = output value in millivolts channel 2
1240 = output value in millivolts channel 3
-9880 = output value in millivolts channel 4
0 = Condition code, 0 or 1
0 = no errors

TABLE OF 22901A HP-MCL COMMANDS

COMMAND	FUNCTION
AB	ANALOG BIPOLAR OUTPUT: Writes sequential bipolar analog output.
AO	ANALOG UNIPOLAR OUTPUT: Writes sequential unipolar analog output.
RO	REPEATED UNIPOLAR ANALOG OUTPUT: Outputs a sequence of voltages to a single unipolar analog output channel.
RB	REPEATED BIPOLAR ANALOG OUTPUT: Outputs a sequence of voltages to a single bipolar analog output channel.

Note: For more details on 22901A commands, see HP 2240A User's Manual (02240-93001).

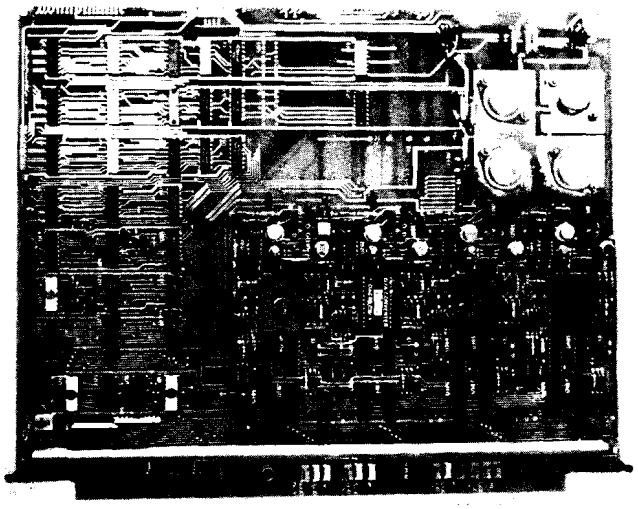
HEWLETT hp PACKARD

4-Channel digital-to-analog converter with voltage or current outputs

model 22901B

Features

- **Voltage or current outputs**
- **12 bit D/A Converter**
- **4 independent channels**
- **Bipolar or Unipolar Voltage Outputs**
- **Kelvin connections per channel to maintain accuracy at load (Voltage mode)**
- **Automatic readback before output on first level storage for error checking**



Description

The 22901B D/A converter card provides 4 independent digital-to-analog converter channels. Each channel is jumper selectable for Unipolar or Bipolar Voltage operation or 4-20 mA current operation.

Specifications

Analog Output: 12 bit voltage or current output, non isolated.

Unipolar: 0 to 10.23 VDC @ 20 mA
Bipolar: -10.24 to 10.22 VDC @ 20 mA
Current: 4 to 20.376 mADC, 700 ohm load max using internal supply, 1000 ohm load max with external 24 VDC power supply.
Resolution: Unipolar 2.5 mV
Bipolar 5 mV
Current 4 μA
Accuracy: ±0.025 full span (25°C), ±.1% (current)
Offset: Unipolar ± 0.0005% full span/°C
Bipolar ± 0.002% full span/°C
Current ± 0.0045% full span/°C
Gain: Voltage ± 0.004% full span/°C
Current ± 0.006% full span/°C

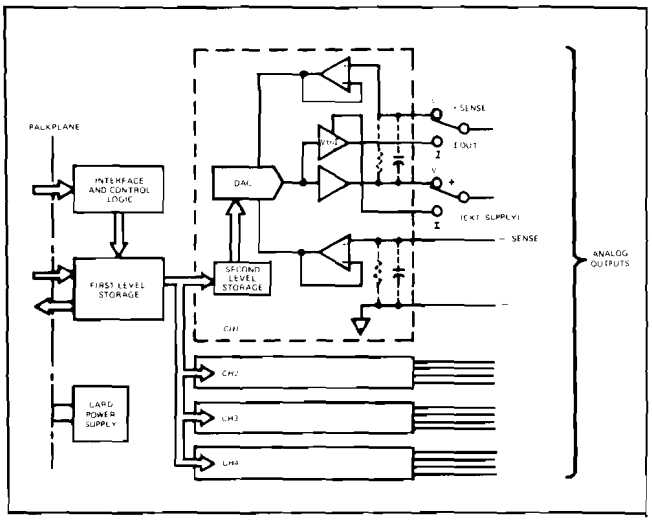
Ripple and noise: 5.0 mV P-P max DC to 500 KHz

Settling Time: 100μS to 0.1% of final value
Maximum Analog Output Update rate from 2240A Buffer: 200μsec/point

Output protection: Can withstand indefinite short circuit (voltage mode) or open circuit (current mode)

Data Output Format: Voltage mode ± millivolts; current mode % of .4-20 mA span; 0=4 mA, 1000=20 mA (1000=100% of span).

Physical Characteristics:
PC Board: 34.80 (13.7 inches) long; 28.91 (11.38 inches) wide



22901B Functional Block Diagram

Net Weight: 0.6 Kg (1.3 lbs)
Power Required: 10 Watts
+24 VDC @ 80 mA/Card for current outputs capable of driving 700-1000 Ohm loads (20 Volt compliance)
Environmental: Same as 2240A Measurement and Control Processor

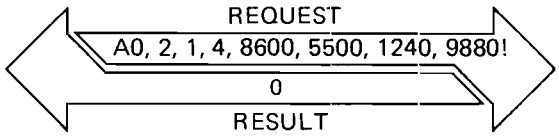
Prerequisite
2240A or 2241A (1 slot)

Hardware Supplied
22901B 4-channel DAC

Software Supplied
None required.

Programming Example

Output 8.6V, 55% of 4-20 mA, 12.4% of 4-20 mA, and 9.88V from 4 channels on DAC in card slot 2 of 2240A. Channels 2 and 3 are 4-20 mA outputs.



Where:

A0 = analog output
2 = start at slot 2
1 = start at channel 1
4 = output 4 channels
8600 = output value in millivolts channel 1
5500 = % of 4-20 mA span in .01% steps channel 2
1240 = % of 4-20 mA span in .01% steps channel 3
9880 = output value in millivolts channel 4

TABLE OF 22901B HP-MCL COMMANDS

COMMAND	FUNCTION
AB	ANALOG BIPOLAR OUTPUT: Writes sequential bipolar analog output.
AO	ANALOG UNIPOLAR OUTPUT: Writes sequential unipolar analog output.
RO	REPEATED UNIPOLAR ANALOG OUTPUT: Outputs a sequence of voltages to a single unipolar analog output channel.
RB	REPEATED BIPOLAR ANALOG OUTPUT: Outputs a sequence of voltages to a single bipolar analog output channel.

Note: For more details on 22901B commands, see HP 2240A User's Manual (02240-93001).

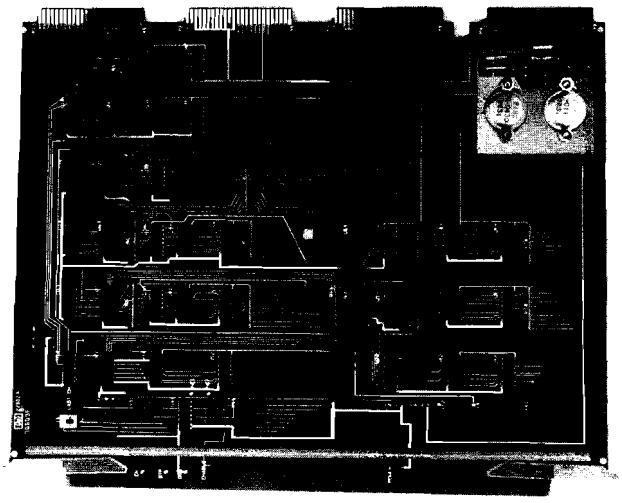
HEWLETT hp PACKARD

32-Channel digital input

model 22902A

Features

- **32 channels per function card**
- **TTL/CMOS compatible logic levels**
- **Input is single-ended, non-isolated voltage or contact sense (internal pull-up to 5V with no filter)**
- **Schmitt trigger input for improved noise immunity**
- **Monitors the binary state of each channel or in groups of 16 channels (a field) at a time.**



Description

The 22902A Digital Input card accepts 32 channels of either TTL or CMOS level inputs. Internal pull-up to +5V (with no filter) is provided for contact sense applications.

Specifications

Signal Input:

Voltage: HI: Maximum 15.0V, Minimum 4.3V } (Logic 1)

LO: Maximum 0.7V, Minimum -1.0V } (Logic 0)

Current: HI: @ 15V; 3.3 mA maximum, @ 4.3V; -0.3 mA maximum } (Logic 1)

LO: @ 0.7V; -1.5 mA maximum, @ -1.0V; -2.0 mA maximum } (Logic 0)

Source Contact Resistance (for Contact Sense):
HI (Contact Open): $\geq 25K\Omega$
LO (Contact Closed): $\leq 500\Omega$

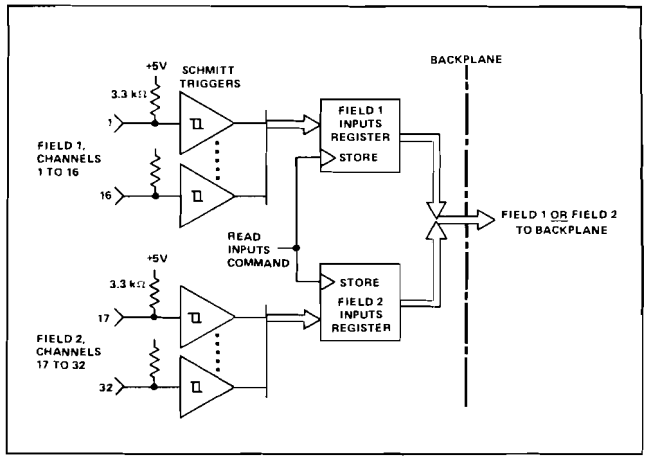
Maximum Operating Voltage:
$-1 \leq$ (common mode + signal) $\leq +15V$

Maximum Input Rate to 2240A Buffer:
Sequential Digital Points: 90 μs per point (11,000 points/sec)
16-Bit Fields: 70 μs per field (14,000 fields/sec)
(See HP 2240A/HP 1000 System Performance, pages 16-17.)

Input Protection: Input voltages between -10V and +20V with reference to 2240A ground will not cause damage.

Physical Characteristics:
PC Board: 34.80 cm (13.7 inches) long; 28.91 cm (11.38 inches) wide.
Net Weight: 0.5 kg (1.0 lb.)

Environmental: Same as 2240A Measurement and Control Processor.



HP 22902A Functional Block Diagram

Power Required: 2.5 watts maximum
Heat Dissipation: 3.1 watts maximum

Prerequisite

2240A or 2241A (1 slot)

Hardware Supplied

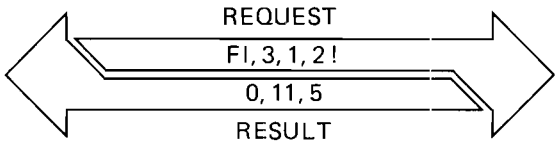
22902A 32-Channel Digital Input card

Software Supplied

None required

Programming Example

Read 2 fields of 16 channels sequentially and return decimal equivalent of each 16-bit field from 22902A card in slot 3.



Where:

FI = Read sequential 16 channel field
3 = Start at slot 3
1 = Start in field 1
2 = Read 2 fields
0 = Condition code, 0 or 1
0 = no errors
11 = Decimal equivalent of 16-bit field number 1
5 = Decimal equivalent of 16-bit field number 2

Binary Bit Pattern of Field 1

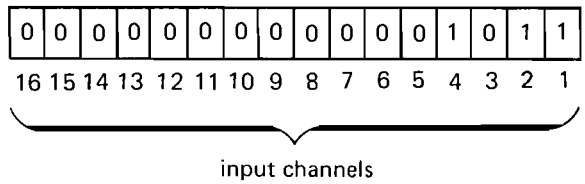


TABLE OF 22902A HP-MCL COMMANDS

COMMANDS	FUNCTION
DI	DIGITAL INPUT: Reads sequential single channel digital inputs.
FI	FIELD INPUT: Reads sequential 16 channel fields of digital input.

Note: For more details on 22902A commands, see HP 2240A User's Manual (02240-93001).

HEWLETT hp PACKARD

16-Channel common interrupt

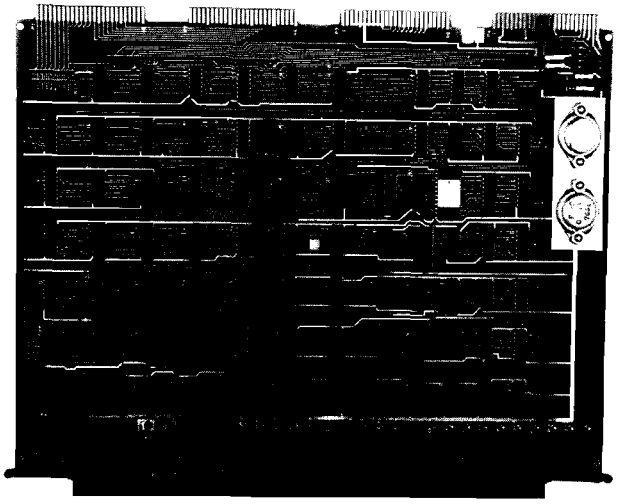
model 22903A

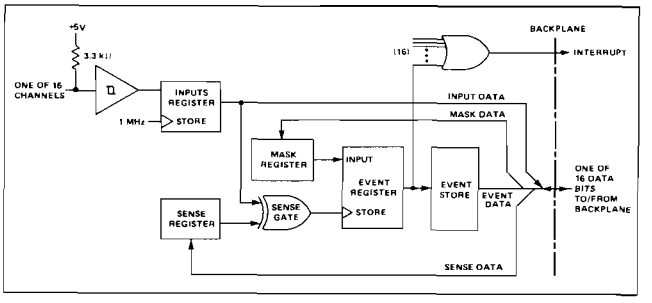
Features

- 16 channels per function card
- All single events saved until controller can respond
- Input characteristics same as HP 22902A
- Individually enabled channels under program control
- Programmable transition sense
- Ideal for event sense, or process interrupt applications
- Channels not required for interrupt monitoring can be status inputs

Description

The 22903A Common Interrupt card generates an asynchronous interrupt (requires service message on HP-IB) on change of state of any channel. It stores and identifies the interrupting channel. User can read interrupt status to find out details on card interrupt. Selection of which channels can interrupt (mask register) and the direction of the change of state (sense register) are both under program control. When the input line changes from the programmed sense state (0 or 1) the sense gate generates a store signal for the event register. The event register stores this event and generates an interrupt if the mask register is set for that channel. The card can also serve as a 16-channel digital input card in which case the data goes directly from the input register to the card/2240A interface and is available to be read by the HP-IB controller.





HP 22903A Functional Block Diagram

Specifications

Signal Input:

Voltage: HI: Maximum 15.0V, Minimum 4.3V } (Logic 1)

LO: Maximum 0.7V, Minimum -1.0V } (Logic 0)

Current: HI: @ 15V; 3.3 mA maximum, @ 4.3V; -0.3 mA maximum } (Logic 1)

LO: @ 0.7V; -1.5 mA maximum, @ -1.0V; -2.0 mA maximum } (Logic 0)

Source Contact Resistance (for Contact Sense):
HI (Contact Open): $\geq 25K\Omega$
LO (Contact Closed): $\leq 500\Omega$

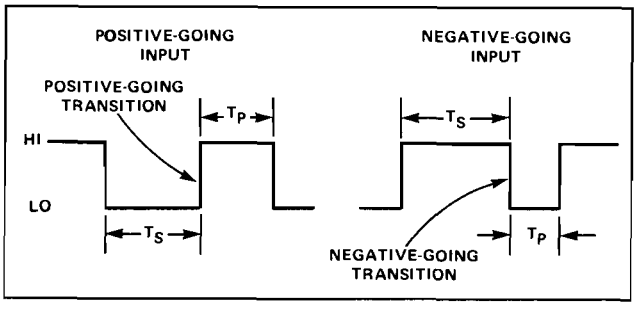
Maximum Operating Input Voltage:
$-1 \leq$ (common mode + signal) $\leq +15V$

Maximum Input Rate to 2240A Buffer (when used as a 16-channel digital input card):
Sequential Digital Points: 90 μs per point (11,000 points/sec)
16-Bit Fields: 70 μs per field (14,000 fields/sec)
(See HP 2240A/HP 1000 System Performance, pages 16-17.)

Input Protection: Input voltage between -10V and +20V with reference to 2240A ground will not cause damage.

Set-Up Time (T_S): Input must remain LO (HI for negative-going input) for a minimum of 25 μsec before it switches to HI (LO).

Pulse Duration (T_P): 25 μs minimum to insure event sense



Specifications (continued)

Number of Interrupts: After the first event on a channel no additional events on that channel are recorded until the first event has been read. Interrupts on other channels are still recorded. Interrupt handling of recurring events is a function of the rate at which the interrupts are read by the HP-IB controller. The HP 2240A can typically process an interrupt from the 22903A and send the HP-IB Require Service message (SRQ) in 300 μs.

Physical Characteristics:
- PC Board: 34.80 cm (13.7 inches) long; 28.91 cm (11.38 inches) wide
- Net Weight: 0.5 kg (1.1 lb.)
- Power Required: 1.6 watts maximum
- Heat Dissipation: 1.9 watts maximum

Environmental: Same as 2240A Measurement and Control Processor

Prerequisite

2240A or 2241A (1 slot)

Hardware Supplied

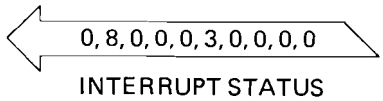
22903A 16-Channel Common Interrupt card

Software Supplied

None required

Interrupt Example

A common interrupt card is in slot 4. The controller was interrupted by a *Require Service* message on the HP-IB. A serial poll identified the 2240A as the source of the interrupt. The interrupt service program resident in the controller then reads status information.



INTERRUPT STATUS

Where:

8 = Slot 4 has interrupted (0000 1000)

3 = Decimal equivalent of 16-bit field. In this case, both channels 1 and 2 have recorded events (0000 0000 0000 0011)

TABLE OF 22903A HP-MCL COMMANDS

COMMAND	FUNCTION
DI	DIGITAL INPUT: Reads sequential single channel digital input values.
FI	FIELD INPUT: Reads sequential 16-channel fields of digital input. There is one input field on each common interrupt card.
MI	MASK REGISTER INPUT: Reads current state of interrupt mask register as a 16-channel field.
MO	MASK REGISTER OUTPUT: Writes a single 16-channel field to the mask register to select which channels can cause event interrupts.
SI	SENSE REGISTER INPUT: Reads current state of interrupt sense register as a 16-channel field.
SO	SENSE REGISTER OUTPUT: Writes 16-channel fields to the sense and mask registers. The sense field selects for each enabled channel the direction of input transition which causes an interrupt.

Note: For more details on 22903A commands, see HP 2240A User's Manual (02240-93001).

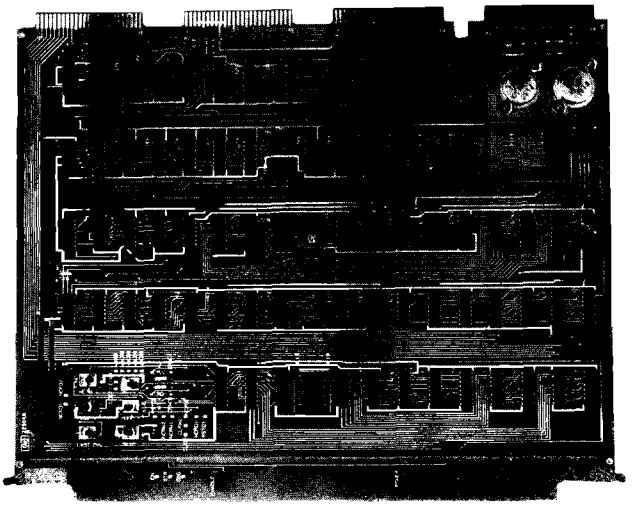
HEWLETT hp PACKARD

32-Channel digital output

model 22904A

Features

- **32 channels per function card**
- **Outputs are single-ended TTL/CMOS from open collector NPN transistors**
- **32 channels can be individually output or in 2 groups of 16-channel fields**
- **Each 16-bit field is jumper selectable for level or pulse output (4 pulse widths)**
- **Dual rank storage allows readback before output (manually selectable)**



Description

The 22904A Digital Ouptut card provides 32 open collector NPN switch outputs utilizing an external DC power source (supplied by user). Dual rank storage for the 32-bit output cards allows convenient checking of the data before output. Output levels can be either TTL or CMOS (depending on voltage chosen by user) with the additional capability of pulse outputs of variable duration (switch selectable) for applications such as process instrumentation.

Specifications

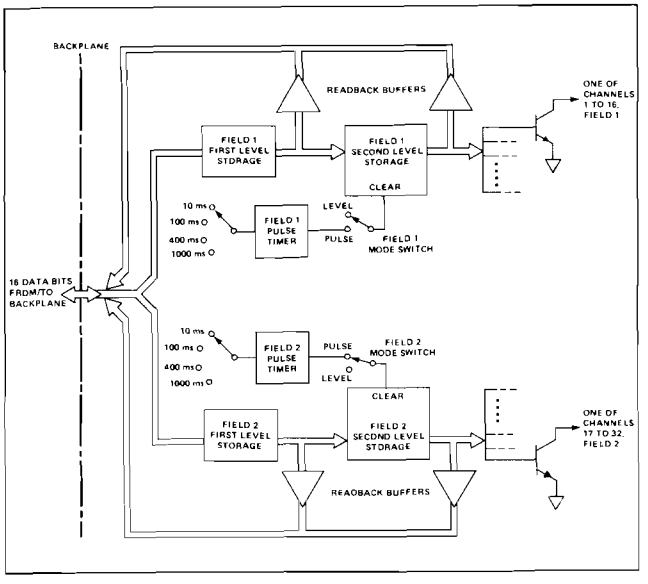
Signal Output:
- Open Circuit Voltage: Maximum 13.2V (supplied by user)
- Steady State Current: Maximum 30 mA
- Voltage Drop: 0.8V @ Maximum output current

Types of Output (Jumper Selectable):
- Level: Output switch maintains OFF or ON state until user commands change of state.
- Pulse: Pulse durations are jumper selectable separately for each independent field of 16 channels.
- Pulse Durations: 10 ms, 100 ms, 400 ms, 1000 ms
  Tolerance: ±1%
  Fixed or extended pulse mode is switch selectable.
  Pulse length extension is accomplished by reprogramming of the appropriate channel.

Maximum Digital Output Update Rate From 2240A Buffer:
- Sequential Digital Output Points: 450 μs per point (2,200 points/sec)
- Sequential 16-Bit Fields: 250 μs per field (4,000 fields/sec)
- (See HP 2240A/HP 1000 System Performance, pages 16-17.)

Physical Characteristics:
- PC Board: 34.80 cm (13.7 inches) long; 28.91 cm (11.38 inches) wide.
- Net Weight: 0.5 kg (1.1 lb.)

Power Required: 1 watt



HP 22904A Functional Block Diagram

Heat Dissipation: 1 watt plus external power supplied to output transistor

Environmental: Same as 2240A Measurement and Control Processor

Prerequisite

2240A or 2241A (1 slot)

Hardware Supplied

22904A 32-Channel Digital Output card

Software Supplied

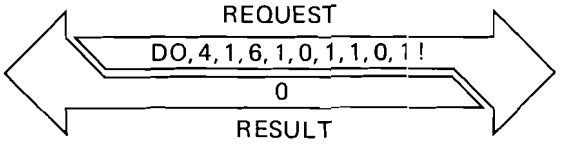
None required

Programming Example

Set channels 1, 3, 4, and 6 of field #1 (Bit Pattern 0000000000101101) to a logic level 1 on card in slot 4.

There are two ways to do this, using a DO (Digital Out) or FO (Field Out) command. Using FO is generally faster.

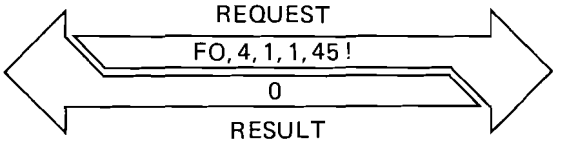
Using DO command:



Where:

DO = Digital output sequential channels
4 = Start at slot 4
1 = Start at channel 1
6 = Number of channels output
1,0,1,1,0,1 = Logic level values for channels 1 - 6
0 = Condition code, 0 or 1
0 = no errors

Using FO command:



Where:

FO = Field output of decimal equivalent of 16-channel field
4 = Start at slot 4
1 = Start at field 1
1 = Number of fields, in this case 1
45 = Decimal equivalent of bit pattern
0 = Condition code, 0 or 1
0 = no errors

TABLE OF 22904A HP-MCL COMMANDS

COMMAND	FUNCTION
DI	DIGITAL INPUT: Reads sequential single channel input. DI of digital output card is current state of card.
DO	DIGITAL OUTPUT: Writes sequential single channel digital output as either levels or pulses.
FI	FIELD INPUT: Reads sequential 16-channel fields of digital input. FI of digital output card is current state of second level storage register.
FO	FIELD OUTPUT: Writes sequential 16-channel fields of digital output as either levels or pulses.

Note: For more details on 22904A commands, see HP 2240A User's Manual (02240-93001).

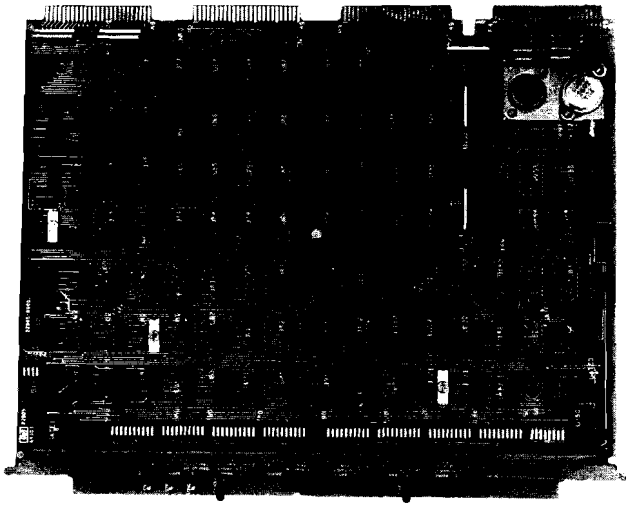
HEWLETT hp PACKARD

4-Channel counter/stepper

model 22905A

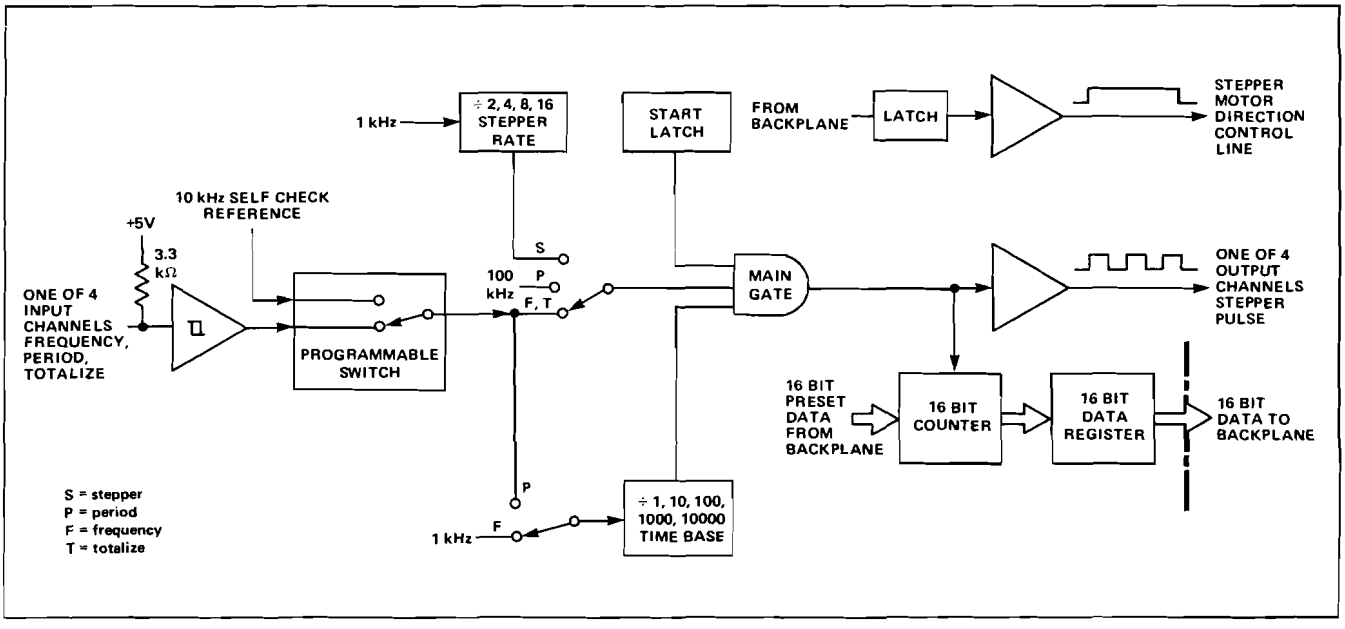
Features

- 4 independent 16-bit counters with associated control logic to perform Frequency Measurement, Period Measurement, Totalizing, and to act as Stepping Motor Controller
- Single-ended, non-isolated, TTL/CMOS level input
- Single-ended, non-isolated, TTL level stepper output
- Maximum count in totalize mode $65{,}535_{10}$
- Presetability under program control of any counter to any count between $0 - 32{,}767_{10}$
- Program controlled reference signal for testing
- Voltage or contact sense (internal pull-up to 5V with no filter)



Description

The 22905A Counter/Stepper card consists of 4 identical channels which are individually configurable by manual switches into one of 4 modes: frequency measurement, period measurement, event counting (totalize), and stepper motor drive. Any mix of the 4 modes is possible. An asynchronous interrupt is switch-selectable for each channel on overflow. Under program control, any counter can be interrogated and the current value read. Frequency gate time, number of periods averaged and stepper motor drive pulse rate are also individually switch-selectable for each channel. A self-checking feature allows a 10 kHz reference signal to be introduced under program control (not included in self-test function) for testing of counters and interrupt functions.



HP 22905A Functional Block Diagram

Period Mode Specifications

Input Period: 0.327 sec maximum
Input Frequency: 100 kHz maximum
Number of Periods Measured: 1, 10, 100, 1000, 10000 (manually selectable)
Resolution: 10 μs, 1 μs, 100 ns, 10 ns, 1 ns
Full Range: 327 ms, 32 ms, 3.2 ms, 327 μs, 32 μs
Time Base: 100 kHz
Accuracy: ±0.01% of reading ± Trigger Error*
Maximum Count: $32{,}767_{10}$
Programmable self check @ 100 μs

$$\text{Period in Sec} = 10^{-5} \times \frac{\text{Data Returned}}{\text{number of periods measured}}$$

**Trigger Error: Maximum transition time for input voltage to go from 0.7V to 4.3V.*

Period Mode Programming Example

Uses the SF (Start Frequency or period measurement) and RC (Read Count) commands as shown in Frequency Mode Programming Example. The card responds in the manner to which it has been configured by the user.

Common Specifications

Signal Input (Frequency, Period, Totalize Modes):
Voltage: HI: Maximum 15V, Minimum 4.3V } (Logic 1)
LO: Maximum 0.7V, Minimum -1.0V } (Logic 0)
Current: HI: @ 15V; 3.3 mA maximum, @ 4.3V; -0.3 mA maximum } (Logic 1)
LO: @ 0.7V; -1.5 mA maximum, @ -1.0V; -2.0 mA maximum } (Logic 0)
Source Contact Resistance (for contact closure):
HI (Contact Open): ≥ 25KΩ
LO (Contact Closed): ≤ 500Ω
Maximum Input Voltage:
-1 ≤ (common mode + signal) ≤ + 15V
Input Protection: Input voltages between -10V and +20V with reference to 2240A ground will not cause damage.
Physical Characteristics:
PC Board: 34.80 cm (13.7 inches) long; 28.91 cm (11.38 inches) wide
Net Weight: 0.57 kg (1.25 lb.)
Power Required: 1.3 watts maximum
Heat Dissipation: 1.5 watts maximum
Environmental: Same as 2240A Measurement and Control Processor

Prerequisite

2240A or 2241A (1 slot)

Hardware Supplied

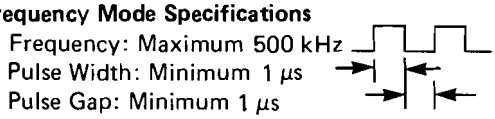
22905A Counter/Stepper card

Software Supplied

None required

Frequency Mode Specifications

Frequency: Maximum 500 kHz
Pulse Width: Minimum 1 μs
Pulse Gap: Minimum 1 μs



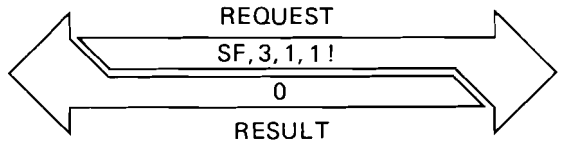
Will measure any signal that is HI for 1 μs and LO for 1 μs.
Gate Time: 1 ms, 10 ms, 100 ms, 1 sec, 10 sec (manually selectable)
Resolution: 1000 Hz, 100 Hz, 10 Hz, 1 Hz, 0.1 Hz
Range: 500 kHz, 500 kHz, 327 kHz, 32 kHz, 3.2 kHz
Accuracy: ±0.01% of reading ± 1 count
Programmable self check @ 10 kHz ± 1 Hz

$$\text{Frequency in Hz} = \frac{\text{Data Returned}}{\text{Gate Time}}$$

Frequency Mode Programming Example

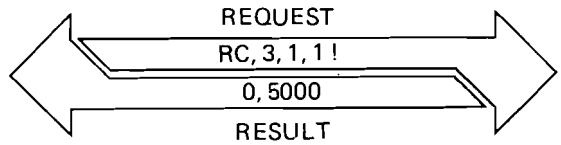
Measure 5 kHz frequency using 22905A card in slot 3 and channel 1 which has been set for frequency measurement. Gate time set at 1 second.

Requires two commands, one command to start the measurement and another one to read the counter.



Where:

SF = Start frequency measurement
3 = Start at slot 3
1 = Start at channel 1
1 = Number of channels
0 = Condition code, 0 or 1 returned
0 = no errors



Where:

RC = Read count
3 = Start at slot 3
1 = Start at channel 1
1 = Number of channels
0 = Condition code, 0 or 1 returned
0 = no errors
5000 = data returned = frequency x gate time

Totalize Mode Specifications

Count Rate: 500 kHz maximum
Presettable Count Range: $0 - 32{,}767_{10}$

Continuous counting after limit is reached.
Will interrupt when preset count has been reached if interrupt control switch is set.

Maximum Count: 65,535
Accuracy: ± Trigger Error*
Self Check: Counts internal 10 kHz self check signal
Event Count

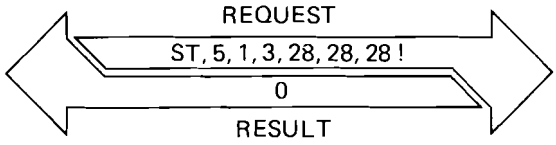
Preset Mode: Generates interrupt when limit is reached if switch is set

Count Mode (preset to 0): Simple counting of events
Range 0 - 32,767
count = data returned
Range 32,768 - 65,535
count = data returned + 65,536

Trigger Error: Maximum transition time for input voltage to go from 0.7V to 4.3V.

Totalize Mode Programming Example

Using the 22905A in slot 5 (2241A Extender), preset the counter to 28_{10} on channels 1, 2, 3 which all have been manually set to interrupt when the preset limit is reached.



Where:

ST = Start totalizer
5 = Start at slot 5
1 = Start at channel 1
3 = 3 channels
28, 28, 28 = Preset levels of 3 channels
0 = Condition code, 0 or 1 returned
0 = no errors

A serial poll would be initiated by the controller upon receipt of the interrupt and then an interrupt service routine would then ask for more information and take appropriate action.

Stepper Motor Output Specifications

Two solid state switches per channel to control the two input lines to a stepper motor translator; stepper pulses are on one line and the direction information is on the other line.

Output pulse rates (manually selectable): 62.5, 125, 250, 500 pps; 50% duty cycle.
Maximum Number of Pulses Available: $32{,}767_{10}$

Direction Line: 0V level for positive number of steps
+5V level for negative number of steps

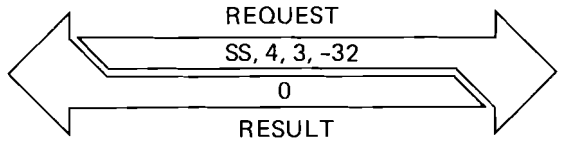
Signal Output (stepper pulse and direction line):

Voltage: HI: Maximum 5.1V, Minimum 4.5V } (Logic 1)
LO: Maximum 0.4V, Minimum 0V } (Logic 0)

Current: HI: Source minimum -0.4 mA @ 4.5V (Logic 1)
LO: Sink maximum 2.1 mA @ 0.4V (Logic 0)

Stepper Motor Programming Example

Output from 22905A in slot 4, channel 3, 32 steps and pull the direction line HI (Logic 1) to the motor translator.



Where:

SS = Start stepper
4 = Slot 4
3 = Channel 3
-32 = Negative (-) means drive direction line HI (Logic 1), 32 = 32 steps
0 = Condition code, 0 or 1 returned
0 = no errors

TABLE OF 22905A HP-MCL COMMANDS

COMMAND	FUNCTION
CR	COUNTER RESET: Stops channel operation.
CT	COUNTER TEST: Initiate channel self-test using 10 kHz clock. Do not use on channels in stepper mode.
RC	READ COUNT: Reads most recent frequency (period) from channel storage or current state of totalize input or stepper output.
SF	START FREQUENCY (or Period): Initiates measurement sequence with gate time (or number of periods per gate) specified by card switches.
SS	START STEPPER MOTOR: Presets counter to number of steps and starts stepper at output rate specified by card switches. Polarity of number of steps sets level of direction bit.
ST	START TOTALIZE: Presets counter to specified count and enables input to counter. An interrupt occurs upon completion of count if interrupt control switch is set on function card. Simple count mode initiated by preset to zero.

Note: For more details on 22905A commands, see HP 2240A User's Manual (02240-93001).

HEWLETT hp PACKARD

16-Channel relay output

model
22912A

Features

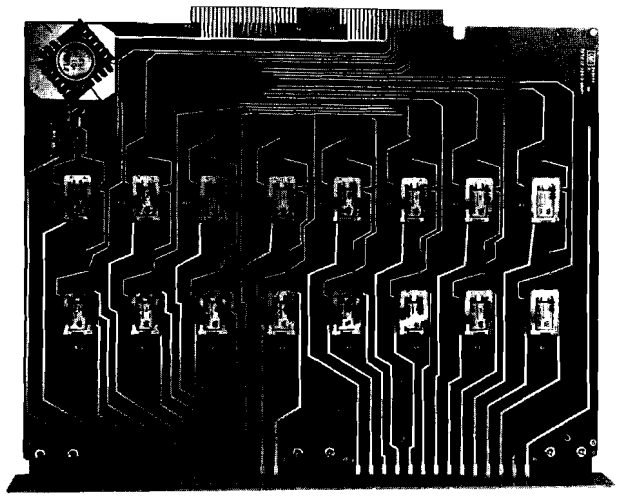
- **16 Form-C (SPDT) Relays**
- **Twin Contact Sets and hermetic seal for high reliability**
- **Maximum Switching Voltage: 250V AC/DC (secondary only)**
- **Maximum Switching Current: 2A**
- **60 VA Maximum Rating**
- **Frequency Range: DC - 100 kHz for signal routing**

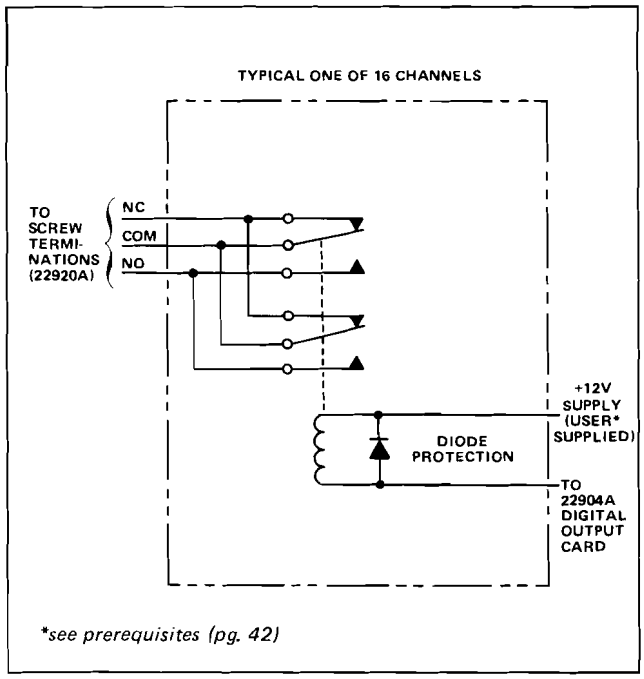
Description

The 22912A Relay Output card provides 16 independent SPDT, hermetically-sealed relays for routing of external voltages. The Relay card requires external power for coil operation and a 22904A Digital Output card for sinking of coil current.

Specifications

Data Input: Operates in conjunction with digital output card (22904A). Program information is shown in Table 1.
Maximum Total Contact Resistance: 0.5Ω (measured from 22920A field connections)
Typical Total Contact Resistance: 0.15Ω
Relay Data (at 25°C, 50% RH unless noted)(switching voltages do not include primary AC line voltages):
- Type: 16 Form C (SPDT) hermetically sealed general purpose relays
- Operate Time to Open or Close: 10 ms maximum
- Release Time: 5 ms maximum
- Coil Resistance: 500Ω ±10%
- Maximum Power Switched: 60 VA peak or continuous
- Maximum Break Current: 2.0 amps @ 30 VDC
- Maximum Carrying Current: 3.0 amperes
- Maximum Break Voltage: 250 VAC @ 0.10A
- Initial Contact Resistance: .050Ω maximum
- Thermal Offset: Maximum 100 μV @ 25°C
- Breakdown Voltage: 750 VDC minimum between all mutually isolated terminals
- Insulation Resistance: Contact (NO) to Contact (NC) 10^8 Ω @ 300 VDC, 40°C, 95% RH
- Maximum Capacitance: Between any mutually isolated terminals 10 pf
- Mechanical Life: 10^7 operations
- Contact Life Within Operating Envelope: After 10^6 operations 90% of the paths will be ⩽ 0.5Ω
- Crosstalk: 0 - 100 kHz
  - Channel-to-Channel: Better than -70 dB with 50Ω termination; better than -50 dB with 600Ω termination.
  - Between Open Contacts on Same Channel: Better than -60 dB with 50Ω termination; better than -40 dB with 600Ω termination.





HP 22912A Functional Diagram (each channel)

Relay Power Requirements: External power supplied by user; 12 VDC ±5% @ 0.5A per 22912A (see prerequisite below).

Environmental:

- Temperature (operating): 0 - 55°C
- Humidity (operating): 95% RH @ 40°C non-condensing
- Shock (non-operating): 30 G, 11 ms duration, 1/2 sine wave
- Vibration (operating):
  - Frequency: 5-55-5 Hz (15 minutes duration)
  - Amplitude: 0.38 mm (0.15 inch) peak-to-peak
  - Dwell at Resonance: 10 minutes
- Hermetic Seal: Sealed at time of manufacture against H_2S, SO_2 gas, high humidity, dust and oil.

Physical Characteristics:

- PC Board: 34.80 cm (13.7 inches) long; 28.91 cm (11.38 inches) wide
- Net Weight: 0.54 kg (1.19 lb.)
- Power Required: 6 watts maximum (coil power requirements)
- Power Dissipation: 10 watts maximum

Prerequisite

Requires one 22920A Signal Conditioning Tray and one 22906A Option 002 Cable per card and 22904A Digital Output card (16 channels of card per 22912A relay card) and external power for relay coils supplied by user; 12 VDC ±5% @ 0.5A per 22912A. An example of the complement of equipment that is recommended for use with the HP 62012 series modular power supplies is shown below.

Relay Output Power Supply and Rack Mounting Tray (Power supply tray may also be used to house power supplies for 22914A breadboard)	
Product No.	Description
62012E	12V, 6.0 Amp Power Supply (handles up to 12 HP 22912A Relay cards)
62410A	Power Supply Tray for rack mounting
62415A	Rear panel for 62410A Tray with power plug
62411A	Front panel for 62410A Tray (Wire for connection to HP 22912A supplied by user.)

Hardware Supplied

22912A 16-Bit Relay Output card

Software Supplied

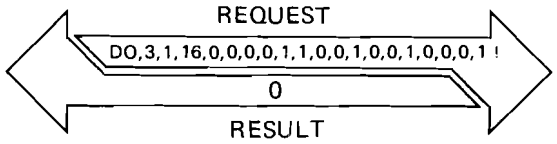
None required

Programming Information

The 22912A works in conjunction with the 22904A Digital Output card. The example below shows the relationship between the outputs of the 22904A using one of the output commands – the DO command – and the resulting state of the relay contacts (see Table 1).*

Programming Example

Use a system normalize command to normalize the system and bring the state of the relay contacts back to their original state, i.e., NO (Normally Open) to open and NC (Normally Closed) to closed state. On channels 5, 6, 9, 12 and 16 cause the NC (normally closed contact) to be open and the NO (normally open contact) to be closed. On channels 1, 2, 3, 4,7, 8, 10, 11, 13, 14 and 15 cause the reverse to happen. The Digital Output card is in slot 3.



where:

DO = Digital output channels sequentially
3 = Start at slot 3
1 = Start at channel 1
16 = Number of channels output
0,0,0,0,1,1,0,0,1,0,0,1,0,0,0,1 = Logical level values for channels 1 - 16
Chan. 1 Chan. 16
0 = Condition code, 0 or 1
0 = no errors

Table 1. Relationship of Request to Relay State

	CHANNEL NUMBER															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Logic levels requested via DO command* of 22904A	0	0	0	0	1	1	0	0	1	0	0	1	0	0	0	1
Digital output card logic state (22904A)	1	1	1	1	0	0	1	1	0	1	1	0	1	1	1	0
Normally Open (NO) contact state	open	open	open	open	closed	closed	open	open	closed	open	open	closed	open	open	open	closed
Normally Closed (NC) contact state	closed	closed	closed	closed	open	open	closed	closed	open	closed	closed	open	closed	closed	closed	open

**This is equivalent to using a FO command and asking for -30416_{10} as the output.*

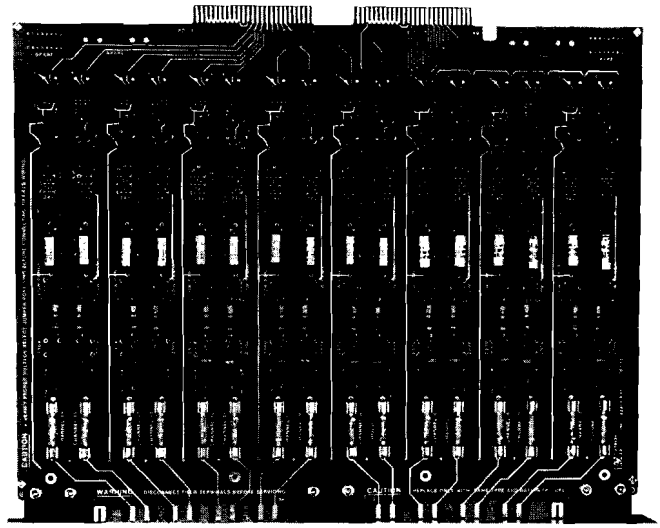
HEWLETT hp PACKARD

16-Channel isolated digital input

model 22913A

Features

- 16 channels of isolated digital input
- Jumper selectable voltage ranges: 5 VDC to 120 VDC; 16 VAC to 230 VAC
- Full isolation between all channels and from channels to common
- All channels fused for overvoltage protection
- Selectable response times for DC inputs for improved noise immunity
- Input current (5 mA) aids noise immunity
- Schmitt trigger input circuit for high noise immunity
- Reverse polarity protection

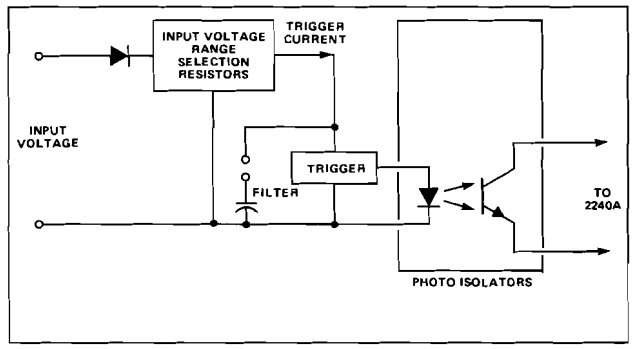


Description

The 22913A Isolated Digital Input card is a signal conditioning card that couples a range of AC and DC digital input signals to the HP 22902A Digital Input card or the HP 22903A Common Interrupt card, or the HP 22905A Counter Stepper card. In addition, the card provides a high degree of electric isolation via photo isolators between each input circuit, the 2240A function card, and other circuits. This isolation may be necessary to prevent ground loops, to permit isolated power supplies for safety or noise immunity reasons, and to permit floating sense circuits above earth grounds with an AC or DC voltage potential of up to 230V AC or DC.

This circuit is designed to sense active circuits or for sensing contact closures which are externally excited. In either case, the sensed circuit must produce a minimum of 5 mA at any of the indicated full range voltages.

The 5 mA input current serves to reduce the possibility of false indications due to contaminated (leaky) contacts or wiring. The current also serves to reduce the buildup of insulating oxide films on contacts which may occur under dry switching conditions.



HP 22913A Functional Block Diagram Each Channel

The Schmitt trigger input circuit typically provides a 10% to 20% differentiation between turn-on and turn-off voltages further increasing immunity to electrical noise or source voltage fluctuations common during start up and shut down sequences.

Input Voltage Ranges:
DC: 5V, 12V, 24V, 48V, (72V, 120V)*
AC: (16V, 72V)**, 115V, 230V
Each of the 16 channels is individually jumper selectable to interface with field wiring voltages. The maximum and typical turn-on (Input - HI) and minimum and typical turn-off (Input - LO) levels for each range are shown in Table 1. This threshold is generally one-half the nominal value with a maximum voltage of 3/4 to turn-on and a minimum voltage of 1/4 nominal to turn-off.

Table 1. Turn-On/Turn-Off Levels

Voltage Jumper Configuration	Maximum Continuous Voltage	Turn-on Voltage Max. 0 - 55°C	Turn-off Voltage Min. 0 - 55°C	Typical @ 25°C	
				ON	OFF
5 VDC	10 VDC	4 VDC	2 VDC	3.4 VDC	3.1 VDC
12 VDC	18 VDC	9 VDC	3 VDC	6.2 VDC	5 VDC
24 VDC (16 VAC)**	36 VDC (26 VAC)	18 VDC (12 VAC)	6 VDC (4 VAC)	11 VDC (8.6 VAC)	8 VDC (7.2 VAC)
48 VDC (72 VAC)**	65 VDC (75 VAC)	36 VDC (50 VAC)	12 VDC (16 VAC)	25 VDC (75 VAC)	17 VDC (30 VAC)
115 VAC (72 VDC)*	130 VAC (100 VDC)	90 VAC (60 VDC)	30 VAC (20 VDC)	70 VAC (38 VDC)	51 VAC (20 VDC)
230 VAC (120 VDC)*	250 VAC (180 VDC)	170 VAC (90 VDC)	60 VAC (35 VDC)	150 VAC (73 VDC)	110 VAC (49 VDC)

* *Equivalent DC range of 115VAC and 230 VAC jumper positions respectively with or without AC jumper installed.*
** *Equivalent AC range of 24VDC and 48VDC jumper positions respectively with AC jumper installed on DC range*

Overvoltage Protection: Fuse blows at voltages greater than the maximum continuous voltage (see table 1).

Isolation Voltage Between Any Two Input Channels:
250 VAC/300 VDC Rated Working
Breakdown Voltage Between Any Input Connection to 2240A Ground: 2500 VDC @ 25°C, 45% RH

Capacitance: 1 pf @ 1 MHz (Input-Output)

Input Signal Timing Requirements:
Minimum Pulse Width of Input Signal During On State (signal > maximum turn-on voltage)
with AC jumper installed (AC or DC input):
100 ms minimum
with AC jumper removed (pulsed DC input):
300 μs minimum
Minimum Pulse Width of Input Signal During Off-State (signal < minimum turn-off voltage)
with AC jumper installed (AC or DC input):
120 ms minimum
with AC jumper removed (pulsed DC input):
200 μs minimum
Maximum Frequency From HP 22913A Input to Associated Function Cards (AC jumper removed):
1.5 kHz (50% duty cycle)
AC Signal Input Frequency Range (AC jumper installed) to guarantee a steady state level at output to function cards:
47 Hz minimum to 1.5 kHz maximum

Power Supply Requirements: No external power supply requirements when used with the 22902A, 22903A, or 22905A.

Physical Characteristics:
PC Board: 34.80 cm (13.7 inches) long; 28.91 cm (11.38 inches) wide
Net Weight: 0.57 kg (1.25 lb.)
Power Dissipation Capacity in 230V Range: 10 watts

Environmental:
Temperature (operating): 0 - 55°C
Humidity (operating): 95% RH @ 40°C non-condensing
Shock (non-operating): 30G, 11 ms duration, 1/2 sine wave
Vibration (operating):
Frequency: 5-55-5 Hz (15 minutes duration)
Amplitude: 0.38 mm (0.15 inch) peak-to-peak
Dwell at Resonance: 10 minutes

Prerequisite

22920A Signal Conditioning Tray, 22906A Option 002 Digital Input cable, and a 22902A Digital Input card, 22903A Common Interrupt card, or 22905A Counter/Stepper card. (Note that the input signals to these function cards are affected by the frequency response of the 22913A.)

Hardware Supplied

22913A Isolated Digital Input card

Software Supplied

None required

Programming Data

Single channel input data state to 22913A	HI (ON) (Logic 1)	LO (OFF) (Logic 0)
22913A single channel output state (input to 22902A, 22903A, or 22905A*)	LO (Logic 0)	HI (Logic 1)
Data returned (results) from DI or FI† command to read the single channel on a 22902A or 22903A card	0	1

* *Data returned from commands requesting frequency, period, or totalize measurements from the 22905A will reflect the inversion that takes place between the input to the 22913A and the input to the 22905A. See 2240A Measurement and Control Processor User's Manual (02240-93001) for further information.*
† *The total data returned from an FI command is the decimal equivalent of the bit pattern of the 16 channels of the 22913A.*

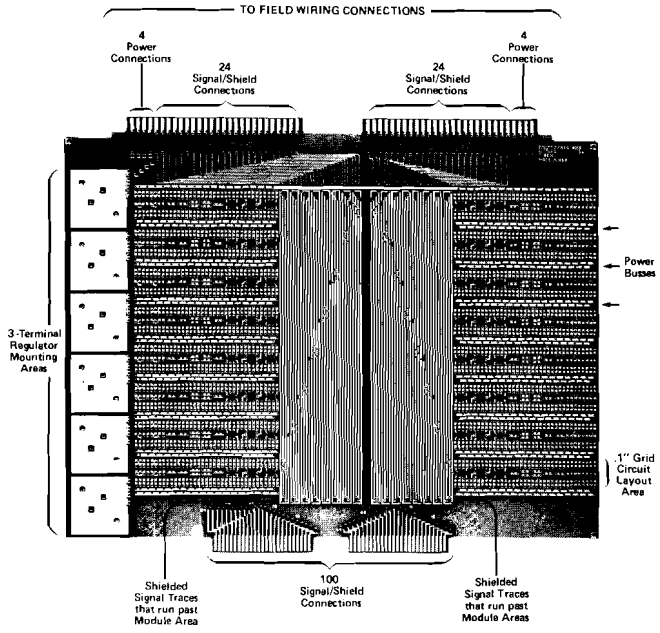
HEWLETT hp PACKARD

16 or 32 Channel general purpose breadboard card

model 22914A

Features

- **Convenient circuit module layout for user mounted:**
  - **Amplifier per channel signal conditioning**
  - **Current loops to voltage conversion resistors**
  - **Active or passive filters**
  - **Multi-pole relays**
  - **Signal attenuation or level shifting**
- **Mounts in separate shielded tray for easy access and noise shielding**
- **Convenient interface to field wiring for power provisioning**
- **Provision for mounting of 3-terminal regulators**
- **Provision for sixteen 3AG fuses per channel**



Description

User-designed input circuits for analog or digital signal conditioning can be mounted on this card. The card has 16 circuit layout areas using a 0.1-inch grid with some 0.15-inch centers for relays. Amplifier-per-channel signal conditioning using module or monolithic instrumentation amplifiers can easily be implemented. Layouts for 8, 10, and 12 pin TO-92 or TO-5 packages are also available. A typical layout for one of 16 redundant channels could contain three 14-pin dual in-line op-amps and 15 discrete components.

Sixteen sets of three traces (HI-LO-SHIELD) are provided for "feed-through" connections of non-signal conditioned channels. These traces can easily be interrupted to divert to a signal conditioning circuit layout area. With appropriate cables, this provides the capability of 16 differential channels.

A Buffer zone at the front and rear of the board provides for mounting of safety resistors where required. Power buses run on the board for convenient access to user-supplied power. There are also layouts for 6 TO-3 type packaged 3-terminal regulators.

Specifications

Physical Characteristics:
PC Board: 34.80 cm (13.7 inches) long; 28.91 cm (11.38 inches) wide
Weight: 0.3 kg (0.6 lb.) (unloaded)
Power Dissipation Capacity: 10 watts
Maximum Dissipation per Regulator: 2.5 watts
Trace Current: 0.5A maximum
Maximum Supply Voltage: ±40V
Environmental: Same as 2240A Measurement and Control Processor.

Caution: The electrical interface between user mounted components and the 2240A/2241A function cards (22900A - 22905A) must conform to the input/output specifications of these cards. See specifications on pages 25 through 37 for further information.

Power Requirements: User must supply external power for operation of mounted circuits.

Prerequisites

Analog:
1. 22920A Signal Conditioning Tray.
2. 22907A Option 001 Analog Input Cable per 8 Differential Channels or 22907A Option 003 Analog Input Cable per 16 Single-ended channels.

Digital:
1. 22920A Signal Conditioning Tray.
2. 22906A Option 002 cable per 16 digital channels.

Hardware Supplied

22914A General Purpose Breadboard

Software Supplied

None required

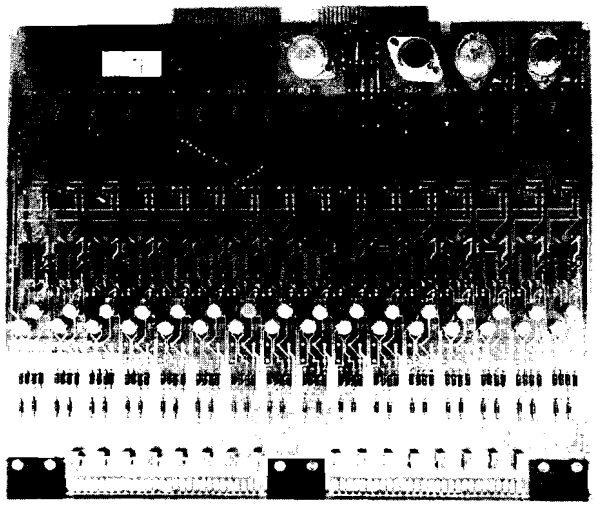
HEWLETT hp PACKARD

16 Channel low-level analog input

models
22915A
22915B

Features

- **16 amplifier/channel low level analog inputs**
- **Jumper selectable voltage ranges: ±20 millivolts to ±10 volts**
- **Input overvoltage protection (±20V)**
- **Mounting pads for customer components**
- **20 kHz scanning across channels**



Description

The 22915A/B Low Level Analog Input card provides 16 differential amplifiers with jumper selected gains for amplifying low-level signals for digital conversion by the 22900A Analog Input Card: Mounting pads on the 22915A/B allow installation of RC low pass filters, open thermocouple detection, and current loop monitoring resistors.

Specifications

HP 22915A

ANALOG INPUT RANGE	±20mV	±50mV	±100mV	±500mV	±10V
INPUT CHANNEL GAIN	500	200	100	20	1
RESOLUTION	10μV	25μV	50μV	25mV	5mV
ACCURACY (% F.S.)*	±.5	±.3	±.2	±.06	±.06
GAIN T.C. (% F.S./°C)	±.0026	±.0016	±.0015	±.001	—
OFFSET T.C. (μV/°E) *	5	5	5	5	5

Temp 23±2°C, Relative Humidity 20 to 80%
* Referred to Input

HP 22915B

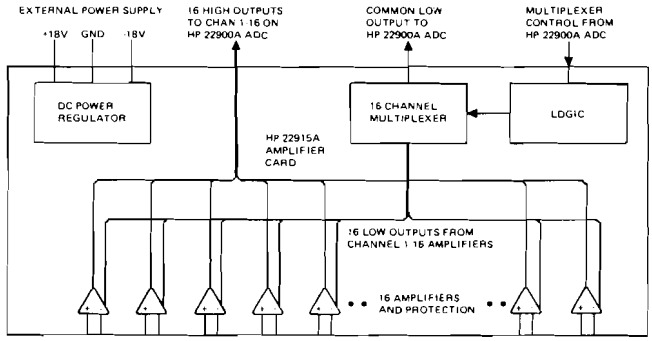
ANALOG INPUT RANGE	±20mV	±50mV	±1.25V	±5V	±10V
INPUT CHANNEL GAIN	500	200	8	23	1
RESOLUTION	10μ	25μV	.6mV	2.5mV	5mV
ACCURACY (% F.S.)*	±.5	±.3	±.06	±.06	±.06
GAIN T.C. (% F.S./°C)	±.0026	±.0016	±.0015	±.001	—
OFFSET T.C. (μV/°E) *	5	5	5	5	5

Temp 23±2°C, Relative Humidity 20 to 80%
* Referred to Input

Repeatability (including HP 22900A:) ±0.06% F.S.
Input Overload Protection: ±20 Volts (any 1 input) to ground or to any other input without damage. All inputs at once, ±20V to ground for 10 seconds.

Input Impedance: 10 megohm
Common Mode Voltage: Signal x Gain + CMV ≤ 10.5 volts
Common Mode Rejection: See HP 22900A
Source Impedance: 1K Ohm maximum
Source Imbalance: 1K Ohm maximum
Common Mode Return Impedance: 10K Ohms maximum
Throughput: Same as HP 22900A
Signal Input Bandwidth: 500 Hz max., V_{out} < 20V p-p

Physical Characteristics:
PC Board: 34.8 (11.37 inches) long x 28.91 (11.38 inches) wide
Weight: 0.5 Kg (1.1lbs)
External Power Required: ± 18.0 Volts DC @ 330 mA
Environmental: Same as HP 2240A except 20-80% relative humidity.



Prerequisite

HP 2240A and HP 22900A. Also requires one HP 22920A Signal Conditioning Tray, 2 each HP 62018 (A,E,G) Series power supplies or equivalent. One HP 22915A-001 verification kit is required per facility.

Hardware Supplied

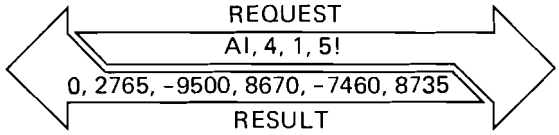
22915-60001 Analog Input Signal Conditioning Card
22915-60002 Interface Cable
03240-60009 Connector Kit
22920-20001 Connector
Option 001: adds self test cable and calibration connector

Software Supplied

Not required.

Programming Example

16 low-level analog input channels are amplified by an HP 22915A connected to channels 1-16 of an HP 22900A Analog Input Card in slot 4 of an HP 2240A measurement and Control Processor. The first five channels on the 22915A are jumpered as follows: Channel 1, x 500 gain (±20 mV full scale); Channel 2, x 200 gain (±50 mV full scale); Channel 3, x 100 gain (±100 mV full scale); Channel 4, x 20 gain (±0.5 volt full scale); Channel 5, x 1 gain (±10 volts full scale). Channels 1-5 have 5.53 millivolts, –47.5 millivolts, 86.7 millivolts, –373 millivolts, and 8.735 volts applied to their respective inputs.



Where:

AI = Analog Input Channels Sequentially
4 = Start at Slot 4
1 = Start at Channel 1
5 = Number of Channels to Input

0,2765, –9500, 8670, –7460, 8735 = RESULTS

0 = Condition Code, 0 or 1, 0 = no errors
2765 = 5.53 millivolts (2765 millivolts/x 500 gain)
–9500 = –47.5 millivolts (–9500 millivolts/x 200 gain)
8670 = 86.7 millivolts (8670 millivolts/x 100 gain)
–7460 = – 373 millivolts (–7460 millivolts/x 20 gain)
8735 = 8735 millivolts (8735 millivolts/x 1 gain)

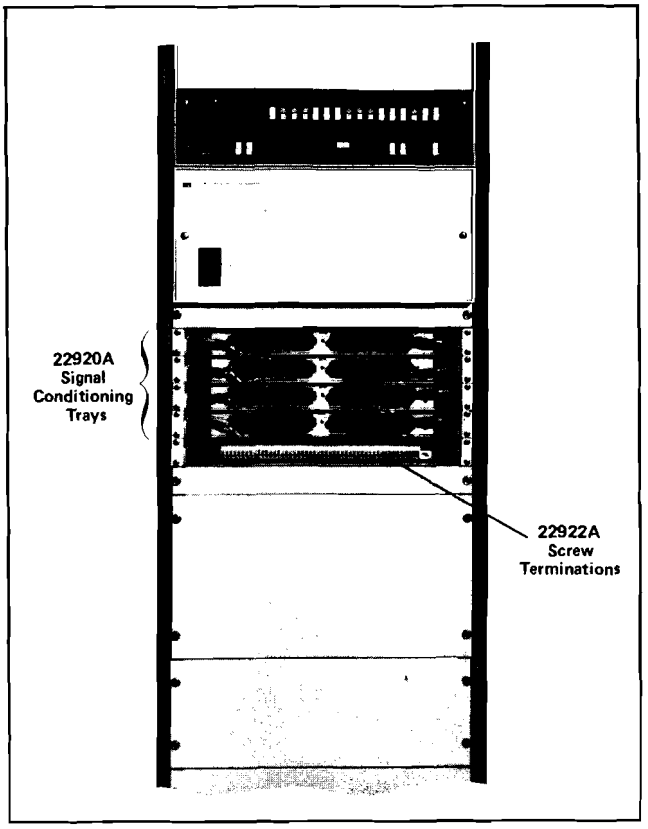
HEWLETT PACKARD

Signal conditioning tray

model 22920A

Features

- **Houses one signal conditioning card**
- **Easy-to-use screw terminations (56) for field wiring (14 - 22 gauge gas tight)**
- **19-inch rack installation includes provision for routing and securing field wiring cables**
- **Snap-together construction requires only a few common tools for assembly**
- **Front access to cards without disconnecting field wiring**
- **Each tray requires only 1.75 inches of rack height**



Description

The 22920A is a signal conditioning tray that is used to hold either the 22912A Relay Output card, the 22913A Isolated Digital Input card, or the 22914A General Purpose Breadboard card. There is provision for field wiring (14-22 AWG) connection to 56 screw terminal connectors which connect to the signal conditioning cards.

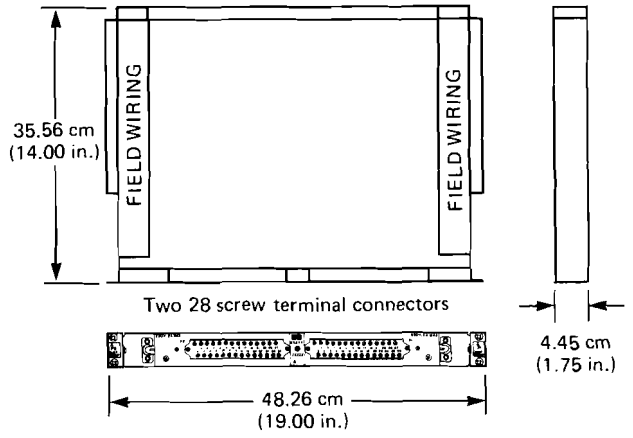
Mounting

The tray may be racked in small bench-type racks that meet the ANSI Rack Standard #C83.9-1922 (or the EIA Standard RS-310-8) or in standard HP racks.

Specifications

Physical Characteristics:

Size:



Net Weight: 1.67 kg (3.69 lb.)

Environmental:

Temperature (operating): 0 - 55°C

Humidity (operating): 95% RH @ 40°C non-condensing

Shock (non-operating): 30G, 11 ms duration, 1/2 sine wave

Vibration (operating):

Frequency: 5-55-5 Hz (15 minutes duration)

Amplitude: 0.38 cm (0.15 inch) peak-to-peak

Dwell at Resonance: 10 minutes

Cooling and Field Wiring Routing: For enclosed cabinets bottom-to-top air flow is recommended. This requires that a gap of a minimum of 1-3/4 inches be between the top of the signal conditioning array and bottom of any instrument mounted above. The same requirement exists for the bottom of the array (see above photo of multiple units installation). A gap is not required between units of the same array or between signal conditioning tray and screw termination trays. Open environment without guaranteed air flow is not recommended.

Power Dissipation Capacity: 10 watts maximum

Compatible Cables (Terminated):

22906A-002 Digital I/O, 16 channels

22907A-001 Analog In, 8 channels, differential

22907A-003 Analog In, 16 channels, single ended

22908A-001 Analog Out, 4 channels

Hardware Supplied

22920A Signal Conditioning Tray

Option 001: Adds secondary connector for connection with 2240A when using 22914A breadboard if desired.

Software Supplied

None required

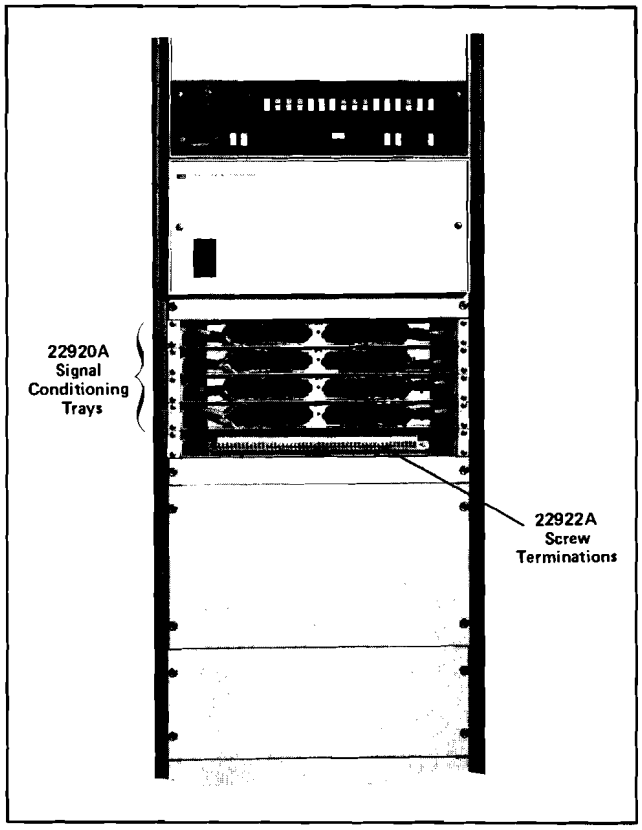
HEWLETT hp PACKARD

General purpose screw termination tray

model 22922A

Features

- **Easy-to-use screw terminations for use with unterminated 2240A cables and your field wiring**
- **Up to 50 field wiring connections per unit (14 - 22 gauge gas tight — up to three wires per terminal)**
- **Easy access screw terminals on both sides of block**
- **19-inch rack installation includes provision for routing and securing field wiring cables**
- **Snap-together construction requires only a few common tools for assembly**
- **Each unit requires only 1.75 inches of rack height**



Description

For those applications in which screw terminations for field wiring is required without the need for signal conditioning, the 22922A provides up to 50 terminal connections to any function card that can be put into a 2240A. This connection to the 22922A is done via a standard HP cable which has a connector to a 2240A function card on one end and is unterminated on the other end for customer connection to the screw terminal connectors. Field wiring is also brought into this same terminal block (see drawing below). A mixture of function cards may be connected to the 22922A. However, proper precautions should be taken to separate Digital I/O from Analog I/O to minimize noise.

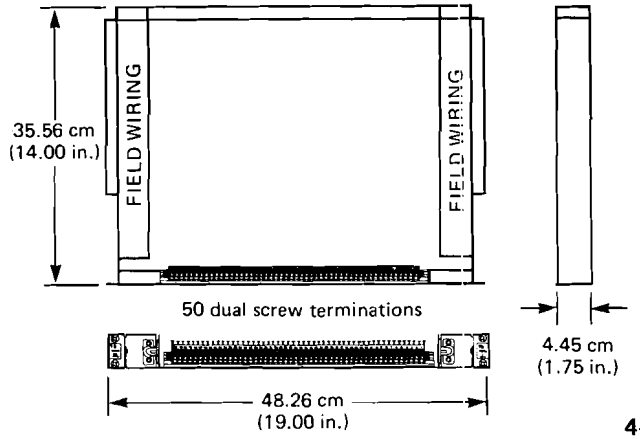
Mounting

This structure may be mounted in a standard HP cabinet with 18 5/16-inch mounting centers (as shown in the photo of multiple installation) or in any rack which meets the ANSI (C83.9-1972) or EIA (RS-310-B) standard. A 1-3/4 inch gap between the top of a multiple unit array and the bottom of any instrument mounted above is required for field wiring access. The same requirement exists for the bottom of the array. A gap is not required between units of the same array or between screw termination trays and signal conditioning trays.

Specifications

Physical Characteristics:

Size:



Net Weight: 1.39 kg (3.06 lb.)

Environmental:

Temperature (operating): 0 - 55°C

Humidity (operating): 95% RH @ 40°C non-condensing

Shock (non-operating): 30 G, 11 ms duration, 1/2 sine wave

Vibration (operating):

Frequency: 5-55-5 Hz (15 minutes duration)

Amplitude: 0.38 mm (0.15 inch) peak-to-peak

Dwell at Resonance: 10 minutes

Compatible Cables (Unterminated):

22906A Digital I/O, 16 channels

22907A Analog In, 8 channnels, differential

22907A-002 Analog In, 16 channels, single ended

22908A Analog Out, 4 channels

Hardware Supplied

22922A General Purpose Screw Terminations

Software Supplied

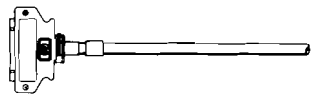
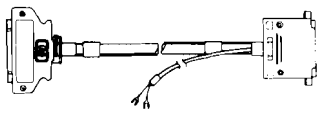
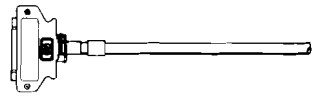
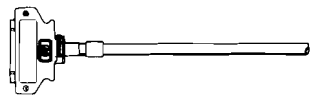
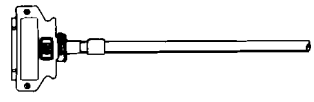
None required

HEWLETT hp PACKARD

Cable assemblies

models
22906A
22907A
22908A

The input/output cable assemblies available for interfacing with various HP 2240A/HP 2241A function cards to external sensor points or to HP supplied signal conditioning modules are listed in the table below.

Cable Product No./Option	Description	Connects To:	2240A Connection End — Terminated or Unterm. End	Connects To:
22906A	Digital Input/Output Cable (Note 1) 16 channel unterminated with common ground 4 meters (13.1 ft.) Net Weight: 0.34 kg (0.75 lb.)	22902A 22903A 22904A 22905A		User terminations or HP 22922A General Purpose Screw Terminations
Opt. 001	Digital Input/Output Cable 16 channel (common ground) with connector to Teledyne Signal Conditioning 4 meters (13.1 ft.) Net Weight: 0.34 kg (0.75 lb.)	22902A 22903A 22904A 22905A		Teledyne Series 671P Mounting Panel
Opt. 002	Digital Input/Output Cable (Note 2) 16 channel with connector to HP Signal Conditioning 1.5 meters (4.9 ft) Net Weight: 0.34 kg (0.75 lb.)	22902A 22903A 22904A 22905A		HP 22912A, HP 22913A, HP 22914A in 22920A Tray
22907A	Analog Input Cable 8 channel, differential, unterminated, individually shielded twisted pairs 4 meters (13.1 ft.) Net Weight: 0.34 kg (0.75 lb.)	22900A		User terminations or HP 22922A General Purpose Screw Terminations
Opt. 001	Analog Input Cable 8 channel, differential, individually shielded twisted pairs with connector to HP Signal Conditioning 1.5 meters (4.9 ft.) Net Weight: 0.34 kg (0.75 lb.)	22900A		HP 22914A in 22920A Tray
Opt. 002	Analog Input Cable 16 channel, single-ended, unterminated twisted pairs with overall shield 4 meters (13.1 ft.) Net Weight: 0.34 kg (0.75 lb.)	22900A		User terminations or HP 22922A General Purpose Screw Terminations
Opt. 003	Analog Input Cable 16 channel, single-ended, twisted pairs with overall shield with connector to HP Signal Conditioning 1.5 meters (4.9 ft.) Net Weight: 0.34 kg (0.75 lb.)	22900A		HP 22914A in 22920A Tray
22908A	Analog Output Cable 4 channel, unterminated (8 twisted pairs) 4 meters (13.1 ft.) Net Weight: 0.34 kg (0.75 lb.)	22901A		User terminations or HP 22922A General Purpose Screw Terminations
Opt. 001	Analog Output Cable 4 channel with connector to HP Signal Conditioning (8 twisted pairs) 4 meters (13.1 ft.) Net Weight: 0.34 kg (0.75 lb.)	22901A		HP 22914A in 22920A Tray

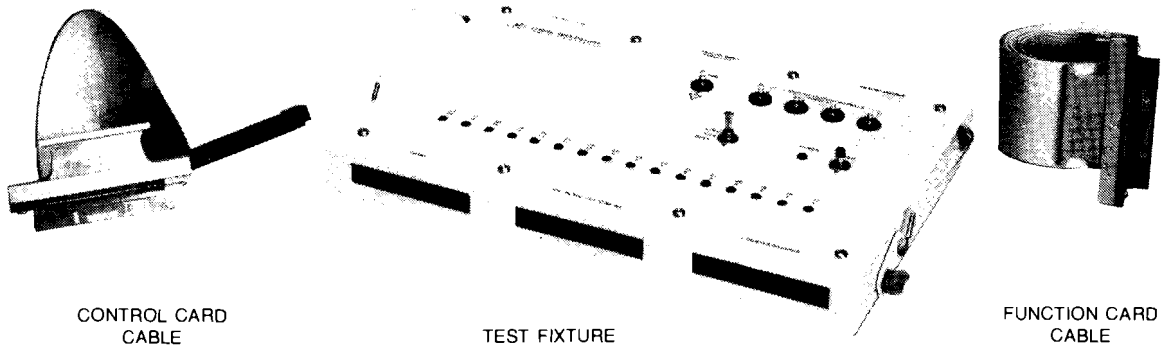
Notes: 1. The rise and fall times of the input digital signals should be restricted as follows: ⩾ 10 μs for source impedances > 100Ω; ⩾ 1 μs for source impedance ⩽ 100Ω. A 0.01 μf capacitor between the signal and the cable common will ensure compliance with these requirements over the source impedance range. In addition, source impedances ⩾ 1KΩ should not be used.

2. Same as note 1 except for the following: 2 μs replaces 10 μs; 0.25 μs replaces 1 μs; 0.005 μf replaces 0.01 μf. The 1KΩ restriction still applies.

HEWLETT hp PACKARD

Verification Kit
Power Supply Extender Board

Models
22909B
22910B



CONTROL CARD
CABLE
22909-60004

TEST FIXTURE
HP 22909A

FUNCTION CARD
CABLE
22909-60005

Note: Function card extender board
22909-60001 not shown.

HP 22909B Verification Kit

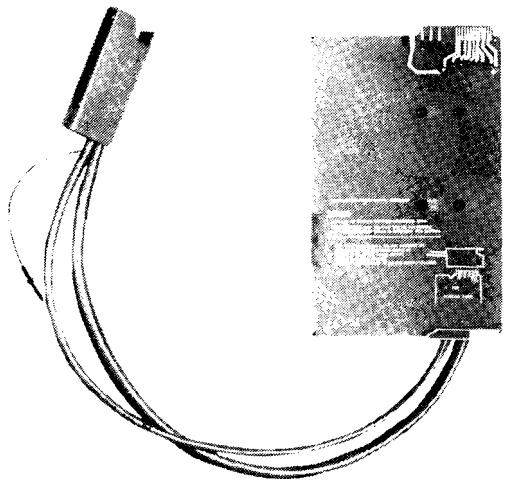
Features

- Functionally tests all 2240A function cards in conjunction with 2240A standard firmware
- Easy-to-follow, step-by-step verification procedure supplied in 2240A Installation and Service manuals
- Can be used as an I/O simulator for program development
- Troubleshooting down to board level is fast and service is easy in conjunction with the HP board exchange program
- Portable, rugged, and easily attaches to the 2240A on a bench or racked in a cabinet

Description

The 22909B Verification Kit provides the capability of functionally verifying all the 2240A/2241A plug-in function cards.* Each of the digital cards, input or output, can be checked for proper operational levels. The logic circuitry of the cards is checked during the 2240A self-check generated by program control and at power on. The analog input is functionally checked in a differential or analog configuration. In order to easily check the analog output card, a set of terminals is mounted on the test fixture to which a HP 3495A or equivalent voltmeter should be attached.

** This verification kit does not perform verification of the signal conditioning cards, HP 22912A, HP 22913A or HP 22914A. Service of these cards is easily accomplished and is described in the 2240A Installation and Service Manual (02240-93003).*



POWER SUPPLY
EXTENDER ASSY
22909-60003

HP 22910B Power Supply Extender Board

Simulation of inputs and outputs is also useful as a programming aid. Certain inputs and/or interrupts can be generated to test the response of the measurement and control program thereby saving time and expensive on-line testing.

The HP 22909B Verification Kit consists of the HP 22909A Test Fixture, a control card cable, a function card cable and a card extender assembly.

The HP 22910B Power Supply Extender allows the power supply in the HP 2240A to be withdrawn from the mainframe during dynamic testing or troubleshooting.

Specifications

Physical Characteristics: For HP 22909A Test Fixture.
Dimensions: 33.02 cm (13 inches) x 5.08 cm (2 inches) x 20.32 cm (8 inches) (width x height x depth).
Net Weight: 1.36 kg (3 lb.)
Environmental: Same as 2240A Measurement and Control Processor.

Power Requirements: +12V (provided by 2240A control card cable assembly connection).

Prerequisite

2240A.

Hardware Supplied

Test Fixture (22909A)
Control Card Interface Cable (22909-60004)
Function Card Interface Cable (22909-60005)
Function Card Extender Board (22909-60001)
Power Supply Extender Assembly (22909-60003)

Software Supplied

None required.

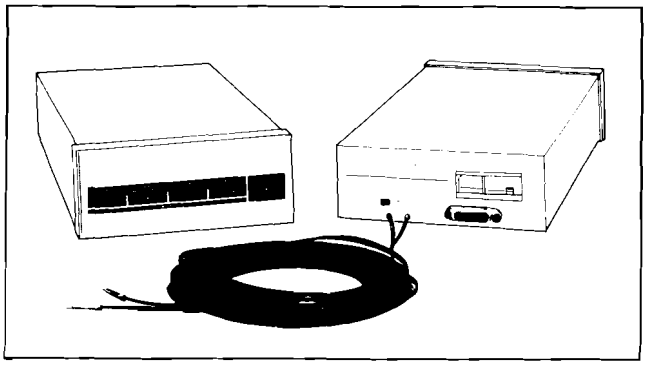
Manuals Furnished

Installation and Service Manual supplied with 2240A.

Other Recommended Accessories

Fiber Optic HP-IB Products

Fiber Optic HP-IB Link products provide a high speed and highly reliable extension of the Hewlett-Packard Interface Bus*. The products include the HP 12050A Fiber Optic HP-IB Link and the 39200 Series of fiber optic cables available in five standard incremental lengths up to 100 metres. These products enable the user to locate HP-IB instrumentation (or other HP-IB devices) remotely from the computer in accordance with specific application needs.



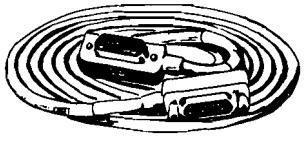
The optical data path ensures complete electrical isolation between the computer and instrumentation at the remote site. Electrical isolation is important in applications where large ground potential differences and other common mode voltage effects can degrade electrical signal integrity. Optical isolation can protect your computer from electrical transients due to power system surges and other unexpected events at the remote site. Thus, the effects of a lightening strike strike cannot be propagated over the fiber optic cable. Electrical isolation is also important in precision measurement applications where measurements must be made in an electrically clean area, such as an RFI screen room

Fiber optic cable can be run safely in explosive environments where the spark from a broken wire cable could prove disastrous. The leaking light energy from a damaged fiber optic cable is harmless in such an area.

In summary, the Fiber Optic HP-IB Link is ideally suited for many demanding industrial and laboratory applications.

HP-IB Cables

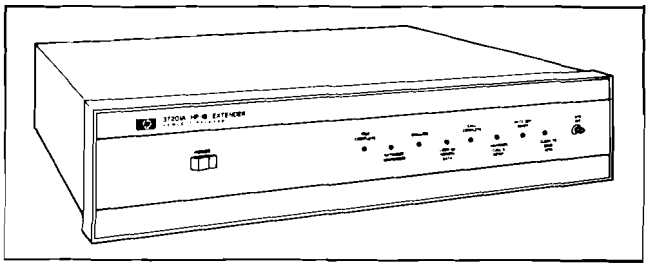
For additional HP-IB cables beyond what is supplied with the computing controller HP-IB interface, order per the product numbers below.



Model No.	Meters	Feet
10631A	1	3.3
10631B	2	6.6
10631C	4	13.2

Note: There is an HP-IB length restriction of 2 meters per device to a maximum of 20 meters.

HP-IB Extender



Hewlett-Packard's 37201A overcomes the range limitation and broadens the scope of HP-IB systems by converting parallel data from the interface bus into serial form suitable for transmission over twin-pair cable or via full duplex modems and the telephone network. A second 37201A, at the remote end of the data link reconverts the serial data into bit-parallel HP-IB format for the remote devices. An HP-IB system can therefore be split into two or more discrete parts, separated by HP-IB Extenders and a serial data link.

Each group of HP-IB devices is still subject to the maximum cable length constraint, but the groups may now be separated by up to 1000m of twin-pair cable, or by virtually unlimited distances if a modem link is used.

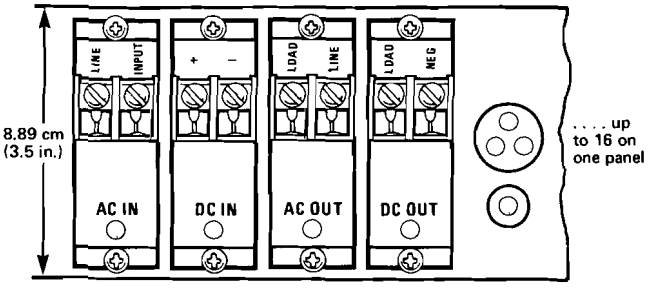
Interconnecting a number of widely scattered HP-IB systems is simple, and a single controller can control the entire network from a central site. With the exceptions of Parallel Poll and Pass Control, the 37201A supports the full range of HP-IB functions. A maximum of 14 HP-IB devices may be connected directly to each Extender.

16-Channel digital I/O signal conditioning cable

The cable (22906A-001) is designed to interface between digital I/O function cards of the HP 2240A and Teledyne 671P Series Solid State I/O Converter modules which mount on a Teledyne 671P Series mounting panel. Each panel accepts up to 16 optically isolated modules and fits on the front of a standard 19-inch rack. These modules are used with the HP 2240A in applications which require faster AC or DC switching times or higher load current than handled by the HP 22912A Relay Output Signal Conditioning card.

An external 5V DC power supply (e.g., one of the HP 62005 series) is required to operate the Teledyne I/O modules. The 22906A-001 cable has convenient terminations for connection to this power supply.

Additional information on the Teledyne Relays — Solid State AC and DC I/O Converters (Series 671 optically isolated) and on the Series 671P mounting panel can be found on Teledyne data sheets.



Teledyne Solid State I/O Converter Modules

Cabinet Mounting of Measurement and Control Subsystems

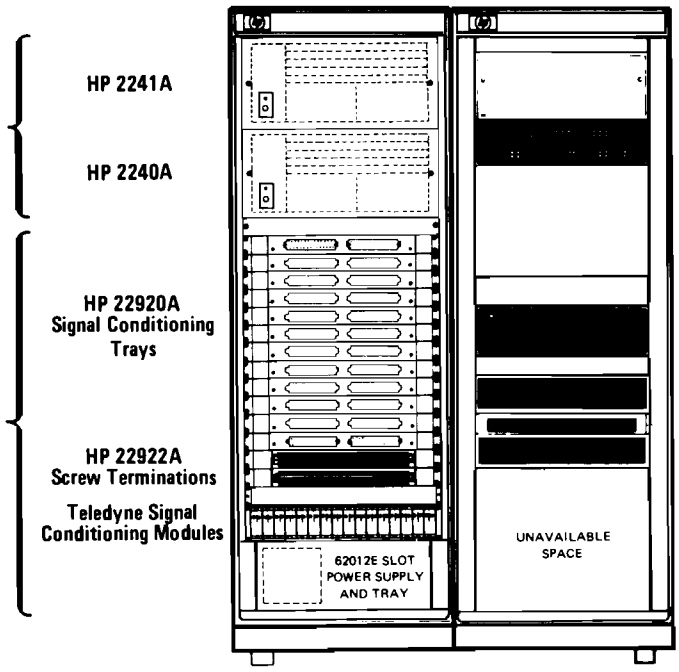
2240A Measurement and Control System Mounted in Vertical Cabinets

The HP 2240A/2241A can be ordered with an HP 29402B-400 or 410 cabinet and HP 1000 Computer System. Hewlett-Packard will rack mount the HP 2240A and HP 2241A in the locations designated in the diagram to the right.

The HP-IB interface will be connected to the HP 1000 and a software functional test will be run in the HP 1000 to verify operation of the HP-IB interface and data and interrupt transfers from the HP 2240A Control Card.

Installation and verification of function card operation at customer site is the responsibility of the customer, using the built-in self test features of the HP 2240A and the HP 22909A Test Fixture.

This space is designated for HP 22920A Signal Conditioning Trays with signal conditioning cards, HP 22922A Screw Terminations, and HP 62000 series slot power supplies for powering relay cards, low level cards, or customer breadboards. Since applications vary considerably in mix of analog and digital signals, both inputs and outputs, HP does not install these items. This gives the customer an opportunity to tailor his rack mounting to his application and allows the electrician to install field wiring in the rack first, before the electronic technician installs the signal conditioning trays and cards.

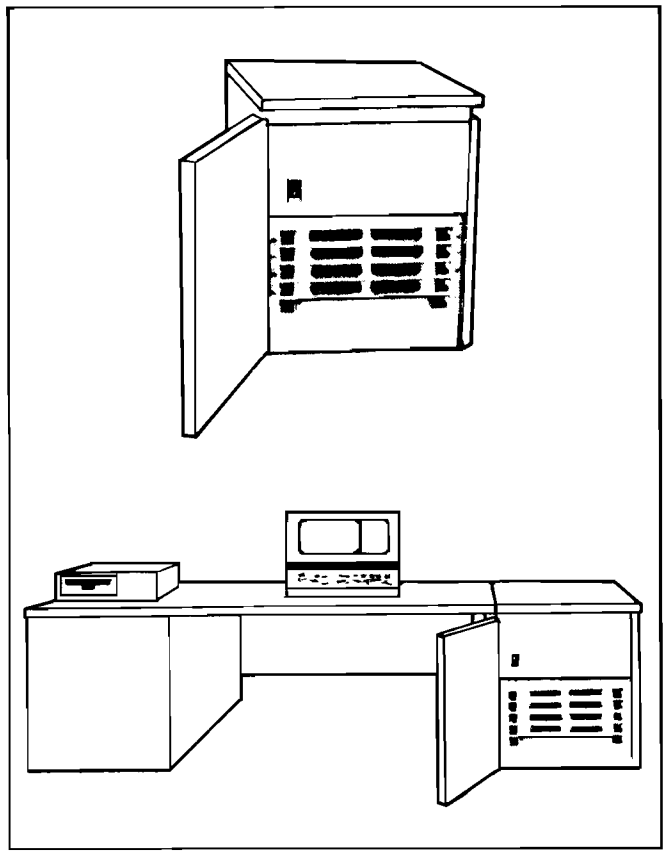


2240A Measurement and Control System Mounted in Mini Rack

The HP 2240A can also be mounted in a minirack configuration as shown in the illustrations to the right. Option 301 can be ordered with a 2240A to provide the following:

1. Rack mount a 2240A in a roll-around mini rack with door.
2. Provides space for mounting of a screw termination and/or signal conditioning assemblies.
3. Provides 120 VAC power distribution and a 3-receptacle power strip for auxiliary power supplies required by signal conditioning cards.

Option 301 provides an attractive match for desk style HP 1000 computer systems for lab or light manufacturing environments, and is a convenient package for small point count remote 2240A applications. Option 301 is also a convenient package on which to place any of HP's 9800 Series Desktop Computers.



HP 2240A Extended Performance Option: provides even more built-in HP 2240A capability

The extended performance option for the HP 2240A provides it with additional intelligence to handle more sophisticated measurement and control tasks. The resulting higher level of decoupled 2240A/computer operation improves total system throughput by allowing each device to better handle the tasks it does best. With the extended performance option the HP 2240A can handle these advanced measurement and control tasks:

- Acquire large amounts of high speed data continuously with a single programmed request
- Monitor a process or machine for critical event occurrence *and* save important data that led up to the event
- Combine continuous data acquisition with simple local control loops using digital decision making commands
- Perform an orderly process, equipment or machine shutdown upon an alarm condition
- Lower computer formatting overhead and improve system throughput by binary results transmission
- Interrupt the computer upon measurement task error detection
- Streamline request programming through enhanced HP 2240A command set

New commands

The HP 2240A extended performance option provides additional new commands to the HP-MCL command set. These additional commands provide more power and flexibility to optimize HP 2240A operation, and are summarized in the table on the right.

More results in less time

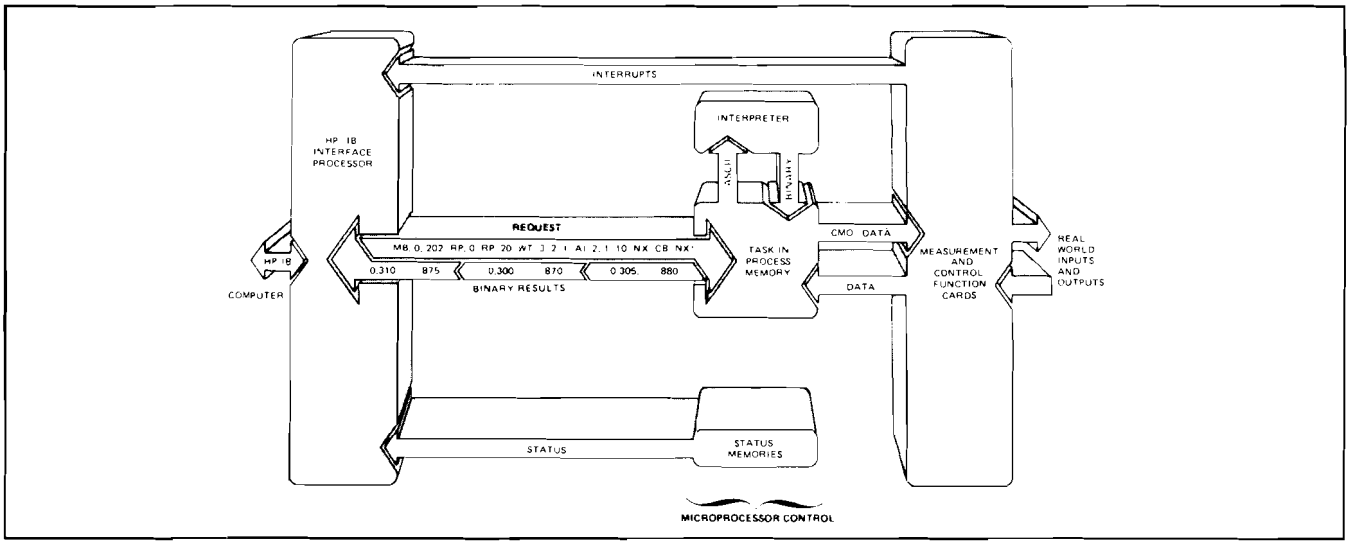
Communications between the 2240A and the computer is still achieved through HP-IB messages that carry request, result, status and interrupt information. Requests, for instance, are made up from the same high level, easily recognized set of HP-MCL commands, and sent to the 2240A via familiar computer languages like FORTRAN, BASIC and HPL.

Additional HP-MCL commands included with the extended performance HP 2240A

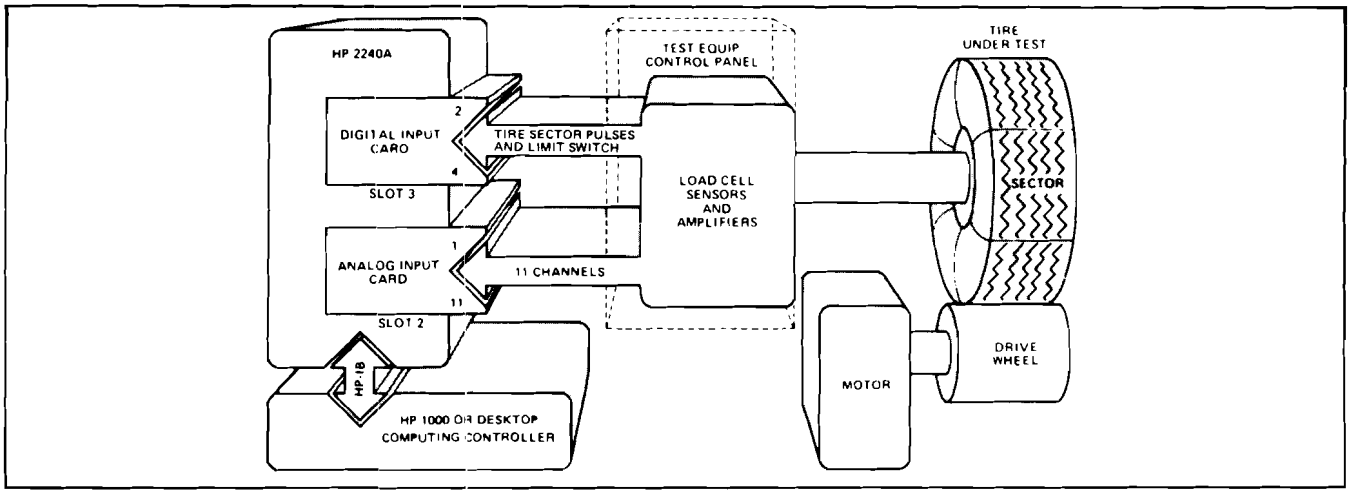
COMMAND MNEMONIC	EXAMPLE COMMAND	RESULT
MB	MB,0,202 or MB,1,202	Sets up bin mode (**M**ark **B**in) and allows user to specify either continuous (0) or history (1) data acquisition mode and define bin size (202 = 200 readings + 2 control words).
CB	CB	Makes results in current bin available for transmission (**C**lose **B**in) and allows further results to be taken and put in next bin.
IF-EI	IF,5,3,1; ...EI,AI,2,1,8	**IF** channel 3 or digital input card in slot 5 is high (1) then proceed with following commands. If not, then branch to **EI**(End-IF) and sequentially scan channels 1 through 8 of analog input card in slot 2. These EI-IF pairs may be nested.
RP-NX	RP,10;...RP,5;...NX;...NX;	Identical to standard 2240A repeat-next loops except up to 6 pairs may be nested with Extended Performance HP 2240A.
EX	EX,2 or EX,0	**EX**it 2 levels of nested RP-NX loops. EXit, 0 terminates the request and returns data.
IE	IE	Interrupt controller upon an Error condition.
WR	WR,0,50	**W**ait 50 milliseconds and **R**eset elapsed time clock. Used for timed pacing.

However, with the extended performance option you'll see two important changes from the standard HP 2240A operation. First, results are now stored and transmitted by the 2240A in a 2's complement binary format, and thus the 2240A formatter is eliminated, resulting in improved command execution speed. Secondly, the 2240A can acquire and transmit data **continuously** from a single request; requests do not need to be resent every time its buffer is emptied. These two differences enable the HP 2240A extended performance option to acquire data and return it to the computer at average continuous rates up to 10,000 readings/second.

Other features are also included with the HP 2240A extended performance option. The following two examples, using the tire equipment measurement and control example previously used, will show the benefits of these other features. Refer to the 2240A processor with extended performance block diagram and the tire equipment with extended performance test setup diagram.



HP 2240A Processor with extended performance option, block diagram



Tire Equipment with extended performance, test setup diagram

Example #1: continuous data acquisition mode

In the 2240A tire equipment example in Section 2, a task was delegated to the standard 2240A to measure out-of-round forces on a rotating tire. The 2240A gathered data for 20 tire sector scand of 10 readings each. Corresponding to the out-of-round forces measured for one tire revolution, the results were returned to the computer at completion of the task. If the identical task were to be performed again, the 2240A request would have to be resent by the computer every time results were returned.

Let's assume that these measurements are to be made for long periods of time rather than for a single revolution. This could be the case for instance in tire life-cycle testing. The test can be done more efficiently with less interrelated 2240A-computer overhead by making use of the continuous data acquisition mode of the Extended Performance HP 2240A. As in the earlier example standard FORTRAN or BASIC statements are used to send the request.

The request, shown below, is sent just once.

ONE REQUEST

MB,0,202;RP,0;RP,20;WT,3,2,1;AI,2,1,10;NX;CB;NX!

The request can be analyzed as a simple program:

MB,0,202;	— Subdivide the buffer into result "bins" (Mark Bin) of 200 readings each. (202 = 200 readings + 1 condition code + 1 control word = Bin Size.) Specify continuous data acquisition (0).
RP,0;	— Repeat everything in outer RP-NX loop indefinitely.
RP,20;	— Repeat everything in inner RP-NX loop 20 times.
WT,3,2,1;	— Synchronize (Wait for Trigger) the data gathering with tire sector pulse on channel 2, card slot 3, wait for pulse to go to high state.
AI,2,1,10;	— Acquire analog inputs from 2240A card slot 2, load cell channels 1 to 10. Put results in current bin.
NX;	— Inner loop completion.
CB;	— Close Current Bin, make 200 readings (each revolution = 20 scans of 10 readings each) available for transmission to computer. Make next bin available for results.
NX!	— Outer loop completion.

Results (in millivolts) are returned continuously with a condition code sent for each group of 200 readings.

0,305...875 **0,310...875** **0,300...870** **0,305...880** ...

MULTIPLE BINARY RESULTS

Examples of reading the binary results is shown below. *Many* of these input statements will be issued to read data from the *one* request.

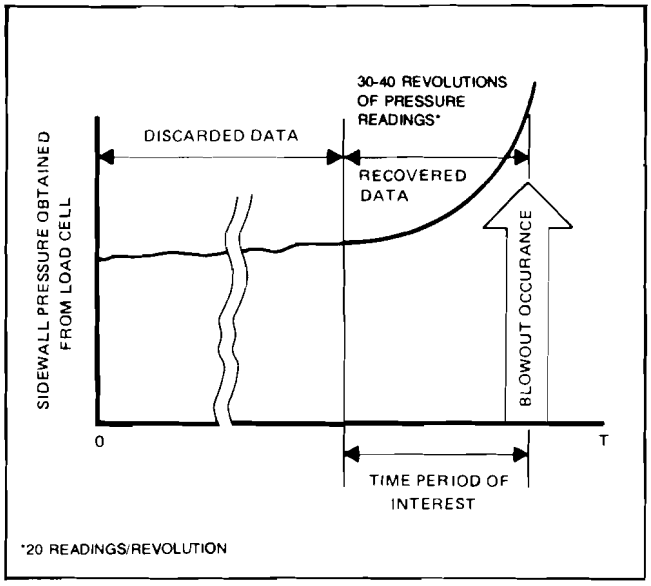
HP 1000 FORTRAN	HP 9835/45A BASIC	HP 9825A HPL
READ (12) IDATA	ENTER 12 NOFORMAT;Idata(*)	tfr 701, "Idata"

Example #2: history data acquisition mode

While continuous data is required for applications like the one described on the previous page, others require only the data leading up to an event. Consider the application described below and diagrammed on the next page.

Certain tires will be subjected to destructive testing by running them for extended periods of time at over-inflated conditions and in the presence of changing temperatures. It's desired to analyze the sidewall forces resulting just prior to a blow out, e.g., the last 30 to 40 or so revolutions worth of measurements. Results obtained up to this time are of no interest and, in fact, unwanted because saving them will occupy computer time as well as use peripheral storage space.

Each sector is read for sidewall loads. The history of one sector is shown in the diagram, with data taken during the shaded portion of the figure being of interest. Recovery of this data is ideally suited for the history data acquisition mode of the Extended Performance HP 2240A.



History data acquisition mode diagram

The request, again, is sent just once.

ONE REQUEST

```
MB,1,22;RP,0;IF,3,4,1;EX,0;EI;RP,20;
WT,3,2,1;AI,2,11,1;NX;CB;NX!
```

It can be analyzed as a simple program;

MB,1,22:	— Set up result bins for 20 readings each (Mark Bin) (22 = 20 readings + 1 condition code + 1 control word = Bin Size). Specify history data acquisition mode (1).
RP,0;	— Repeat everything in outer RP-NX loop indefinitely.
IF,3,4,1;	— IF a blow out is sensed via limit switch wired to channel 4, card slot 3, via signal high (1) then EX; if not, then EI.
EX,0;	— Terminate the request (EXIT) and return the stored data.
EI;	— End IF; proceed with request.
RP,20;	— Repeat everything in inner loop 20 times.
WT,3,2,1;	— Synchronize (Wait for Trigger) the data gathering with tire sector pulse on channel 2, card slot 3, wait for pulse to go to high state.
AI,2,11,1;	— Read the sidewall load cell connected to channel 11, card slot 2.
NX;	— Inner loop completion.
CB;	— Close Bin and make next bin available to store results.
NX!	— Outer loop completion.

Results, (in millivolts), returned only upon task completion, are shown below; a condition code will be sent with each bin.

MULTIPLE BINARY RESULTS

```
0,100...125  0,130,...210  ...  0,950...985
```

Reading these binary results is similar to the previous example.

History data acquisition differs from continuous data acquisition in that results are returned to the computer only when the task completes, i.e., via the EX,0 command. Data is acquired and, in the absence of a blowout condition, discarded to make room for new data. Note the use of IF-END IF pair. This built-in decision making capability allows the Extended Performance HP 2240A to alter its measurement task based on the status of a digital input. At any one time the results from the latest 32 revolutions (determined from result buffer capacity) could be available for transmission if a blowout occurred. Also, if required, satisfaction of the IF test condition could be followed by additional commands before termination, e.g., the elapsed time for the blow-out to occur after start of test could be obtained using the TE command.

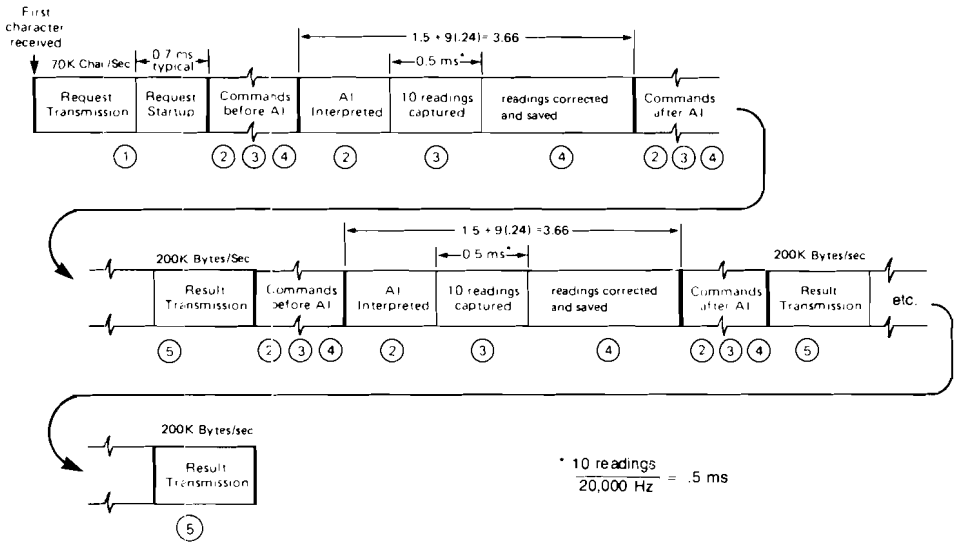
HP 2240A Extended Performance: reduced communications overhead and faster command execution

With the extended performance option the HP 2240A can operate with less computer intervention because continuous results can be obtained from a single task request. The extended performance features do not affect HP 2240A function card hardware specifications. Real time response to interrupts, and the acquisition of analog and digital data still proceeds at the defined hardware rates from the function cards to the 2240A. However, since results are sent in binary format, ASCII result formatting is no longer done and the 2240A formatter is eliminated, resulting in faster command execution time.

As in the case of the standard HP 2240A, task timing is done by simply adding up the appropriate command execution lines. However, calculating continuous data acquisition rates through the 2240A to the HP-IB involves a different procedure because the one time request transmission and startup overhead is usually unimportant; only execution and result transmission times need be considered. The timing elements of a request with extended performance option is summarized on the next page.

REQUEST

```
MB,0,202;RP,0;RP,20;WT,3,2,1;AI,2,1,10;NX;CB;NX!
```



(1) **Request Transmission and Start-Up** — As with the standard HP 2240A, requests are received at up to 70K characters/sec. and require about .7ms for start-up. However, in the case of continuous or history data acquisition modes, this request transmission and start-up overhead is incurred just once, regardless of the number of result transmissions.

Command Execution

Command processing proceeds left-to-right, one command at a time.

(2) Commands are interpreted and output data is prepared.

(3) Data is captured for a measurement command, output channels are updated for a control command.

(4) Analog results are corrected as before. However, no ASCII formatting is done; i.e., results are saved in binary format in the 2240A buffer. Elimination of the results formatter greatly reduces execution time.

(5) **Result Transmission** — When a bin has filled it is ready for transmission. After 1 ms for bin closing results are transferred to the computer at 200 kbytes/sec. Binary format uses only 2 bytes per reading so result transmission times become faster. When result transmission completes (and the request is not terminating) execution resumes with step (2) .

Sample computation of HP 2240A extended performance operation

Again using the tire equipment measurement and control example, performance calculations for both standard and extended performance 2240A operation are shown in the table below. Comparing standard and extended performance figures show that the latter results in lower execution time and higher throughput.

	Command	Standard HP 2240A Execution Time in Milliseconds	Command	Extended Performance HP 22404 Execution Time in Milliseconds (First Bin of 200 Readings))	(Succeeding Bins of 200 Readings)
	Request receipt and startup	$\frac{28 \text{ bytes}}{70K \text{ char sec}} + .7 = 1.1$	Request receipt and startup	$\frac{48 \text{ bytes}}{70K \text{ char sec}} + 7 = 1.40$	—
			MB.0.202	80	—
			RP.0	55	—
	RP.20	.55	RP.20	55	.55
Inner	WT.3.2.1	.90	WT.3.2.1	.90	.90
Measurement	AI.2.1.10	2.0 + 9 (.75) = 8.75	AI.2.1.10	1.5 + 9 (.24) = 3.66	3.66
Loop	NX	.35	NX	.35	.35
			CB	80	80
			NX	.35	.35
	Request cleanup and result transmission*	$5 + \frac{200 \times 6 \text{ bytes}}{200Kb \text{ sec}} = 6.50$	Result (bin) transmission*	$1.0 + \frac{200 \times 2 \text{ bytes}}{200Kb \text{ sec}} = 3.00$	$1.0 + \frac{200 \times 2 \text{ bytes}}{200Kb/sec} = 3.00$
	Total time for inner loop (sector time)	.90 + 8.75 + .35 = 10.0ms	Total time inner measurement loop (sector time)	.90 + 3.66 + .35 = 4.91 ms	.90 + 3.66 + .35 = 4.91 ms
	Maximum number of inner loop executions per second	$\frac{1}{10.0ms} = 100$ loops sec	Maximum number of inner loop executions per second	$\frac{1}{4.91 \text{ ms}} = 203$ loops/sec	$\frac{1}{4.91 \text{ ms}} = 203$ loops/sec
	Total time for entire task (one tire revolution)	1.1+.55+20(10.0)+6.5 = 208.15 ms	Total time for outer loop (one tire revolution)	1.40+.80+.55+.55+ 20(4.91)+.80+.35+3.00=105.65 ms	.55+20(4.91)+.80 +.35+3.00=102.90 ms
	Maximum number of tasks/sec (tire revs/sec)	4.8 revolutions/sec	Maximum number of tire revolutions/sec	Not applicable	9.7 revolutions/sec

* This rate does not allow for computer overhead in reading results and assumes the computer can read results at HP 2240A transmission speeds. In the case of continuous data acquisition mode, results must be read by the controller at an average rate faster than they are being acquired so no results will be overwritten and lost. When data acquisition timing is critical a command can be used to shut off interrupt sources (including result transmissions) during parts of the request.

The table below shows command execution times with the Extended Performance HP 2240A. Compare these figures with the standard HP 2240A on page 2-4 and predict the performance of your particular application.

EXTENDED PERFORMANCE HP-MCL COMMAND EXECUTION TIMES

2240A Command	EXECUTION TIME IN MILLISECONDS: First Channel or Field (ms)	EXECUTION TIME IN MILLISECONDS: Each Add'l. Channel or Field (ms)	
			Execution Times are worst case ignoring delays due to interrupts. Note that the times shown for additional channels include the time for correction and do not indicate the rate at which channels are actually scanned or updated. See the comments below keyed to each command for typical rates.
MEASUREMENT			Keyed Comments*
AI	1.5	.24	A
AU	1.2	.08	A
DI	1.1	.11	B
FI	.95	.09	C
RC	1.0	.07	D
CONTROL & STIMULUS			
AO	1.6	.75	E
DO	1.6	.6	F
FO	1.5	.65	G
SS	1.5	—	H
SYNCHRONIZATION AND TIMING			
WT	.9	—	
WB	.5	—	
TI	.9	—	I
TE	.40	—	I
TASK SUPERVISION			
RP	.55	—	
NX	.35	—	
IC	.4	—	
EXTENDED PERFORMANCE COMMANDS			
MB	.8	—	
CB	.8	—	J
IF	1.0	.06	K
EI	.35	—	
EX	.65	.06	K
WR	.7	—	K
IE	.4		

A Maximum 20 kHz scan rate into buffer across channels, or 20 kHz sample rate on one channel for 700 - 800 sample buffer load. This rate can be guaranteed using a special command which inhibits interrupts. An additional 0 - 50 μsec is required when crossing a card boundary.

B Sequential digital points are gathered into HP 2240A buffer at a rate of 90 μsec per point (11,000 points/sec).

C 16-bit fields of digital points are gathered into 2240A buffer at a rate of 70 μsec per field (14,000 field/sec).

D Totalizer counts at 500 kHz maximum. Frequency counter at 500 kHz maximum. Period counter at 100 kHz maximum.

E Maximum analog output update rate from 2240A buffer is 200 μsec per point (5,000 points/sec).

F Sequential digital output points are updated from 2240A buffer at a rate of 450 μsec per point (2,200 points/sec).

G Sequential 16-bit fields of digital outputs can be updated from 2240A buffer at a rate of 250 μsec per field (4,000 fields/sec).

H Adjustable stepper pulse output rates to 500 pulses/sec.

I Interval Timer (TI) and elapsed time counter (TE) are updated every 10 milliseconds.

J Additional set-up time is required when the data is read immediately.

K .06 μsecs are required for each additional character between IF and and EI or between EX and NX.

** Data gathering and update rates are typical.*

Complete Command Timing for all commands is available in the HP 2240A User's Manual (02240-93001) and User's Manual Supplement (02240-93007). Contact your local HP Systems Engineer for performance predictions tailored to your application.

HEWLETT hp PACKARD

Measurement and control processor extended performance option and field upgrade kit

models
2240A opt. 001
22919A

Features

- **Acquire and return data continuously to the computer at average rates up to 10,000 readings/sec. from a single request.**
- **History data acquisition for recovery of data leading up to and following a critical event (pre and post trigger capability).**
- **Built-in decision making capability for request branching based on a digital input status.**
- **Larger HP 2240A result buffer capacity and faster throughput in data acquisition and control applications.**
- **Nested repeat/next loops for programming convenience and efficiency.**
- **Seven new programming commands for greater programming flexibility.**
- **Same high level command capabilities of HP 2240A.**

Description

Overview:

The HP 2240A Extended Performance Option replaces the standard 2240A ROM set with ROM's providing enhanced 2240A performance that may be required in certain applications. This improved performance results specifically from (1) storage and transmission of results in 2's complement binary (rather than ASCII) format that effectively increases buffer size and data rate throughput over the HP-IB link back to the computer and (2) a more efficient management of the 2240A data buffer that permits the 2240A to acquire and return data to the computer continuously from a single request. Furthermore, new features such as built-in decision making capability and additional programming commands are included with the Extended Performance Option.

The overall impact of the Extended Performance Option is to make the HP 2240A an even more independent, intelligent device. Interrelated 2240A/computer activity is reduced allowing each more time to spend on the specific tasks it was designed to do.

Use of the Extended Performance Option precludes all ASCII results transmission and will require programmer responsibility to insure proper reading and manipulation of the 2's complement binary results.

Binary Results Storage and Transmission

With the standard HP 2240A, results are obtained in a binary representation, formatted, and then stored in an ASCII format in the 2240A buffer. A five digit + sign + comma result item takes seven bytes in the standard 2240A buffer. The Extended Performance Option directly stores the 2's complement binary results relieving the 2240A from ASCII formatting activity. So, the 2240A command set execution times are faster using the Extended Performance Option. Furthermore, each result item takes only two bytes of the 2240A result buffer, a 3 to 1 increase in buffer capacity. The larger capacity means less frequent buffer emptying and consequently, less 2240A/computer interactive overhead.

Results are also transmitted in this binary format, providing greater transmission efficiency since only two bytes per reading is sent back to the computer. Some computers can perform numerical operations directly on the results without any need for reformatting.

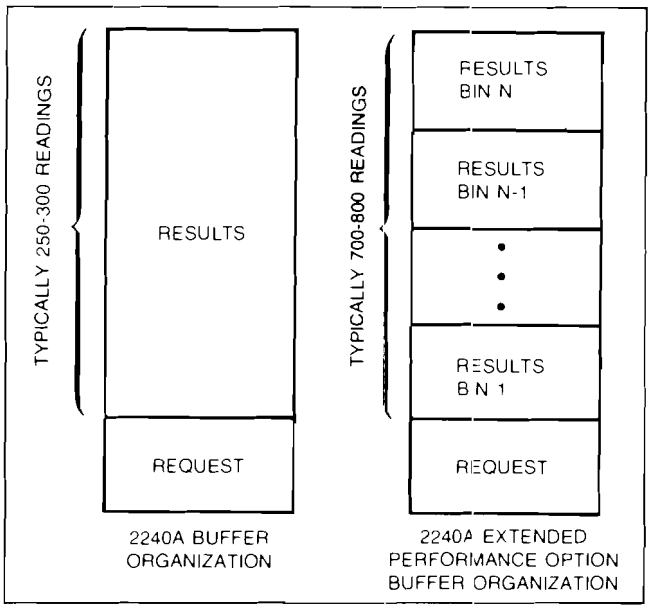
This binary result handling capability does not change the manner in which requests are sent to the HP 2240A. Requests are still built from the same high level 2240A command set and sent to the 2240A using the standard programming conventions. That is, requests are transmitted in ASCII format; results are returned in 2's complement binary format.

Multiple Results from a Single Request

The standard HP 2240A limits the number of results obtained from a single request to the quantity that fills the 2240A result buffer. Everytime the buffer is emptied, a request must be reissued to the 2240A.

The Extended Performance Option offers a more flexible buffer organization for the HP 2240A. The buffer is divided into segments called "bins". Each bin stores a user defined set of results, e.g., the results for one or more analog scans. The results of many such scans can reside in 2240A result buffer concurrently. The user specifies how results are returned to the controller by specifying the appropriate "bin mode", i.e., either "continuous data acquisition mode" or "history data acquisition mode". *In either case only one request is sent to the 2240A regardless of the number of scans that are processed.*

An important difference between continuous and history data acquisition modes is the way results are made available to the computer. In continuous data acquisition mode, filled bins are read continuously by the computer; in history data acquisition mode, the reading of filled bins is done once and only after occurence of a digital event. History data acquisition mode implies that bins are emptied of old results as new results become available to fill the bins. These old results are no longer available to be read by the computer. When history data acquisition mode terminates, all filled bins (containing the most recently acquired data) become available for transmission to the computer.



Continuous Data Acquisition Mode

In continuous data acquisition mode, each bin is filled and it becomes available for transmission to the computer. At the same time the next bin is allocated and starts filling using the request residing in the request buffer. The computer is able to continuously read full bins even while another bin has started filling (however, actual 2240A data acquisition is suspended during result transmission). Bins that have been read are again available for new result storage. Full bins need not be read immediately; this "elastic buffering" decouples the computer from the real time data gathering of the 2240A. However, the computer must be able to read results at an average rate that always provides one empty bin for new incoming results. This prevents results from being overwritten and lost. Each bin returns a condition code indicating whether data in it is valid. The process continues until termination of the continuous data acquisition mode. Because the 2240A can return data to the computer continuously from one request, overhead incurred by repeated computer requests is eliminated, resulting in higher system performance.

Continuous data acquisition mode can be used to perform repeated multiple channel scanning at highest possible 2240A speeds while minimizing 2240A/computer communications overhead. *It is intended for applications where it is important to scan a group of channels at high speeds and transmit the readings to the computer while waiting for the start of the next scan. This can be done continuously from one request.* Continuous data acquisition mode is valuable in many machine and process monitoring, control, test and data acquisition applications. These applications benefit from the ability to return multiple channel scan results continuously to the computer from a single request. Aggregate data acquisition rates for multiple channel scanning (aggregate meaning # scans/sec times # channels/scan) achieved using continuous data acquisition mode are much higher than can be achieved by the standard HP 2240A.

However, this mode of operation is not well suited to high speed continuous signal construction applications because periods of uniform data acquisition must be interleaved with periods of no data acquisition. For example, a single channel can be sampled repetitively at 20,000 readings per second until a bin is filled (e.g. 250 readings); then sampling will stop (typically for several milliseconds) for internal 2240A result processing, bin closing, possible result transmission, and further command interpretation before resuming data acquisition.

Likewise, a single multiple channel scan can be completed at 20,000 readings/second; however, at scan completion, scanning will be suspended for these same reasons.

Many applications can afford this suspension while waiting for the next scan to begin. With this type of operation aggregate rates at which data can be acquired and continuously returned to the computer will be maximized assuming 1) the analog input card(s) (22900A) acquire data at full unpaced (and uncorrected for temperature drift) speeds, i.e., 20,000 readings/sec. into the 2240A buffer, and 2) the computer be able to read results at full 2240A transmission speed (200K bytes/sec.).

Increasing the number of channels per scan increases the aggregate continuous rate at which data is acquired and returned to the computer. Rates as high as 10,000 readings/second are obtainable when each scan includes the full 2240A complement of 256 channels.

History Data Acquisition Mode

Bin mode operation can also be used in history data acquisition. History data acquisition allows data to be continuously sampled and subsequently discarded in the absence of a specific event occurence. If a specific event (e.g., closing an alarm switch) occurs the data taken immediately prior to, and possibly after, the event can be recovered for analysis and correlation. Although the recovered data may be analog and/or digital in nature, the event that initiates the data recovery must be sensed as a digital input.

The operation of history mode is basically the same as continuous data acquisition mode. The difference is that results are transmitted only once, at the completion of the task. Hence, at the completion of a single scan, data acquisition is suspended for internal 2240A result processing, further command interpretation, and bin closing; however since results are transmitted only once the overall data acquisition suspension period will be less than for continuous data acquisition mode.

Decision Making and Branching Capability

The Extended Performance Option provides decision making and branching within a request. The IF-End IF format allows two independent courses of action to be taken depending on the status of a digital input (for instance, a push button or limit switch). Digital input sensing and branching is completely built in the Extended Performance Option, i.e., no computer intervention is required when making a decision of this type. Any number of IF-End IF commands may be nested in the request. IF-End IF pairs can be used along with the EXIT command to terminate the continuous and history data acquisition modes.

Additional New Programming Conveniences

New programming features have been added to the HP 2240A by the Extended Performance Option. Nested Repeat-Next (RP-NX) loop capability conserves task buffer space. Up to six RP-NX pairs may be active at one time.The EX command allows branching out of RP-NX loops. A new Wait and Reset (WR) command simplifies paced sampling and scanning and automatically resets the 2240A elapsed time clock after the sampling occurs. The Interrupt on Error (IE) command lets the 2240A interrupt the controller immediately upon an error condition. The returned condition code (or codes in the case of a bin mode) indicates whether the stored data is valid.

Choosing Between Standard and Extended Performance Features

Many applications can benefit from use of the HP 2240A Extended Performance Features. Three broad groupings of these applications include:

1. *A measurement task continuously repeated for long periods of time. In this application the user is interested in large amounts of data acquired from multiple sensor scans.* The results may be processed immediately by the computer or analyzed offline. The application will also be characterized by minimal need to change the request executing in the HP 2240A; i.e., almost all communications will be from the HP 2240A to the computer.

   By eliminating the need to reissue a request to the HP 2240A every time the result buffer is read, the Extended Performance Option reduces 2240A request handling overhead and increases the time the 2240A is available to gather data. Faster 2240A command execution times further improve data acquisition performance. Binary result transmission eliminates formatting time at the computer end of the link.

   The HP 2240A Extended Performance Option will be ideal in applications requiring fast, continuous, multiple channel scanning. This requirement is found in many machine and process monitoring, control, and test applications. The Extended Performance Option may be mandatory to satisfy such applications.

2. *Indefinite repetition of a measurement task where subsequent results are of no interest unless they are accompanied or initiated by a specific unpredictable event occurrence.* This type of operation, known as "history data acquisition" or "sequence of event recording", implies both pre and post triggering capability for data acquisition. For example, monitoring of a continuous process is required to isolate, identify, and analyze a failure occurrence. During steady state operation the process variables may be well behaved and predictable. However, transient process variable changes may immediately precede an alarm condition.

   The HP 2240A Extended Performance Option permits the user to discard unwanted steady state data rather than store it using an expensive peripheral device. Tripping of the alarm switch initiates the recovery of stored data that represents the process variable changes as they occurred prior to the alarm condition. Furthermore, tripping of the switch may also initiate an emergency shutdown procedure that stops machinery and alerts personnel.

   The same operation may be used in "sequence of events recording" where the recovered information of interest is mainly digital in nature. For instance the results may indicate the sequence of relay and contact closures that preceded a jammed machine condition in a materials handling application.

3. *Tasks that require fast local response to machine, process, or operator inputs (e.g. relays, limit switches, or push buttons) because the task is to change in accordance with the state of these digital input devices.* The HP 2240A Extended Performance Option puts this decision making and branching capability in the 2240A where execution speeds are not affected by 2240A/computer communications.

   This capability gives the HP 2240A simple closed loop control capabilities. An example is the case where a potential tank overflow condition (level switch closing) requires positioning several valves to reduce the tank level. Until the switch closes the 2240A could be acquiring thermal data describing material in the tank. When the switch closes, analog outputs could be provided for the value actuators. When the level returns to its normal state, the thermal data acquisition would be resumed.

   Decision making capability is beneficial in continuous and history data acquisition applications as one means of task termination.

Unless the application specifically has one of these requirements, the Extended Performance Option may not be necessary or even desirable. If these requirements do not exist, the determining choice factors include:

1. *There is no ASCII result transmission capability with the Extended Performance Option.* All results are returned in 2's complement binary representation.

2. *Reading binary results may be less straightforward than reading ASCII results for some computer/language combinations.* (Consult the specific computer programming manuals for more details.) If floating point calculations are to be performed on the results, then conversion from 2's complement binary to the appropriate floating point representation must be done at the computer.

3. *Due to 1 and 2, existing programs now running in 2240's will require modification (only for reading results) to use the Extended Performance Option, whether the new features are needed or not.*

Summary of HP 2240A Commands Added By The Extended Performance Option

COMMAND	FUNCTION
MB	**MARK BIN**: Subdivides the buffer into two or more result bins and allows user to specify either continuous or history data acquisition mode.
CB	**CLOSE BIN**: Seals the data in the bin and allows further results to be taken and put into the next bin. In continuous data acquisition mode a "closed" bin is immediately available to be read. In history mode, the data is available when the request terminates.
IF-EI	**IF-END IF**: Allows branching (within a request) based on testing the condition that follows the IF portion of the command. If true, commands following the IF are executed. If not true, commands following the EI are executed. Nested IF-EI pairs are permitted.
RP-NX	**REPEAT NEXT**: Identical to RP-NX in standard 2240A except these pairs can be nested with six levels active concurrently. Also permits indefinitely long data acquisition when used in bin mode.
EX	**EXIT**: Used within an IF-EI statement to terminate the request and return data or exit to a given level of nested RP-NX loops.
WR	**WAIT AND RESET**: Used to pace data samples or scans (at 10 ms or greater intervals) by using the 2240A's elapsed time clock. Provides improved execution speed in tight timing loops.
IE	**INTERRUPT ON ERROR**: Causes Request Service message to be sent to the computer upon detection of an error.

Compatibility of Extended Performance Option with User Programs and HP 2240A Accessories

With exception in the following areas, programs written for the standard HP 2240A do not require modification when used with the Extended Performance Option.

1. Reading 2's complement binary results will require different or modified computer input statements. Conversion to floating point representation must be done by the computer if floating point calculations are made using the results. Consult the appropriate computer programming manual for details.

   IMPORTANT NOTE: The user does not have ASCII result transmission capability when using the HP 2240A Extended Performance Option.

   Status results are also binary with Summary, Extended, and Interrupt status returning one, four, and ten words respectively.
2. If HP 1000 BASIC is used, a user written FORTRAN subroutine must be called to read the binary results.
3. The BK (Blocking) and BD (Block Default) commands are not included in the HP 2240A Extended Performance Option. The MB and CB commands perform a similar function for binary data by allowing results to be transmitted in small, well defined groups.
4. Routines C2240 and R2240 (for ASCII/binary conversion) included in the 92400A DAS Utility Library are not applicable to the Extended Performance HP 2240A.

Specifications

Interface Specifications

All interface specifications applicable to the HP 2240A Extended Performance Option are identical to the standard HP 2240A (see HP 2240A Technical Data Book 5952-8532).

Prerequisites

An HP 2240A with its standard prerequisites (found in HP 2240A Technical Data Book) is required for use of the Extended Performance Option.

Hardware and Software Supplied

The Extended Performance Option replaces the standard HP 2240A ROM set with the Extended Performance Option ROM set. All other HP supplied hardware and software is identical to the standard HP 2240A.

Documentation Furnished

The Extended Performance Option provides the following additional documentation to the HP 2240A.

02240-93007	HP 2240A Extended Performance Option User's Manual Supplement.

Ordering Information

Order HP 2240A Option 001 to replace the standard HP 2240A ROM set with the HP 2240A Extended Performance Option ROM set.

Installation and Warranty

Installation and Warranty is identical to that of the standard HP 2240A.

22919A: HP 2240A Extended Performance Field Upgrade Kit

Field upgrades of standard HP 2240A's can be done by the user via the 22919A Field Upgrade Kit. This kit provides the user with the Extended Performance ROM set and the following documentation.

1. HP 22919A Installation and Service Manual (22919-90001).
2. HP 2240A Extended Performance Option Users Manual Supplement (02240-93007).
3. HP 2240A Quick Reference Guide (02240-93005).

The 22919A Field Upgrade Kit is compatible with all existing HP 2240A's and their associated hardware. Modifications to existing 2240A programs will be needed to use the upgrade kit. Refer to the discussion found earlier in this document.

Installation of the 22919A upgrade kit is a user responsibility. The HP Computer Systems Group parts warranty applies to the 22919A Upgrade Kit.

HP 2240A/Computer System Performance

Using standard high level I/O commands like BASIC's "READ/PRINT," FORTRAN's "READ/WRITE" and HPL's "red/wrt", you can offload your computer by letting the 2240A execute measurement and control tasks written in HP-MCL. The interpretation and execution of these tasks by the 2240A is independent of the computer; hence tasks written in HP-MCL execute in the 2240A at the same speed regardless of which computer is used. And while they are executing, the computer is free to do other work. However, it is sometimes necessary to perform more complicated functions using a computer for data reduction, analysis, and decision making algorithms. For these cases you will want to know the performance of the combined computer/2240A system.

The benchmark measurement and control tasks described and exemplified on the next few pages allow you to estimate the applicability of the 2240A and your computer in several common measurement and control situations. A typical block diagram of a 2240A/computer configuration used to test system performance is shown below.

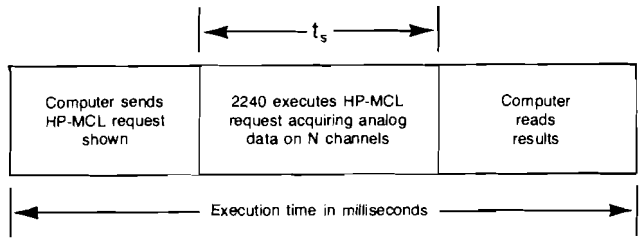
How to Use Combined System Performance Information

The following steps enable you to determine the performance of the 2240A with your HP Computer:

1. Unfold page 7-2. With this page unfolded, turn to the pages that specify 2240A performance with your computer. (HP 1000, HP 9825, or HP 9835).
2. Choose the measurement and control task of interest to you and read across the facing pages. The left page contains data for the Standard 2240A; the right page contains data for the Extended Performance 2240A.
3. Performance, as given by the "performance definition" is the inverse of the "execution time in milliseconds."
4. Interpret the performance data using the following information for the benchmark measurement and control tasks.

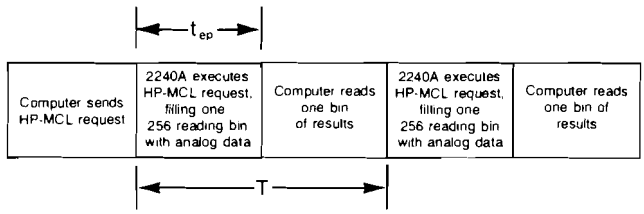
Multiple Channel Scanning

a. **Standard 2240A:** The "Execution time in milliseconds" figure is the time taken to perform the following:



The time, t_s is the time the Standard 2240A takes executing the HP-MCL request. It is independent of the computer being used and can be determined using information found on page 2-4.

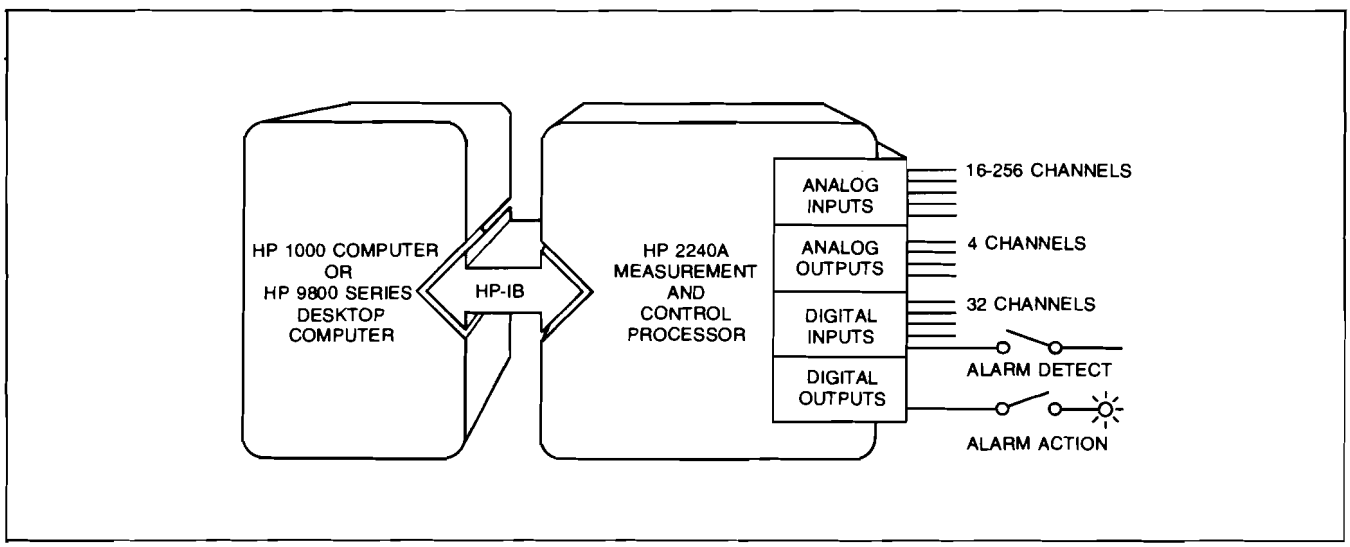
b. **Extended Performance 2240A:** Continuous data acquisition mode is used. The following shows what actually takes place in continuous data acquisition mode.



Note that each bin contains 256 readings or M scans of data, where

M = 256/N (N = # of channels/scan).

Thus, "execution time in milliseconds" = T/M which is the **average** time it takes to acquire one N-channel scan of data and transmit it to the computer. Since, the



Typical Block Diagram of the Computer HP 2240A Configuration

HP-MCL request is issued just once by the computer, the time to and the request is small when many bins are read in a continuous mode of operation. Hence, request time, is ignored.

The time, t_{ep}, of course is independent of the computer; it can be calculated using page 6-5 and the HP-MCL request

RP,M;AI,1,1,N;NX

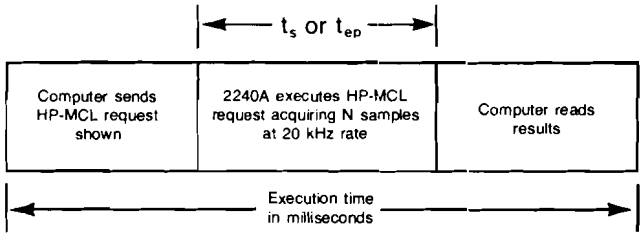
where M and N are described above.

c. To determine average continuous data acquisition rates, multiply appropriate "number of N-channel scans/sec" by the number of channels/scan, "N." This rate is from the 2240A to computer main memory. Long periods of data acquisition may require a mass storage device; outputting the data to such a device is a user responsibility.

d. Numbers in parentheses refer to HP-MCL request in parentheses, i.e., faster rates can be achieved using AU (uncorrected for the temperature drift) command.

Burst signal reconstruction

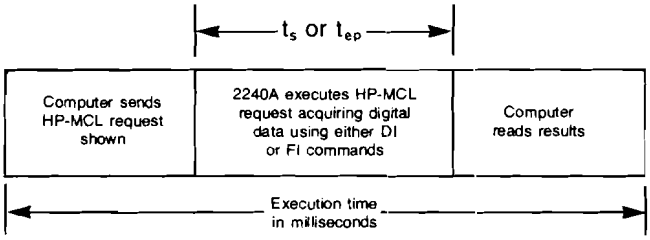
For both the Standard and Extended Performance 2240A the "Execution time in milliseconds" is



The times t_s and t_{ep} are the times taken by the Standard and Extended Performance 2240A respectively to acquire and process the N samples. Refer to pages 2-4 and 6-5 respectively for determination of these times. They are independent of the computer being used. Numbers in parentheses refer to RU (uncorrected for temperature drift) command.

Digital input scanning

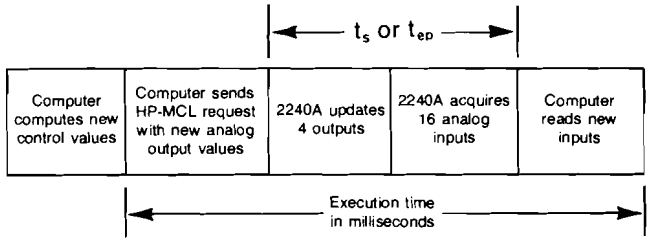
For both the Standard and Extended Performance 2240A, the operation and definition of "Execution time in milliseconds" is shown below.



The times t_s and t_{ep} are the times taken by the Standard and Extended Performance 2240A respectively to acquire and process the N samples. Refer to pages 2-4 and 6-5 respectively for determination of these times. They are independent of the computer being used. Continuous data acquisition mode of the Extended Performance 2240A was not used for digital point scanning.

Supervisory control

The scenario is the same for both the Standard and Extended Performance 2240A.



t_s and t_{ep} again refers to the time taken by the Standard or Extended Performance 2240A to execute the HP-MCL request shown. They are independent of the computer being used.

Closed loop alarm response

The following applies to both the Standard and Extended Performance 2240A.

a. Using the computer, the "Execution time in milliseconds" is the time from detection of an alarm condition via the 2240A common interrupt card to the time an alarm is actuated by the 2240A digital output card. This requires a user written computer alarm routine and can be done with both the Standard and Extended Performance 2240A.

b. The Extended Performance 2240A can check status on a digital line using local intelligence. If necessary it can initiate an alarm routine without the computer. The "Execution time in milliseconds" is the maximum time the 2240A takes to execute the HP-MCL command shown. It is independent of the computer used.

History data acquisition

The "Execution time in milliseconds" is the time taken to execute the HP-MCL request shown. It is independent of the computer being used.

HP 2240A/COMPUTER
SYSTEM PERFORMANCE DATA

(UNFOLD THIS PAGE)

HP 1000/HP 2240A EXTENDED PERFORMANCE

N	EXECUTION TIME IN MILLISECONDS			PERFORMANCE (SEE PERFORMANCE DEFINITION)			PERFORMANCE DEFINITION
	BASIC[4]	FORTRAN[5]	FORTRAN[6]	BASIC[4]	FORTRAN[5]	FORTRAN[6]	
16	NA	5(4)	4(3)	NA	200(250)	250(333)	Number of N-channel scans/sec.
32	NA	7(5)	7(5)	NA	143(200)	143(200)	
128	NA	24(16)	22(14)	NA	41.7(62.5)	45.5(71.4)	
256	NA	43(31)	41(25)	NA	23.3(32.3)	24.4(40)	
250	NA	61(46)	48(33)	NA	16.4(21.7)	20.8(30.3)	Number of N-Sample acquisitions/sec.
750	NA	161(116)	121(76)	NA	6.2(8.6)	8.3(13.2)	
—	NA	18	16	NA	55.6	62.5	Number of 32 point digital scans/sec.
—	NA	17	16	NA	58.8	62.5	Number of 32-bit (2 fields) updates/sec.
—	NA	21	20	NA	47.6	50.0	Number of control loop updates/sec.
—	NA	38	36	NA	26.3	27.8	Number of actions/sec.[3]
—	NA	3	3	NA	333	333	Number of actions/sec.
—	NA	8	8	NA	125	125	Number of 32 channel scans/sec.

NOTES (continued):

[3] Interrupt service program in main memory at time of interrupt.

[4] BASIC must call a user written FORTRAN subroutine to use the Extended Performance 2240A.

[5] FORTRAN using READ/WRITE statements and standard RTE formatter for requests. Binary results of Extended Performance 2240A are available for immediate processing by the HP 1000 without further formatting (i.e., FORTRAN unformatted READ statements were used).

[6] FORTRAN using WRITE statement and standard RTE formatter for requests. EXEC read used for binary results. Results are available for immediate processing.

HP 9825A/2240A STANDARD PERFORMANCE

N	EXECUTION TIME IN MILLISECONDS: FORMATTED READ[1]	EXECUTION TIME IN MILLISECONDS: BUFFERED READ[2]	PERFORMANCE (SEE PERFORMANCE DEFINITION): FORMATTED READ[1]	PERFORMANCE (SEE PERFORMANCE DEFINITION): BUFFERED READ[2]	PERFORMANCE DEFINITION
16	78(76)	25(23)	12.8(13.2)	40.0(43.5)	Number of N-channel scans/sec.
32	148(146)	39(37)	6.8(6.8)	25.6(27.0)	
128	566(559)	129(120)	1.8(1.8)	7.8(8.3)	
256	1130(1120)	246(233)	.9(.9)	4.1(4.3)	
250	1110(1090)	242(226)	.9(.9)	4.1(4.4)	Number of N-sample acquisitions/sec.
750	NA	NA	NA	NA	
—	108	21	9.3	47.6	Number of 32 point digital scans/sec.
—	14	11	71.4	90.9	Number of 32-bit (2 fields) updates/sec.
—	86	28	11.6	35.7	Number of control loop updates/sec.
—	22	22	45.5	45.5	Number of such actions/sec.
—	NA	NA	NA	NA	Number of such actions/sec
—	NA	NA	NA	NA	Number of 32 channel scans/sec.

Benchmark test setup conditions

- All tests done on HP 9825A with HP-IB interface, extended I/O ROM, string advanced programming ROM, and 24K bytes memory.
- Voltage values measured were typical (9.995 volts).

NOTES:

[1] ASCII results formatted using red 701,E,V(1),V(2),. . .V(N) or equivalent "for-next" input loops. Data available for immediate processing.

[2] ASCII results read using fast read/write into "Type 3" I/O buffer. Data is available for immediate processing.

HP 9825A/2240A EXTENDED PERFORMANCE

	EXECUTION TIME IN MILLISECONDS		PERFORMANCE (SEE PERFORMANCE DEFINITION)		
N	FORMATTED READ[3]	UNFORMATTED READ[4]	FORMATTED READ[3]	UNFORMATTED READ[4]	PERFORMANCE DEFINITION
16	87(86)	5(4)	11.4(11.6)	200(250)	Number of N-channel scans/sec.
32	158(156)	8(7)	6.3(6.4)	125(143)	
128	595(588)	43(23)	1.6(1.7)	23.3(43.4)	
256	1185(1170)	85(44)	.8(.8)	11.7(22.7)	
250	1160(1150)	71(55)	.9(.9)	14.1(18.2)	Number of N-sample acquisitions/sec.
750	3490(3450)	190(145)	.3(.3)	5.3(6.9)	
—	150	16	6.6	62.5	Number of 32 point digital scans/sec.
—	24	10	41.6	100	Number of 32-bit (2 fields) updates/sec.
—	91	18	11.0	55.6	Number of control loop updates/sec.
—	64	19	15.6	52.6	Number of such actions/sec.
—	3	3	333	333	Number of such actions/sec.
—	8	8	125	125	Number of 32 channel scans/sec.

NOTES (continued):

[3] Binary results read using fast read/write into "Type 3" I/O buffer and then formatted using itf statement. Formatting time is included. Data is then available for immediate processing. Continuous data acquisition mode of 2240A not used in any of the described tasks.

[4] Binary results read using fast read/write into "Type 3" I/O buffer. Binary results are not in format for processing. This must be done at a later time.

HP 9835A/2240A STANDARD PERFORMANCE

	EXECUTION TIME IN MILLISECONDS		PERFORMANCE (SEE PERFORMANCE DEFINITION)		
N	FORMATTED READ[1]	UNFORMATTED READ[2]	FORMATTED READ[1]	UNFORMATTED READ[2]	PERFORMANCE DEFINITION
16	216(216)	47(47)	4.6(4.6)	21.3(21.3)	Number of N-channel scans/sec.
32	392(390)	56(52)	2.6(2.6)	17.9(19.2)	
128	1481(1473)	159(139)	.7(.7)	6.3(7.2)	
256	2933(2919)	197(256)	.3(.3)	3.4(3.9)	
250	2864(3849)	291(250)	.3(.4)	3.4(4.0)	Number of N-Sample acquisitions/sec.
750	NA	NA	NA	NA	
—	281	43	3.6	23.3	Number of 32 point digital scans/sec.
—	59	41	16.9	24.4	Number of 32-bit (2 fields) updates/sec.
—	234	51	4.3	19.6	Number of control loop updates/sec.
—	143	143	7.0	7.0	Number of such actions/sec.
—	NA	NA	NA	NA	Number of such actions/sec.
—	NA	NA	NA	NA	Number of 32 channel scans/sec.

Benchmark test setup conditions

- All tests done on HP 9835A with HP-IB interface and I/O ROM.
- Voltage values measured were typical (9.995 volts).

NOTES:

In all cases refer to HP 9835A I/O Programming Manual 09835-90060 for details.

[1] ASCII data read using appropriate IMAGE statement. Data is available for immediate processing.

[2] ASCII data read into string array using byte fast handshake transfer. Data must be formatted later for processing.

HP 9835A/2240A EXTENDED PERFORMANCE

	EXECUTION TIME IN MILLISECONDS		PERFORMANCE (SEE PERFORMANCE DEFINITION)		
N	FORMATTED READ[3]	INTEGER FORMATTED READ[4]	FORMATTED READ[3]	INTEGER FORMATTED READ[4]	PERFORMANCE DEFINITION
16	117(117)	5(4)	8.5(8.5)	200(250)	Number of N-channel scans/sec.
32	193(193)	9(7)	5.1(5.1)	111(143)	
128	650(649)	42(24)	1.5(1.5)	23.8(41.6)	
256	1275(1260)	84(47)	.7(.7)	11.9(21.2)	
250	261(246)	80(65)	3.8(4.1)	12.5(15.4)	Number of N-Sample acquisitions/sec.
750	748(640)	199(155)	1.3(1.6)	5.0(6.5)	
—	182	43	5.4	23.2	Number of 32 point digital scans/sec.
—	49	39	20.4	25.6	Number of 32-bit (2 fields) updates/sec.
—	62	50	16.1	20.0	Number of control loop updates/sec.
—	80	80	12.5	12.5	Number of such actions/sec.
—	3	3	333	333	Number of such actions/sec.
—	8	8	125	125	Number 9f 32 channel scans/sc.

NOTES (continued):

[3] Binary data read using appropriate IMAGE statement. Data is available for immediate processing. Continuous data acquisition mode of 2240A not used in any of the described tasks.

[4] Binary data read into integer array using byte fast handshake transfer. Integer data available for immediate processing.

NOTES

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