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Note

Title & Document Type: 5527A/B Laser Position Transducer Designers Guide Version 1.1 (Added missing schematics)
Manual Part Number: 05527-90015
Revision Date: August 1992

HP References in this Manual

This manual may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies.

Changes to this Manual

No changes have been made to this manual.

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HEWLETT PACKARD

HP 5527A/B LASER POSITION TRANSDUCER

DESIGNER'S GUIDE

Including:

HP 5507A	Laser Position Transducer Electronics
HP 5517A	Laser Head
HP 5517B	Laser Head
HP 5517C	Laser Head
HP 5518A	Laser Head
HP 10567A	Dual Beam-Beam Splitter
HP 10700A	33% Beam Splitter
HP 10701A	50% Beam Splitter
HP 10702A	Linear Interferometer
HP 10703A	Retroreflector
HP 10704A	Retroreflector
HP 10705A	Single Beam Interferometer
HP 10706A	Plane Mirror Interferometer
HP 10706B	High Stability Plane Mirror Interferometer
HP 10707A	Beam Bender
HP 10710A	Adjustable Mount
HP 10711A	Adjustable Mount
HP 10715A	Differential Interferometer
HP 10716A	High Resolution Interferometer
HP 10717A	Wavelength Tracker
HP 10722A	Plane Mirror Converter
HP 10723A	High Stability Adapter
HP 10724A	Plane Mirror Reflector
HP 10751A/B	Air Sensor
HP 10757A/B/C	Material Temperature Sensor
HP 10780B	Receiver
HP 10790A/B/C	Receiver Cable
HP 10793A/B/C	Laser Head Cable
HP 10932A	Axis Board
HP 10936A	Servo-Axis Board
HP 10941A	Prototyping Kit
HP 10946B	Automatic Compensation Board

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CERTIFICATION

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. Hewlett-Packard further certifies that its calibration measurements are traceable to the United States National Bureau of Standards, to the extent allowed by the Bureau's calibration facility, and to the calibration facilities of other International Standards Organization members.

WARRANTY

This Hewlett-Packard instrument product is warranted against defects in material and workmanship for a period of one year from date of shipment. During the warranty period, Hewlett-Packard Company will, at its option, either repair or replace products which prove to be defective.

For warranty service or repair, this product must be returned to a service facility designated by HP. Buyer shall prepay shipping charges to HP and HP shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to HP from another country.

HP warrants that its software and firmware designated by HP for use with an instrument will execute its programming instructions when properly installed on that instrument. HP does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

LIMITATION OF WARRANTY

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

The design and implementation of any circuit used on this product is solely the responsibility of the buyer. Hewlett-Packard Company does not warrant the Buyer's circuitry or malfunctions of the Prototyping Kit or HP 10932A Axis Board that result from the Buyers circuitry. In addition, HP does not warrant any damage that occurs as a result of the Buyer's circuit, including but not limited to the following:

1. HP 5507A Power Supply limitations are exceeded.
2. Component height/protrusions restrictions are exceeded.
3. Maximum input voltage on the digital lines are exceeded.

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ELECTRICAL SAFETY CONSIDERATIONS

GENERAL

This product and related documentation must be reviewed for familiarization with safety markings and instructions before operation.

This product is a Safety Class I instrument (provided with a protective earth terminal).

BEFORE APPLYING POWER

Verify that the product is set to match the available line voltage and the correct fuse is installed. Refer to Installation Section.

SAFETY EARTH GROUND

An uninterruptible safety earth ground must be provided from the mains power source to the product input wiring terminals, power cord, or supplied power cord set.

SAFETY SYMBOLS



Instruction manual symbol: the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual.



Indicates hazardous voltages.



Indicates earth (ground) terminal.



The **WARNING** sign denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in personal injury. Do not proceed beyond a **WARNING** sign until the indicated conditions are fully understood and met.



The **CAUTION** sign denotes a hazard. It calls attention to an operating procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product. Do not proceed beyond a **CAUTION** sign until the indicated conditions are fully understood and met.



Any interruption of the protective (grounding) conductor (inside or outside the instrument) or disconnecting the protective earth terminal will cause a potential shock hazard that could result in personal injury. (Grounding one conductor of a two conductor outlet is not sufficient protection.)

Whenever it is likely that the protection has been impaired, the instrument must be made inoperative and be secured against any unintended operation.

If this instrument is to be energized via an autotransformer (for voltage reduction) make sure the common terminal is connected to the neutral (earthed pole) of the power source.

Servicing instructions are for use by service-trained personnel only. To avoid dangerous electric shock, do not perform any servicing unless qualified to do so.

Adjustments described in the manual are performed with power supplied to the instrument while protective covers are removed. Energy available at many points may, if contacted, result in personal injury.

Capacitors inside the instrument may still be charged even if the instrument has been disconnected from its source of supply.

For continued protection against fire hazard, replace the line fuse(s) only with 250V fuse(s) of the same current rating and type (for example, normal blow, time delay, etc.). Do not use repaired fuses or short circuited fuseholders.

From 1.2 kilovolts to 12 kilovolts dc is present on the anode of the laser tube in the 5517A, 5517B, and 5518A. Exercise extreme caution when working inside the instrument. The high voltage could cause serious personal injury if contacted. Any adjustments performed should be by service trained personnel only.

LASER HEAD SAFETY CONSIDERATIONS



LASER RADIATION IS EMITTED FROM THE APERATURE OF THE 5518A, 5517A, AND 5517B LASER HEADS AS ILLUSTRATED ON THE FOLLOWING PAGE. DO NOT STARE INTO BEAM. THIS PRODUCT IS A CLASS II LASER PRODUCT CONFORMING TO FEDERAL BUREAU OF RADIOLOGICAL HEALTH REGULATIONS 21 CRF 1040.10 AND 1040.11 AND TO INTERNATIONAL LASER SAFETY REGULATIONS. THE MAXIMUM RADIANT POWER OUTPUT IS 1 MILLIWATT, THE PULSE SPECIFICATION IS CONTINUOUS WAVE, THE LASER MEDIUM IS HELIUM-NEON, AND THE WAVEFLENGTH IS 632.991 NANOMETRES.

LASER RADIATION IS ACCESSIBLE WHEN THE 5518A AND 5517A COVER (OR 5517B COVERS) ARE REMOVED AND THE TEST-NORM SWITCH IS IN THE TEST POSITION.

USE OF CONTROLS OR ADJUSTMENTS OR PERFORMANCE OF PROCEDURES OTHER THAN THOSE SPECIFIED HEREIN MAY RESULT IN HAZARDOUS RADIATION EXPOSURE.

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LASER HEAD SAFETY LABELS

HP 5517A, HP 5517B, and HP 5518A

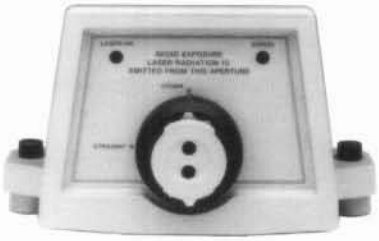
CAUTION

LASER RADIATION
(ALSO WHEN OPEN AND INTERLOCK
FAILED OR DEFEATED)
DO NOT STARE INTO BEAM

MAXIMUM OUTPUT: 1 mw
PULSE SPEC: continuous wave
LASER MEDIUM: helium neon
CLASS II LASER PRODUCT







HP 5517A

HP 5517B

HP 5518A







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GENERAL INFORMATION

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SECTION 1

GENERAL INFORMATION

MANUAL DESCRIPTION

This manual is intended for system designers concerned with designing and installing the HP 5527A Laser Position Transducer into precision measuring or positioning equipment. Typical applications are for equipment used in the integrated circuit, disk drive, and precision machining industries.

MANUAL CONTENTS AND ORGANIZATION

This manual includes information necessary to unpack, prepare, design, and install the equipment into a variety of applications. The manual is structured as follows:

SECTION I, GENERAL INFORMATION. This section explains how to use the manual and gives the designer a quick overview of the system, its intended use, composition, capabilities, limitations, and system performance. Major topics covered are: system description, equipment description, configuration guidelines, and safety classification.

SECTION II, HP LASER INTERFEROMETRY. This section describes the fundamentals of HP Laser Interferometry including an overview of the HP 5527A Laser Position Transducer, fundamental measurement concepts, measurement components, multiaxis measurement systems, and electronic components. The intent of this section is to provide the background necessary to understand information in the subsequent sections.

SECTION III, HP 5507A INPUTS AND OUTPUTS FOR POSITION SENSING/CONTROL (HARDWARE). This section gives an overview of the electronics hardware and describes how to use the HP 5507A inputs and outputs for position sensing or control. Topics included are HP-IB, automatic compensation, axis board, servo-axis board, prototyping kit, cabling, electronics interface, and how to integrate the laser system into the overall servo loop.

SECTION IV, CONTROLLING THE HP 5527A SYSTEM (SOFTWARE). The section covers how to control the HP 5527A system. Major topics covered include system considerations, controller interfacing, and programming.

SECTION V, IMPORTANT NOTES ON INSTALLATION AND ACCURACY. This section provides the information necessary to correctly design the system into an application. Major topics covered are proper installation of the optical components and accuracy considerations.

SECTION VI, INSTALLATION AND OPTICAL ALIGNMENT. This section covers installation procedures for the electronics, laser head, receiver and optics. Also covered are the alignment procedures for the different measurement optics.

SECTION VII, SYSTEM THEORY AND TROUBLESHOOTING. Explains the system theory as a background to system troubleshooting. The troubleshooting is designed to isolate trouble to either HP equipment of other system equipment. The troubleshooting can also determine which HP module is faulty.

SECTION VIII, SPECIFICATIONS. This section contains the detailed specifications for the system and the individual components.

How To Locate Information

Three methods are used to assist in locating information: a table of contents, a tab system that divides the manual into sections, and an alphabetical index of subjects.

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The table of contents is located in front of Section I and lists all first, second, and third paragraph headings, all tables, and all figures used throughout the manual.

The tab system divides the contents of the manual into sections. In addition, a table of contents for the section is included on the back of each tab divider.

The index is located at the back of the manual and includes both alphabetical listings of subjects and numerical listings of product model numbers.

SYSTEM DESCRIPTION

The HP 5527A Laser Position Transducer (Figure 1-1) is a linear displacement measuring device that provides laser interferometer accuracy to builders and users of precision positioning equipment. Designers can select from a variety of optics and electronics using only those components which solve specific measurement or control problems. With a single laser head, up to six axes of motion and one Wavelength Tracking Compensator axis may be monitored simultaneously. This flexibility benefits both end users and original equipment manufacturers (OEM's).

The HP 5527A system consists of a two-frequency laser source, measurement optics, and electronics. Before the laser beam is emitted from the laser head, a portion of it is sampled to determine the difference in frequency between the two optical components. This difference frequency is called the Reference Frequency. The beam emitted from the laser head is directed through a configuration of optics and then to a receiver. The receiver provides a Measurement Frequency, which when compared to the Reference Frequency from the laser head, yields displacement information. In systems equipped with Wavelength Tracking Compensation, the above comparison yields wavelength information which is used to update the system compensation number. Three laser sources are available: the HP 5517A, HP 5517B, and HP 5518A Laser Heads. The HP 5527 system uses the HP 107XX series of optics. The electronics are the HP 109XX series of boards and are housed in the HP 5507A Laser Position Transducer Electronics chassis. These boards are also available as HP 5507A options.

WIDESPREAD APPLICATIONS

All machines requiring an accurate positioning feedback system are candidates for the HP 5527A Laser Position Transducer. Typical applications are:

a. Integrated circuit manufacturers (wafer steppers, projection aligners, electron beam machines, X-ray machines, and reticule/mask inspection equipment).

b. Disk manufacturing (magnetic and optical servo track writers, media checkers, and head positioning testers).

c. Precision machining (coordinate measuring machines).

d. R & D applications (research tools where high precision position measurements are required).

HIGH PRECISION MEASUREMENTS

The wavelength of light from the laser head serves as the length standard for the HP 5527A transducer system. Using the HP 5517A or 5518A, the wavelength accuracy (in a vacuum) is 0.1 parts per million (1×10^{-7}) or 0.1 micrometre per metre (0.1 microinch per inch). This accuracy remains in calibration indefinitely. For non-vacuum applications, the wavelength accuracy depends on how accurately the environmental parameters are known. The basic resolution is one quarter wavelength, or 0.158 micrometres (6.23 microinches). Using optical and electronic resolution extension, the resolution is increased to 2.5 nanometre (0.1 microinches). Nominal optical measurement range for the system is 40 metres (130 feet). For multiaxis configurations, the sum of up to 6 axes should meet this range specification.

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HARDWARE COMPATIBILITY

Except for differences in laser tubes, laser beam difference frequencies, and measurement velocity capabilities allowed, the HP 5517C Laser Head is identical to the HP 5517B Laser Head. The primary difference between these two Laser Heads is that the frequency difference between the two laser beam frequencies of the HP 5517C laser beams is approximately 2.8 MHz, versus the 2.1 MHz difference in the HP 5517B. The larger frequency difference allows measurements involving motion to be made at higher velocities (slew rates). (Velocity is an HP 5527A/B system Measurement Capability specification.)

The higher difference frequency of an HP 5517C Laser Head does not allow its use with HP 5527A electronics in making a measurement.

HP 5527B versus HP 5527A

In order to handle the larger frequency difference of the HP 5517C, changes were made in the HP 5527A, and its Model Number was changed to HP 5527B. An HP 5527B can replace an HP 5527A, but the reverse is not always true.

For making a measurement, an HP 5517B (lower frequency) Laser Head can be used with an HP 5527A or an HP 5527B.

For making a measurement, an HP 5517C (higher frequency) Laser Head can be used with an HP 5527B, but not with an HP 5527A.

TEST, ADJUSTMENT, AND TROUBLESHOOTING PROCEDURES

When an HP 5517B is used with an HP 5527B, installation, operation, and indications for procedures described in this manual are the same as with an HP 5527A.

If an HP 5527B is not available (for use as a power source for an HP 5517C), an HP 5527A can be used. The test, adjustment, and troubleshooting procedures in this manual do not depend on or require a particular laser frequency difference. In these procedures, test points, adjustment points, and expected test results for an HP 5517C are the same as those for an HP 5517B, except where noted.

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Optics And Electronics To Meet Most Requirements

The HP 5527A/B System provides five optical techniques for making linear measurements:

a) The HP 10702A Linear interferometer for standard configurations.

b) The HP 10705A Single Beam interferometer for low mass and space-limited applications (also useful for non-contact applications).

c) Plane mirror interferometers for monitoring the motion of X-Y stages. HP offers 3 plane mirror interferometers; HP 10706A for non-critical applications, HP 10706B for high-stability, and HP 10716A for increased resolution and high-stability.

d) The HP 10715A and HP 10719A Differential interferometers for high-stability, minimum dead-path measurements and X-Y stages.

e) The HP 10721A, HP 10735A, and HP 10736A Multi-Axis interferometers for measuring linear position and angular information simultaneously (see the Laser and Optics Users' Manual for details).

The HP 5527A/B System provides three communication options in addition to the standard HP-IB interface:

a) Two RS-232C serial interfaces are available when the HP 10934A A-Quad-B Axis board is installed. These interfaces support baud rates up to 19.2 kHz.

b) An 8-bit parallel interface is available when the HP 10934A A-Quad-B Axis board is installed. It can transfer 2000 bytes per second.

c) A 16-bit binary interface is available when the HP 10936A/B Servo-Axis board is installed. It can output position data at rates up to 10 kHz.

The HP 5507A/B provides four electronic output options in addition to the position output capability included in all systems (environmentally compensated position data in mm, inches or fractional-wavelength counts):

a) The HP 10936A/B Servo-Axis board provides servo outputs for closed-loop system control. Motor drive outputs include ± 10V analog, pulse-width modulation, or 16-bit digital.

b) The HP 10934A A-Quad-B Axis board provides change in position information as either A-Quad-B signals or Up/Down pulses. These outputs are useful in CNC/NC machine-tool applications.

c) The HP 10932A/B Axis board provides position-error information (current position minus desired position) as a 32-bit word. This output is useful for custom servo electronics and high data rate data collection. The board also generates an analog velocity signal.

d) The HP 10941A Prototyping Kit provides a platform for integrating custom circuits into the HP 5507A/B. An included cable connects the outputs from the HP 10932A/B Axis board to the prototyping board. Use the special cable C46 59995 to obtain the position error signal from the HP 10934A A-Quad-B Axis board and the HP 10936A/B Servo-Axis board.

The HP 5527A/B System provides two environmental compensation techniques to maintain high accuracy during changing atmospheric conditions:

a) The HP 10751A/B Air Sensor, which measures atmospheric temperature, pressure and humidity, provides absolute compensation information.

b) The HP 10717A Wavelength Tracker, which optically measures any changes in laser wavelength caused by atmospheric conditions, provides high accuracy differential (relative) compensation information.

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Key Features of the HP 5507A/B Laser Position Transducer Electronics

The HP 5507A/B offers high performance and reliability, ease-of-use, and specifications which exceed most requirements for precision control systems. Major features are:

- *CLOSED-LOOP SERVO ELECTRONICS.* The Servo-Axis board (HP 10936A/B or HP 5507A/B Option 036) provides hardware and software to implement a complete closed-loop positioning system up to the amplifier and motor. Two servo algorithms are available, plus the capability to download your own custom algorithm. A key feature is the ability to change various parameters by computer, and quickly determine the servo response, thus speeding system optimization.
- *SIMPLE INTERFACE TO CUSTOM SERVO.* The Axis Board (HP 10932A/B or HP 5507A/B Option 032) has many features that simplify the interface to custom servo electronics. Among these are a data valid line, a variable-width, high- speed, position error word, an adjustable null setting, and an analog velocity output.
- *SIMPLE INTERFACE TO A-QUAD-B SERVO.* The A-Quad-B Axis Board (HP 10934A or HP 5507A/B Option 034) has features similar to the HP 10932A/B and also provides A-Quad-B or Up/Down pulse output signals for use with CNC/NC machine-tool applications.
- *POSITION INFORMATION.* English, Metric or fractional-wavelength position information for distance monitoring applications is available from the Axis Board, the A-Quad-B Axis Board, and the Servo-Axis Board.
- *RESOLUTION.* The HP 5507A/B gives high resolution measurements of either 2.5, 5, or 10 nanometers (depends on optics).
- *SLEW RATE.* The HP 5507A/B accommodates velocities up to 700 mm/second depending on the optics and laser head used.
- *HP-IB CONTROLLABLE.* All configurations of the HP 5507A/B use HP-IB to greatly simplify the task of data transfer and controlling the electronics.
- *BINARY INTERFACE.* Systems equipped with the HP 10936A/B can be controlled through a high speed 16-bit binary interface.
- *SERIAL INTERFACE.* Systems equipped with the HP 10934A can be controlled through an RS-232C serial interface.
- *PARALLEL INTERFACE.* Systems equipped with the HP 10934A can be controlled through an addressable 8-bit parallel interface.
- *INTEGRAL POWER SUPPLIES.* The HP 5507A/B has a built-in power supply to power the Laser Head (HP 5517A/B/C), the 10780C/F Receivers, and the HP 5507A/B electronics. Additional power is available for non-HP servo electronics.
- *SELF-CONFIGURATION.* The HP 5507A/B performs a self-configuration during power-up. The HP-IB Board recognizes which compensation and function boards are in place, thus accommodating any system configuration.
- *AUTOMATIC COMPENSATION.* The HP 10946B/C receives atmospheric data from the HP 10751A/B Air Sensor (which yields absolute wavelength-of-light information) and/or the HP 10717A Wavelength Tracker (which yields relative wavelength-of-light information), and/or material temperature from HP 10757A/B/C Material Temperature Sensors. Using these inputs, the HP 10946B/C provides a correction factor to the controller to compensate for changing atmospheric conditions and thermal expansion or contraction of machine or workpiece.
- *REAR PANEL CONNECTORS.* All connections to the HP 5507A/B are through connectors on the rear panel of the instrument. This simplifies connections to the instrument and improves the reliability of the connections.
- *NUMBER OF FUNCTION BOARDS.* The HP 5507A/B accommodates up to six function boards in addition to the HP-IB board and the Automatic Compensation board.

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- *SELF-TESTING.* The HP 5507A/B has been designed with extensive system level self-tests.
- *FAN COOLING.* The HP 5507A/B package includes an integral cooling fan to help minimize internal temperature rise, thus increasing reliability.
- *EMI COMPLIANCE.* The design of the HP 5507A/B package keeps EMI problems to a minimum.
- *UPGRADEABILITY.* The HP 5507A/B design allows for easy add on or upgrade of new functions.

EXPANDING CAPABILITIES

HP is engaged in an ongoing development program to increase the capabilities of the Laser Position Transducer system. For the latest information on available accessories and options, consult your nearest HP sales office. A list of HP Sales and Service Offices is located at the back of the manual.

EASY INSTALLATION

The Laser Position Transducer system is specifically designed for ease of installation by the OEM or end-user. It is modular and simple in concept. Optical and electronic modules are small in size and ruggedly constructed for easy machine mounting.

Although the laser source generates some heat, it can be located well away from the measurement area. This isolation prevents distortion of thermally sensitive components. A small beam of light is all that connects the laser to the measurement area.

PROVEN RELIABILITY

Many of the components of the HP 5527A/B Laser Position Transducer are the same reliable designs used in previous HP laser systems, which have logged many thousands of instrument hours of demanding usage.

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LOW MAINTENANCE REQUIREMENTS

Since there are no moving parts, the Laser Position Transducer requires very little maintenance. All machine-mounted parts are ruggedly designed to ensure long life. The laser head has excellent reliability, and remains in calibration indefinitely. When used in conjunction with one another, the air and material temperature sensors, and the HP 10946B require periodic (yearly) calibration. The HP 10946B requires no calibration when its only input is from the HP 10717A.

The major components of the Laser Position Trnasducer system are easy to replace. When repairs are required, the modular design of the laser head and the electronics allows for rapid replacement of the defective module, thus minimizing down-time.

Worldwide Repair Service

When purchasing a Hewlett-Packard Laser Position Transducer you receive assurance of continued performance to the published specifictions. To assure prompt response for service assistance, we maintain a worldwide network of HP service centers. You are never far from qualified service assistance.

Equipment Description

Laser Heads

The wavelength of light from the laser head is used as the length standard for the HP 5527A transducer system. The head generates a coherent collimated light consisting of two orthogonally polarized frequency components.

HP offers four models of laser heads (HP 5517A, HP 5517B/C, and HP 5518A) to fill a variety of requirements. The HP 5517B/C is a smaller package than the larger HP 5517A or the HP 5518A. The HP 5518A is similar to the HP 5517A except that an internal receiver is included.

HP 5517A LASER HEAD

The HP 5517A Laser Head (*Figure 1-2*) is supplied with 3 Mounting Screws, M8 ×1.25 ×25 mm, HP Part Number 0515-0798. Laser Head Cable HP 10793A/B/C is available as an accessory.

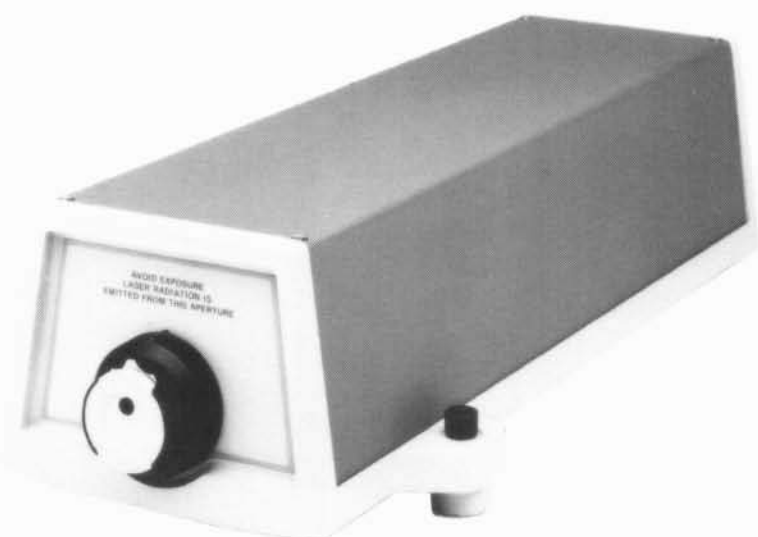


Figure 1-2. HP 5517A Laser Head

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HP 5517B/C LASER HEAD

The HP 5517B/C Laser Head (*Figure 1-3*) is supplied with a Test Polarizer (HP Part Number 1000-0616). Two cables are available as accessories: the HP 10791A/B/C Power Supply/Reference Cable, which connects the laser head to the HP 5501A system electronics, and the HP 10793A/B/C Laser Head Cable, which connects the laser head to the HP 5527A/B system electronics (i.e., HP 5507A/B). The HP 5517C, HP 5517B, and HP 5517A are similar with respect to their laser beam polarizations and current requirements. The HP 5517C has the highest reference frequency of the laser heads, allowing fastest measurement velocities (slew rates). The HP 5517B reference frequency is lower than that of the HP 5517C, but higher than that of the HP 5517A or the HP 5518A.



Figure 1-3. HP 5517B/C Laser Head

HP 5518A LASER HEAD

The HP 5518A Laser Head (*Figure 1-4*) is supplied with 2 Mounting Screws, M8 x 1.25 x 25mm, HP Part Number 0515-0798 and a Leveling Foot and Locking Nut, HP Part Numbers 05518-20316 and 05518-20317. Laser Head Cable HP 10793A/B/C is available as an accessory. The HP 5518A is similar to the HP 5517A except that an internal receiver is included.

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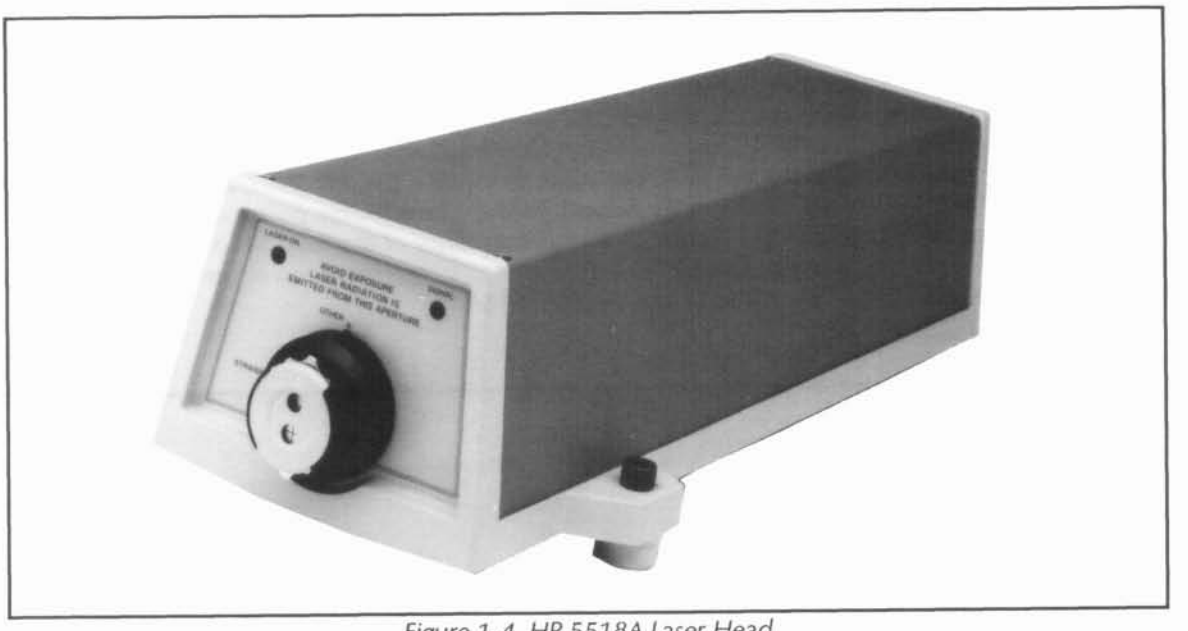


Figure 1-4. HP 5518A Laser Head

Electronics

The electronics available include the HP 5507A/B Laser Position Transducer Electronics, HP 10932A Axis Board (Option 032), HP 10936A Servo-Axis Board (Option 036), HP 10780B Receiver, HP 10751A/B Air Sensor, and the HP 10757A/B/C Material Temperature Sensor.

HP 5507A/B LASER POSITION TRANSDUCER ELECTRONICS

The HP 5507A/B Laser Position Transducer Electronics (*Figure 1-5*) consists of a main chassis, power supply, an HP-IB board, and plug-in slots for up to six function boards plus the HP 10946B Automatic Compensation board.

The HP-IB board is the primary data channel between HP 5507A/B function boards and an external controller. It is designed to meet IEEE-488, IEEE-728, and IEEE-P754 standards for general purpose instrument programming.

Function boards can be factory installed by ordering the HP 5507A/B with the desired number of options.

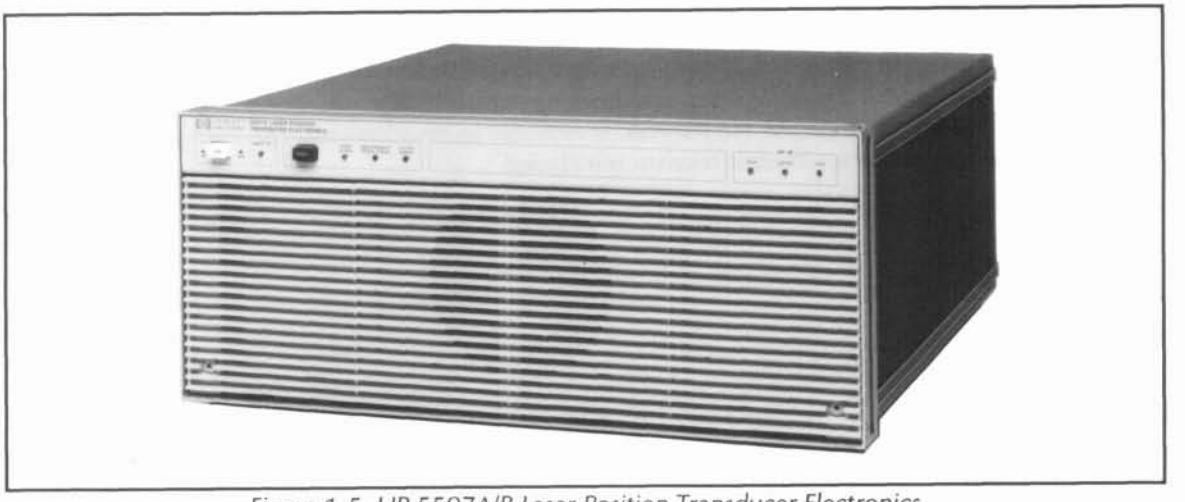


Figure 1-5. HP 5507A/B Laser Position Transducer Electronics

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HP 10934A A-Quad-B Axis Board

The HP 10934A A-Quad-B Axis Board *(Figure 1-5a)* implements the laser axis function along with units conversion and pulse generation on one circuit board for use by a CNC/NC controller. The board monitors position and outputs any changes as up/down pulses or A-quad-B signals for use by a CNC/NC controller. The data rate and pulse resolution can be programmed to match most applications. An on-board EEPROM stores setup information so the system can operate without being connected to an external control computer.

To facilitate board setup and monitoring, two RS-232C serial ports and an 8-bit parallel data channel are provided in addition to the HP 5507's HP- IB interface. All three of these added interfaces have access to all boards installed in the HP 5507A/B.

Application information for this board is presented in sections III and IV-E of this manual.

This board can be ordered separately to add another axis to a system or it can be integrated into an HP 5507A/B at the factory by ordering the HP 5507A/B with up to six Option 034s.

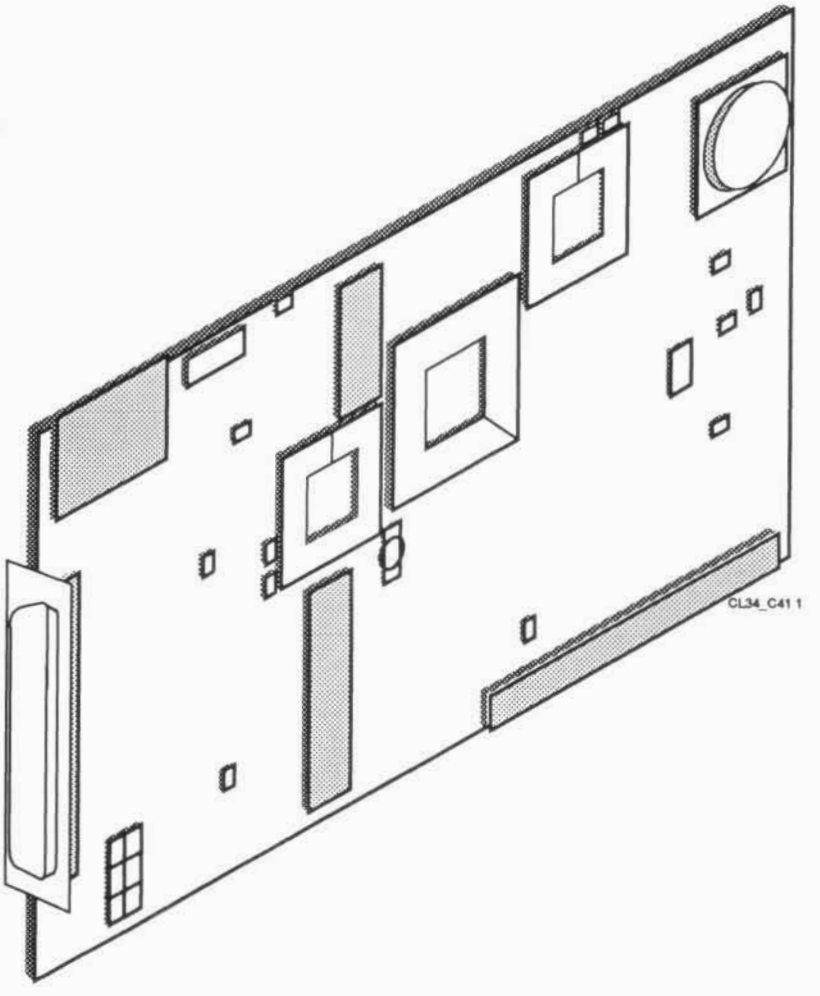


Figure 1-5a. HP 10934A A-Quad-B Axis Board

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HP 10932A AXIS BOARD (HP 5507A/B Option 032)

The HP 10932A Axis Board (*Figure 1-6*) provides resolution extension and counter/comparator functions on one board. It offers fast data transfer to external servo loops through a rear panel interface to internal servo loops through an internal interface. Internal servo loops can be implemented by means of the Prototyping Kit or a custom-designed board. Additional features include fast slew rate, flexible null detection and clipping format, forced zero for cutting off servo drive, selectable two's complement/signed magnitude outputs, synchronous sampling capability, analog velocity, automatic destination compensation, and clocked position error outputs.

Section III of this manual presents example applications of the axis board.

This board can be ordered separately to add another axis to a system or it can be integrated into an HP 5507A/B at the factory by ordering the HP 5507A/B with one or more Option 032's. Up to five Option 032's may be ordered for an HP 5507A/B with compensation; up to six may be order for an HP 5507A/B without compensation.

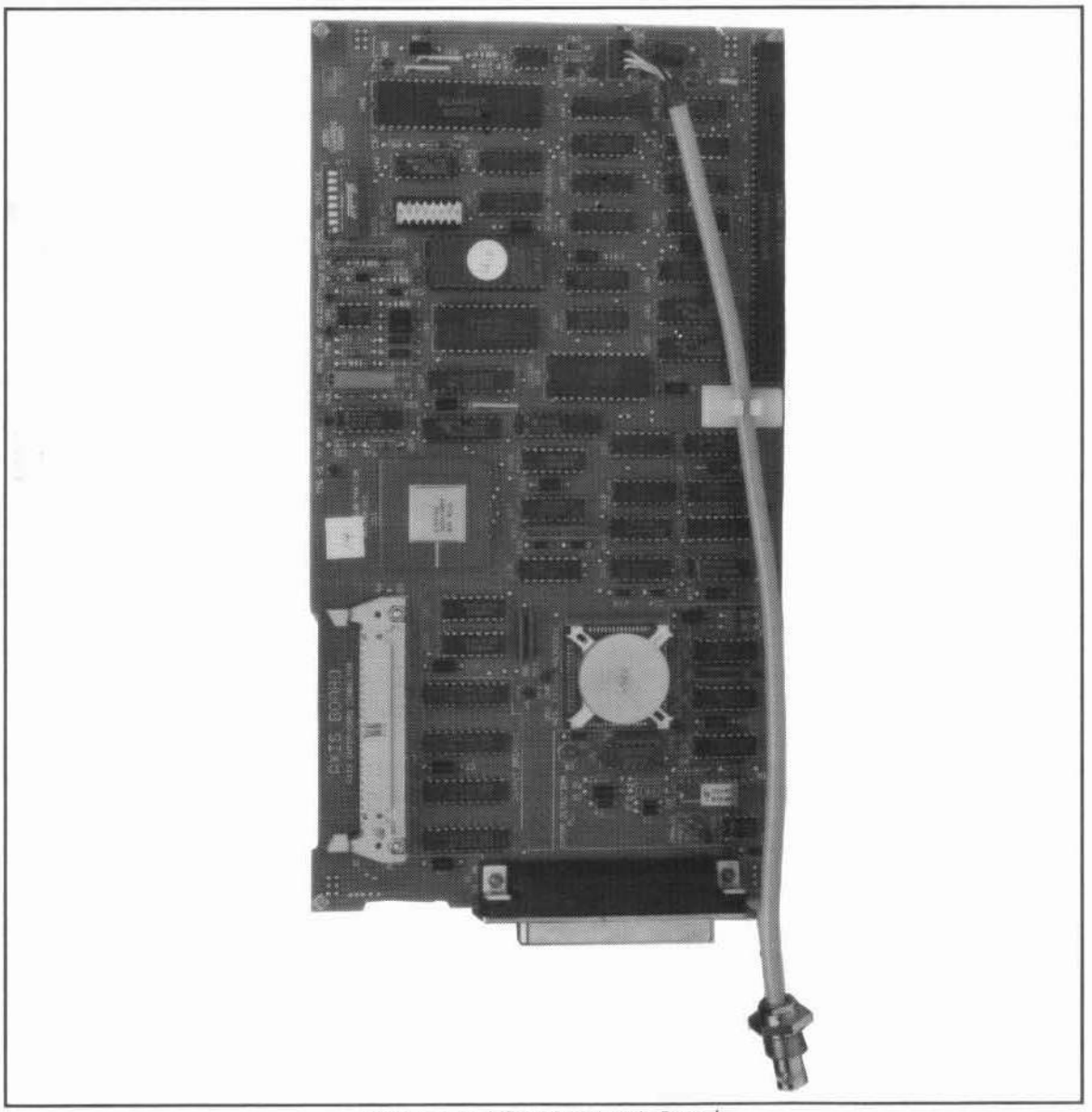


Figure 1-6. HP 10932A Axis Board

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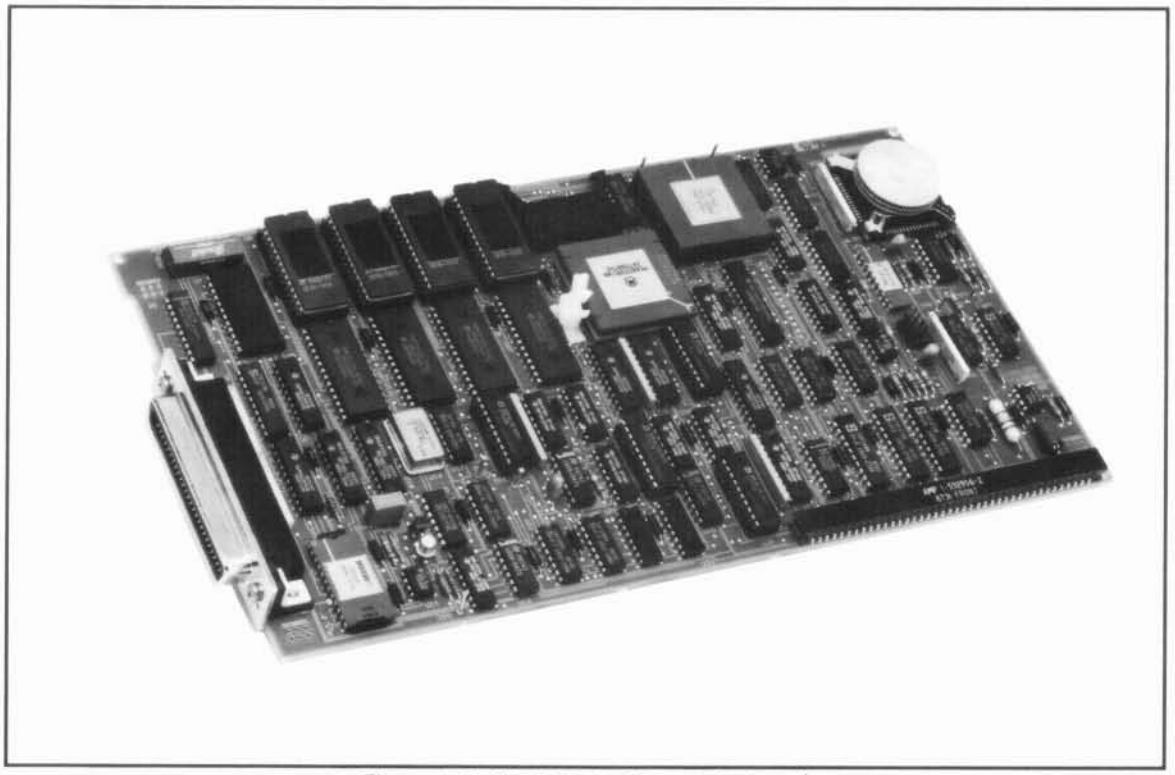


Figure 1-7. HP 10936A Servo-Axis Board

HP 10936A SERVO-AXIS BOARD

The HP 10936A Servo-Axis Board (*Figure 1-7*) provides the HP 5527A/B system with flexible, high-performance, servo-positioning capability. It consists of a circuit card for the HP 5507A/B Laser Position Transducer Electronics that implements the entire servo function (excluding power amplifier and motor) for one axis of motion. The board has a built-in binary interface for high-speed communication with a system controller, and the capability of being linked with up to three additional servo-axis boards for coordinated multiaxis moves. Two servo algorithms are implemented in firmware, and a custom one may be downloaded. The main output, an amplifier drive signal, has several formats (±10 Volt analog, pulse-width modulated, and 16-bit digital). All servo parameters are programmable and real-time data can be automatically collected to optimize servo performance.

Application information is contained in Section III and IV-F of this manual and in Application Note 325-10, "Sub-Micron Positioning with the HP 5527A Laser Positioning Transducer System".

This board can be ordered separately to add to a system or can be integrated into an HP 5507A/B at the factory by ordering the HP 5507A/B with one or more Option 036's; up to four Option 036's may be ordered for an HP 5507A, up to six may be ordered for an HP 5507B.

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HP 10941A PROTOTYPING KIT

The HP 10941A Prototyping Kig (*Figure 1-8*) allows custom circuitry to be designed into the HP 5507A/B Laser Position Transducer Electronics. Approximately 219 square centimeters (34 square inches) of prototyping area (75% power-gridded) is supplied for breadboarding and testing of circuitry in actual use. The Prototyping Kit includes an extender board, a prototyping board and two cables to interface with an axis board. Since all designs will use the same interface circuitry for the backplane communication, the interface circuits are factory loaded on the prototyping board. Input and output data are controllable by the HP 5507A/B's HP-IB. The interface circuits and the PROM code may be copied for mass producing any added custom circuitry. Cable lengths and part numbers are:

225mm length — HP P/N 10941-60101
75mm length — HP P/N 10941-60102

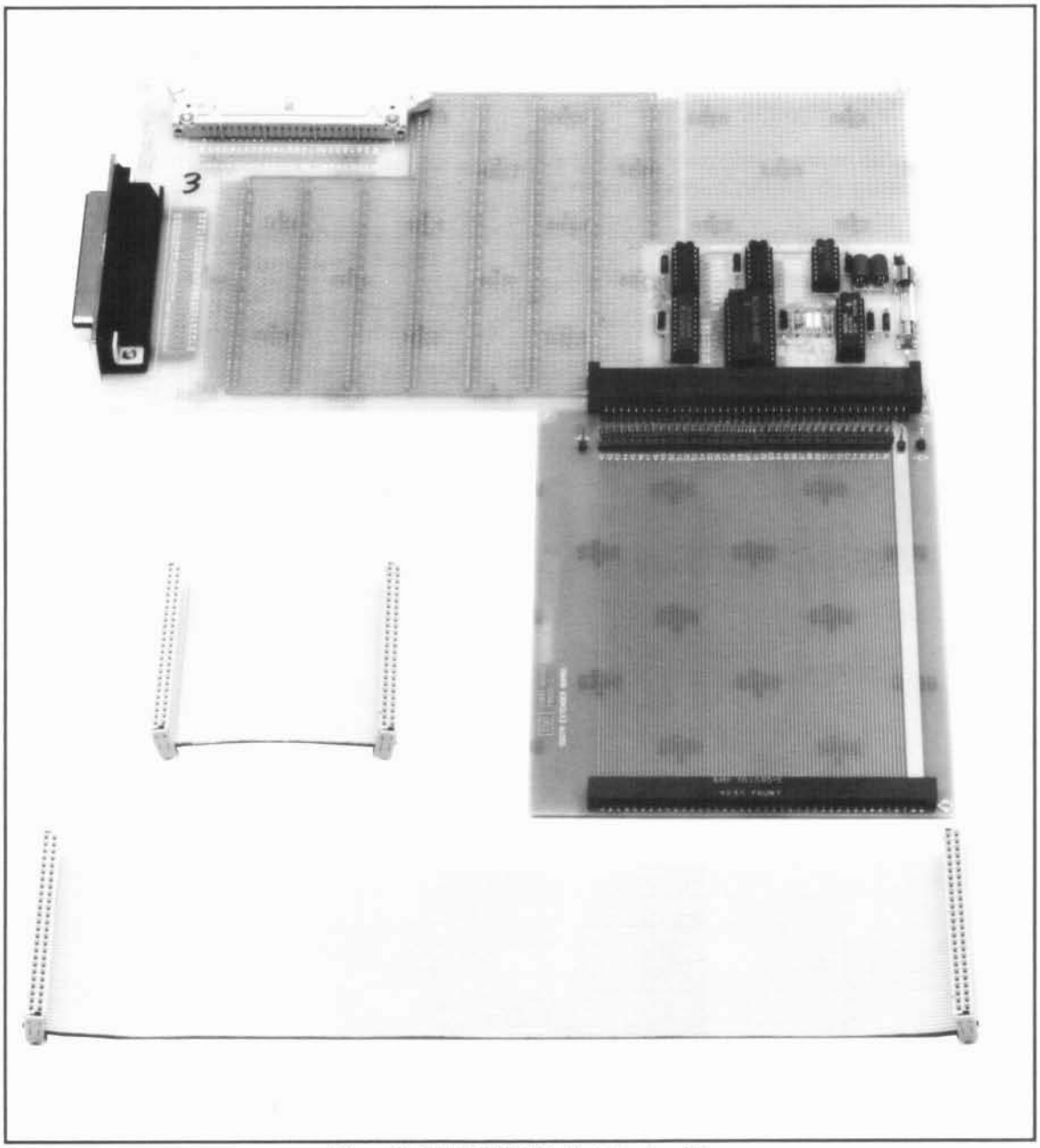


Figure 1-8. HP 10941A Prototyping Kit

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HP 10946B AUTOMATIC COMPENSATION BOARD (HP 5507A Option 046)

The HP 10946B Automatic Compensation Board (*Figure 1-9*) interfaces with remote sensors (HP 10751A/B Air Sensor and HP 10757A/B/C Materal Temperature Sensor) and with the HP 10717A Wavelength Tracker, providing compensation information for air variations and material temperature. It accommodates one air sensor, two material temperature sensors, and one HP 10780B Receiver input from the Wavelength Tracking Compensator axis. Calibration is fast and accomplished through software. Additionally, it can generate an alert when a significant change in index of refraction occurs or when the laser beam to the Wavelength Tracking Compensator axis is interrupted for a predetermined length of time.

The HP 10946B has two operating modes; Air Sensor and Wavelength Tracker. In the Air Sensor mode, the wavelength-of-light information is derived from the HP 10751A/B Air Sensor information (air temperature, pressure, and humidity). In Wavelength Tracker mode, wavelength-of-light information is updated from the HP 10717A Wavelength Tracker information. Additionally, both modes support material temperature compensation (HP 10757A/B/C).

The HP 10946B can also be used for manual compensation. The environmental parameters are entered and the HP 10946B calculates the compensation information required.

This board can be ordered separately to add to a system or can be integrated into an HP 5507A/B at the factory by ordering HP 5507A/B with Option 046.

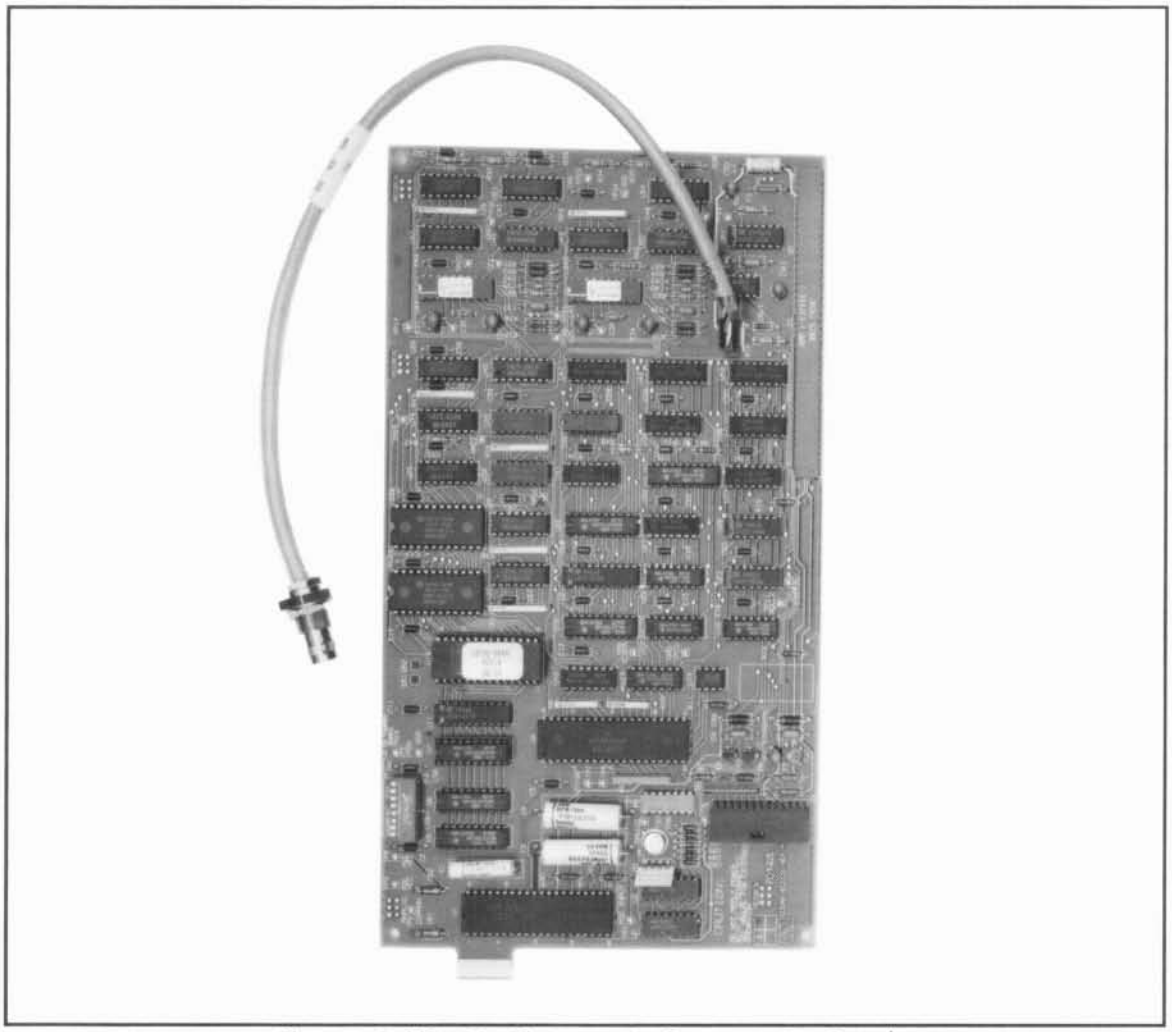


Figure 1-9. HP 10946B Automatic Compensation Board

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HP 10780B RECEIVER

An optical receiver is required for each axis of measurement. (The 5518A has a built-in receiver). The HP 10780B Receiver (*Figure 1-10*) is a photodetector/preamplifier module which senses the laser beam returning from the interferometer for one axis of measurement. The resultant signal is the measurement signal. This signal is transmitted to the HP 5507A via the HP 10790A/B/C Receiver Cables.



Figure 1-10. HP 10780B Receiver

HP 10751A/B Air Sensor

The HP 10751A/B Air Sensor (*Figure 1-11*) measures air pressure, temperature, and has a switch for selecting one of three values of ambient humidity (low, mid, or high). These measurements are sent to the HP 10946B Automatic Compensation Board where they are used to compensate for the dependence of laser wavelength on the index of refraction of air. The difference between the A and B models is the cable length; the HP 10751A cable length is 5 metres (16 feet) and the HP 10751B cable is 15 metres (49 feet).

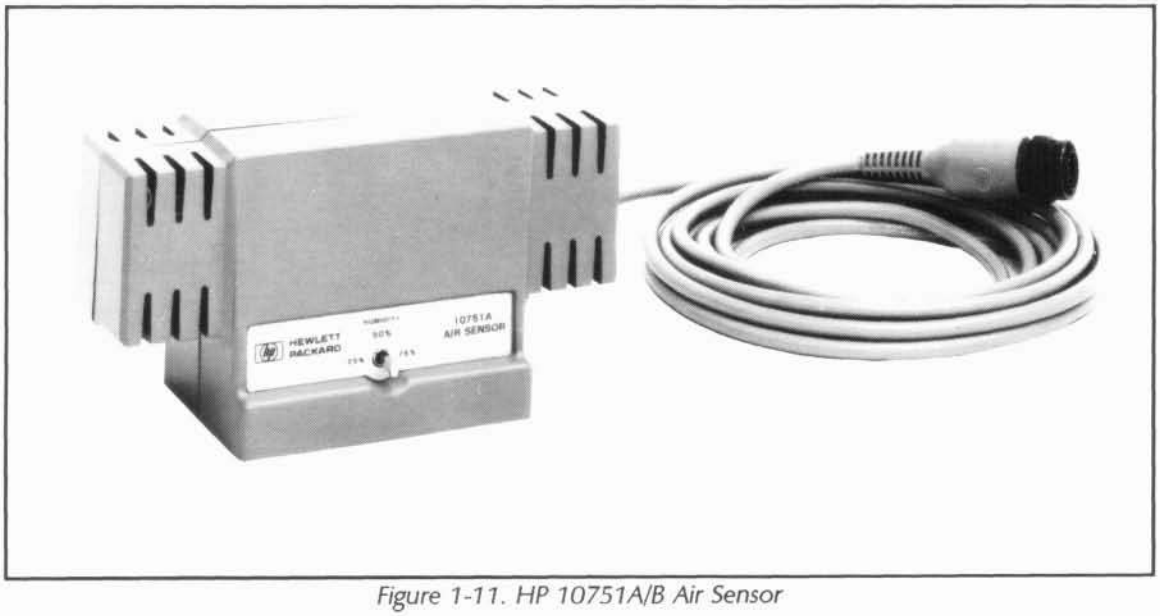


Figure 1-11. HP 10751A/B Air Sensor

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HP 10757A/B/C MATERIAL TEMPERATURE SENSOR

To compensate for dimensional changes of the workpiece or machine temperature, two items of information are required: the workpiece (machine) temperature and its thermal coefficient of expansion. One or two HP 10757A/B/C Material Temperature Sensors (*Figure 1-12*) can be used to sense the temperature. The HP 10946B Automatic Compensation Board receives the workpiece (machine) coefficient of expansion via HP-IB. Material temperature and coefficient of expansion are used by the HP 10946B in computing the total compensation factor used for computations. The difference in the A, B, and C models is the cable length. The HP 10757A cable length is 5 metres (16 feet), the B model is 15 metres (49 feet) long, and the C model is 25 metres (82 feet) in length.



Figure 1-12. HP 10757A/B/C Material Temperature Sensor

Optics

The Measurement optics for the HP 5527A are the HP 107XX series of optics consisting of the following:

- HP 10567A Dual Beam Beam-Splitter
- HP 10700A 33% Beam Splitter
- HP 10701A 50% Beam Splitter
- HP 10702A Linear Interferometer (and Option 001 Windows)
- HP 10703A Retroreflector
- HP 10704A Retroreflector
- HP 10705A Single Beam Interferometer
- HP 10706A Plane Mirror Interferometer
- HP 10707A Beam Bender
- HP 10715A Differential Interferometer
- HP 10716A High Resolution Interferometer
- HP 10722A Plane Mirror Converter
- HP 10724A Plane Mirror Reflector

Each Laser Position Transducer axis must have an interferometer and a reflector. Machine design considerations determine which type of interferometer is optimum. The choice of the interferometer for each axis usually specifies the reflector for that axis.

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HP 10702A LINEAR INTERFEROMETER (and Option 001 Windows) AND HP 10703A Retroreflector *(Figure 1-13)*

The HP 10702A Linear Interferometer, being the simplest unit, is used whenever possible. The measurement retroreflector for this interferometer is the HP 10703A Retroreflector. Displacement is measured between the interferometer and the retroreflector (cube corner). Either one or both can move. If the linear interferometer must move, the HP 10702A, Option 001, must be used.



Figure 1-13. HP 10702A Linear Interferometer (and Option 001 Windows)

HP 10722A PLANE MIRROR CONVERTER *(Figure 1-14)*

The plane mirror converter is an accessory for the HP 10702A Linear Interferometer. With the HP 10722A Plane Mirror Converter, and an additional HP 10703A Retroreflector, the HP 10702A Linear Interferometer can be converted to an HP 10706A Plane Mirror Interferometer. This configuration allows measurements of axial displacement of a plane mirror.



Figure 1-14. HP 10722A Plane Mirror Converter

HP 10705A SINGLE BEAM INTERFEROMETER AND HP 10704A RETROREFLECTOR *(Figure 1-15)*

In the single beam interferometer the outgoing and returning beam are superimposed on each other giving the appearance of only one beam traveling between the interferometer and the retroreflector. Functionally, this interferometer operates the same as a standard one but is more desirable when space for optics and beam paths is limited. The retroreflector is also a cube corner but it is considerably smaller than the HP 10703A. When using a single beam interferometer, the receiver is mounted at right angles to the measurement beam and the interferometer cannot be moved.

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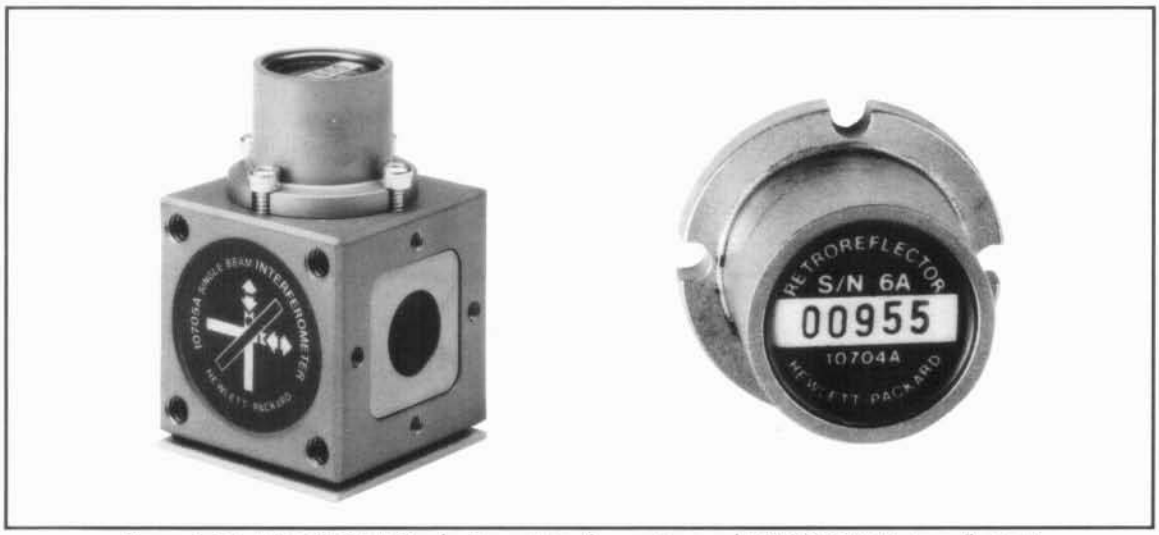


Figure 1-15. HP 10705A Single Beam Interferometer and HP 10704A RetroreflectorF

HP 10706A PLANE MIRROR INTERFEROMETER *(Figure 1-16)*

The plane mirror interferometer can use a flat mirror as the reflector and provides resolution doubling since the measurement beam travels twice between the interferometer and the plane mirror. Both retroreflectors of a two-axis system can be mounted on the same moving part. Use of the Plane Mirror Interferometer is ideal for eliminating Abbé Error.

The HP 10706A can be converted to the HP 10706B high stability configuration by retrofitting the A model with an HP 10723A High Stability Adapter. See HP 10706B and HP 10723A descriptions below. Information for the conversion is contained in Section 6.



Figure 1-16. HP 10706A Plane Mirror Interferometer

HP 10706B HIGH STABILITY PLANE MIRROR INTERFEROMETER

The HP 10706B High Stability Plane Mirror Interferometer *(Figure 1-17)* is an improved version of the HP 10706A and offers very high thermal stability. It can be used in the same applications as the "A" version but requires different alignment techniques. See Section 6 for a alignment procedures.

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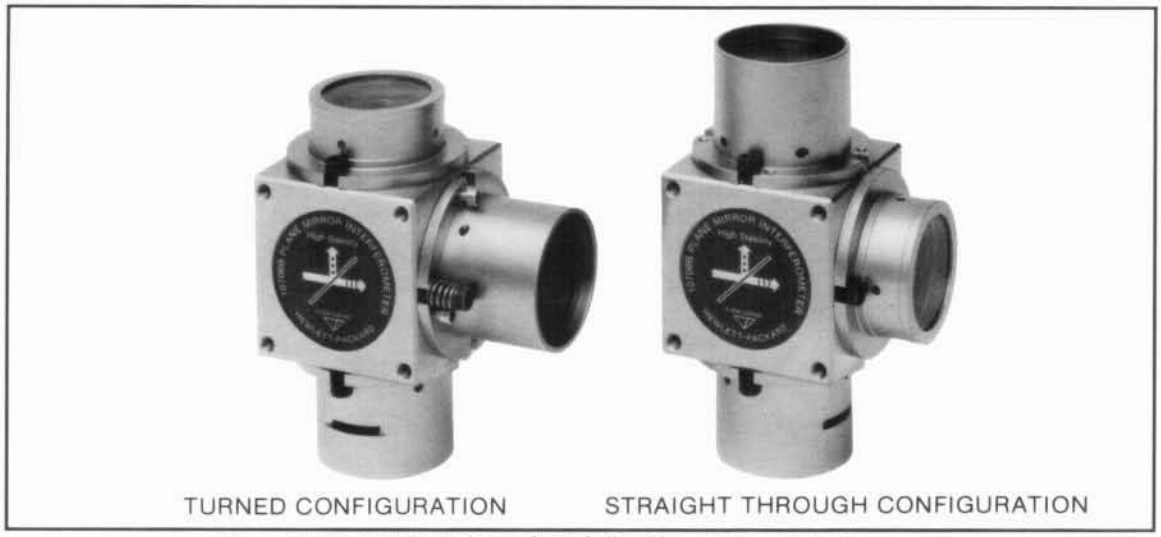


Figure 1-17. HP 10706B High Stability Plane Mirror Interferometer

HP 10723A HIGH STABILITY ADAPTER

The High stability adapter (*Figure 1-18*) is designed to convert the HP 10706A Plane Mirror Interferometer to the HP 10706B high thermal stability configuration. The conversion consists of replacing the reference cube corner on the HP 10706A with the HP 10723A High Stability Adapter. Section 6 contains drawings and instructions for the conversion.

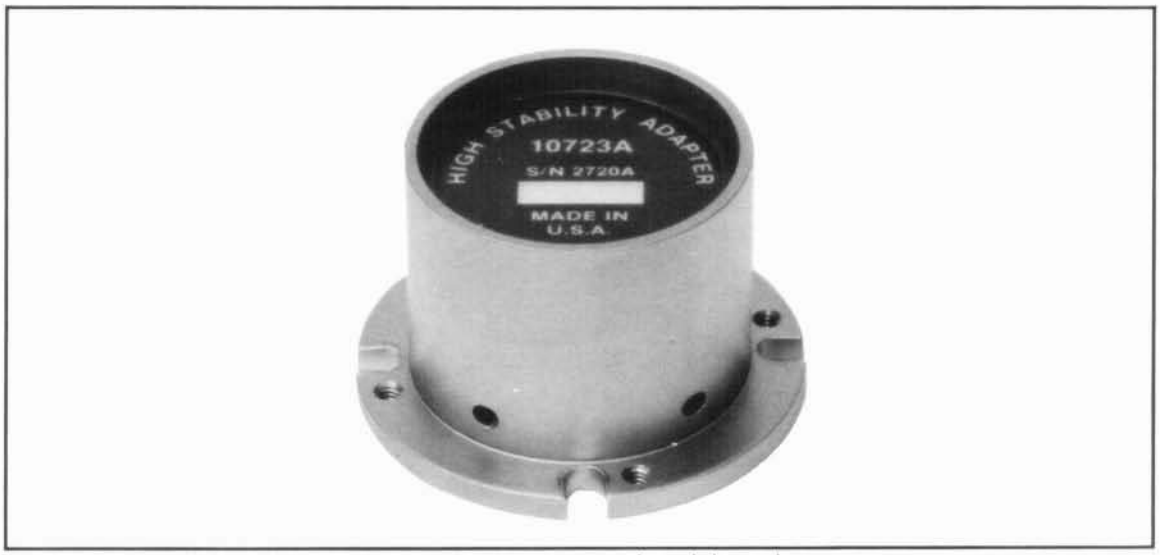


Figure 1-18. HP 10723A High Stability Adapter

HP 10716A HIGH RESOLUTION INTERFEROMETER

The HP 10716A High Resolution Interferometer (*Figure 1-19*) provides twice the resolution of other HP plane mirror interferometers and offers very high thermal stability. Measurement drift is typically 1/12 of that exhibited by a conventional plane mirror interferometer. These features result in improved accuracy, repeatability, and positioning capability. The HP 10716A can be used in the same applications as other HP plane mirror interferometers but with different alignment techniques. A turned configuration (Option 001) is available to turn the beam 90 degrees, thereby eliminating the need for a beam bender.

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Figure 1-19. HP 10716A High Resolution Interferometer

A matching optic, the HP 10724A, is also available for applications which require a plane mirror reflector for non X-Y applications.

HP 10724A PLANE MIRROR REFLECTOR

For applications requiring a plane mirror reflector, the HP 10724A Plane Mirror Reflector shown in *Figure 1-20* is recommended. It can be used with the HP 10716A as well as all other HP plane mirror interferometers.



Figure 1-20. HP 10724A Plane Mirror Reflector

HP 10715A DIFFERENTIAL INTERFEROMETER *(Figure 1-21)*

The HP 10715A permits differential measurements to be made between two plane mirrors, the reference plane mirror and the measurement plane mirror. A major benefit is the common optical path to both reference and measurement beams, resulting in extremely high stability and resistance to spurious changes in the optical path. Since the measurement beam travels twice between the interferometer and the plane mirror, the resolution of the measurement is twice that of the linear or single beam interferometers.

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Figure 1-21. HP 10715A Differential Interferometer

HP 10700A 33% BEAM SPLITTER, HP 10701A 50% BEAM SPLITTER, AND HP 10707A BEAM BENDER *(Figure 1-22)*

These 25 mm (1 inch) cubes allow a portion of the laser beam to be directed along each measurement axis. Since the cubes can be mounted within a machine, they offer considerable flexibility in the mounting arrangement resulting in a highly durable installation.

The Model HP 10700A 33% Beam Splitter deflects one-third of the laser beam intensity at right angles to the original beam direction while the remaining two-thirds continues through the optic. The Model HP 10701A 50% Beam Splitter operates in a similar manner with a 50% ratio of beam splitting. By using combinations of these two accessories, the beam may be split into several paths to perform multiaxis measurements. For example, using a 33% and a 50% Beam Splitter, one-third of the laser beam intensity can be directed to each measurement axis in a three-axis machine.

The Model HP 10707A Beam Bender contains a 100% reflectance mirror which turns the direction of an incoming laser beam at a right angle.

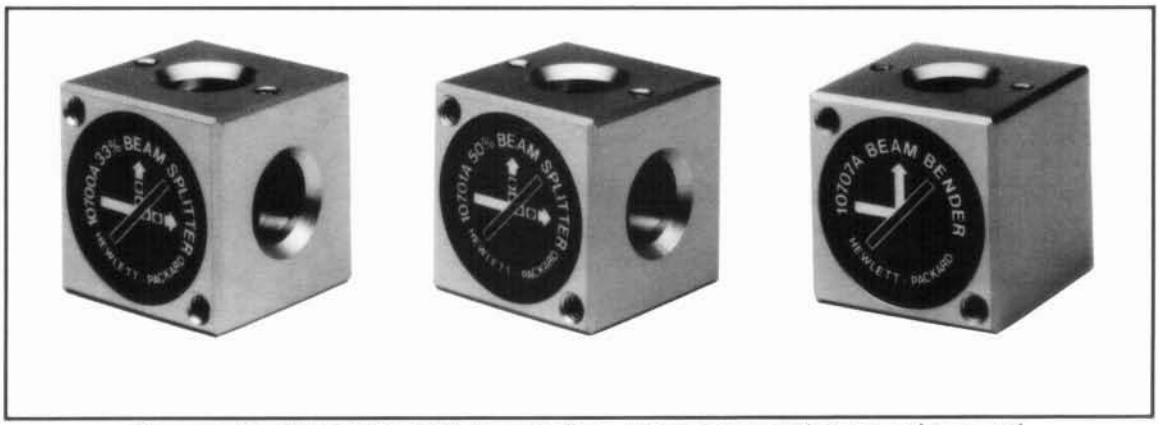


Figure 1-22. HP 10700A 33% Beam Splitter, HP 10701A 50% Beam Splitter, and HP 10707A Beam Bender

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HP 10567A DUAL BEAM BEAM-SPLITTER *(Figure 1-23)*

The HP 10567A Dual Beam Beam-Splitter consists of a beam splitter with three different coatings. The beam splitter divides the laser beam into two beams at right angles to each other and directs them to two sets of measurement optics. The return beams pass through the HP 10567A again and exit parallel to the Laser Head output beam. This beam-splitter is typically used for applications

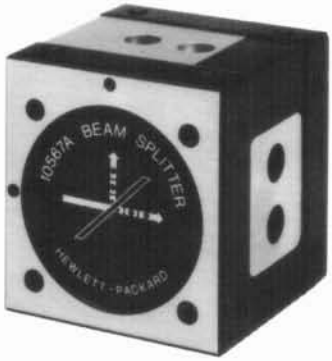


Figure 1-23. HP 10567A Dual Beam-Beam Splitter

where two axes of measurement are required to go through a window.

HP 10710A AND HP 10711A ADJUSTABLE MOUNTS *(Figure 1-24)*

The adjustable mounts provide a convenient means of mounting and aligning optical accessories. Since both mounts allow angular adjustment in two directions, the need for custom fixturing is minimized. Another convenient feature allows a component to be rotated about its optical centerline providing simple, time-saving installations. The HP 10710A Adjustable Mount accepts the HP 10700A and HP 10701A Beam Splitters, the HP 10705A Single Beam Interferometer, and the HP 10707A Beam Bender. The HP 10711A Adjustable Mount accommodates the HP 10702A Linear Inter-



Figure 1-24. HP 10710A and HP 10711A Adjustable Mounts

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ferometer, the HP 10706A/B Plane Mirror Interferometers, the HP 10716A High Resolution Interferometer, and the HP 10715A Differential Interferometer.

HP 10717A WAVELENGTH TRACKER

The HP 10717A Wavelength Tracker (*Figure 1-25*) monitors any change in the wavelength of light as it occurs in the measurement environment. The optics consist of a pre-aligned HP 10715A Differential Interferometer and an optical reference cavity (also called an etalon) that together, measure any optical path length change over a fixed distance. Built-in adjustments simplify installation and alignment to the laser system.

The HP 10717A Wavelength Tracker provides a higher degree of accuracy than does the HP 10751A/B Air Sensor, thereby improving the laser system measurement performance. For a more detailed comparison of compensation methods, see "Compensation Method Comparison" in Section V of this manual.

The HP 10717A Wavelength Tracker's output must be directed to an HP 10780B Receiver where a measurement signal is generated. The HP 10946B used this signal and the laser head's reference signal to monitor changes in the wavelength of light. For maximum accuracy, the etalon's length (number written on end of etalon) must be sent to HP 10946B using the *WRL mnemonic (see page 4K-11).

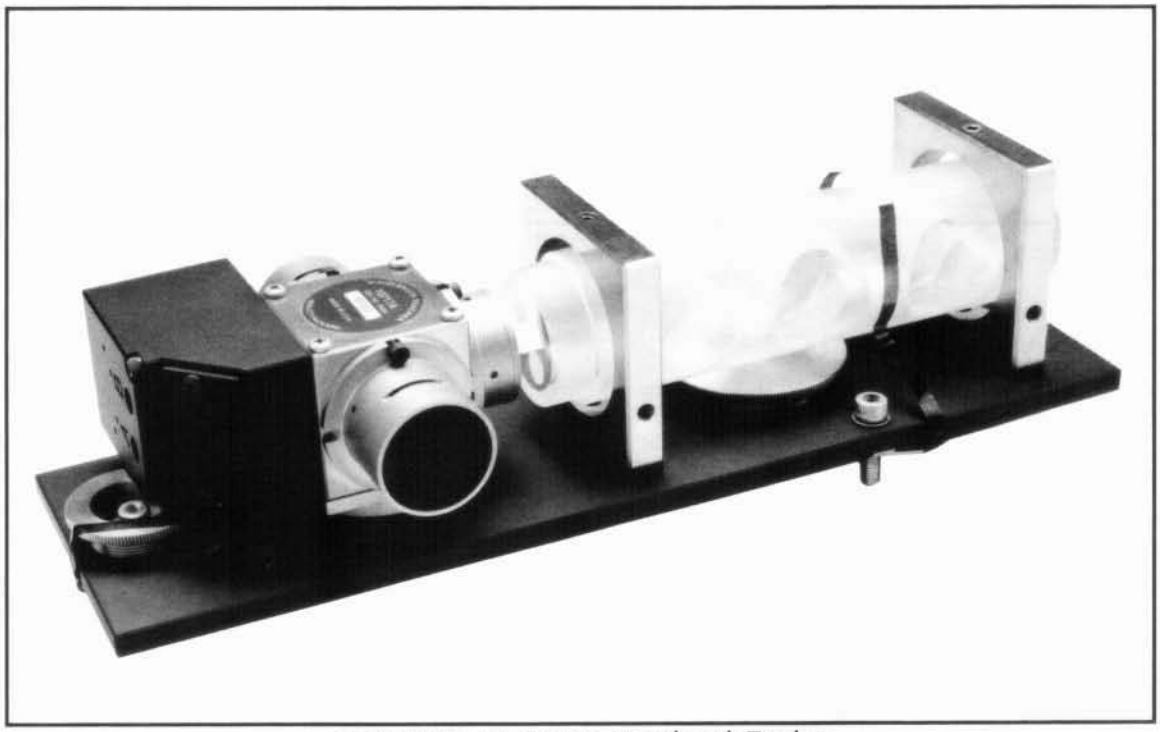


Figure 1-25. HP 10717A Wavelength Tracker

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CABLES

HP 10790A/B/C RECEIVER CABLE

The HP 10790A/B/C Receiver Cable (*Figure 1-26*) transmits the measurement signal from the HP 10780B Receiver to the HP 5507A. The model is 5 metres (16 feet) in length, the B model is 10 metres (3 feet), and the C model is 20 metres (65 feet).



Figure 1-26. HP 10790A/B/C Receiver Cable

HP 10793A/B/C LASER HEAD CABLE

The HP 10793A/B/C Laser Head Cable (*Figure 1-27*) is used to connect the HP 5517A, HP 5517B, or HP 5518A Laser Head to the HP 5507A. The A model is 3 metres (10 feet) in length, the B model is 7 metres (23 feet), and the C model is 20 metres (65 feet).



Figure 1-27. HP 10793A/B/C Laser Head Cable

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A-QUAD-B CABLES

The HP 10935A Quad/Serial cable is used to connect an HP 10934A A-Quad-B Axis board to the user's CNC/NC controller. An additional serial interface cable is required to use the serial connection.

INTERFACE CABLES

At least one interface cable must be used for all systems. Select the appropriate cable(s) from those listed on page 1-26/27.

INTERNAL JUMPER CABLES

When more than one of either the HP 10934A or the HP 10936B will be installed, an internal cable may be required (the proper cable will be included with all factory installed boards). Select the HP 10934A or HP 10936B option (002, 003, 004, or 006) corresponding to the number of boards that will be bussed together. Only one option is required for each set of boards.

CONFIGURING A LASER POSITION TRANSDUCER

I. CHOOSE THE LASER HEAD. All systems require one laser head. This instrument houses the laser source and its associated circuitry, and also produces the reference signal. There are four laser heads from which to choose. The HP5517A and HP5518A are larger packages than the HP5517B or HP5517C. Unlike the other laser heads, HP5518A has a built-in receiver. (The HP5518A is not recommended for multiaxis configurations.)

II. CHOOSE MEASUREMENT OPTICS FOR EACH AXIS (UP TO 6 AXES). Three optical elements are needed per axis:

A. Interferometers (select one)

1. HP 10702A Linear Interferometer
2. HP 10705A Single Beam Interferometer
3. HP 10706A Plane Mirror Interferometer
4. HP 10706B High Stability Plane Mirror Interferometer
5. HP 10715A Differential Interferometer (includes reference mirror)
6. HP 10716A High Resolution Interferometer
7. HP 10719A One-Axis Differential Interferometer
8. HP 10721A Two-Axis Differential Interferometer
9. HP 10735A Three-Axis Interferometer
10. HP 10736AThree-Axis Interferometer

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B. Reflectors (depends on interferometer choice)

1. HP 10703A Retroreflector (used with HP 10702A)
2. HP 10704A Retroreflector (used with HP 10705A)
3. HP 10724A Plane Mirror Reflector (used with HP 10706A, HP 10706B, HP 10715A and HP 10716A).
4. Custom Optics (for applications requiring large block mirrors).

C. Receivers

1. HP 10780C Receiver
2. HP 10780F Fiber-optic Receiver

III. CHOOSE OPTICS TO DIRECT THE LASER BEAM TO THE MEASUREMENT AXES The HP 10707A Beam Bender and HP 10700A/10701A/10567A Beam Splitters direct a portion of the laser beam to each axis.

IV. ADJUSTABLE MOUNTS. An adjustable mount is required for each optical component (interferometers, beam splitters and beam benders). The HP 10710A Adjustable Mount accepts the HP 10700A and HP 10701A Beam Splitters, the HP 10705A Single Beam Interferometer, and the HP 10707A Beam Bender. The HP 10711A Adjustable Mount accommodates the HP 10702A Linear Interferometer, the HP 10706A/B Plane Mirror Interferometers, the HP 10716A High Resolution Interferometer, and the HP 10715A Differential Interferometer.

V. CHOOSE AXIS ELECTRONICS. Match the number of HP 10932B Axis Boards (HP 5507B Option 032), HP 10934A A-Quad-B Axis boards (HP 5507B Option 034), or HP 10936B Servo-Axis boards (HP 5507B Option 036) with the number of measurement axes. If custom-designed electronics such as servo control electronics are planned, include an HP 10941A Prototyping Kit for each axis.

VI. CHOOSE COMPONENTS TO IMPLEMENT AUTOMATIC COMPENSATION FUNCTION IN YOUR SYSTEM. To determine if environmental compensation is required, refer to "System Accuracy" in Section V of this manual. Environmentsl compensation consists of atmospheric and material temperature compensation. The following components are required for automatic environmental compensation.

A. HP 5507B Option 046 (factory installed and tested HP 10946C Automatic Compensation board). This board is required to implement any method of environmental compensation.

B. Atmospheric Compensation. There is a choice of two atmospheric compensation techniques:

1. The HP 10751A/B Air Sensor, which measures certain atmospheric conditions (air temperature, pressure, and humidity), provides absolute wavelength-of-light compensation. The difference between the A and B models is their cable length:

a. HP 10751A - 5 metre cable (16 feet)

b. HP 10751B - 15 metre cable (49 feet)

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2. The HP 10717A Wavelength Tracker, which optically measures any changes in the wavelength-of-light, provides high-accuracy relative (differential) wavelength-of-light compensation, resulting in high measurement repeatability. An initial compensation value is needed to achieve absolute measurement accuracy (refer to "Automatic Compensation" in Section V of this manual for details on obtaining this initial compensation value). The following components are required to implement Wavelength Tracking Compensation.

   a. HP 10700A or HP 10701A Beam Splitter (dependent on total number of axes)

   b. HP 10710A Adjustable Mount (one required for beam splitter)

   c. HP 10717A Wavelength Tracker

   d. HP 10780B Receiver (one required)

   e. HP 10790A/B/C Receiver Cable (select one)

C. Material Temperature Compensation. The HP 10757A/B/C Material Temperature Sensor is required to implement automatic material temperature compensation. A maximum of two sensors can be used in each system. The difference in the A, B, and C models is the cable length.

   1. HP 10757A - 5 metre cable (16 feet)

   2. HP 10757B - 15-metre cable (49 feet)

   3. HP 10757C - 25 metre cable (82 feet)

VII. DETERMINE POWER REQUIREMENTS. Use this worksheet to calculate your power requirements to verify that there will be sufficient power available to meet your needs. Total power dissipated cannot exceed 82 W (HP 5507A) or 122 W (HP 5507B).

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Table 1-1. System Power Requirements Worksheet

Voltage	Unit	Qty	X	Current Required	=	Total
+5 V						12.2 A Available (HP 5507A) 20 A Available (HP 5507B)
	HP 10932A/B (HP 5507A/B Opt 032)	____	X	2.0 A	=	____
	HP 10934A (HP 5507A/B Opt 034)	____	X	2.6 A	=	____
	HP 10936A/B (HP 5507A/B Opt 036)	____	X	2.5 A	=	____
	HP 10946B/C (HP 5507A/B Opt 046)	____	X	1.75 A	=	____
	HP 10941A (I/O Interface only)	____	X	0.25 A	=	____
	Other Requirements	____				____
				TOTAL		____
+15 V						1.2 A Available (HP 5507A) 3 A Available (HP 5507B)
	HP 10932A/B (HP 5507A/B Opt 032)	____	X	0.006 A	=	____
	HP 10934A (HP 5507A/B Opt 034)	____	X	0.040 A	=	____
	HP 10936A/B (HP 5507A/B Opt 036)	____	X	0.030 A	=	____
	HP 10946B/C (HP 5507A/B Opt 046)	____	X	0.018 A	=	____
	HP 10780C/F	____	X	0.136 A	=	____
	HP 10751A/B	____	X	0.053 A	=	____
	HP 10757A/B/C	____	X	0.007 A	=	____
	Other Requirements					____
				TOTAL		____
–15 V						1.8 A Available (HP 5507A) 4 A Available (HP 5507B)
	HP 10932A/B (HP 5507A/B Opt 032)	____	X	0.003 A	=	____
	HP 10934A (HP 5507A/B Opt 034)	____	X	0.045 A	=	____
	HP 10936A/B (HP 5507A/B Opt 036)	____	X	0.045 A	=	____
	HP 10946B/C (HP 5507A/B Opt 046)	____	X	0.009 A	=	____
	HP 10751A/B	____	X	0.053 A	=	____
	HP 10757A/B/C	____	X	0.007 A	=	____
	Other Requirements					____
				TOTAL		____
Power						82 W Available (HP 5507A) 122 W Available (HP 5507B)
	HP 10932A/B (HP 5507A/B Opt 032)	____	X	10.1 W	=	____
	HP 10934A (HP 5507A/B Opt 034)	____	X	14.3 W	=	____
	HP 10936A/B (HP 5507A/B Opt 036)	____	X	13.6 W	=	____
	HP 10946B/C (HP 5507A/B Opt 046)	____	X	9.2 W	=	____
	HP 10780B/C/F	____	X	2.0 W	=	____
	HP 10751A/B	____	X	1.6 A	=	____
	HP 10757A/B/C	____	X	0.2 A	=	____
	Other Requirements					____
				TOTAL		____

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VIII. CABLES. Cables for transmission of power, reference, and measurement signals must also be ordered.

A. Laser Head Cable (one per system)
HP 10793A/B/C (used with HP 5517A/B/C or 5518A)

Available in three cable lengths:

1. HP 10793A - 3 metre cable (9.8 feet)
2. HP 10793B - 7 metre cable (23.0 feet)
3. HP 10793C - 20 metre cable (65.6 feet)

B. Receiver Cable (one per measurement and Wavelength Tracking axis)
HP 10790A/B/C

Available in three cable lengths:

1. HP 10790A - 5 metre cable (16.4 feet)
2. HP 10790B - 10 metre cable (32.8 feet)
3. HP 10790C - 20 metre cable (65.6 feet)

NOTE

A receiver cable is not needed if the HP 5518A Laser Head's internal receiver is used.

IX. INTERFACE CABLES. Cables for connecting the HP 5527B Laser Position Transducer system to the users other equipment must also be ordered.

A. Communications Cables (at least one per system) - selection depends on interface being used.

1. HP-IB Interface. HP 10833A/B/C/D (1, 2, 4, and 0.5 Meters respectively).
2. Serial Interface. HP 24542M US/European Modem Cable for connection to a computer or terminal that has a 25-pin female connector.
3. 16-bit Binary Interface.

   If you use an HP 9000 Series 200/300 Controller, order the HP 98622A GPIO Interface Card and specify Option 001 for an unterminated cable. Also order a 50-pin connector with cover, HP Part Number 1251-7673, and bushing, HP Part Number 1251-0170. For bulk (unterminated) cable for use in this application, order HP part Number 1251-0086. The wiring diagram and connector pinout are shown in Section III.

   For other controllers, a custom cable will be required. Order HP Part Number 1251-7673 for the 50-pin connector, also order bushing, HP part Number 1251-0170. For bulk (unterminated) cable for use in this application, order HP part Number 1251-0086. Purchase the cable with the controller's binary interface. The connector pinout for wiring this cable is shown in Section III.
4. 8-bit Parallel Interface - see options 1 and 2 below or option 3 above.

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B. Function Board Cables (one for each measurement axis that is connected to the user's equipment).

1. Custom cable (requires 50-pin connector/cover and bushing; HP part numbers 1251-7673 and 1251-0170 or equivalent)
2. HP 10935A Quad/Serial Cable for HP 10934A (serial portion requires additional serial cable above). Additional wires may be added by the user for customization.

SAFETY CLASSIFICATION

The laser sources used in the Laser Position Transducer system (HP 5501A, HP 5517A, HP 5517B, HP 5517C, and HP 5518A Laser Heads) are Class II Laser Products conforming to U.S. National Center for Devices and Radiological Health Regulations 21 CFR 1040.10 and 1040.11.

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SECTION II
HP LASER INTERFEROMETRY

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SECTION II
HP LASER INTERFEROMETRY

INTRODUCTION

This section describes the fundamentals of HP Laser Interferometry, supplying the background necessary to understand information in subsequent sections. The material is organized as follows:

a. OVERVIEW OF HP 5527A LASER POSITION TRANSDUCER. A brief description of the basic measurement system and a comparison to other position transducers.

b. FUNDAMENTAL MEASUREMENT CONCEPTS. Covers definition of terms, basic measurement theory, and accuracy considerations.

c. MEASUREMENT COMPONENTS. Describes laser heads, splitting and bending optics, measurement optics, and the receiver.

d. MULTIAXIS MEASUREMENT SYSTEMS.Covers 2, 3, and 4 axis systems, and angular measurements made with multiaxis systems.

e. ELECTRONIC COMPONENTS. Details the HP 5507A Laser Position Transducer Electronics (Backplane and HP-IB Circuits), HP 10932A Axis board, HP 10936A Servo-Axis board, HP 10941A Prototyping Kit, and the HP 10946B Automatic Compensation board.

OVERVIEW OF HP 5527A LASER POSITION TRANSDUCER SYSTEM

The HP 5527A Laser Position Transducer System uses interferometry techniques to measure position with exceptionally high resolution and accuracy. System accuracy (in vacuum) is ± 0.1 parts-per-million (ppm) and is based on the accuracy of the laser head. It is customary to specify laser accuracy in vacuum because the variable characteristics of air (such as temperature, humidity, pressure, and gas mixture) have a significant effect on the wavelength of light. The HP 5527A offers automatic compensation for air environments and also for temperature changes of the work material. For a temperature controlled environment (20 ±0.5°C), typical system accuracy using air sensor automatic compensation is 1.5 ppm. Using the HP 10717A Wavelength Tracker for compensation, the measurement repeatability is on the order of 0.2 ppm, depending on environment. The total (sum of all axes) measurement range is 40 metres (130 feet). The equipment is ruggedly built to withstand industrial environments and requires no more attention to safeguards than other less precise position transducers.

Compared to other position transducers such as glass or Inductosyn scales and single frequency laser interferometers, the HP system requires similar setup time and complexity. However, the total system accuracy is significantly better and considerably more stable. For example, in the HP system, alignment shifts do not usually result in position errors. If an alignment shift is so severe that a measurement is no longer possible, the user will be alerted. In contrast, glass and Inductosyn scales are prone to alignment shifts introducing positioning errors which may remain undetected until either a recalibration is performed or improperly fabricated parts are discovered. Single frequency interferometers, on the other hand, are subject to inaccuracies due to slight intensity changes caused by the environment.

As with any measuring device, improper installation or operation can degrade measurement accuracy. Prior to installation of the equipment, you are encouraged to study the basic measurement capabilities of the system along with the considerations of relevant sources of errors. Many of the potential problems that could be encountered during installation and initial operation can be avoided by careful planning and a thorough knowledge of laser interferometry.

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A correctly installed system results in high accuracy and resolution, increased reliability, and less maintenance and calibration than other types of positioning transducers. Although the HP 5527A system may appear somewhat complex, once the concepts and requirements are thoroughly understood, it will become apparent that designing HP laser positioning capability into a system is comparable to other types of position transducer installations.

FUNDAMENTAL MEASUREMENT CONCEPTS

Definitions

Following are definitions of terms as used in laser interferometry.

ACCURACY: The maximum deviation of a measurement from a known standard. For the HP Laser System, the accuracy of the system is based on the wavelength of the laser light.

DEADPATH: The optical path difference between reference and measurement beams when the stage is at zero position.

DEGREES OF FREEDOM: As an object moves linearly in the X-axis direction (*Figure 2-1*), there are 6 degrees of motion that will affect the final position of the object. Besides the positioning error along the X-axis which relates directly to the accuracy of the linear scale, the object can also undergo angular rotations about the X, Y, and Z axes known as roll, yaw, and pitch, respectively. Pure translational motions in the Y and Z axes are identified as vertical and horizontal out-of-straightness movements respectively.

A typical 3-axis positioning system has 18 degrees of freedom (6 degrees of freedom per axis) plus errors introduced by out-of-squareness between axes, 21 potential error sources in all, which combine together to define the final position achieved.

ETALON: An etalon is an optical reference cavity. When used with the Wavelength Tracker, the etalon presents a fixed distance to the differential interferometer.

FOLLOWING ERROR: The following error is the distance between the actual position and the reference position during a closed-loop position move. It indicates how closely the controlled object followed the desired motion profile.

HETERODYNE: To mix two ac signals of different frequencies in a non-linear device for the purpose of producing two new frequencies, corresponding respectively to the sum and difference between the two original frequencies.

INTERFEROMETER: The term interferometer may be applied to any optical arrangement where a beam of light from a light source is separated into two or more parts by a beam splitter, the parts are subsequently recombined after traversing different optical paths. The two components then produce interference.

LASER: An acronym for "Light Amplification by Stimulated Emission of Radiation". A laser is a device that utilizes the natural oscillations of atoms or molecules between energy levels for generating coherent light.

REPEATABILITY: This term refers to the capability of a measurement instrument to produce an identical measurement, when measurements are repeated under unchanged conditions.

RESOLUTION: The smallest measurable linear increment. The units of resolution are units of length including fractions of Lambda (λ). Lambda is the symbol for the wavelength of light. For the Helium Neon laser, lambda is 632.8 nanometres.

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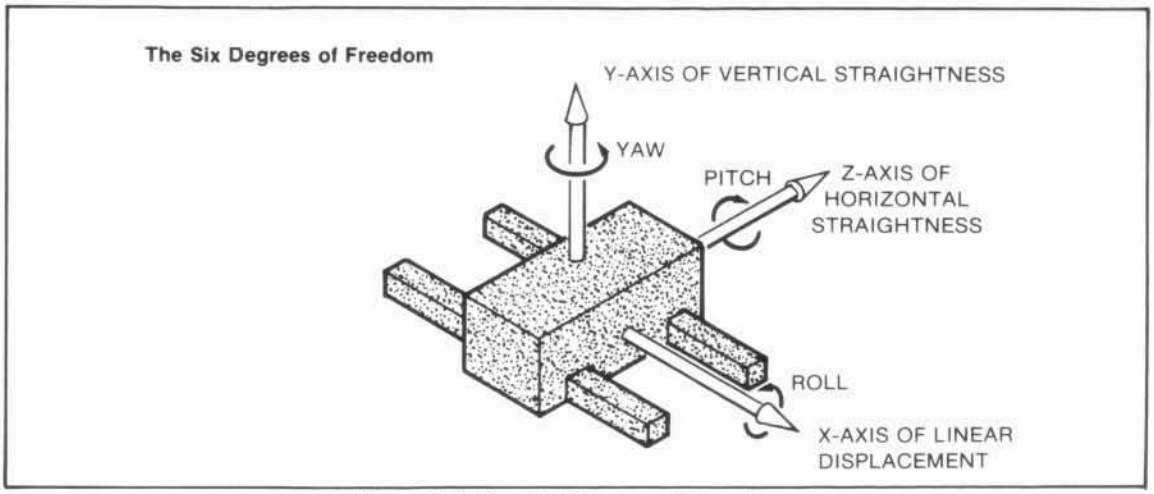


Figure 2-1. The Six Degrees of Freedom.

Basic Measurement Theory

To understand the principles of laser interferometry, we will examine the Michelson interferometer, followed by a discussion of two-frequency laser systems, and then the HP 5527A Laser Position Transducer.

MICHELSON INTERFEROMETER

In the 1880's, Albert Michelson developed the principle of interferometry while experimenting with velocity of light tests. In the basic Michelson interferometer shown in *Figure 2-2*, monochromatic light is directed at a half-silvered mirror that acts as a beam splitter to pass half the beam to a movable mirror and bend the remainder 90° to a fixed mirror. The reflected beams from the movable mirror and the fixed mirror recombine at the beam splitter. With the mirrors exactly aligned and motionless, an observer will see a constant intensity of light.

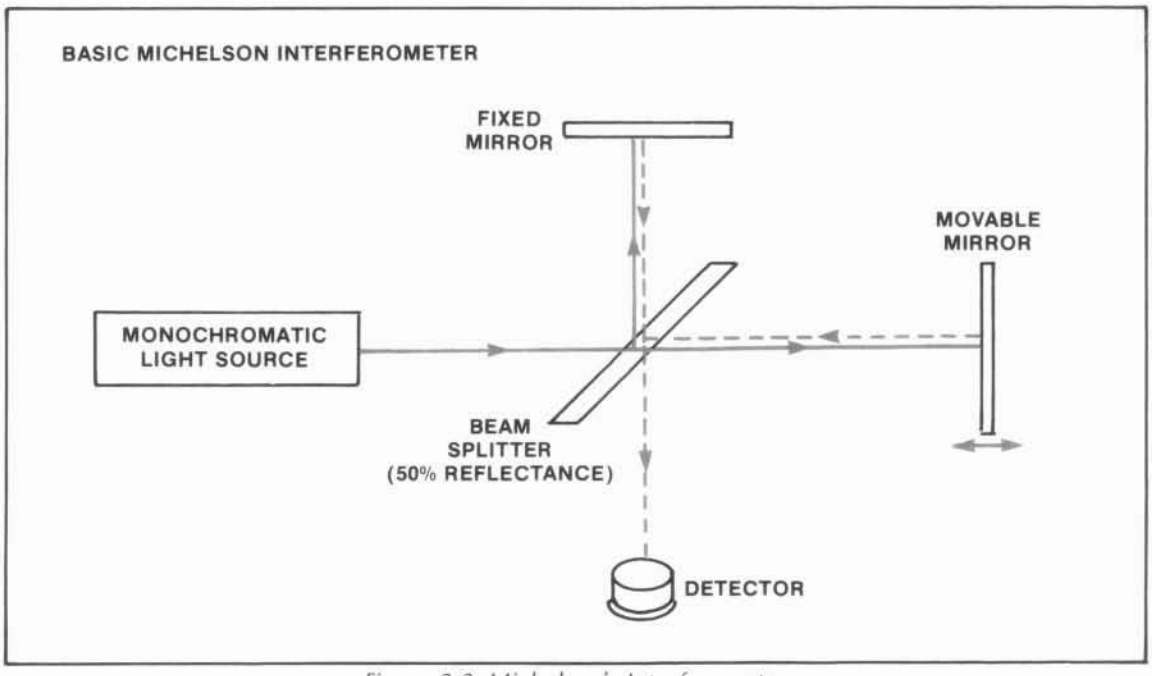


Figure 2-2. Michelson's Interferometer.

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When one of the mirrors is moved very slowly, the observer will see the beam increasing and decreasing in intensity as the light waves from the two paths add and cancel. This interference of the reflected beams produces characteristic fringe patterns where each cycle of intensity change represents a half wavelength of movable mirror travel. If the wavelength of the light is known, then the travel of the mirror can be accurately determined.

An important characteristic of interferometry is that the initial distance to the movable mirror is not measurable, only the change of position of the mirrors with respect to each other can be detected.

To convert Michelson's apparatus into an electronic measuring device requires a photocell to convert beam intensity into an electrical signal, and an electronic counter to tally the cycles of beam intensity. To make such a device practical, however, several other improvements are necessary.

Because alignment of ordinary mirrors is extremely critical, modern interferometers use cube corners (retroreflectors). Cube corners reflect light parallel to the angle of incidence regardless of alignment with respect to the beam.

The accuracy of interferometers over any practical distance is dependent upon a precisely known wavelength of pure light (i.e., a highly stable single wavelength). Laser light is extremely well-suited to this task.

Since a single photocell can not determine the direction of retroreflector movement, some form of direction-sensing electronics is required. One commonly used method is to split the return beam into two portions, delay one portion in phase by 90°, and then detect each portion of the beam using a separate photocell. This technique yields two signals that vary sinusoidally in intensity as the reflector moves. The signals differ in phase by 90° and are used to drive a suitable counter. The phase separation allows the counter to determine the direction of retroreflector motion.

The basic Michelson interferometer with the added improvements previously described comprise a functional measuring system. However, problems occur when the intensity of the light beam changes due to aging of the light source or when turbulence either deflects the beam slightly or warps the wavefront. These intensity changes could be interpreted as motion, thus introducing measurement errors.

TWO FREQUENCY LASER INTERFEROMETRY

HP interferometry makes use of a principle that completely eliminates this problem. While conventional interferometers mix two light beams of the same frequency, the HP interferometer employs a two-frequency laser and mixes light beams of two different frequencies. *Figure 2-3* illustrates a typical HP system.

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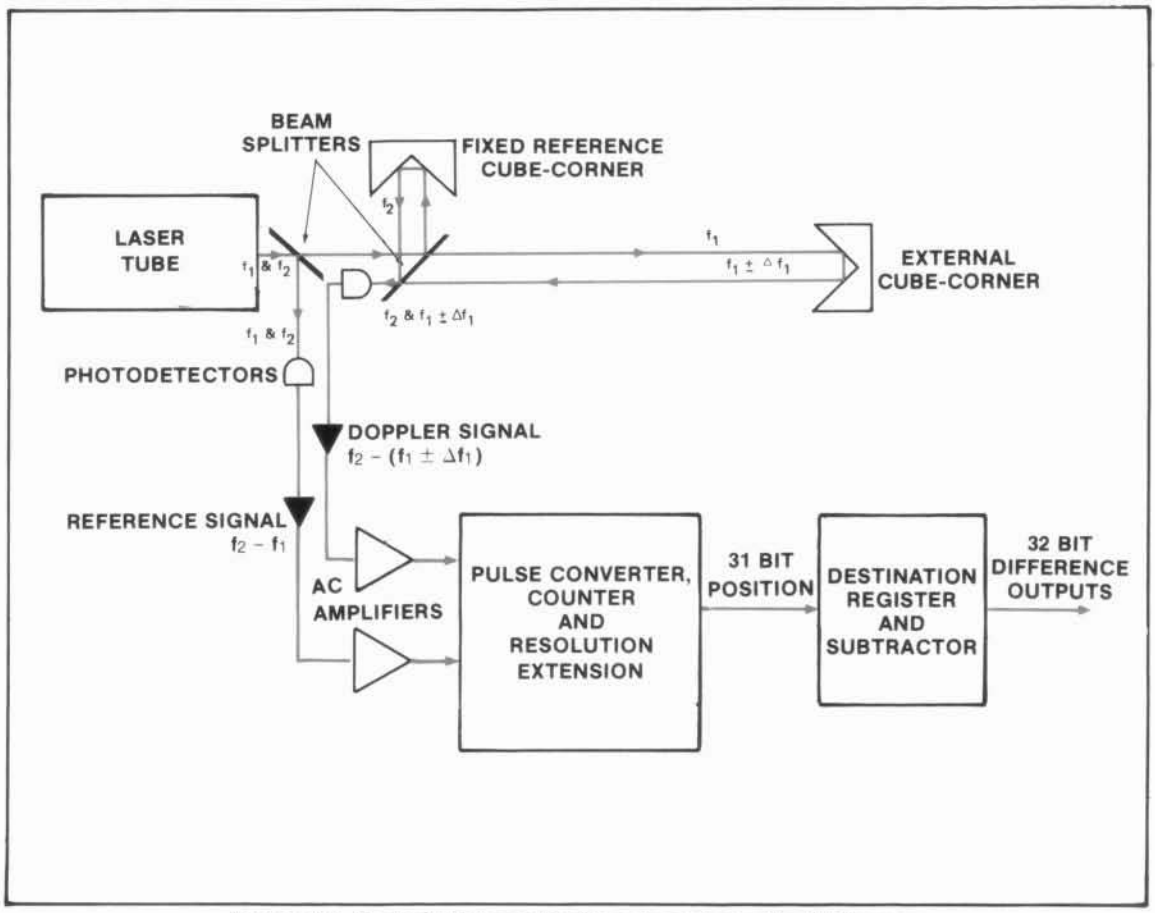


Figure 2-3. Typical HP Laser Position Transducer Block Diagram

The prime virtue of the two-frequency system is that the distance information is carried on ac waveforms, or carriers, rather than in dc form. Since ac circuits are insensitive to changes in dc levels, a change in beam intensity cannot be interpreted as motion.

The ac signals representing distance change are analogous to the intermediate frequency carriers in FM heterodyne receivers. The ac signal or "intermediate frequency" is produced by mixing two slightly different frequencies, near 5×10^{14} Hz (500,000 GHz), differing by only a few megahertz.

Using different sources to generate these two frequencies would require ultra stable sources and periodic calibration. Lasers, however, can be forced to oscillate at two frequencies simultaneously, simply by applying an axial magnetic field. The two resultant frequencies are very close together but with opposite circular polarizations. A polarizing beam splitter easily separates the two beams. Both frequencies are extremely stable and do not require recalibration.

One of the frequency components (f_1) is used as the measuring beam and reflects from the external cube-corner back to the beam splitter. Here the measuring beam mixes with the second frequency or reference frequency (f_2) to produce fringe patterns. These patterns are composed of alternate light and dark bands caused by successive reinforcement and cancellation (interference) of the beams. If the movable cube-corner reflector remains stationary, the interference rate (beat frequency) will be the exact difference between the laser's two frequencies, about 2 million fringes/second.

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When the cube corner moves, the frequency of the returning beam will be shifted up or down by the doppler effect ($f_1 \pm \Delta f$) depending on the direction of retroreflector motion. Doppler shift is the well known phenomenon experienced when one hears the pitch of a train's whistle change as the train approaches or departs. A retroreflector velocity of 30 centimetres/second (one-foot per-second) causes a Doppler shift of approximately 1 MHz. This shift is monitored by a photodetector and converted to an electrical signal ($f_2 - (f_1 \pm \Delta f)$). A second photodetector monitors the fringe frequency before the paths are separated and provides a reference signal that corresponds to zero motion ($f_2 - f_1$).

The two frequencies from the photodetectors are routed to a special counter. The counter counts up on the doppler-shifted signal from the retroreflector and down from the reference signal. With no retroreflector motion, the frequencies are equal, and no net count is accumulated. When the retroreflector moves, the Doppler frequency increases or decreases to produce net positive or negative cumulative counts corresponding to the distance and direction traversed in wavelengths of light.

THE HP 5527A LASER POSITION TRANSDUCER

Although there are many possible configurations of the laser and optics, all HP systems have five basic parts in common. These are:

a. A two-frequency laser source to produce optical frequencies f_1 and f_2 and generate the reference signal.

b. A set of splitting and bending optics (HP 107XX series) to bend part or all of the laser beam at right angles.

c. A set of measurement optics (HP 107XX series) to selectively redirect the optical frequencies over the reference and measurement paths.

d. A set of receivers (one per measurement axis) to detect the difference in optical frequencies and produce the measurement signal.

e. Electronics to convert the measurement and reference signals into displacement data.

Two important characteristics of HP interferometers must be emphasized; first, only the change in relative position of the optics is detected. Second, either optical component may move as long as optical alignment is maintained. If the interferometer is fixed and the retroreflector is the moving component (toward or away from the interferometer), motion with respect to its original position is detected. Conversely, if the retroreflector is fixed, the interferometer can be the moving component.

The HP 5527A Laser Position Transducer can detect and measure all linear measurements, i.e., 3 degrees of the 18 degrees of freedom defined in definitions above. Small angle measurements may be made by multiple measurements on the same axis.

The measurement system is relatively insensitive to all other motions, as briefly described below. See *Figure 2-4*.

a. Motion of the receiver or laser head in a direction parallel to the beam path (X) has no effect on the measurement, since both f_1 and f_2 would exhibit doppler shift.

b. Motion of the laser head, receiver, interferometer, or retroreflector in a direction lateral to the beam path (Y or Z) has no effect on the measurement. The only restriction is that sufficient light returns to the receiver.

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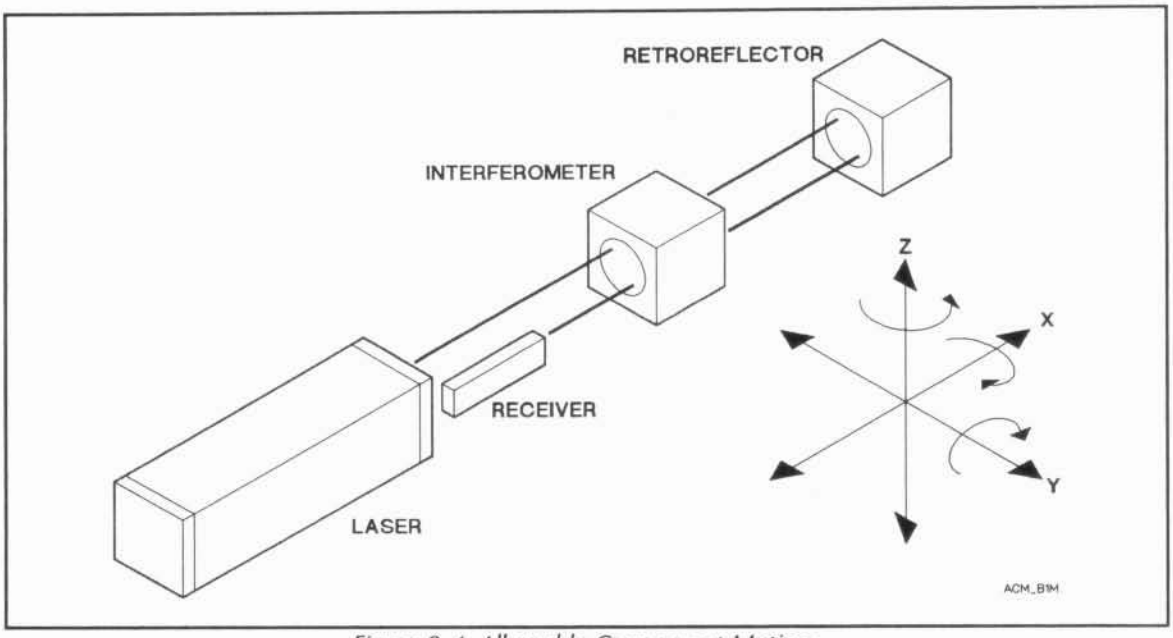


Figure 2-4. Allowable Component Motions

c. Angular motion of the laser head about the Z and Y axes has two effects as described below:

   1. Introduces a measurement error (cosine error).
   2. May displace the laser beam so that insufficient light returns to operate the receiver.

d. Although the Laser Head or the Receiver may be rotated in 90° increments about the beam axis (roll), other roll deviations from the four optimum positions degrade the measurement signal.

e. Angular motion of the receiver about the Y and Z axes has no effect on the measurement within certain limits.

f. Angular motions of the interferometer and retroreflector are dependent on the particular components for limitations.

Accuracy Considerations

Several factors external to the Laser Position Transducer can affect the system accuracy. These factors (the measurement environment, machine and material temperature, and the optics installation) and their interrelationship must be understood in order to predict the performance of the system. Detailed descriptions and methods of compensation are contained in Section V.

MEASUREMENT COMPONENTS

The measurement components comprise that portion of the Laser Position Transducer used to generate, direct, and detect the laser beam and are selected from the following units:

a. HP 5517A, HP 5517B, HP 5517C, or HP 5518A Laser Head

b. HP 10700A 33% Beam Splitter

c. HP 10701A 50% Beam Splitter

d. HP 10707A Beam Bender

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e. HP 10567A Dual Beam-Beam Splitter

f. HP 10702A Linear Interferometer (and Option 001 Windows)

g. HP 10703A Retroreflector

h. HP 10704A Retroreflector

i. HP 10705A Single Beam Interferometer

j. HP 10706A Plane Mirror Interferometer

k. HP 10715A Differential Interferometer

l. HP 10710A Adjustable Mount

m. HP 10711A Adjustable Mount

n. HP 10780B Receiver

Laser Heads

Hewlett-Packard offers a choice of four different Laser Heads to meet a wide variety of applications. Following is a general discussion of Laser Head characteristics and descriptions of each type including comparisons, benefits and features.

GENERAL CHARACTERISTICS

FREQUENCIES AND POLARIZATIONS. HP Laser Heads produce a coherent collimated two-frequency laser beam consisting of two orthogonally polarized frequency components. To differentiate between the frequencies, the lower frequency is identified as F_1 and the higher F_2. Frequencies F_1 and F_2 are always orthogonally polarized with respect to one another. However, either may be vertically (or horizontally) polarized. Some HP models have F_1 vertically polarized, and in others F_1 is horizontally polarized. This will affect the direction sense. For example, if F_1 is in the measurement path, F_2 is in the reference path, and the optics are moving away from each other, the fringe counts will be increasing. Interchanging F_1 and F_2 in this example will cause the fringe counts to decrease.

AUTOMATIC TUNING. To maintain a stable frequency output, HP laser heads have variable cavity lengths controlled by some form of automatic tuning circuitry. All HP laser head models (HP 5517A, HP 5517B, HP 5517C, and HP 5518A) are thermally tuned. Thermally-tuned lasers require a 10-minute warmup period (maximum) and offer better stability, accuracy, and reliability at lower cost than earlier laser sources manufactured by HP.

BEAM SHUTTERS. To facilitate alignment and meet safety standards, the laser heads have shutter controls installed at the laser beam aperture. The beam may be blocked entirely for safety, or reduced for alignment, or unimpeded for normal operation.

HP 5517A, HP 5517B, HP 5517C, AND HP 5518A LASER HEADS

These four different laser heads have different shutter arrangements, and the HP 5518A has a built-in receiver.

POLARIZATION ORIENTATION. The HP 5517A/5517B/5517C/5518A produces F_1 with horizontal polarization and F_2 with vertical polarization.

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AUTOMATIC TUNING. Thermal tuning is used and requires a warmup period of less than 10 minutes (4 minutes typical).

HP 5517A/B/C BEAM SHUTTER. The three-position shutter on the HP 5517A/B/C can be set for open, reduced, or closed apertures.

HP 5518A BEAM SHUTTER. The HP 5518A has two shutters. The exit (upper) shutter has three positions for open, reduced, or closed apertures. The return (lower) shutter has two positions for open and alignment target. In addition, the HP 5518A has a two-position turret ring to configure the head for straightness measurements (requires special optics, see HP 5528A literature for additional information) in one position and all other measurements in the other.

HP 5517A INDICATORS. The HP 5517A has two LED indicators on the rear panel. The "LASER ON" LED alerts the operator that the laser head is activated and emitting a laser beam. About halfway through the warm-up period, the "READY" LED blinks on and off to indicate that the laser is in the process of warming up. When the head is ready for use, the "READY" LED remains on. Any necessary retuning is performed automatically and is indicated by the "READY" LED flashing.

HP 5517B/C INDICATORS. The HP 5517B/C has four indicators on the rear panel to indicate the status of the ±15 Volt power supply input, laser output and tuning, and the reference frequencfy output. The "+15V POWER ON" and "–15V POWER ON" indicate that power has been applied and that both .15 Volt fuses are OK. The "LASER ON" LED alerts the operator that the laser head is activated and emitting a laser beam. About halfway through the warm-up period, the "READY" LED blinks on and off to indicate that the laser is in the process of warming up. When the head is read for use, the "READY" LED remains on. Any necessary retuning is performed automatically and is indicated by the "READY" LED flashing.

HP 5518A INDICATORS. the HP 5518A has two LED indicators on the rear panel and two LED indicators on the front panel. The rear panel LEDs are the same as on the HP 5517A. The front panel "LASER ON" LED performs the same function as the rear panel "LASER ON" LED. The remaining front panel LED, "SIGNAL", indicates when a sufficient laser beam measurement signal is returned to the receiver within the HP 5518A.

Splitting and Bending Optics

The splitting and bending optics consist of the following units:

HP 10700A 33% Beam Splitter

HP 10701A 50% Beam Splitter

HP 10707A Beam Bender

HP 10567A Dual Beam Beam-Splitter

These optics allow a portion of the laser beam to be directed along each measurement axis. They are rugged and easy to mount in a wide variety of applications.

The HP 10700A 33% Beam Splitter deflects about one-third of the laser beam at right angles to the original beam direction and allows the remaining two-thirds to continue straight through. The HP 10701A 50% Beam Splitter deflecfts one-half of the laser beam at right angles and passes the remaining half. Combinations of these two accessories allow flexibility in directing the desired fraction of beam intensity to each axis of a multiaxis configuration. For example, using a 33% and a 50% Beam Splitter, one can direct one-third of the laser beam intensity to each measurement in a three-axis machine.

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The HP 10707A Beam Bender contains a 100% reflectance mirror that turns the direction of an incoming laser beam at a right angle. To maintain proper polarizations, only right-angle turns should be used in routing the beam of the laser head within a machine.

The HP 10567A Dual Beam Beam-Splitter allows alternate optical layouts. The HP 10567A consists of a beam splitter glass plate with three different coatings; one third of the plate is mirror coated for 100% reflectance, a second one-third is coated for 50% reflectance, and the final one-third has a nonreflecting coating.

The HP 10567A Dual Beam Beam-Splitter divides the Laser Head output beam into two equal beams at right angles to each other (see *Figure 2-5*). These two beams go to two sets of measurement optics and the return beams pass through the HP 10567A again. These two measurement beams exit the HP 10567A parallel to the Laser Head output beam.

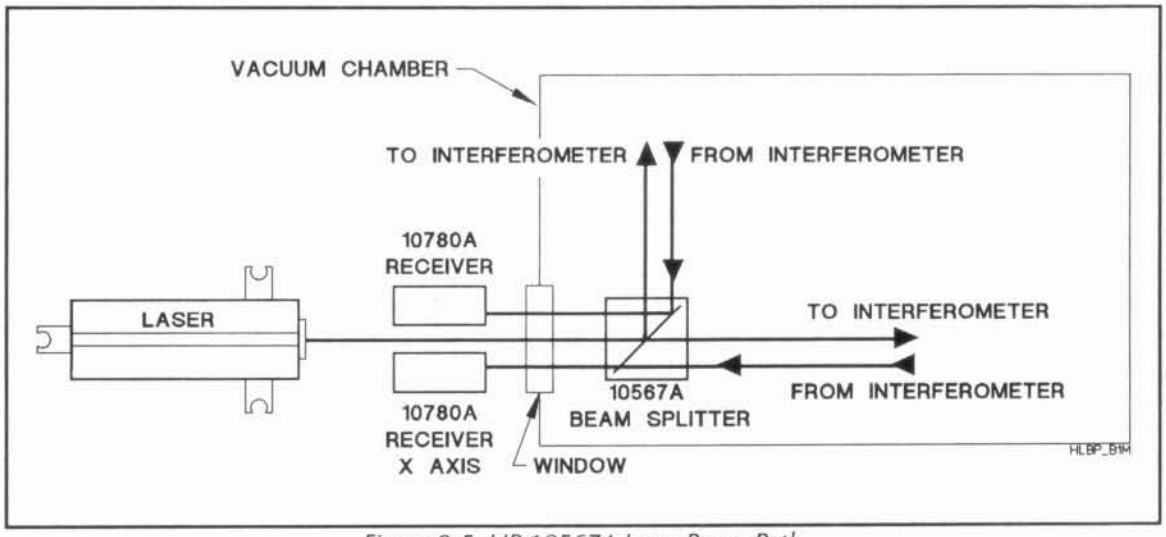


Figure 2-5. HP 10567A Laser Beam Path

Measurement Optics

Each Laser Transducer axis must have an interferometer and a reflector. Machine design considerations determine which type of interferometer is optimum. The choice of the interferometer for each axis usually specifies the reflector for that axis.

Direction sense is determined by which optical frequency, F_1 or F_2, is in the measurement path. The Laser Head determines the polarization (vertical or horizontal) of F_1 and F_2. But the optics orientation determines which polarization, F_V or F_H, is in the measurement path.

HP 10702A LINEAR INTERFEROMETER AND HP 10603A RETROREFLECTOR

The HP 10702A Linear Interferometer is the basic unit and is used whenever possible. The measurement reflector for this interferometer is the HP 10703A Retroreflector. Displacement is measured between the interferometer and the cube corner. Either one or both can move.

Normally, one optic is mounted on a moving part and the other is mounted on a fixed part and the displacement between the two is measured. A diagram of this is shown in *Figure 2-6*. Note that for multiaxis installations each axis must be mechanically independent of the other. In other words, motion in the Y-axis should have no effect on the alignment of the X-axis optics.

If the linear interferometer must move, the HP 10702A, Option 001, must be used (*Figure 2-7*).

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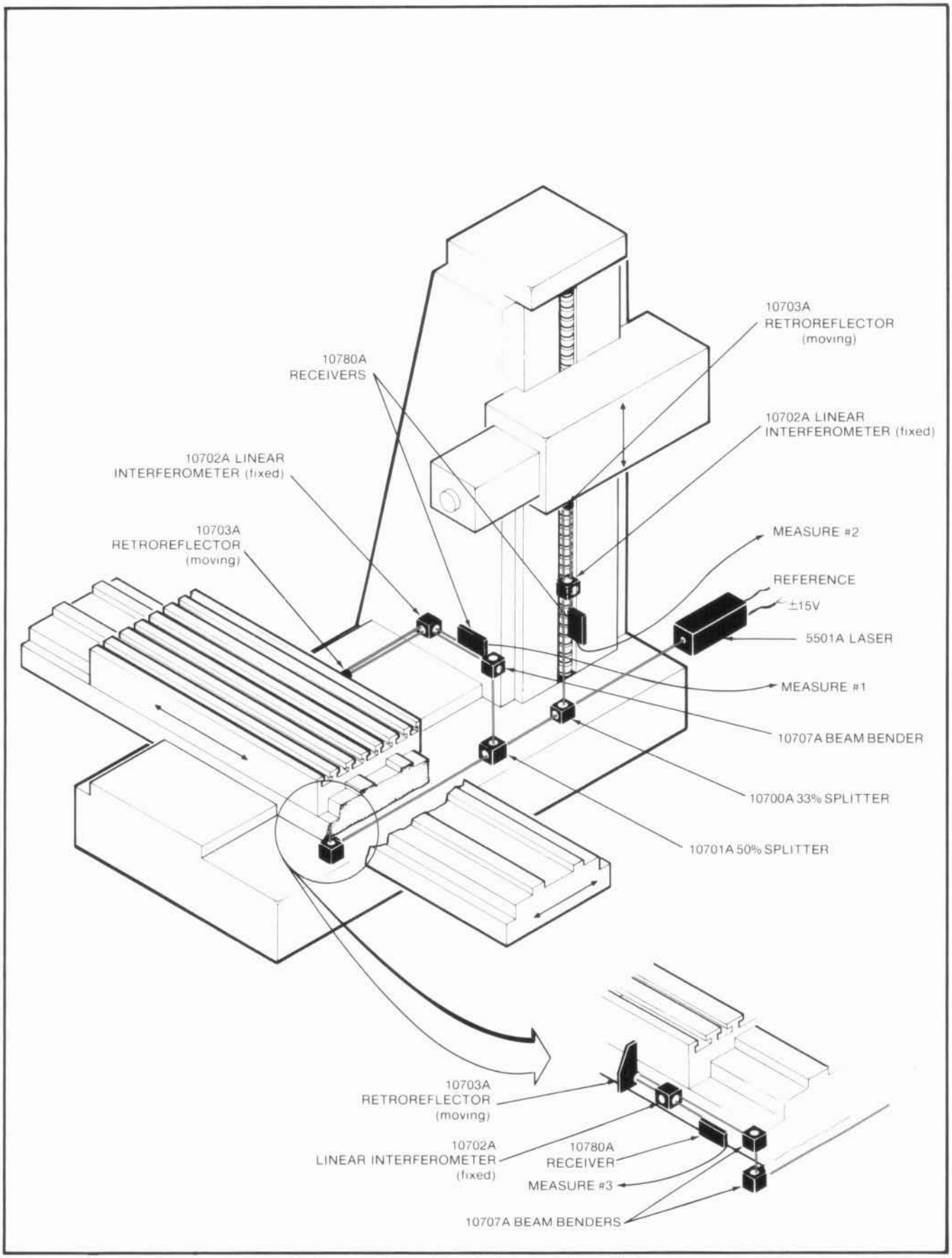
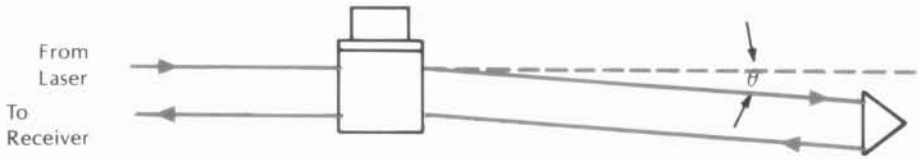


Figure 2-6. Three-Axis Machine Tool Installation

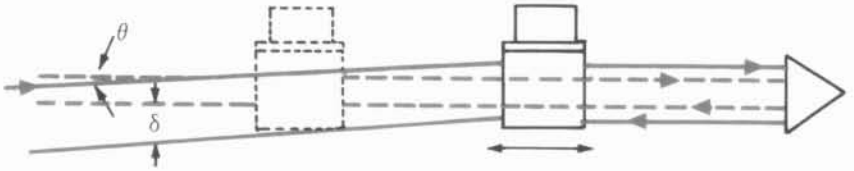
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If the 10702A Linear Interferometer is placed in a beam which has been aligned parallel to the motion of travel, the outgoing beam can be deflected by as much as 30 arc-minutes (θ) due to the incoming-outgoing beam parallelism specifications of the 10702A. This could cause not only cosine error but also possible loss of signal during movement of the 10703A Retroreflector.



To compensate for this, the alignment is performed with the 10702A Linear Interferometer in place. This allows the laser beam to be aligned parallel to the motion of travel to minimize cosine error and maximize signal. Since the incoming beam is now not parallel to the motion of travel, the 10702A Linear Interferometer **must remain stationary.** (See below)



If the 10702A Linear Interferometer is moved during the measurement instead of the 10703A Retroreflector, the beam in the measurement path will remain parallel but will be displaced. This displacement δ will occur at the receiver causing a decrease and eventual loss of signal depending on the distance traveled.



If motion of the Linear Interferometer is required, the 10702A Option 001 should be used. This provides special wedge windows which makes the outgoing beam parallel to the incoming beam. This allows motion by either the 10703A Retroreflector or the 10702A Option 001 Linear Interferometer.

Figure 2-7. HP 10702A Linear Interferometer with Option 001 Windows

LINEAR INTERFEROMETER LASER BEAM PATH

The beam exiting from the Laser Head is split at the surface of a polarizing beam-splitter, with one frequency, F_V, reflected to the reference cube corner mounted on the housing (*Figure 2-8*). The other frequency, F_H, is transmitted to the HP 10703A Retroreflector and returned parallel to, but displaced from, the outgoing beam. Both frequencies are reflected back along a common axis to the photodetector in the receiver. One of these frequencies includes a Doppler frequency shift whenever the HP 10703A Retroreflector (or HP 10702A Linear Interferometer) moves. Rotating the interferometer 90° about the beam path switches which optical frequency is in the measurement path, thus changing the direction sense.

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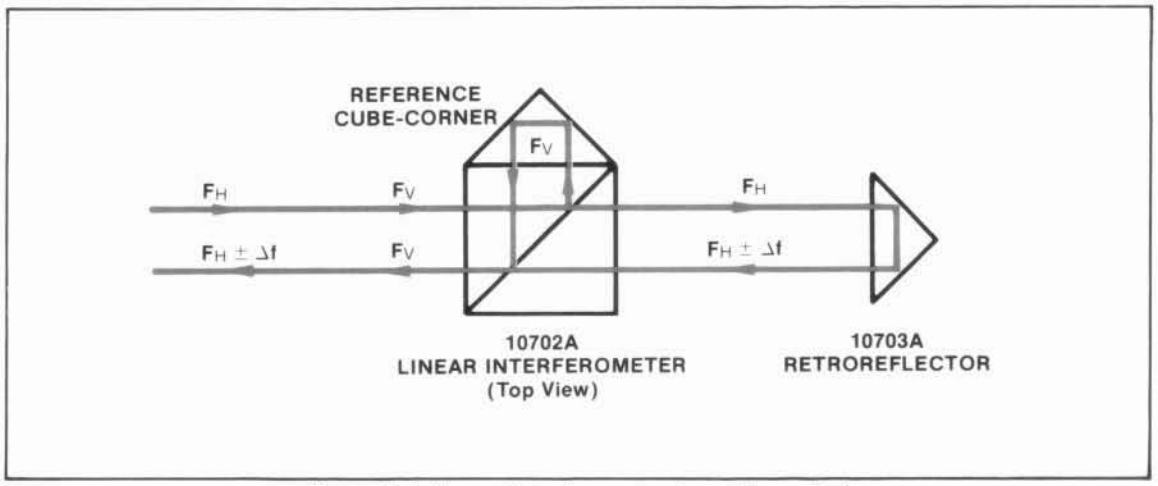


Figure 2-8. Linear Interferometer Laser Beam Path.

HP 10705A SINGLE BEAM INTERFEROMETER AND HP 10704A RETROREFLECTOR

A single beam interferometer is so named because the outgoing and returning beam are superimposed on each other giving the appearance of only one beam traveling between the interferometer and the retroreflector. Functionally, this interferometer operates the same as the standard interferometer but is advantageous when space for optics and beam paths is at a premium. The retroreflector is again a cube corner but it is considerably smaller than the standard cube corner. One significant difference is that the receiver is mounted at right angles to the measurement beam and the interferometer cannot be moved. A diagram of this interferometer is shown in *Figure 2-9*.

SINGLE BEAM INTERFEROMETER LASER BEAM PATH

A polarizing beam-splitter reflects F_V to the reference cube corner and transmits F_H to the HP 10704A Retroreflector (*Figure 2-9*). The return path is superimposed on the outgoing path. Since both beams leaving the beam-splitter pass through a quarter-wave plate, the returning polarizations are rotated through 90°. This causes F_V to be transmitted and $F_H \pm \Delta f$ to be reflected so that they are directed coaxially to the receiver along a path perpendicular to the measurement path. Again, rotating the interferometer 90° switches which optical frequency is in the measurement path, and thus changes the direction sense.

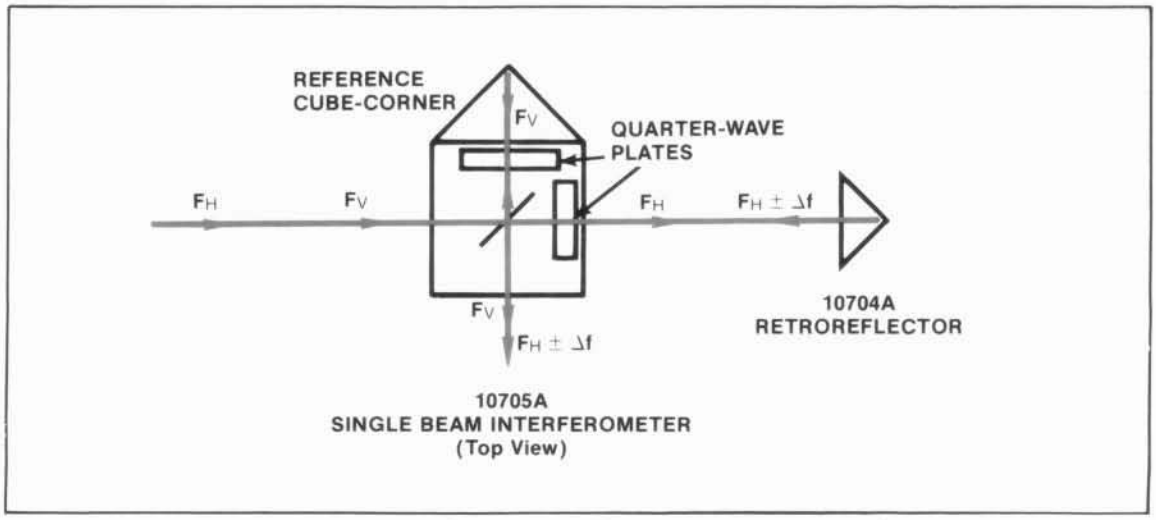


Figure 2-9. Single Beam Interferometer Laser Beam Path

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HP 10706A PLANE MIRROR INTERFEROMETER

The plane mirror interferometer can be used with a plane mirror reflector to give distinct advantages. Since interference fringes are detectable even though the measurement beam is not at perfect right angles to the mirror, several worthwhile applications are possible. For example, in a two axis system, the X reflector can be allowed to move in the Y direction without affecting the signal strength or the X measurement. Consequently, both reflectors of a two-axis system can be mounted on the same moving part to minimize Abbe offset error. Defining the measuring point as the point where the two axis beams cross, the measurement is essentially independent of yaw of the moving stage. Such a design is shown in *Figure 2-10.*

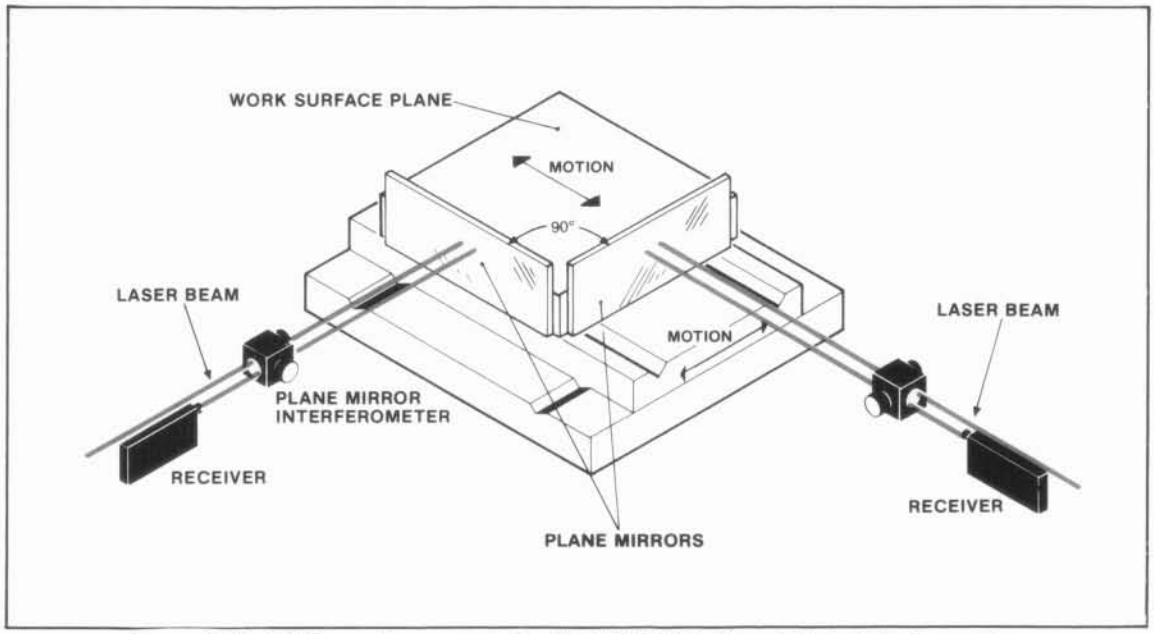


Figure 2-10. X-Y Stage Measurement with HP 10706A Plane Mirror Interferometer

Contrast this system to a two-axis system using standard interferometers. The x-axis retroreflector must be mounted on a part of the stage that moves in the X direction and not in the Y direction. Also, the y-axis retroreflector must be mounted on a different part of the stage that is allowed to move in the Y direction and not in the X direction. These constraints prevent two-axis measurements from being made on the same part of the stage. Further, there will be some geometry error in the system if it is not perfectly rigid.

Since the measurement beam travels twice between the interferometer and the plane mirror, the resolution of the measurement is twice that of the linear or single beam interferometers. The standard resolution extension of the HP 10932A Axis Board results in resolutions of $\lambda/128$ (5 nanometres or 0.2 microinches) with the plane mirror interferometer, or $\lambda/64$ (10 nanometres or 0.4 microinches) with the linear or single beam interferometers.

PLANE MIRROR INTERFEROMETER LASER BEAM PATH

As in the other interferometers, the vertical polarization (F_V) is reflected to the receiver after retroreflection by the reference cube corner. The horizontal polarization (F_H) is transmitted out to the plane mirror reflector and is reflected back on itself (*Figure 2-11*). The quarter-wave plate causes the polarization of the return frequency to be rotated through 90° so that $F_H \pm \Delta f$ is reflected out a second time where it is Doppler shifted again. The polarization of $F_H \pm 2\Delta f$ is rotated again through 90° so it is now transmitted back to the receiver. Resolution doubling is inherent because of the double Doppler shift.

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The unique contribution of the HP 10706A Plane Mirror Interferometer is its tolerance of angular misalignment of the reflecting mirrors. Other mirror reflectors are required to remain perpendicular to the laser beam within several arc-seconds. With the HP 10706A, angular deviations of minutes of arc are commonly acceptable.

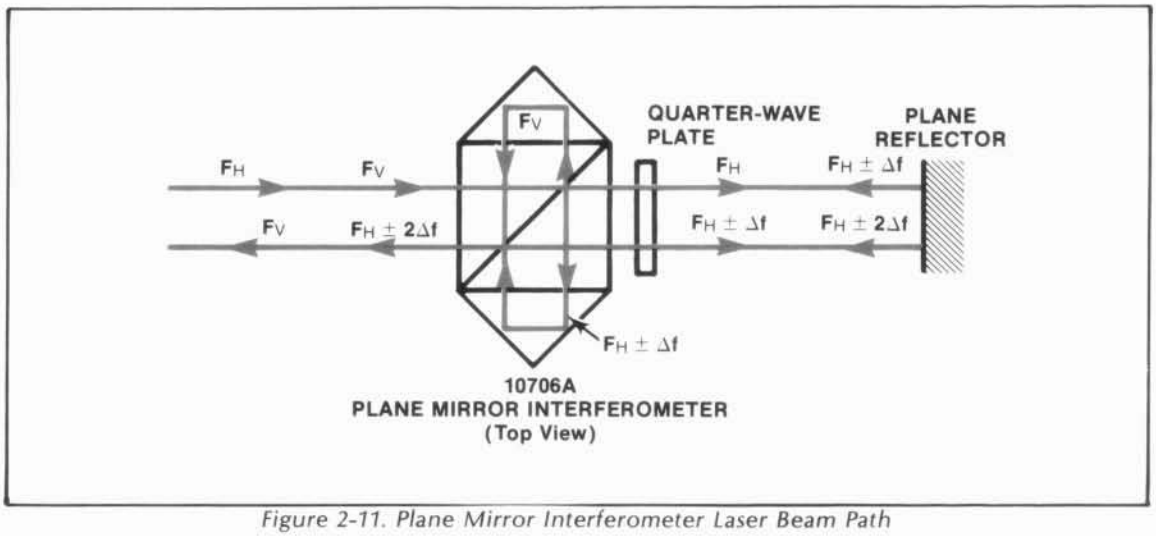


Figure 2-11. Plane Mirror Interferometer Laser Beam Path

HP 10706B HIGH STABILITY PLANE MIRROR INTERFEROMETER

HP's high stability plane mirror interferometer provides a significant improvement in thermal stability over conventional designs. Typically, an HP 10706B exhibits a thermal sensitivity that is 1/12 that of other plane mirror interferometers. This allows for a marked improvement in measurement stability thereby reducing the designer's error budget for HP equipment. Existing system designs can be easily upgraded, since the HP 10706B is an exact functional replacement for the HP 10706A and is the same size and weight.

Figure 2-12 shows the optical schematic for the HP 10706B High Stability Plane Mirror Interferometer. Note that the usual reference beam cube-corner has been replaced with a quarter-wave plate with a high reflectance coating on the back. In this configuration, the measurement and reference beams have the same optical path length which virtually eliminates measurement errors due to the temperature changes in the optic. The remaining thermal errors are due to mechanical tolerances in the geometry of the device. Typically, the HP 10706B exhibits drifts of 0.04 microns/degree C of optics temperature change.

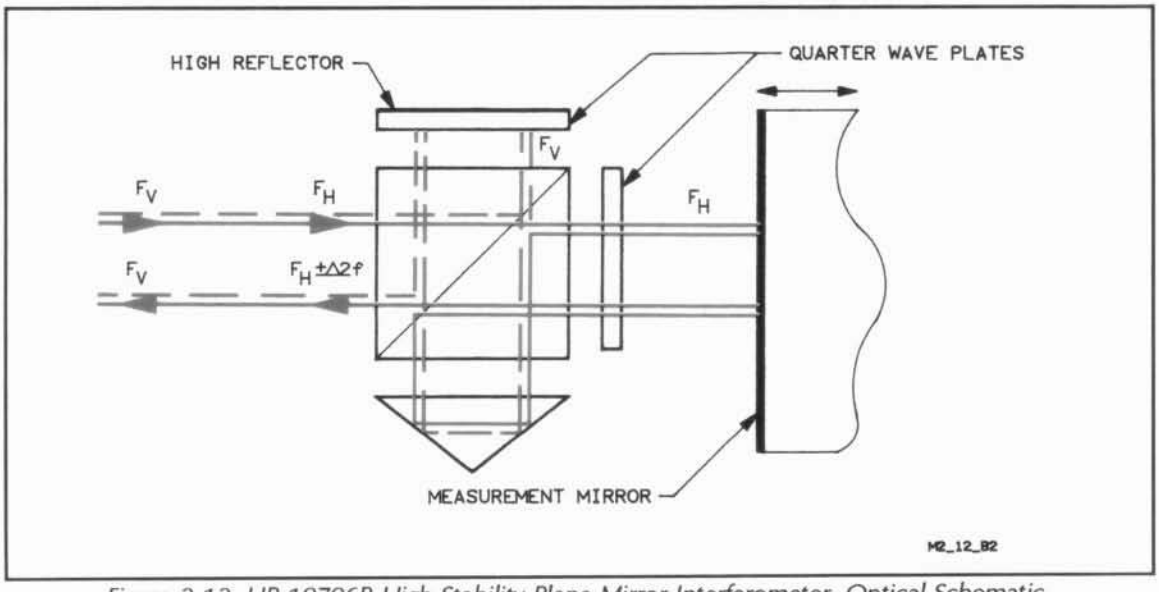


Figure 2-12. HP 10706B High Stability Plane Mirror Interferometer, Optical Schematic.

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HP 10716A HIGH RESOLUTION INTERFEROMETER

This optic offers twice the resolution of conventional plane mirror interferometers and has excellent thermal characteristics, typically, only 0.04 micrometres of drift per degree C. Although the HP 10716A is larger than the conventional plane mirror interferometer and the slew rate is halved, the finer resolution of this optic allows system measurement resolution of 2.5 nanometres (0.1 microinch).

Figure 2-13 shows the optical schematic of the HP 10716A High Resolution Interferometer. The unit consists of a cube corner, a plane mirror converter, a retroreflector, a high-stability adapter, and a polarizing beam splitter.

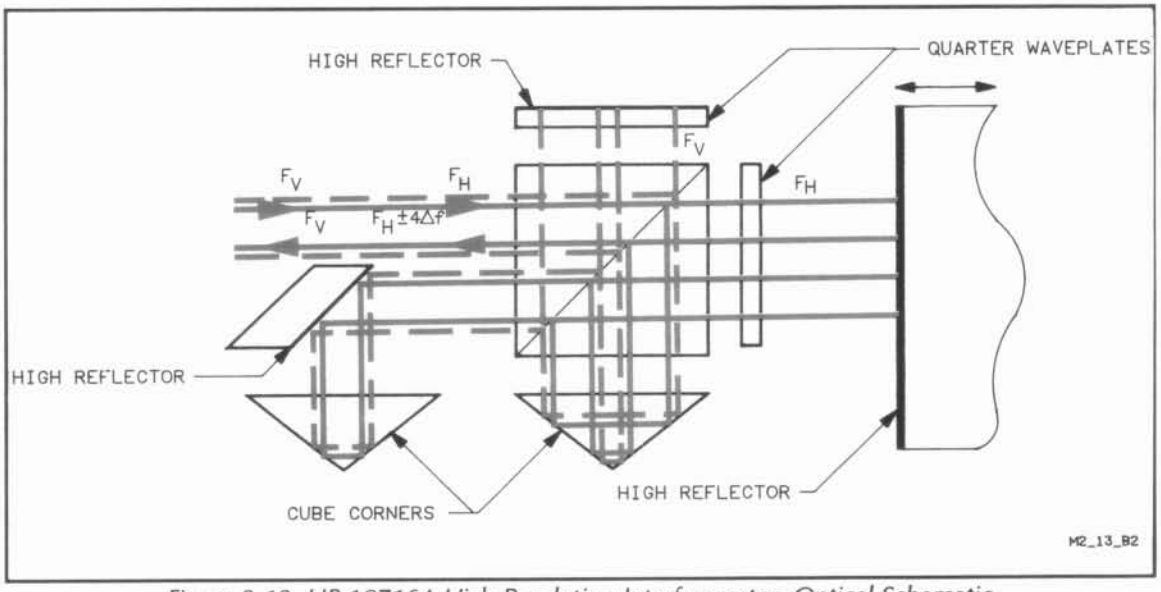


Figure 2-13. HP 10716A High Resolution Interferometer, Optical Schematic

HP 10715A DIFFERENTIAL INTERFEROMETER

The HP 10715A (*Figure 2-14*) permits differential measurements between two plane mirrors. Since the optical path is common to both reference and measurements beams, it is extremely tolerant of changes such as thermal expansion or variations of air characteristics. When used in a positioning system, the small reference mirror can be mounted very close to the measurement mirror. The advantages of the common beam path and the small reference mirror combine to significantly reduce deadpath. Deadpath is the optical path difference between reference and measurement beams when the stage is at zero position.

The orientation of the optics determines which frequency polarization is in the measurement or reference path thus affecting direction sense. Section V provides a complete breakdown of possible configurations and the resulting polarization orientations.

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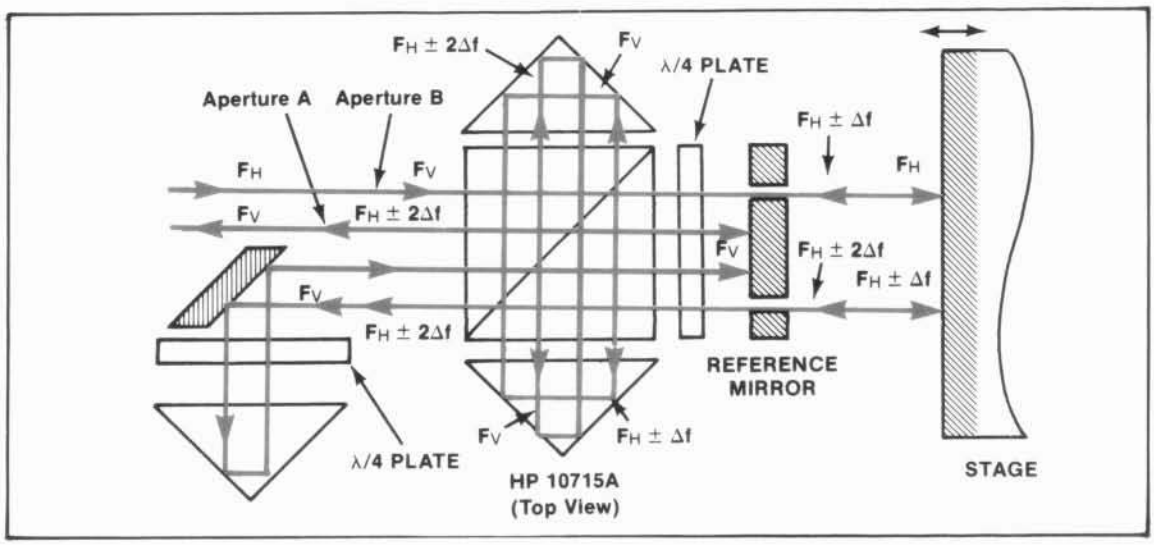


Figure 2-14. HP 10715A Differential Interferometer Laser Beam Path

HP 10717A WAVELENGTH TRACKER

The HP 10717A Wavelength Tracker (see *Figure 2-15*), when configured with a dedicated HP 10780B Receiver and HP 10946B Automatic Compensation Board (HP 5507A Option 046), monitors changes in the wavelength of laser light. The HP 10946B uses the measurement signal from the associated HP 10780B Receiver to generate a differential compensation number that can be used by the rest of the HP 5507A electronics.

The HP 10717A is comprised of an optical reference cavity (called an etalon) and an HP 10715A Differential Interferometer. Both components are mounted on a common metal baseplate and prealigned at the factory. Baseplate adjustment controls are provided to make installation and alignment easier.

Operation is quite simple. The etalon, consisting of two mirrors separated by a thermally stable spacer, presents a fixed distance to the differential interferometer. The interferometer monitors the optical path length between these two mirrors. Any change in the Wavelength (i.e.,changes in the air density/index of refraction within the etalon cavity) causes an optical path length change, which is detected as a phase shift in the measurement frequency. The HP 10946B uses this phase information to update the compensation number for use by the rest of the system.

Maintaining the 0.20 ppm typical accuracy of this compensation technique requires that air within the etalon's cavity have the same temperature, pressure, and humidity as the air in the measurement paths. To accomplish this, the HP 10717A Wavelength Tracker should be mounted as close to the measurement axes as possible.

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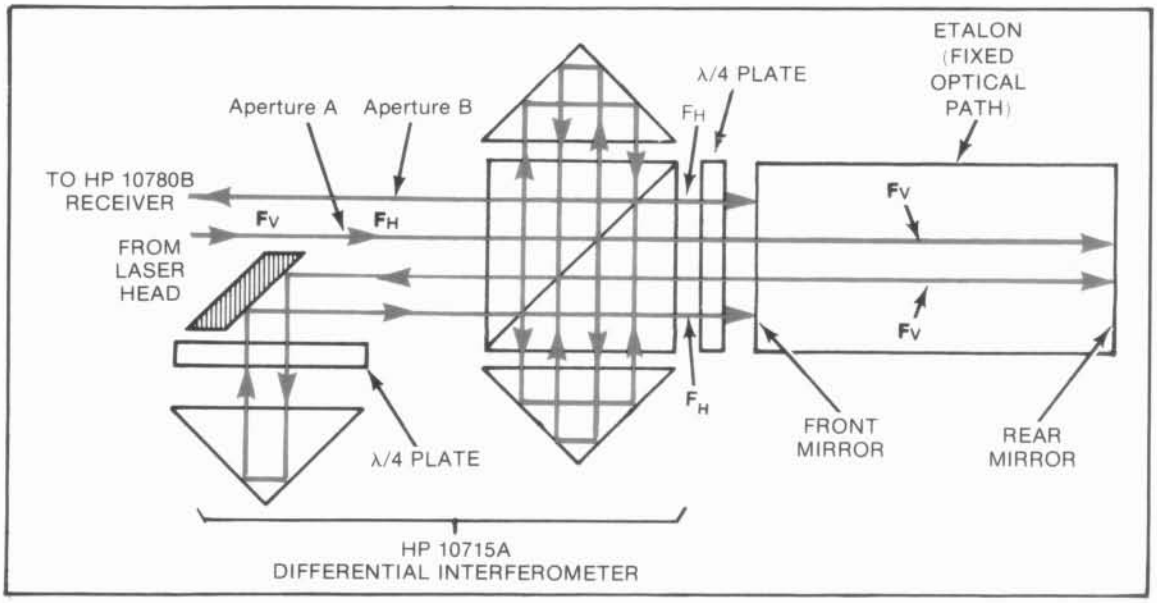


Figure 2-15. HP 10717A Wavelength Tracker Laser Beam Path

HP 10710A AND HP 10711A ADJUSTABLE MOUNTS

The adjustable mounts are a convenient means of mounting, aligning, and securely locking the optics in position. The HP 10710A allows ±8 degrees in tilt and yaw adjustment, the HP 10711A allows ± 5 degrees in tilt and yaw adjustment. The mounts minimize the need for custom fixturing in most installations. Another unique feature allows a component to be rotated about its optical centerline providing simple, time-saving installations. The HP 10710A Adjustable Mount accepts the HP 10700A and 10701A Beam Splitters, the HP 10705A Single Beam Interferometer, and the HP 10707A Beam Bender. The HP 10711A Adjustable Mount accepts the HP 10702A Linear Interferometer, any of the HP Plane Mirror Interferometers and the HP 10715A Differential Interferometer.

HP 10780B Receiver

An HP 10780B optical receiver is required for each measurement axis except in the case of a single axis system using an HP 5518A Laser Head with its own built-in receiver. Receivers are used to convert the Doppler component of the laser beam into a measurement signal for the electronics. The HP 10780B contains optics, a photodetector, and a preamplifier. Power requirements range between 2.0 and 2.7 watts from an external +15 Volt source. The HP 10780B's sensitivity is factory set at 5.0 μW but can be set to its maximum of 1.5 μW by performing the "Receiver Alignment and Gain Adjustment Procedure" found in Section VI of this manual. Power and signal connections with the system are via the 10790A/B/C Receiver Cable.

Since many applications require a machine-mounted receiver, the HP 10780B was designed with the following important features:

- Packaged in a small lightweight rugged module.
- Plastic mounting hardware to electrically isolate the receiver from the machine and reduce problems with heat conduction.
- Offset aperture to allow flexibility in mounting of the receiver (i.e., the bulk of the receiver can be mounted above, below, right, or left of the incoming laser beam).
- An LED indicator to signal beam capture. Useful for alignment.
- Easily accessible gain adjustment potentiometer.
- Supplied with a snap-on beam target to facilitate coarse alignment.
- An available dc voltage indicative of incoming laser beam intensity. Useful for fine tuning.

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MULTIAXIS MEASUREMENT SYSTEMS

The system is designed to measure multiple axes with any combination of interferometers and retroreflectors. In general, the laser measurement concepts discussed above apply equally to any multiaxis measurement system (see *Figure 2-16*).

The multiaxis system is similar to the basic measurement system with the exception that a beam splitter is introduced in the laser beam to provide a second axis of measurement. The X and Y axes are completely independent and generate separate measurement signals. These X and Y measurement signals are compared individually to the reference signal by the electronics to provide displacement data for measurement or control applications. Additional beam splitters can be introduced along with corresponding interferometers, reflectors, and receivers to allow up to four axes.

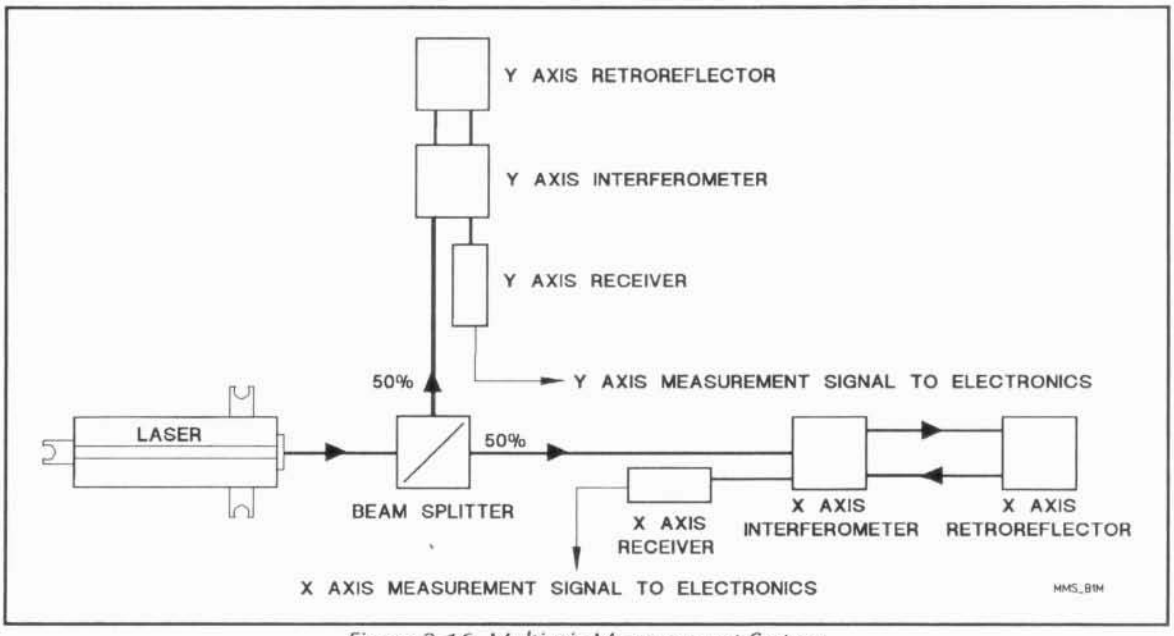


Figure 2-16. Multiaxis Measurement System

NOTE

The sum of axes length should not exceed 40 metres (130 feet).

ELECTRONIC COMPONENTS

HP 5507A/B Laser Position Transducer Electronics

The HP 5507A/B Laser Position Transducer Electronics consists of a main chassis, a power supply, an HP-IB Interface board, and a fan. The main chassis serves as a backplane for interconnecting up to six function boards plus the HP 10946B Automatic Compensation board with the HP-IB Board and the power supply.

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BACKPLANE CIRCUITRY

The backplane provides power and signal flow paths for function boards installed in the main chassis. It allows communication between boards by effectively becoming an extension of the controller board's memory space. The backplane is completely asynchronous, and uses a distributed technique for arbitration between contending backplane controller boards (e.g., the HP-IB board).

HP-IB CIRCUITS

The HP-IB board is the interface betweem the system controller and the HP 5507A/B function boards. It meets IEEE-488, IEEE-728, and IEEE-P754 standards for general purpose instrument programming. It accepts command and data mnemonics, accompanied by numeric data, and channels the data or commands to the appropriate HP 5507A/B boards.

When the HP 5507A/B is first powered up, the HP-IB board performs board and system level self tests and builds up an internal table of installed boards. This table allows the HP-IB board to accommodate any system configuration automatically.

The only external input to the HP-IB board is a standard IEEE-488 connector on the HP 5507A/B rear panel. A reset key on the front panel commands the HP-IB board to issue a soft reset, capable of clearing error conditions and returning certain variables to their power-up state.

HP 10932A Axis Board (HP 5507A/B Option 032)

The HP 10932A Axis Board is the prime interface to the user's servo control loop. The board combines the reference signal from a laser head with fringe counts from an HP 10780B Measurement Receiver or an HP 5518A internal receiver and generates useful velocity, position and position error signals. Connectors, located on both the top edge of each axis board and the HP 5507A/B rear panel, allow internal and external access to these signals for connection to other electronics (servo loop, data capture, etc.).

Each board in the HP 5507A/B backplane is individually programmed and may be operated independently of the others. For example, different axis boards in the backplane may be programmed to read out in different I/O units at different times, with each axis using a different kind of optical setup and different W.O.L. (Wavelength of Light) compensation index. Measurement errors on one axis may be reset independently of the other axes.

HP 10936A Servo-Axis Board (HP 5507A/B Option 036)

The HP 10936A Servo-Axis Board eliminates the need for custom servo electronics. It is a complete, high-performance servo feedback system. The board does the following:

- combines the reference and measurement signals to produce a position value,
- generates a reference position from programmable destination, velocity, acceleration, and delta acceleration values,
- combines the position and reference position values with servo compensation terms and feedforward terms to produce a motor drive signal, and
- stores real-time data for servo system analysis and optimization.

Servo-axis boards may be linked together for synchronized multi-axis moves, or each may be operated independently. The maximum number of boards that may be used (and linked) is four for the HP 5507A or six for the HP 5507B. Additionally, an on-board 16-bit binary interface enables high-speed communication between a control computer and the entire HP 5507B (the HP-IB board is an additional communication path and must remain in the HP 5507B).

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HP 10941A Prototyping Kit

The HP 10941A Prototyping Kit facilitates custom designed circuitry in the HP 5507A/B Laser Position Transducer Electronics. Approximately 219 square centimeters (34 square inches) of prototyping area (75% power-gridded) is supplied for breadboarding and testing of circuitry in actual use. The Prototyping Kit includes an extender board, prototyping board, and two cables (75 mm and 255 mm) to connect to an axis board. Since all designs use the same interface circuitry for the backplane communication, these circuits are factory loaded on the prototyping board. Input and output data (up to 64 bits each) are controllable by the HP 5507A/B's HP-IB, the binary interface on an HP 10936A/B Servo-Axis Board, or the serial and parallel ports on an HP 10934A A-Quad-B Axis Board.

HP 10946B/C Automatic Compensation Board (HP 5507A/B Option 046)

The HP 10946B/C Automatic Compensation board provides both absolute and differential compensation numbers that can be used by the HP 5507A/B electronics.

The HP 10946B/C Automatic Compensation board can receive analog temperature, pressure, and humidity information from off-board sensors. It converts this information into absolute wavelength-of-light or total compensation number data. The off-board sensors used are the HP 1075A/B Air Sensor and the HP 10757A/B/C Material Temperature Sensor.

The Automatic Compensation board can also receive a signal from an HP 10780B/C/F Receiver installed on the HP 10717A Wavelength Tracker axis. It uses this signal, and the reference signal generated by the system laser head, to track wavelength changes. The result of this operation is combined with material temperature sensor information and used to update the Wavelength Tracking Compensation number.

The Automatic Compensation board recognizes commands that execute the following functions:

- Enable or disable sensors on selected channels
- Enable or disable the Wavelength Tracking function
- Read/write the pressure, temperature, humidity, and coefficient of expansion values (writing values allows manual compensation without using look-up tables).
- Read the Wavelength Tracking and total compensation numbers and the board's status.
- Set the measurement units (English of metric).

The board also recognizes service-related commands that read/write the reference values, calibrate the board, and read the channel voltages.

HP 10934A A-Quad-B Axis Board

The HP 10934A A-Quad-B Axis Board provides a simple interface between an HP laser interferometer system and a CNC/NC controller. The board does the following:

- It keeps track of position (like an axis board).
- It automatically monitors the environmental compensation number (from a compensation board).
- It combines position, compensation, offsets, units conversion, and deadpath correction to generate A-qaud-B or up/down pulses.

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- It is capable of including geometric correction offsets in its output pulse stream (requires an external computer).
- It provides two RS-232C serial ports and an 8-bit parallel port for the HP 5507A/B Laser Position Transducer.
- It stores its setup information in non-volatile storage for operation without a permanent connection to a control computer.

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SECTION III
HP 5507A INPUTS AND OUTPUTS FOR POSITION SENSING/CONTROL (HARDWARE)

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SECTION III
HP 5507A/B INPUTS AND OUTPUTS FOR POSITION SENSING/CONTROL (HARDWARE)

INTRODUCTION

This section contains details on the hardware and information on how to use the HP 5507A/B outputs for position sensing and control in a variety of applications. The section is organized mostly as reference material, however, suggestions and examples are given along the way to aid system designers. The information is divided into the following eight subsections.

- BACKPLANE BASICS. Describes power and signal flow paths, function board addressing and mailboxes, and bus arbitration.
- HP-IB BOARD. Discusses the hardware interface capabilities, the power-up self-test, warm-up operation, and data rate capabilities.
- HP 10932A/B AXIS BOARD. Describes both the internal and rear panel hardware inputs and outputs.
- HP 10934A A-QUAD-B AXIS BOARD. Describes the hardware interface setup, the 8-bit parallel interface handshaking, and the internal and rear-panel hardware inputs and outputs.
- HP 10936A/B SERVO-AXIS BOARD. Describes the Binary Interface handshaking and data transfer, the rear panel inputs and outputs, and the inter-servo signals.
- HP 10941A PROTOTYPING KIT. Describes the signals available on the prototyping board and their intended use.
- HP 10946B/C AUTOMATIC COMPENSATION BOARD. Describes the basic operation and covers its seven rear panel connectors.
- CABLING. Describes the cables required and their part numbers. Connection to servo systems is also covered.
- ELECTRONICS INTERFACE EXAMPLES. Gives the details of digital system interconnections, and analog servo loop interconnections.

Figure 3-1 shows the location of all rear panel connectors for a four axis HP 5507A/B. The enclosed color coded stickers are provided to label all cables and connectors for easy identification.

HP 5507A/B BACKPLANE BASICS

The transducer backplane provides power and signal flow paths (busses) for the boards installed in the HP 5507A/B system frame. It consists of 8 data lines, 14 address lines, and several bus control lines. The bus is bidirectional and is similar in detail to commonly used microprocessor busses. The transducer backplane communicates between boards by effectively becoming an extension of the controller board's memory space.

Each function board plugged into the backplane is assigned a unique address (see *Table 3-1*). There are 16 possible addresses that occupy 16K bytes (14 address lines) of the controller's memory space.

Each board's 1K of memory space is called its mailbox. The controller will read or write portions of this "memory" in order to communicate with the board. During initialization, each function board fills part of its mailbox with the board name and a mnemonic list. The controller will then read this information from all boards and build a complete list of allowed mnemonics and

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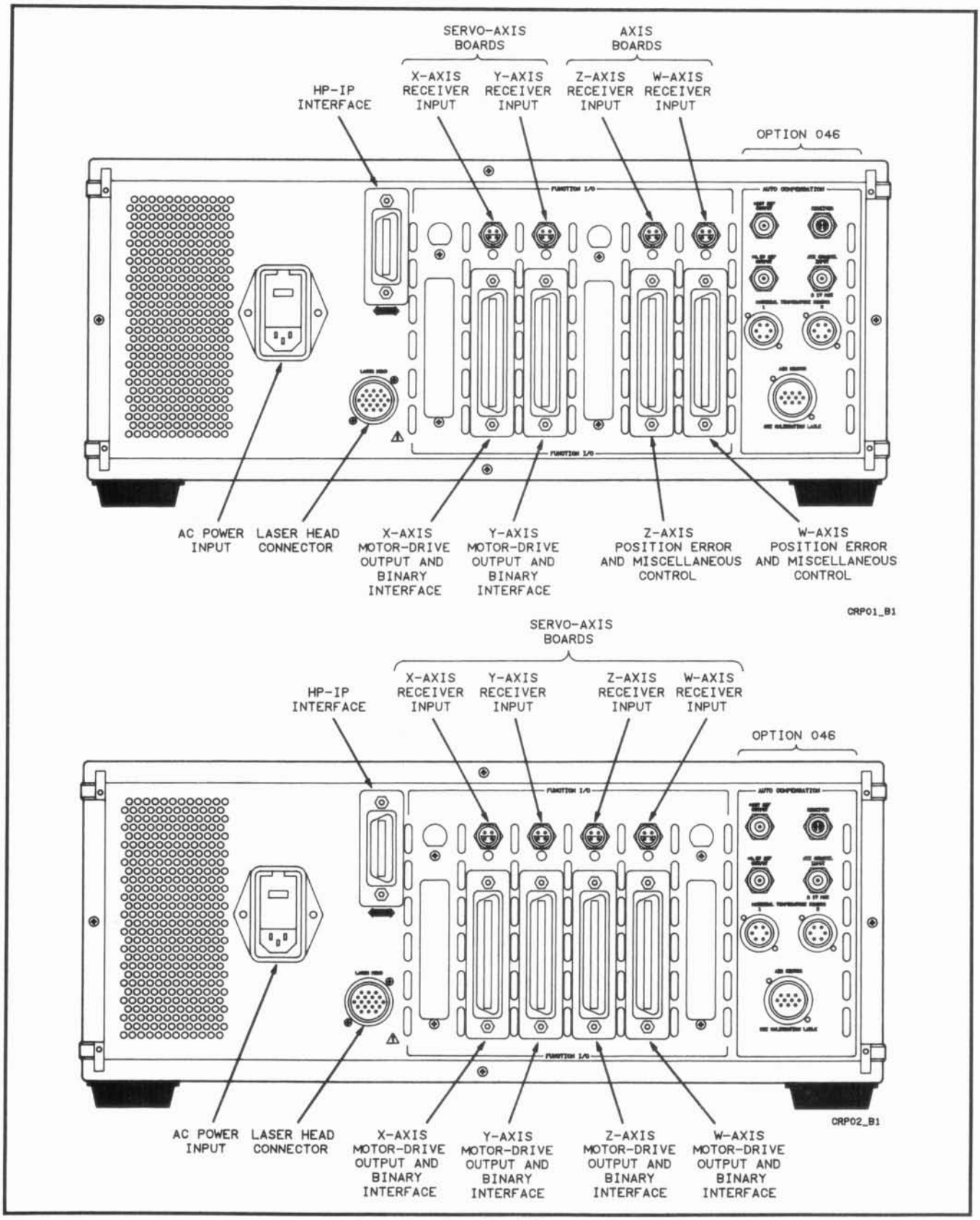


Figure 3-1. Rear Panel Connectors

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addresses for the current configuration. Some boards may have few mnemonics and only need a minimal mailbox (mnemonic list in ROM and a few registers for data and command transfers). Other boards may need to transfer many data items and could use 512 bytes of RAM for a mailbox. In either case however, the same bus protocol will be followed by the controller in communicating with the boards.

That protocol includes gaining access to the backplane itself. A bus arbitration method accommodates multiple controllers on the bus. To access the backplane, a controller must activate the bus request line (a semi-analog signal indicating how many controllers want to use the bus) and verify that the bus is not already in use. If it is, then the requesting controller must release the bus request and wait a few microseconds before trying again. Otherwise, the controller is free to use the bus, but should release bus request when it is done so other controllers, if present, can gain access.

Once backplane access is acquired, flags within the mailboxes are used to arbitrate between a function board's processor and the controller board.

Table 3-1. Function Board Address Switch Settings

SWITCH SETTING (Binary)(1)	MNEMONIC PREFIX(†)	FUNCTION BOARD ASSIGNMENT
0000	K	Reserved for future use
0001	L	Reserved for future use
0010	M	Reserved for future use
0011	N	Reserved for future use
0100††	O	Prototyping board
0101	P	Prototyping board
0110	Q	Prototyping board
0111	R	Prototyping board
1000	S	Compensation, Axis, or Servo-Axis board
1001	T	Compensation, Axis, or Servo-Axis board
1010	U	Compensation, Axis, or Servo-Axis board
1011††	V	Compensation, Axis, or Servo-Axis board
1100(5)	W	Axis or Servo-Axis board
1101(2)	X	Axis or Servo-Axis board
1110(3)	Y	Axis or Servo-Axis board
1111(4)	Z	Axis or Servo-Axis board

† Throughout the manual an asterisk (*) will be used to represent this mnemonic prefix.

†† Factory set switch setting for the prototyping and compensation boards.

(1) Refer to each board subsection for actual switch setting as the most significant bit of the address for the Axis board, and the two most significant bits of both the Compensation and Prototyping boards are hardwired.

(2) Factory switch setting of both a single-axis system and the first Axis board or Servo-Axis board of a multiaxis HP 5507A.

(3) Factory switch setting of the second Axis board or Servo-Axis board installed in a multiaxis system.

(4) Factory switch setting of the third Axis board or Servo-Axis board installed in a multiaxis system.

(5) Factory Switch setting of the fourth Axis board or Servo-Axis board installed in a multiaxis system.

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HP-IB BOARD

The HP-IB board is a dual-purpose board. First, it frequency-multiplies the laser head's reference signal and puts the resulting signal on the backplane. Second, it provides a communication channel between HP 5507A function boards and an external controller. The interface is designed to meet IEEE-488, IEEE-728, and IEEE-P754 standards for general purpose instrument programming.

When the HP 5507A is first powered up, the HP-IB board performs card and system level self tests and builds up an internal table of installed boards. This table allows the HP-IB board to accommodate any system configuration without special programming.

The only external hardware input to the HP-IB board is a standard IEEE-488 connector on the HP 5507A rear panel (See *Figure 3-2*). A Reset key on the transducer front panel commands the HP-IB board to issue a soft reset, capable of clearing error conditions and returning certain variables to their power-up state.

Summary of HP-IB Standards

IEEE-488 STANDARDS

The HP-IB board furnishes the following IEEE-488 interface functions:

SH1 Source Handshake capability
AH1 Acceptor Handshake capability
T2 Talker, Serial Poll, no Talk Only
TE0 No Extended Address Talker
L2 Listener, no Listen Only
LE0 No Extended Address Listener
SR1 Serial Poll capability
RL0 No Remote-Local capability
PP0 No Parallel Poll capability
DC1 Device Clear, Selected Device Clear
DT1 Device Trigger capability
C0 No Controller capability

IEEE-728 STANDARDS

The HP 5507A is compatible with the following IEEE-728 Instrument Programming Standards (refer to Section IV for a description of the standard).

Program Message Header Type: HR3
Numeric Input Format: NR1, NR2, NR3, BDFA, BDFD
Numeric Output Format: NR1, NR2, BDFA, BDFD

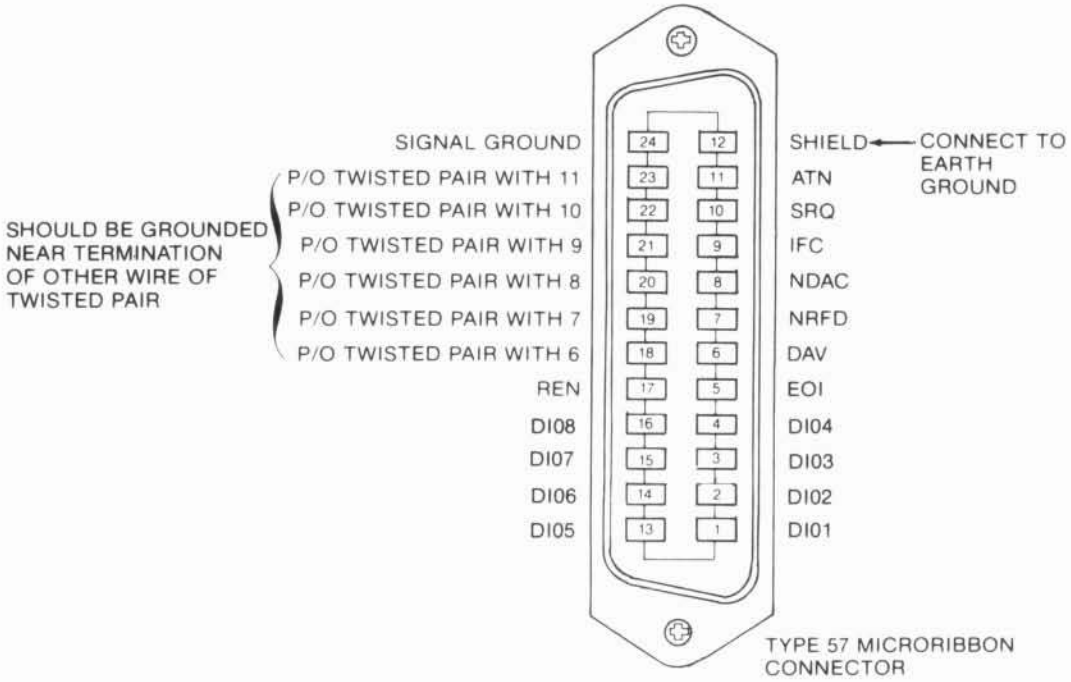
IEEE-P754 STANDARDS

All block data formats use eight IEEE-P754 floating point data bytes (double precision).

Description of IEEE-488 Standards

The capabilities of a device connected to the HP-IB bus are specified by its interface function. These functions provide the means for a device to receive, process, and send messages over the HP-IB bus. *Table 3-2* lists the HP-IB interface functions defined by the IEEE 488-1978 standard. A subset identifier, the interface function mnemonic followed by a number, indicates the specific HP-IB interface function capabilities of the HP 5507A. A brief subset description is also listed.

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Logic Levels:

The Hewlett-Packard Interface Bus logic levels are TTL compatible, i.e., the true (1) state is 0.0 Vdc and the false (0) state is +2.5 Vdc to +5.0 Vdc.

Mating Connector:

HP 1251-0293; Amphenol 57-30240

Mating Cables Available:

HP 10833A. 1.0 metre (3 feet)
HP 10833B. 2.0 metres (6 feet)
HP 10833C. 4.0 metres (12 feet)
HP 10833D. 0.5 metre (1.5 feet)

Figure 3-2. HP-IB Connector

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Table 3-2. HP 5507A IEEE 488-1978 HP-IB Interface Function Capabilities

IEEE FUNCTION CODE	DESCRIPTION	SUBSET IDENTIFIER FOR THE HP 5507A	DESCRIPTION
Source Handshake (SH)	Provides a device with the capability to properly transfer a multiline message.	SH1	The HP 5507A can generate message bytes.
Acceptor Handshake (AH)	Provides a device with the capability to guarantee proper reception of multiline messages.	AH1	The HP 5507A can receive message bytes.
Talker (T)	Provides a device with the capability to transmit device dependent data over the bus when addressed.	T2	The HP 5507A can function as as a talker and will respond to serial poll.
Extended Talker (TE)	Talker capability with address extension (i.e., 2-byte address).	TE0	The HP 5507A cannot function as an extended talker.
Listener (L)	Provides a device with the capability to receive device dependent data (including status data) over the bus.	L2	The HP 5507A can function as a listener.
Extended Listen (LE)	Listen capability with address extension (i.e., 2-byte address)	LE0	The HP 5507A cannot function as an extended listener.
Service Request (SR)	Provides a device with the capability to asynchronously request service from the system controller.	SR1	The HP 5507A can generate a service request.
Remote/ Local (RL)	Provides a device with the capability to select between two input sources: local (front panel controls) and remote (input from the data bus).	RL0	The HP 5507A has no Remote-Local capability.
Parallel Poll (PP)	Provides a device with the capability to uniquely identify itself if it requires service and the controller is requesting a response.	PP0	The HP 5507A has no Parallel Poll capabilities.
Device Clear (DC)	Provides a device with the capability to be cleared (initialized) to a predefined state.	DC1	The HP 5507A supports Clear (DCL) and Selected Device (SDC) commands.
Device Trigger (DT)	Provides a device with the capability to have its basic operation initiated by the talker on the bus.	DT1	The HP 5507A can be remotely triggered.
Controller (C)	Provides a device with the capability to send addresses, universal commands, and addressed commands to other devices on the HP-IB. It may also include the ability to conduct polling to determine devices requiring service.	C0	The HP 5507A cannot function as a controller.

See *Appendix D* for a detailed discussion of the HP-IB (IEEE-488) interface concept.

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HP-IB Address Capabilities

The HP-IB address is set to 03 at manufacture, and may be changed through a dip switch on the top edge of the HP-IB board. The address may be set from 0 through 30 by setting the desired address in binary on this switch (read only during a "hard" reset or power-up). The least significant address bit is located at the end of the switch closest to the front of the instrument, with the most significant bit the fifth from the front. Logical "ones" are indicated when the switch levers point away from the board — zeros are toward the board. The three highest switch bits are used during service, and must be set at zero for normal operation.

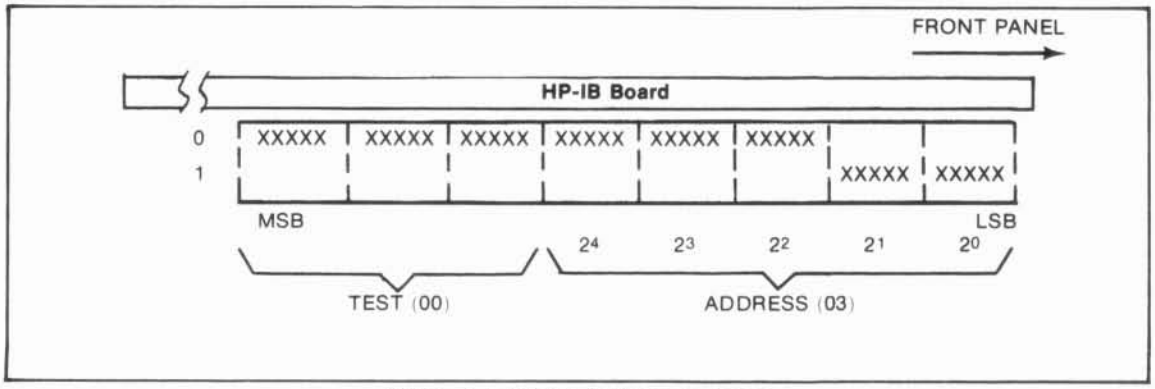


Figure 3-3. HP-IB Address Switches.

HP-IB Power-up and System Self Test

At power-up or following a BOOT command (hard reset), most system boards perform an internal self-test to verify proper operation. The HP-IB board's self test takes about 15 seconds to complete. During this time, the HP 5507A front panel LEDs will flash to indicate the progress of the test. If any of the LEDs never turn on, or if the "Error" LED is on and any of the Talk, Listen, or SRQ LEDs remain on or flashing after 15 seconds have elapsed, an HP-IB or front panel board hardware failure is indicated (see Section VII).

If the Error LED is on, but the Talk, Listen, and SRQ LEDs are off, one of the function boards is not working. The faulty board may be pinpointed by sending "CNFG?" to the HP 5507A over HP-IB and reading out the resulting configuration string or by removing the top cover and checking the self-test indicator LEDs on each board. If any are on or flashing, or if any never flash during the self-test, that particular board is defective (see Section VII).

During the system self-test period, the HP-IB board will not respond to HP-IB inputs. Fifteen seconds after power-up, the system is completely initialized and will begin to wait for the Laser Head to warm up. During this waiting period, the front panel Talk, Listen, and SRQ indicators will cycle until the Laser Head outputs a stable reference signal. HP-IB transfer operations are slowed to approximately two string transfers per second until the laser warms up.

The instrument status byte may be read during the warm-up period via serial poll or with an ISTA? query. The status byte is zero until the Laser Head warms up. Once this happens, the HP-IB board sends a soft reset to initialize all other system boards.

Transfer Rates

The HP-IB board's burst output transfer rate is approximately 35K bytes/sec. The data rate in measurements/sec depends on the output format (see Section IV) and the actual data value when in format 0. These rates range from 60 measurements/sec to 1500 measurements/sec. See Section VIII, Specifications, for the data rates corresponding to the different operating conditions.

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The burst input data rate is approximately 20K bytes/sec. The rate at which the HP 5507A will process mnemonics though, depends on which ones are sent. Most mnemonics are processed within 6 milliseconds, but some will take up to 2.5 seconds.

HP 10932A AXIS BOARD

The axis card receives the measurement signal from a receiver, the reference signal from a Laser Head and translates the fringe counts into velocity, position and position error signals. The measurement signal is produced by either the HP 10780B Receiver or the measurement channel of an HP 5518A. The reference signal is generated by the laser head (HP 5517A, HP 5517B, or HP 5518A) and routed to the axis boards over the HP 5507A backplane from the HP-IB board.

Each axis board in the HP 5507A Laser Position Transducer Electronics is individually programmed and operates independently.

The address of the axis board may be set to S, T, U, V, W, X, Y, or Z by setting a dip switch at the top edge of the board as shown in *Figure 3-4*. Each Axis board installed in an HP 5507A must be set to a unique address (throughout this section, the "*" preceding a mnemonic represents the address selected by these DIP switches).

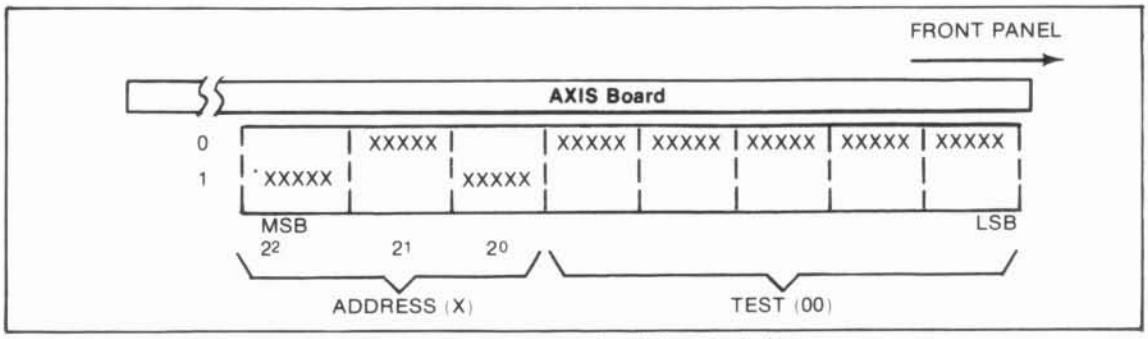


Figure 3-4. Axis Board Address Switches

The additional switches are used to enter various service modes and must be in the off (zero) position for normal operation.

Basic Operation

The axis board consists of the following four main functional blocks:

- Resolution Extension IC
- Counter/Subtractor IC
- Microprocessor
- Mailbox

The measurement signals (Meas Freq and ×32 Ref) are routed to the resolution circuit contained in a custom IC. Here the 5 least significant position bits are derived along with up/down pulses. These signals go to the custom counter/subtractor IC. This chip counts an additional 26 bits of position information. It then subtracts a 31 bit destination value from the 31 bit position value to produce a 32 bit value (including sign) which gets clocked out to the position error outputs.

The onboard microprocessor's job is to continuously (>500 Hz) read the position from the counter/subtractor IC, convert it to the programmed units, and check for any error conditions. It also updates the destination register, operating mode and compensation value when requested. It uses the fourth block, the mailbox, to communicate with the backplane controller. The mailbox is a dual port RAM with a software scheme to prevent both the onboard processor and the backplane controller from accessing the memory at the same time.

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Together, these four blocks comprise the heart of the Laser Position Transducer Electronics. The position information can be transferred to the system controller over HP-IB (see Section IV). Additionally, the position error outputs can be used for high speed data acquisition or closed loop position control (remainder of this subsection).

Rear Panel Connector

A 50 pin female connector, located on the rear panel, allows for connections to external equipment. Example mating connectors are:

Amp: Champ® Connectors
3M: Delta Ribbon Connectors
T & B: Ansley® Ribbon Connectors

®Champ is a registered trademark of Amp
®Ansley is a registered trademark of T & B

Rear Panel Hardware Inputs

NOTE

Unless otherwise noted, hardware inputs on the rear panel are TTL compatible and use a 4.7K ohm pullup resistor. All inputs also have a 330 pF capacitor to ground to decrease noise and crosstalk problems. A dash (—) following a signal name indicates a negative true signal.

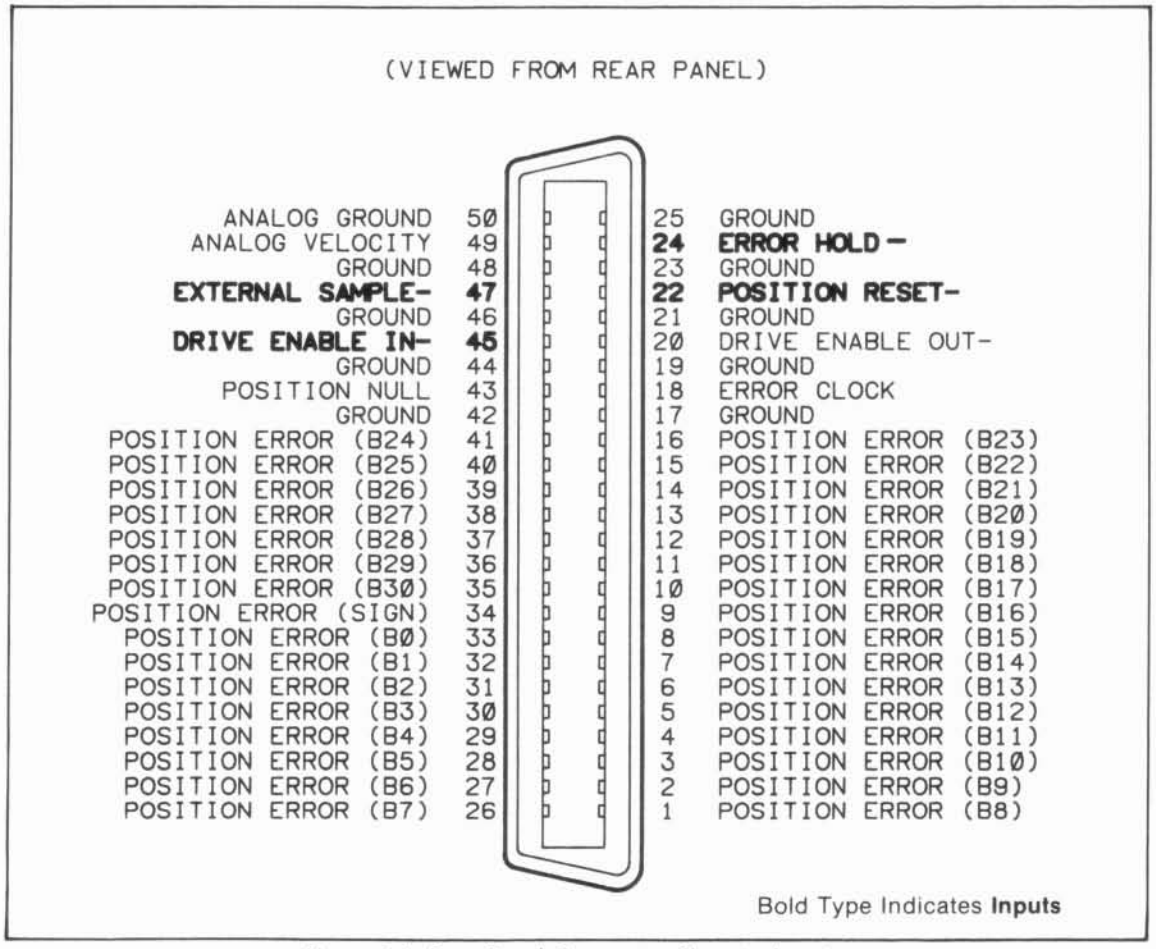


Figure 3-5. Rear Panel Connector Pinouts, Inputs

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POSITION RESET–

When pulled low, this negative true line resets the position counter to zero within 2.0 microseconds. Normal counting resumes 2.0 microseconds after the line returns to the high state.

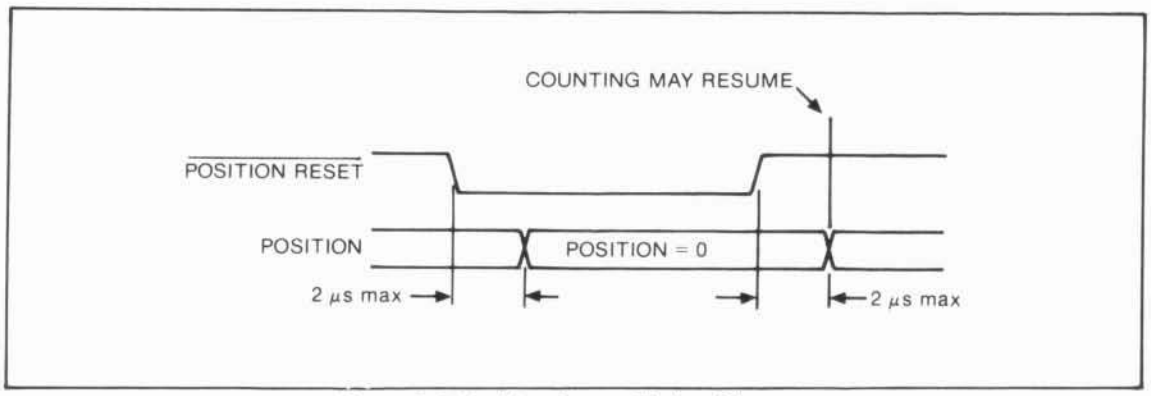


Figure 3-6. Position Reset– Timing Diagram.

DRIVE ENABLE IN–

This negative true line allows Drive Enable Out– to go true and activate the Position Error outputs. The Position Error outputs are forced to zero whenever Drive Enable In– is false (High). Also see the paragraphs on Position Error outputs, Drive Enable Out– and Error Hold–.

Drive Enable In– will act on the Drive Enable Out– within 15 nanoseconds and the Position Error outputs will be zero within 1 microsecond (provided Error Hold is not asserted).

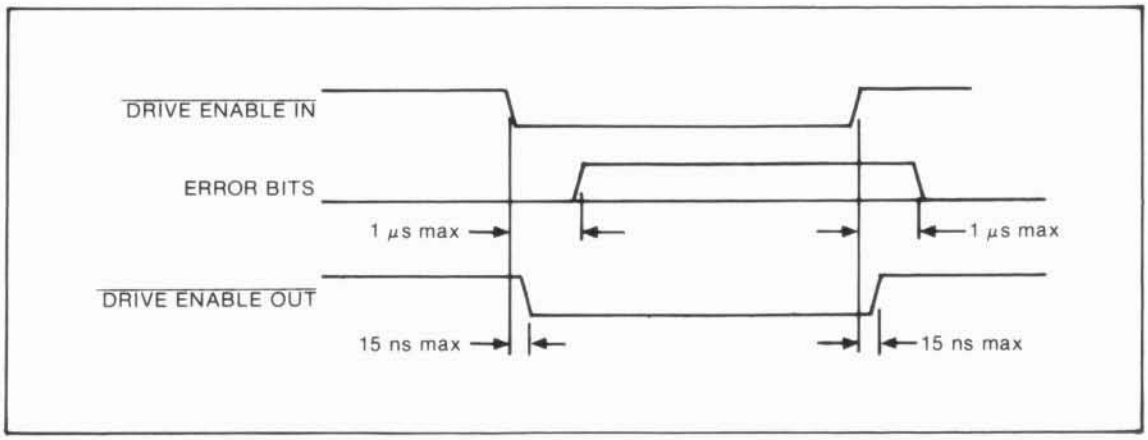


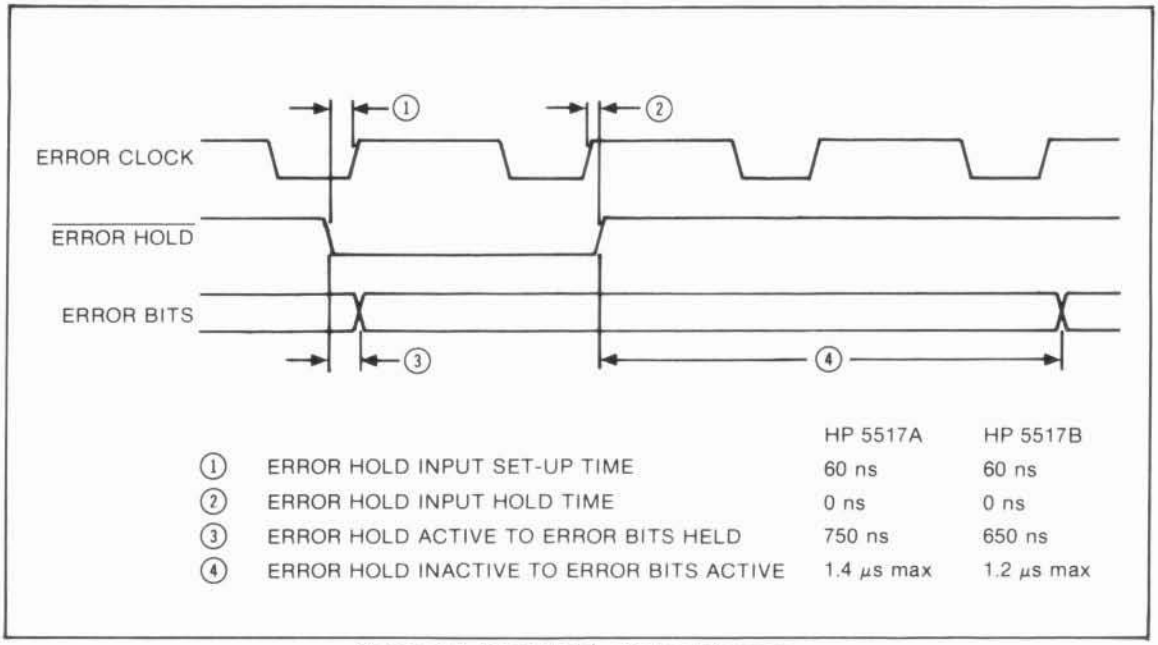
Figure 3-7. Drive Enable In– and Drive Enable Out– Timing Diagram

ERROR HOLD–

When pulled low, this negative true line freezes the Position Error outputs. Maximum response time is 750 nanoseconds (one Error Clock period) for freezing the outputs and 1.4 microseconds (two Error Clock periods) for reenabling them. See *Figure 3-8* for these specifications for the different laser heads.

Drive Enable In– will not zero the Position Error outputs during the time they are frozen using Error Hold–, although Drive Enable Out– will still be forced false.

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		HP 5517A	HP 5517B
①	ERROR HOLD INPUT SET-UP TIME	60 ns	60 ns
②	ERROR HOLD INPUT HOLD TIME	0 ns	0 ns
③	ERROR HOLD ACTIVE TO ERROR BITS HELD	750 ns	650 ns
④	ERROR HOLD INACTIVE TO ERROR BITS ACTIVE	1.4 μs max	1.2 μs max

Figure 3-8. Error Hold– Timing Diagram

EXTERNAL SAMPLE–

When the axis board is placed into external sample mode using the *EXT command, the External Sample– input may be used to sample the position counter (accessed with the *POS mnemonic) to 1.4 microseconds (see *Figure 3-9*) of temporal accuracy. The hardware Position Error outputs are not affected by this sampling mode, only the software *POS position output.

The External Sample– input also flags the HP-IB board that a sample operation has occurred, and that data may be fetched. This flag is used when the HP-IB board is put in the sample handshaking mode with the HSON mnemonic. See Section IV for more information.

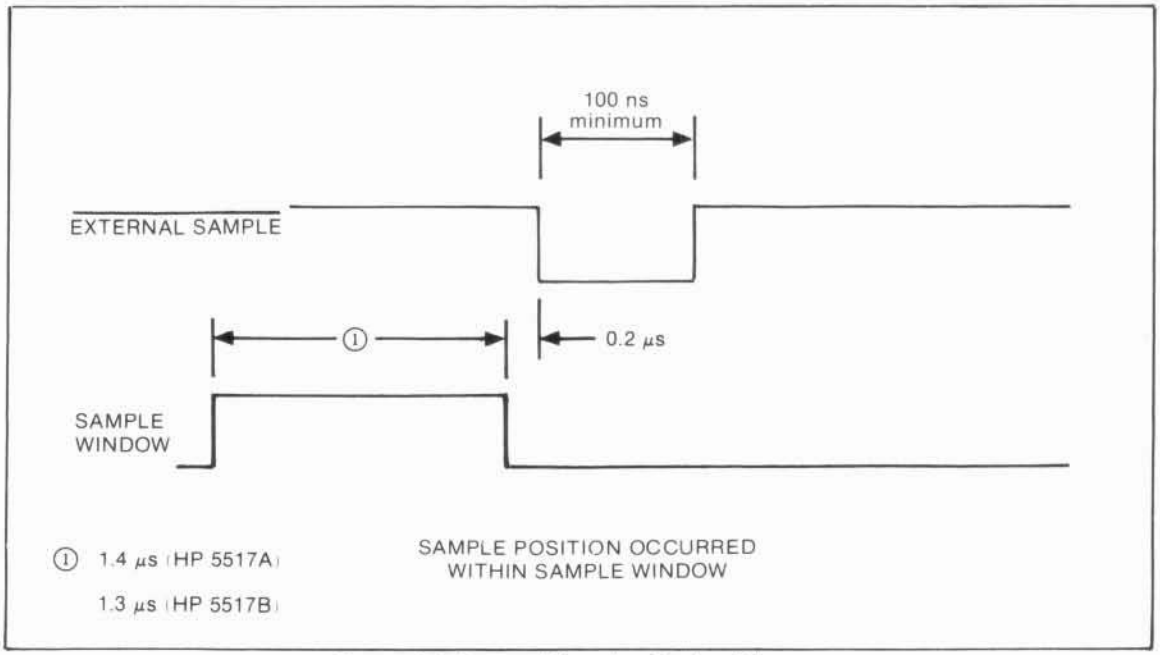


Figure 3-9. External Sample– Timing Diagram

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Rear Panel Hardware Outputs

NOTE

All rear panel hardware outputs are TTL compatible and may drive a properly terminated shielded flat cable up to 3 metres long. See *Figure 3-10* for recommended termination. A dash (—) following a signal name indicates a negative true signal.

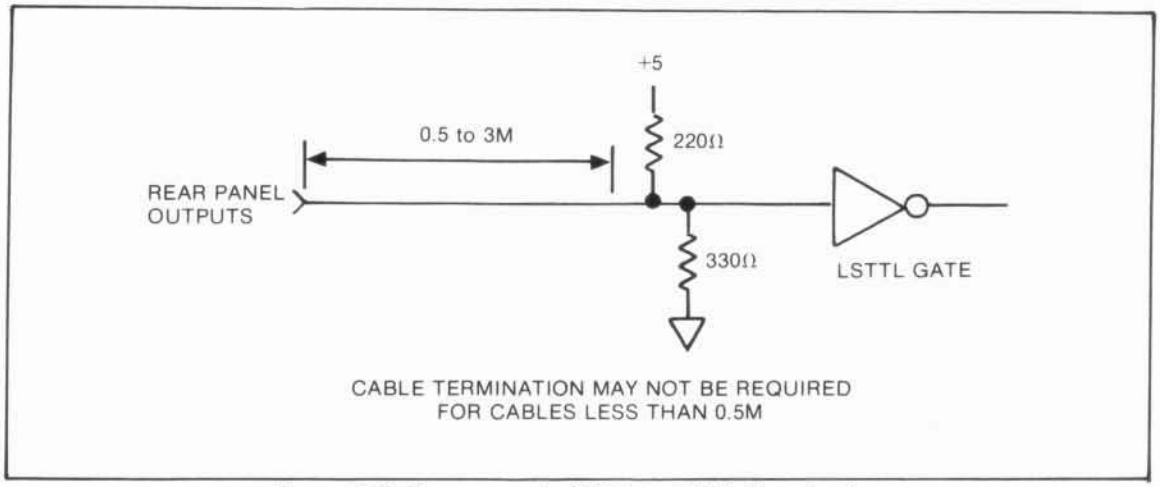


Figure 3-10. Recommended 3 Metre Cable Termination

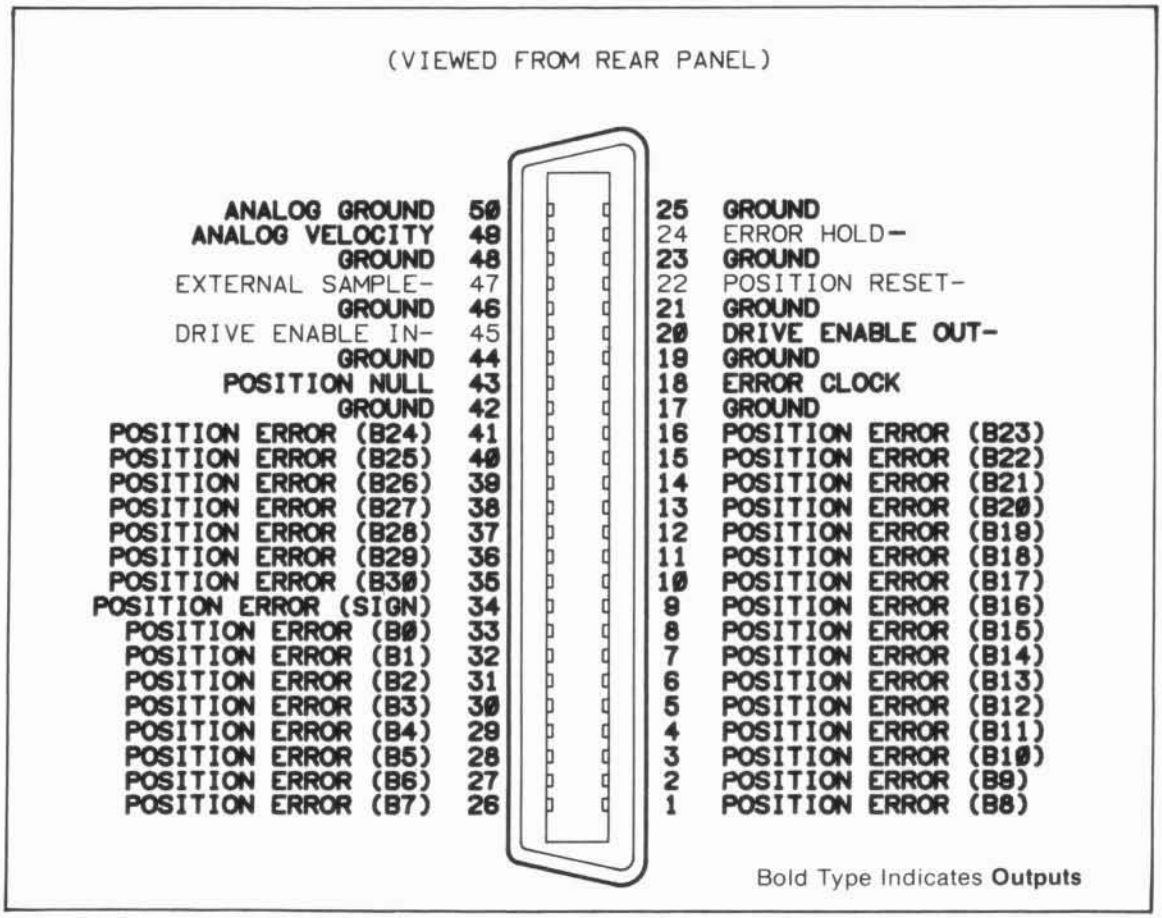


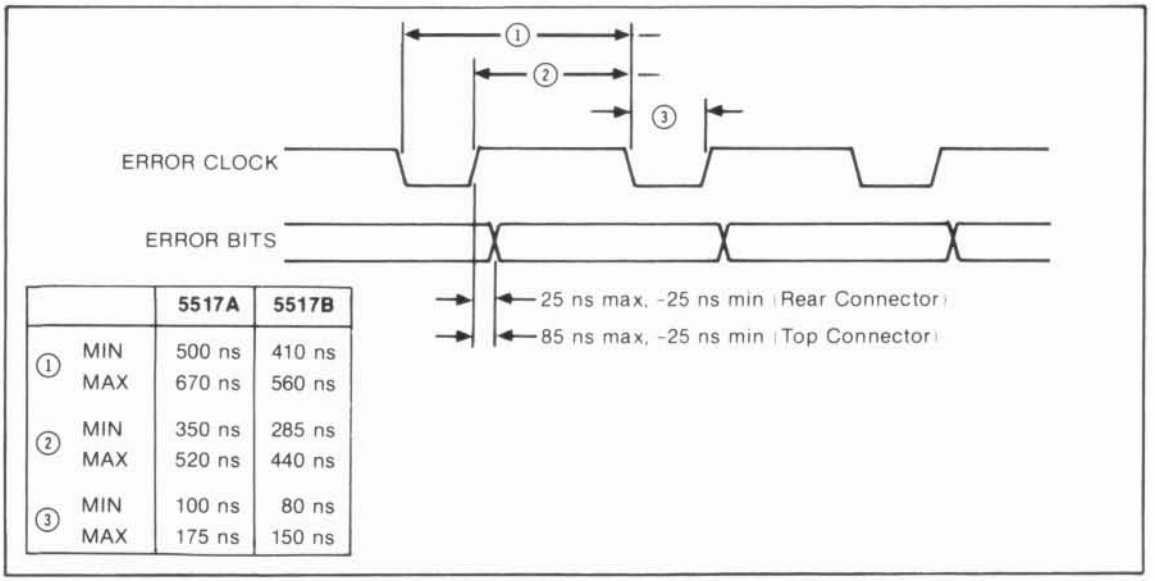
Figure 3-11. Rear Panel Connector Pinouts, Outputs

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ERROR CLOCK

This signal may be used to synchronize external equipment to Position Error output transitions. The Position Error outputs will change within ±25 nanoseconds of the Error Clock low-to-high transition. The Error Clock has a 75% duty cycle frequency and may vary from 1.5 to 2.0 MHz when using the HP 5517A Laser Head or from 1.9 to 2.4 MHz when using the HP 5517B Laser Head. Error Clock may be used to drive up to 10 LSTTL loads. The individual Error Clock outputs of axis boards within the HP 5507A are the same frequency but are unrelated in phase.

Sampling the Position Error outputs on the Error Clock high-to-low transition is recommended.



		5517A	5517B
①	MIN	500 ns	410 ns
	MAX	670 ns	560 ns
②	MIN	350 ns	285 ns
	MAX	520 ns	440 ns
③	MIN	100 ns	80 ns
	MAX	175 ns	150 ns

Figure 3-12. Error Clock Timing Diagram

DRIVE ENABLE OUT–

Drive Enable Out– may be used to disable the drive circuitry of the stage actuator to protect the stage in case of measurement errors (in addition to this protection, it is good practice to also use mechanical limit switches). The following conditions force Drive Enable Out– false (high):

a. Power-up initialization or system BOOT command.

b. An HP-IB Drive Off (*DR0) command.

c. A measurement error on this axis.

d. Position counter over/underflow error on this axis.

e. If in Error Mode 1 (*EM1), any other system or programming error.

f. The Drive Enable In– held high or floating (false)

NOTE

The hardware Position Error outputs are forced to zero whenever Drive Enable Out– is false, unless Error Hold– has been asserted to freeze them at their current value.

The only way to set Drive Enable Out– true (low) is with the *DR1 command (provided none of the above conditions are true). See *Figure 3-7* for Drive Enable Out– Timing Diagram.

Drive Enable Out– can drive up to 8 LSTTL loads.

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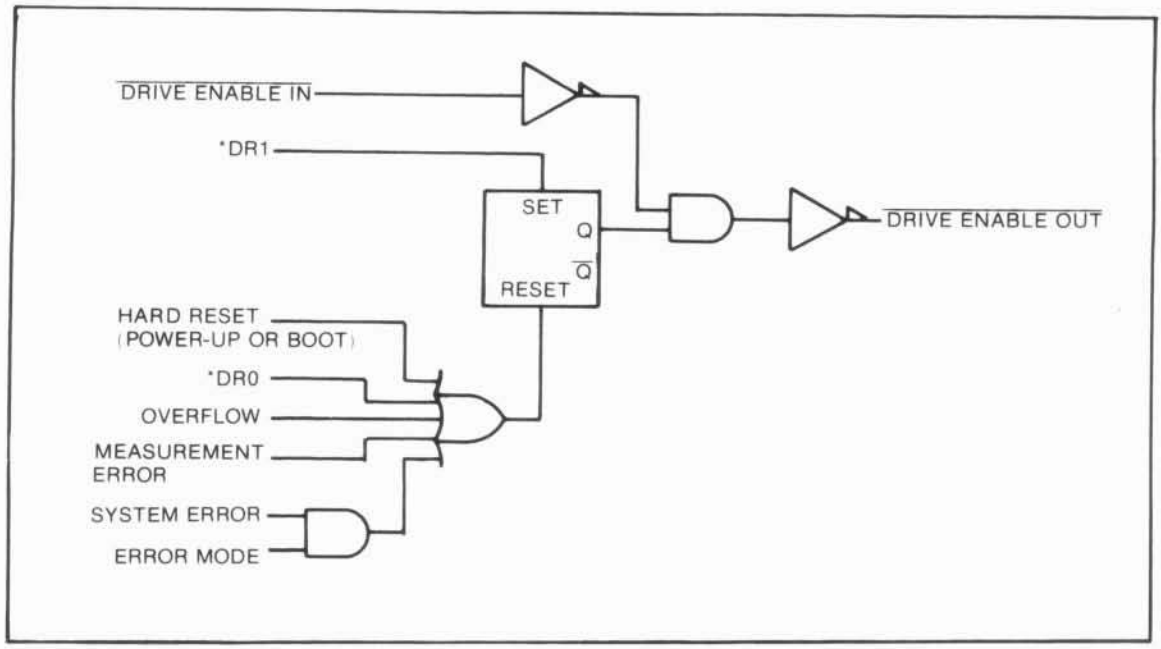


Figure 3-13. Drive Enable Out- Logic Diagram

POSITION NULL

The Position Null output line is true (high) whenever the position error is smaller than the limit set by the Null Mask specifier, *NUL. Position Null output transitions occur on the rising edge of Error Clock, one clock cycle earlier than the corresponding Position Error output state which caused it to occur. The null function can be used to signal that the stage is close to its destination.

Position Null can drive up to 8 LSTTL loads.

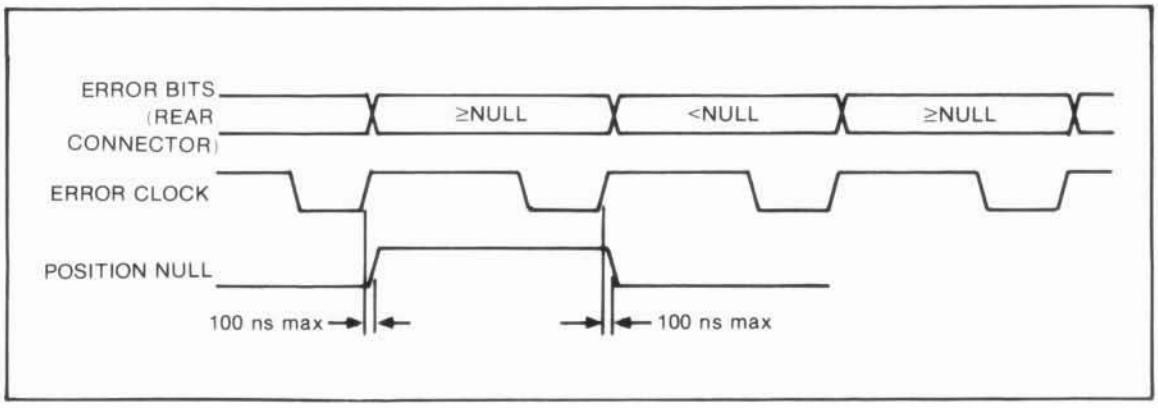


Figure 3-14. Position Null Timing Diagram

POSITION ERROR

The Position Error output lines give a 32-bit sign-magnitude or two's complement representation of the difference between the position counter and the destination register, updated at the Error Clock rate (1.5 to 2.0 MHz when using the HP 5517A Laser Head and 1.9 to 2.4 MHz when using the HP 5517B Laser Head). Note that although the destination has been compensated for WOL, this difference is not. The least-significant Position Error bit represents a difference of λ/128 when using plane mirror optics or λ/64 with cube corner optics.

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The Position Error outputs change within ±25 nanoseconds of the rising edge of Error Clock (*Figure 3-12*) and are forced to zero whenever the Drive Enable Out– line is false (high). See the description of the Drive Enable lines for more information.

The Position Error outputs may be held at any value indefinitely by pulling the Error Hold– input low. The outputs will stabilize within one Error Clock cycle.

The Position Error outputs can drive up to 10 LSTTL loads.

Clipping

The word width may be reduced from 32 bits to any size between 8 and 20 bits. When this option is programmed, the selected low order bits function normally until their range is exceeded, at which point they retain their maximum value (high order bits are unaffected). This feature matches the HP 5507A outputs to most servo systems (see example in *Figure 3-28*). *Figure 3-15* graphically illustrates this operation.

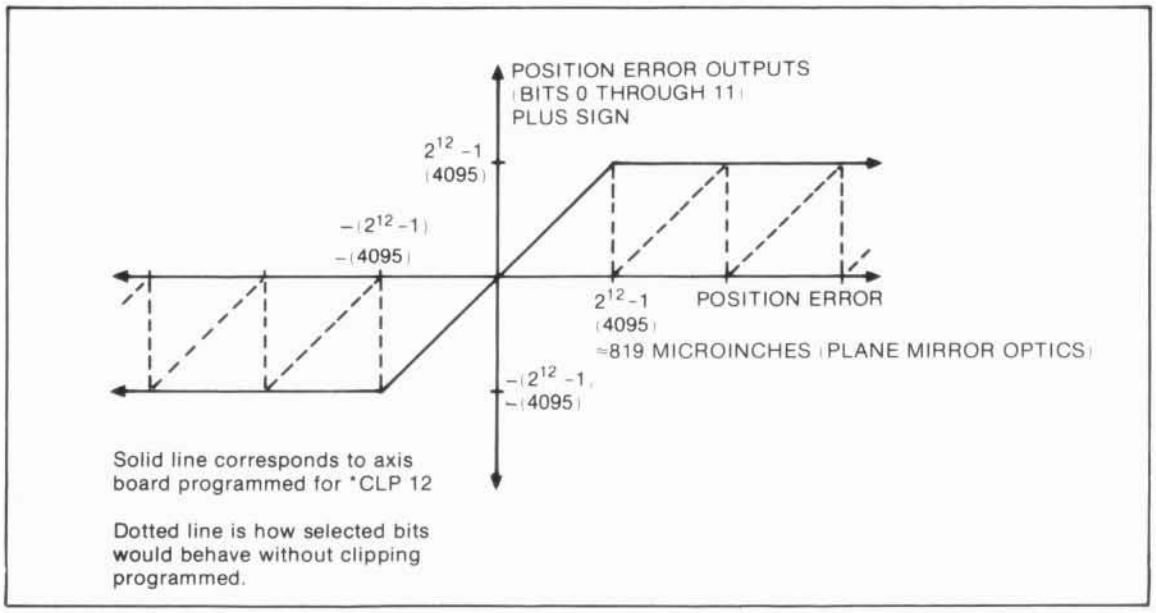


Figure 3-15. Position Error Output Clipping

Axis Board Position Error Data Format

The Position Error output lines may be switched to two's complement representation or sign-magnitude representation with the *TCP and *SMG commands, respectively. The Axis Board powers up in two's complement mode.

Sign Bit	Bit 30	Bit 29	.....	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	MSB							LSB

When in sign-magnitude or two's-complement format, the sign bit is high when the Position Error is negative.

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ANALOG VELOCITY AND GROUND

The Analog Velocity output line is a bipolar analog signal which is proportional to the velocity of motion. An Analog Ground line is used to keep digital noise and ground currents from compromising accuracy.

Output scaling is 197 mV per cm per second ±20% when using plane mirror optics (98 mV/cm/sec ±20% with linear or single beam optics). Residual offset at zero velocity is less than 20 mV, and in-band noise is less than ±40 mV (see specifications). The output is filtered with two poles at 10 kHz, and has a 464 ohm series resistance for short circuit protection.

Internal (Axis Inter-Card) Connector

GENERAL

A connector on the top edge of each axis board allows connections between boards within the HP 5507A. The mating connector is 3M 3425-6050. Signals on the 50 pin connector are similar to those provided on the rear panel connector, with a few important exceptions.

The major difference is the absence of output latches on the Position Error lines, resulting in no Error Hold capability and less delay of the Position Error data (one less Error Clock cycle) relative to the Position Null and Drive Enable lines.

ERROR CLOCK

This signal is the same as the Error Clock signal on the rear panel connector.

DRIVE ENABLE IN- AND OUT-

These signals are identical to those on the rear panel connector.

POSITION NULL OUTPUT

This signal is identical to the one on the rear panel connector except it occurs on the same error clock cycle as the corresponding Position Error output.

ANALOG VELOCITY AND ANALOG GROUND OUTPUTS

These signals are identical to those on the rear panel connector.

POSITION RESET- AND EXTERNAL SAMPLE- INPUTS

These inputs are identical to those on the rear panel connector.

POSITION ERROR OUTPUTS

As noted above, the Position Error outputs are not latched, and thus appear one Error Clock cycle earlier relative to the other output signals.

CAUTION

The Position Error outputs on this connector are not buffered, and can only drive two LSTTL loads and 12 inches of flat cable. Care must be taken not to short circuit these signals, as expensive board damage may result.

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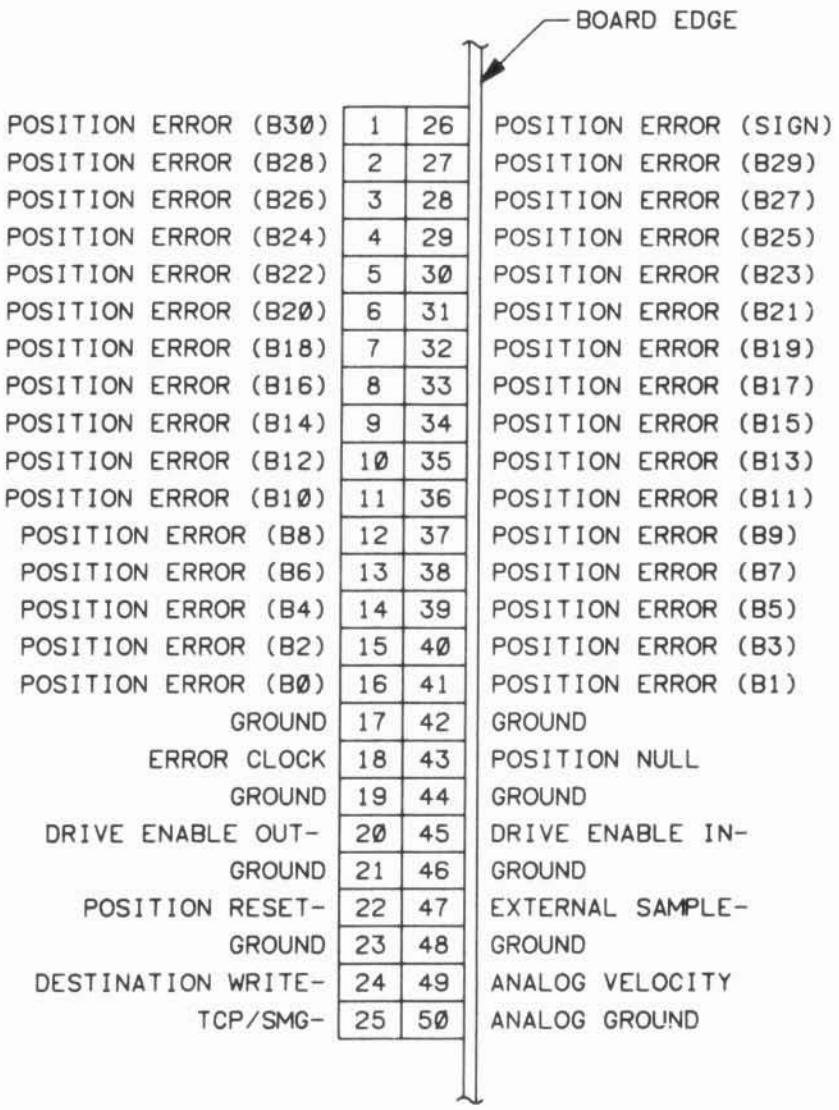


Figure 3-15a. HP 10932A/B Inter-Card Connector Pinouts

DESTINATION WRITE- OUTPUT

The Destination Write- Output is a decoded write pulse which strobes a new destination value into the Position Error subtractor. It is an active-low output approximately 260 nanoseconds long and may be used to signal other circuitry that the stage may be starting to slew to a new position. The Destination Write- Output is not present on the rear panel and can drive 8 LSTTL loads.

TCP/SMG- OUTPUT

This line indicates the position error output data format. TTL high (+3V) indicates two's complement coding and low (0V) indicates sign-magnitude. It is unbuffered and can drive only 2 LSTTL loads.

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HP 10934A A-QUAD-B AXIS BOARD

The HP 10934A A-Quad-B Axis Board monitors the reference (from a laser head) and measurement (from a laser receiver) signals to measure position changes. These measurement changes are accumulated, converted to English or Metric units, and then output as pulse or quadrature signals.

These output signals can be automatically compensated for wavelength-of-light changes by use of an HP 10946B/C Automatic Compensation Board with either an HP 10751A/B Air Sensor or an HP 10717A Wavelength Tracker. Additionally, HP 10757A/B/C Material Sensors are available to compensate for material temperature variations. Each A-Quad-B Axis board also accepts a compensation offset number that affects only that axis (used for minor scaling adjustments to each axis).

To enable operation without a permanent connection to a control computer, the A-Quad-B Axis board stores all of its setup information in non-volatile storage. Once saved, the board will power-up with the user's settings instead of the factory settings.

The board also provides three additional interfaces (two RS-232C serial and one 8-bit parallel) to the HP 5507A/B. Any of these interfaces may be used at any time to set or request any information from any function board installed in the HP 5507A/B.

Basic Operation

Figure 3-15b is a simplified block-diagram of the HP 10934A A-Quad-B Axis Board. The A-Quad-B Axis Board consists of the following six main functional blocks:

- Axis Circuits
- Data Conversion
- Pulse Generation
- Backplane Interface
- Microprocessor, ROM and RAM
- I/O Circuits

Reference (from a laser head) and measurement (from a laser receiver) signals enter the Axis Circuits block where they are used to derive a raw laser-position signal. This signal is routed to the Data Conversion block, conditioned with units conversion and compensation, and sent to the Pulse Generation block.

The Pulse Generation block converts the Data Conversion block output to either A-Quad-B or Up/Down Pulse data signals as programmed by the Processor Core block. The Axis Circuits, Data Conversion, and Pulse Generation blocks are continuously monitored and controlled by the Processor Core block.

The HP 5507A/B Backplane Interface block controls the interaction between the A-Quad-B Axis Board local bus and the HP 5507A/B backplane. Measurement commands/data are managed and buffered via this interface.

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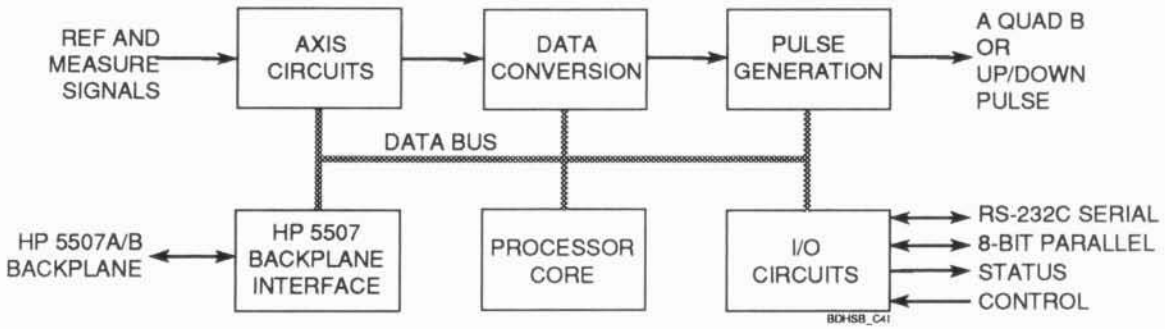


Figure 3-15b. HP 10934A Simplified Block Diagram

The Processor Core consists of a Microprocessor, ROM, and RAM. It receives, stores, processes, and transmits information (commands and data) that arrive from the other five blocks of the A-Quad-B Axis Board. This block performs all onboard programmable operations, manages local housekeeping activities, and supervises backplane I/O operations. This block communicates with the other five blocks via the local data bus.

The I/O Circuits block provides the A-Quad-B Axis Board with Status, Control, and Parallel/Serial data pathways for external data communication. This block converts information on the local data bus into RS-232C, 8-bit parallel data protocols, and provides status information.

Hardware Configuration

Eight switches in the upper left corner of the board set the board's backplane address, test mode, setup mode, and default data rate for serial port A as listed in *Table 3-3* . (the listed switch functions and numbers correspond to the same switch functions as depicted in *Figure 4E-1* of Section 4E.) Moving a switch lever to the OPEN position (away from the circuit board) corresponds with a logic 1 and selects the specified function.

Table 3-3. HP 10934A Configuration Switch Functions

Mainframe Select	Backplane Address			Test Mode	Setup Enable	Serial Port A Baud Rate	
D7	D6	D5	D4	D3	D2	D1	D0
MSB							LSB

Mainframe Select

This switch is used when one parallel interface connects with two A-Quad-B boards that each have the same backplane address in separate HP 5507s. Set it to a 1 in one box and a 0 in the other. It is the MSB of the parallel port's 4-bit address bus.

Backplane Address

These three switches set the backplane address and are the lower three bits of the parallel port's 4-bit address bus. The switches can be set to 0 through 7 binary corresponding to backplane addresses S through Z (substitute the letter in place of the "*" found in mnemonic descriptions throughout this manual).

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Test Mode

Set this switch to 0 for normal operation or "1" for a special service test mode.

Setup Enable

This switch enables (set to 1) or disables (set to 0) changes to the board's setup information. When setup is disabled, the board will not accept changes to the following mnemonics (see Section 4E for descriptions of each mnemonic):

*AVS, *CMD, *DIR, *DPD, *KHZ, *MPO, *OPT, *PUN, *QAD, *RES, *WCM

Additionally the *MEX, *MIN, and *SAV commands will be disabled. When setup is enabled, the board will accept changes to the above mnemonics and commands.

When the A-Quad-B Axis board goes through its hard reset (power-up or BOOT) cycle with setup enabled, serial port A is set to eight bits per character, 1.5 stop bits, even parity and echo on. The baud rate is set by switches D1 and D0 (see Serial A Baud Rate). When a hard reset executes with setup disabled, serial port A is set according to the *SAM and *SAR mnemonic values that have been saved in EEPROM by the *SAV command.

Return the setup enable switch to the disable (0) position after programming the setup parameters and issuing the *SAV command (also see *TST 254 in section 4E).

Serial A Baud Rate

These two switches set the baud rate for serial port A during setup only. After setup (Setup Enable switch returned to the disable position), the serial-port A baud rate is determined by the data stored in EEPROM. To be effective, these switches must be set prior to turning on the HP 5507, or a hard reset (BOOT command or reset switch on HP-IB board) must be issued. Switch settings and baud rate are related as follows:

D1	D0	Baud
0	0	300
0	1	1200
1	0	2400
1	1	9600

Voltage Select Jumper

The HP 10934A supports three logic voltages, 5V, 12V, and 24 V. The jumper block in the lower left hand corner of the board must be set to the voltage in use. The factory setting is +24V (jumper on the left). Move the jumper to the center for +12V operation, and to the right for +5V (HP 5507B Opt. 012 and 005). Input Transition voltages are approximately 2V, 8V, and 14V for the three voltage settings.

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Rear Panel Connector

A 50 pin female connector, located on the rear panel, allows for connections to external equipment. Example mating connectors are:

- Amp: Champ® Connectors (57-33500-2)
- 3M: Delta Ribbon Connectors
- T&B: Ansley® Ribbon Connectors
- TRW: TRW-57-30500-375
- HP: 1251-7673 Connector and 1251-0170 Bushing

®Champ is a registered trademark of Amp.
®Ansley is a registered trademark of T&B.

Rear-Panel Hardware Inputs/Outputs

The following paragraphs describe the rear-panel hardware inputs and outputs for the HP 10934A A-Quad-B Axis Board. *Figure 3-15c* shows the rear-panel connector pinout.

All optically isolated inputs (START–, STOP–, ERROR_RESET–, AXIS_INITIALIZE–, PRESET_ENABLE–, COMP_UPDATE–, X_RAW_SAMPLE–, X_MULT_SAMPLE–, and MARK_IN–) are negative true and are activated by pulling the line to the external ground voltage level (transition voltages are approximately 2V, 8V and 14V for 5V, 12V and 24V operation respectively). No pull-up resistors are required for the inputs.

The optically isolated outputs (READY, SYSTEM_ERROR–, and AXIS_ERROR–) are open-collector and require an external pull-up resistor for the desired voltage level (max 24V). Each output can sink 50 mA, maintaining the output voltage to within 1V of external ground (Refer to the I/O schematic on page 3-16k).

External Power and Ground

These two inputs provide power and ground for the optically isolated signals. Current is drawn from the power signal when one or more of the control/status signals is low. The ground signal is connected to the emitter of the open collector output opto-isolators. The intended voltages are +5V, +12V, and +24V.

The fused +5 volt power output and the ground output can be connected to the external power and ground signals when no external power source is available.

Start and Stop

These two negative true, optically isolated signals are the board's main control lines. At least one board in a system should have its START– line connected to an external Start switch. Pulling this line low causes all boards to stop and get ready to initialize. Pulling this line high causes all boards to start at the same time. Operation is equivalent to receiving a system go mnemonic (*SGO).

The STOP– line can be used to stop individual boards without affecting other boards in the system. Stopping a board prevents it from putting out additional pulses (it will still keep track of position which can be read through one of the interfaces).

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VIEWED FROM REAR PANEL

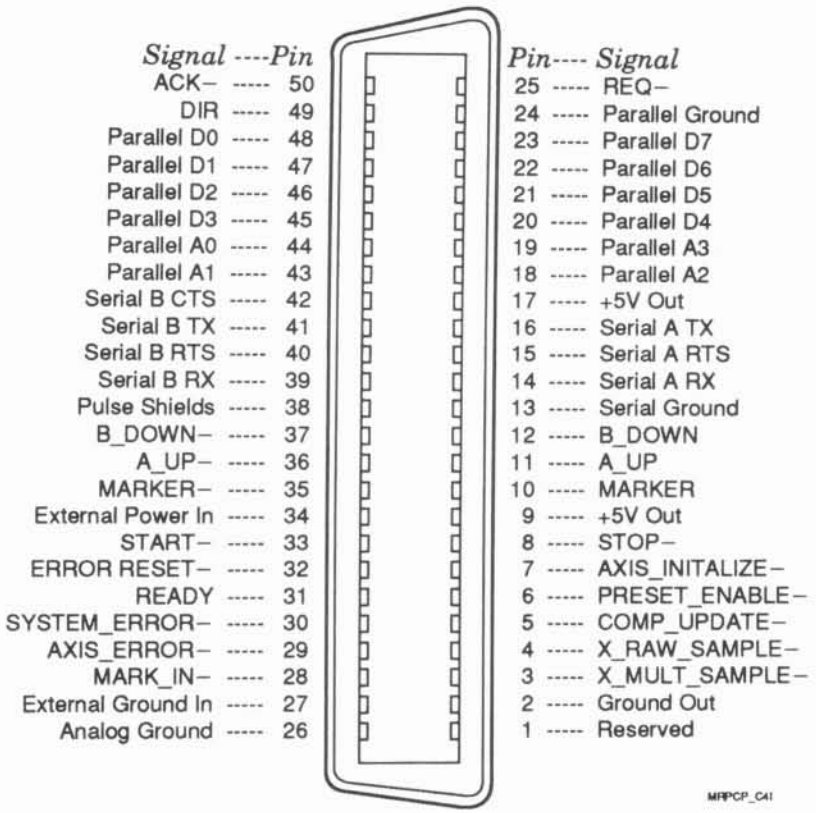


Figure 3-15c. HP 10934A Rear-Panel Connector Pinout

CAUTION

Do NOT plug cables wired for this board into ANY other 109xx boards. Pinouts for each board in the HP 5507 are incompatible with cables for other boards. Connecting the cables incorrectly may cause permanent damage to the HP 10934A board as well as to external equipment.

Error Reset

Activating this negative-true input is equivalent to sending an ERST mnemonic or pushing the front panel reset button. (See "Soft Reset" on page 4E-40 for complete details.)

Axis Initialize

Activating this negative-true input is equivalent to sending a *AGO mnemonic. (See "Axis Initialize" on page 4E-42 for complete details.)

Preset Enable

This line enables the programmed preset distance (*PRD x) to be used during initialization. The line must be low (true) before the start command is issued.

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Compensation Update

Activating this negative-true input is equivalent to sending a *CUR 0 mnemonic, except that the update mode is not changed to manual.

External Samples

These two lines (X_RAW_SAMPLE–, and X_MULT_SAMPLE–) cause the board to sample internal registers. The sampling takes place after the falling edge of the input signal. External sampling must be enabled with the *MEN and *PEN mnemonics.

Mark Input

This negative-true input produces a Marker output pulse synchronized with the A-quad-B output signals. The output pulse is true during the first time that both A and B are true, after both A and B are false, following the falling edge of the MARK_IN– input. The MARK_IN– input is optically isolated, but the MARKER output is a differential TTL pair driven by a 9638 driver IC. *Figure 3-15d* shows the timing relationship between the MARK_IN– input and MARKER output.

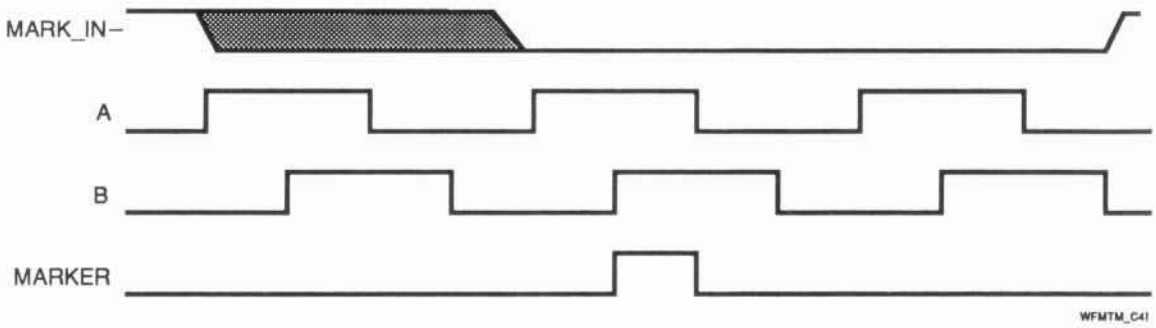


Figure 3-15d. MARK_IN– to MARKER and A-Quad-B Timing

Pulse/Quadrature Outputs

These differential output signals indicate how far the optics have moved in the programmed units. They are driven by a standard differential driver (9638) and are not optically isolated. When the board is set to up/down pulse output format, the pulses are 75 ns wide. (Use the sign of *RES to match the pulse direction with the direction sense of the system.)

Status Outputs

The READY status output indicates when this board has completed its initialization and enabled the pulse output circuit. The AXIS_ERROR– output indicates when this axis has a problem while the SYSTEM_ERROR– line goes true any time the front panel Error LED is lit (Laser Head, Measurement and programming errors).

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Serial Ports A and B

These signals are standard RS-232C signals for serial communication. The baud rate is set either by the dip switches or the *SAR and *SBR mnemonics. Serial port B implements a full hardware handshake (the CTS input must be true to enable the TX data output line, and RTS output line will be true when the RX input line is ready to receive data). Serial port A only implements half of this handshake, assuming that the CTS line is always true (note that there is no CTS line for serial port A).

The default setup for both serial ports is 8-bits per character, 1.5 stop bits, even parity, echo on, and 2400 baud.

8-bit Parallel Port

The 8-bit Parallel Port includes 16 lines that implement a full-handshake, addressable, parallel data-communications port. Multiple 10934A's may be connected together using an internal ribbon cable connected to J1 in the upper left corner of the board. (*Figure 3-15f* shows the pinout for J1.) These signals are the same as those on the rear panel connector.

Cable options HP 10934A Options 002, 003, 004 and 006 connect 2, 3, 4, and 5 or 6 boards together. (The appropriate cable otpion will be installed when the HP 10934A is ordered as an HP 5507B Option 034.)

Additional HP 5507A/B's may also be connected in parallel provided there are no address conflicts (maximum is sixteen HP 10934A boards). Each line is terminated by a 10k ohm pull-up resistor.

The ACK– line should be terminated with 220 ohm pull-up and 330 ohm pull-down resistors. The data lines may also require termination depending on cable length. The pull-down resistors should be at least 50% greater resistance than the pull-up resistors with a minimum pull-up value calculated as follows:

$$\frac{5000}{\left(18 - 0.7 \times (\text{number of A–Quad–B boards})\right)}$$

The following paragraphs and timing diagram (*Figure 3-15e*) illustrate the sequence of events for each data transfer.

a. The Parallel Interface Bus Master (Bus Master) verifies that the ACK– line is high, indicating that the last transaction is complete.

b. The Bus Master puts the desired address on the PA0 through PA3 lines and sets the DIR line (low for Master to Slave transfer, high for Slave to Master transfer).

c. If the DIR line was set low in the last step, then the Bus Master drives the data lines with the desired data value.

d. The Bus Master asserts the REQ– line by bringing it low.

e. The Parallel Interface Bus Slaves, detecting the low on the REQ– line, compare their address with the one on the PA0 through PA3 bus lines. If they are not equal, they do nothing.

f. The Bus Slave that matches the address lines looks at the DIR line. If DIR is high, it drives the data lines with the data it has to transfer.

g. The selected Bus Slave asserts its ACK– line by pulling it low.

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h. The Bus Master detects the assertion of the ACK– line, and sets the REQ– line false (high). If DIR is high, it reads the data lines before raising REQ– (the data lines are valid the entire time ACK– is low).

i. If DIR is low, then the Bus Slave latches the data lines on the rising edge of REQ–.

j. The Bus Slave detects the negation of REQ– and also sets ACK– false. It then disables the data line drivers if they were enabled.

k. The Bus Master detects the false ACK– signal and disables the data lines if DIR was low. It is now free to initiate another transfer.

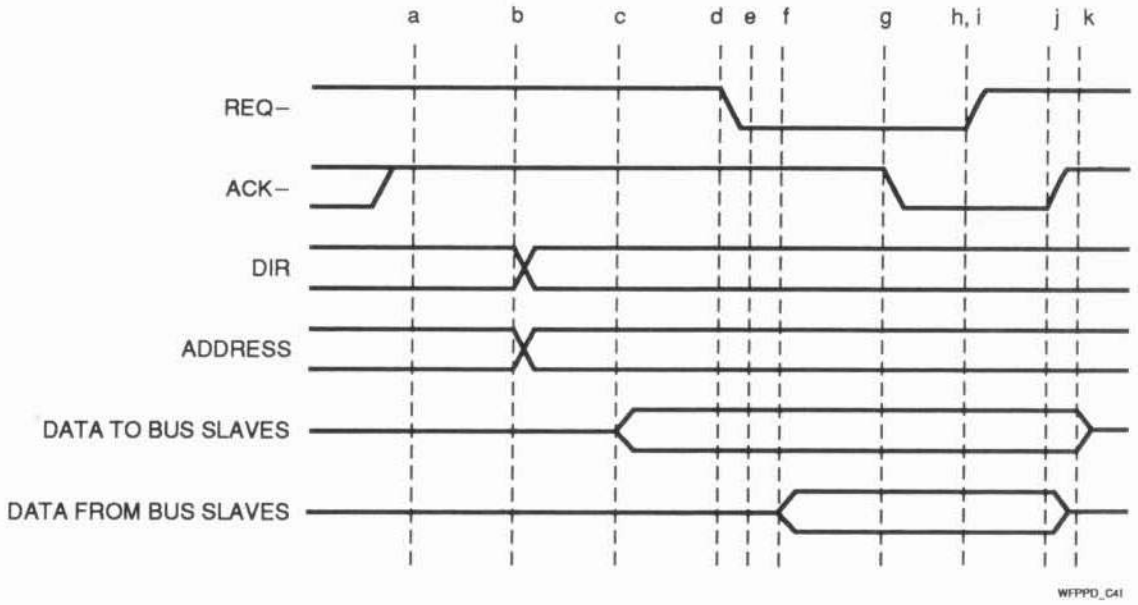


Figure 3-15e. Parallel Port Data Transfer Sequence

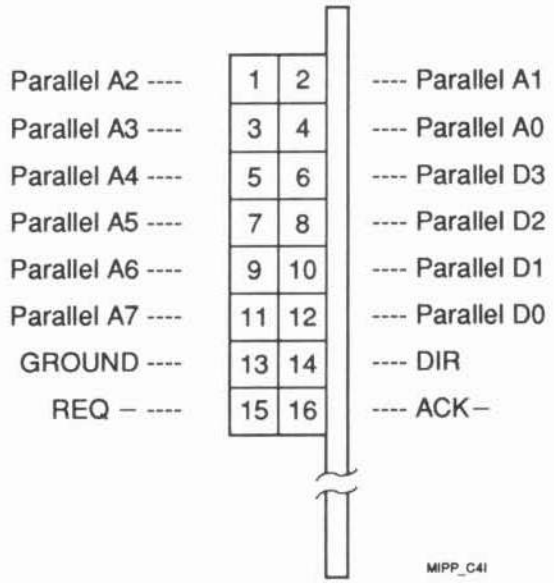


Figure 3-15f. Parallel Port J1 Pinout

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I/O Schematic

Figure 3-15g illustrates the HP 10934A external-Input/Output hardware design. They are provided to assist with the resolution of interface design issues.

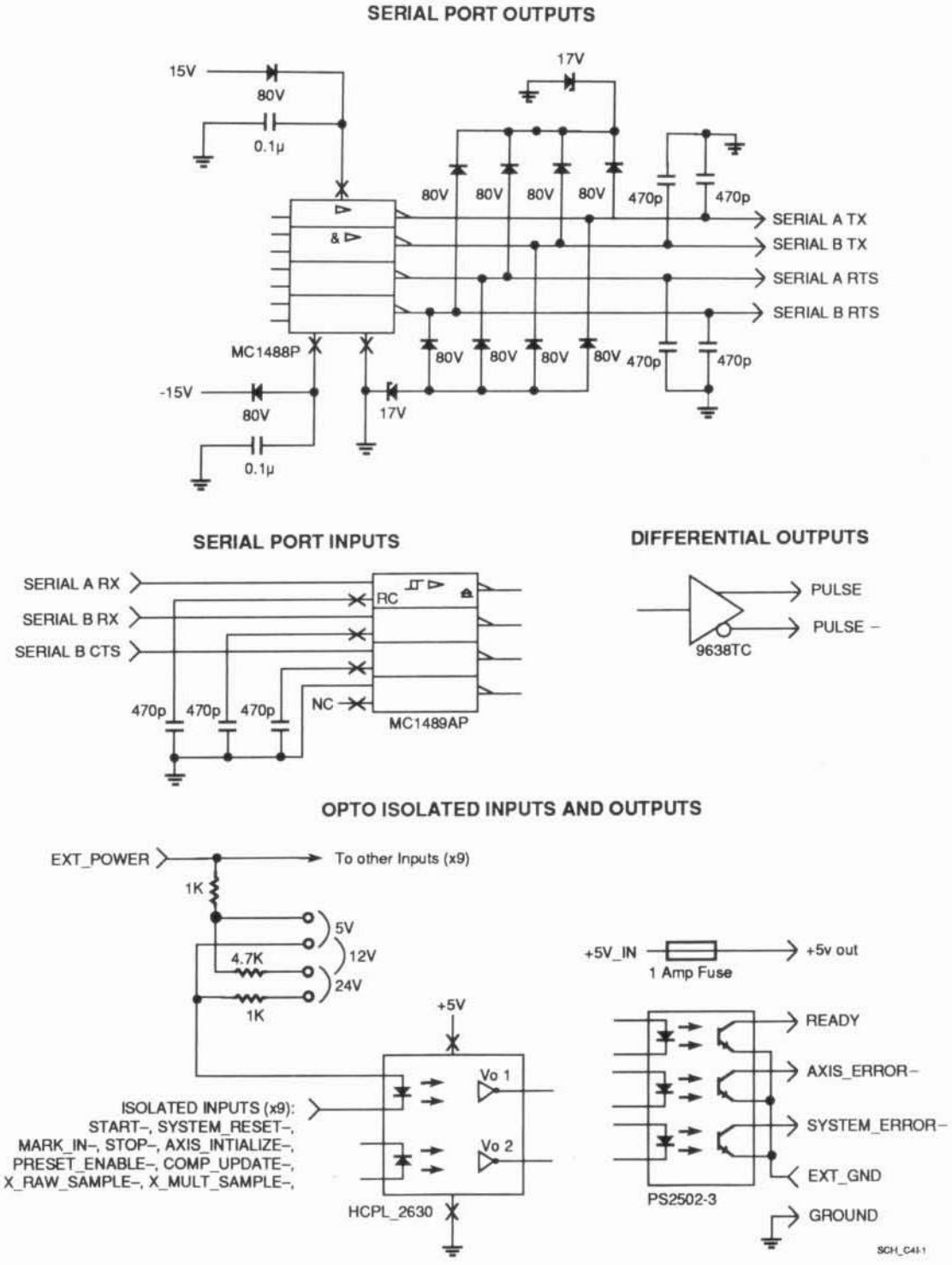


Figure 3-15g. HP 10934A I/O Schematic Diagram

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