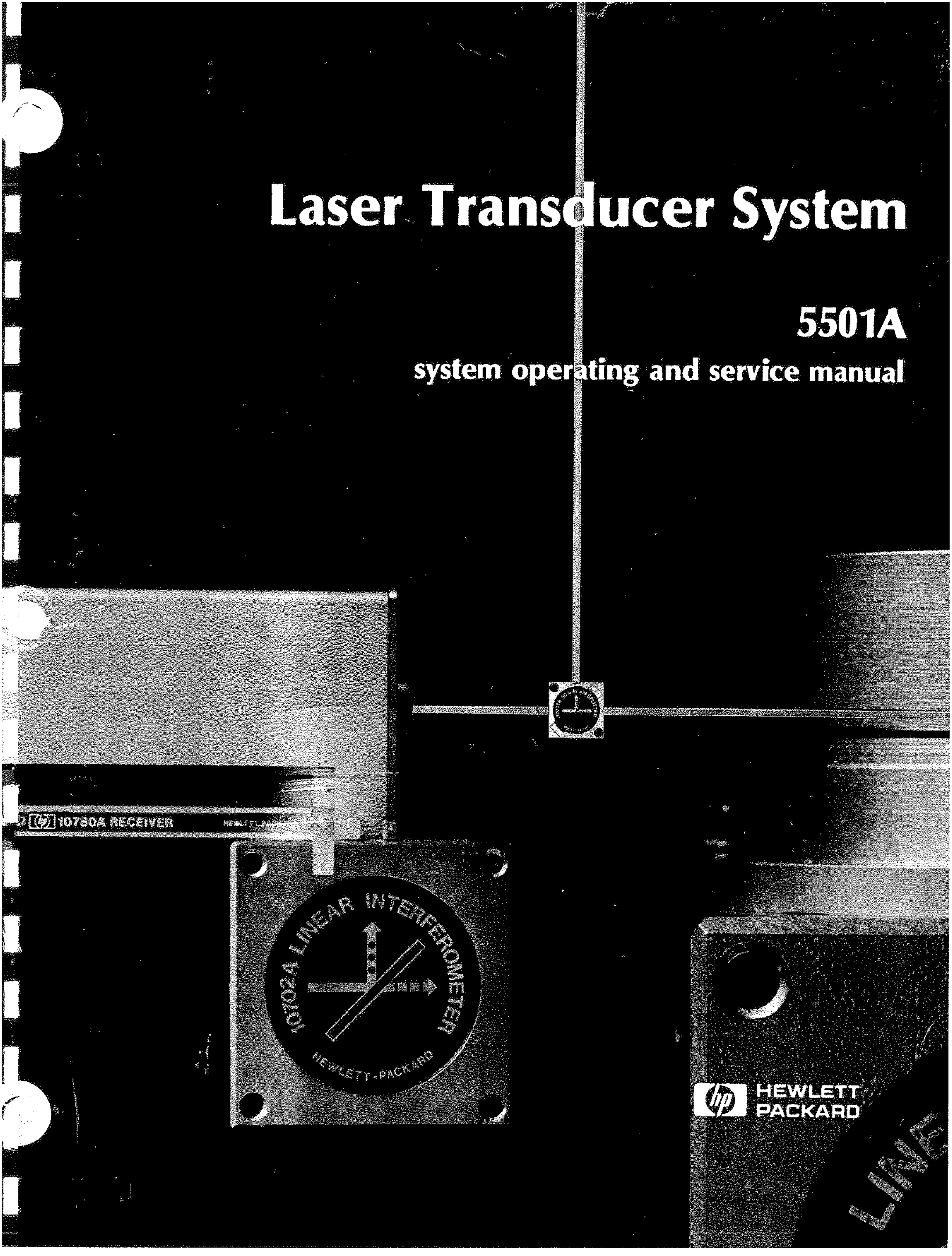
Laser Transducer System

5501A

system operating and service manual



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SAFETY

This product has been designed and tested according to International Safety Requirements. To ensure safe operation and to keep the product safe, the information, cautions, and warnings in this manual must be heeded. Refer to Section 1 for general safety considerations applicable to this product.

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 product is warranted against defects in materials and workmanship for a period of 90 days from date of shipment, except that in the case of certain components listed in Section 1 of this manual, this warranty shall be for the specified period. During the warranty period, HP will, at its option, either repair or replace products which prove to be defective.

Warranty service of this product will be performed at Buyer's facility at no charge within HP service travel areas. Outside HP service travel areas, warranty service will be performed at Buyer's facility only upon HP's prior agreement and Buyer shall pay HP's round trip travel expenses. In all other cases, products must be returned to a service facility designated by HP.

For products returned to HP for warranty service, 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.

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.

NO OTHER WARRANTY IS EXPRESSED OR IMPLIED. HP SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

EXCLUSIVE REMEDIES

THE REMEDIES PROVIDED HEREIN ARE BUYER'S SOLE AND EXCLUSIVE REMEDIES. HP SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

ASSISTANCE

Product maintenance agreements and other customer assistance agreements are available for Hewlett-Packard products.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

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OPERATING AND SERVICE MANUAL

5501A
LASER TRANSDUCER SYSTEM

SERIAL PREFIXES

This manual applies to 5501A Laser Transducer Systems with serial prefix 1948A. For serial prefixes above 1948A, a change sheet is included with the manual. For serial prefixes below 1948A, refer to Appendix E, Backdating.

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SAFETY PRECAUTIONS

This is a Safety Class I system. This system has been designed and tested according to IEC Publication 348, "Safety Requirements for Electronic Measuring Apparatus".

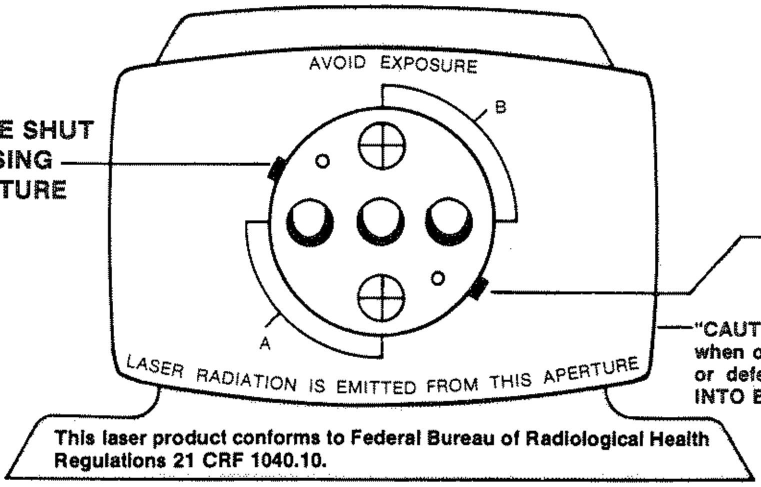
CAUTION

LASER RADIATION

DO NOT STARE INTO BEAM

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

CLASS II LASER PRODUCT



BEAM CAN BE SHUT OFF BY CLOSING BLACK APERTURE

ALIGNMENT APERTURE FOR REDUCED BEAM

"CAUTION" — Laser radiation when open and interlock failed or defeated. DO NOT STARE INTO BEAM.

This laser product conforms to Federal Bureau of Radiological Health Regulations 21 CRF 1040.10.

SERVICE

Although this system has been designed in accordance with international safety standards, this manual contains information, cautions, and warnings which must be followed to ensure safe operation and to retain the system in safe condition. **Removal of the cover and subsequent service or adjustments should be performed only by qualified service personnel.**

WARNING

HIGH VOLTAGES ARE GENERATED WITHIN THE LASER HOUSING. THE COVER OF THE MODEL 5500C LASER IS PROVIDED WITH AN VIDED WITH AN INTERLOCK TO PREVENT ACCIDENTAL ACCESS TO VOLTAGES. FOR SAFETY, THERE ARE NO HIGH VOLTAGES ON THE INTERCONNECTING CABLE.

CAUTION

Any adjustment, maintenance, and repair of an opened instrument under voltage should be avoided as much as possible and, when inevitable, should be carried out only by a skilled person who is aware of the hazard involved.

Capacitors inside the instruments may still be charged even if the instruments have been disconnected from their source of supply.

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

Use of controls or adjustments, or performance of procedures other than those specified herein may result in hazardous radiation exposure.

1.2 Section I, General Information

In addition to explaining what the System Manual covers, Section I also covers the following subjects:

a. How to use the other manuals supplied with your system.

b. An overall system level discussion of what a laser system is and how it makes measurements.

c. Types and examples of typical measurements made with the Laser Transducer System.

d. An explanation of the available system configurations and what is contained in each system. By first determining what type of system you are going to use it will be easier to selectively read those sections of the manual that apply directly to your problems.

In summary, Section I contains the information you will need to familiarize yourself with the Laser Transducer System, and the support documentation and equipment.

1.3 Section II, Laser Transducer and Optics

This section provides the background information on the physical layout of the Laser Transducer head and receiver, and the optics necessary to direct the laser beam between them. It is very important that you know and understand the material contained in this section **prior to** mounting these units. The material is covered as follows:

a. An overall discussion of what constitutes a basic measurement system. This includes only the optical portion of the Laser Transducer System. For information on the system electronics refer to Section III.

b. Measurement components. Detailed descriptions of the individual measurement components of the Laser Transducer System including dimensions, mounting, and installation information. Also discussed are the allowable measurement configurations for the optical components including interferometers, beam benders, and beam splitters.

c. Accuracy considerations. Deals with factors affecting the ultimate measuring accuracy of the Laser Transducer System. Centers on the effect of the environment under which the measurement is made along with techniques for compensating for these effects. Specific types of measurement errors including the effect of thermal expansion of the part being measured or cut are discussed. Consideration is also given to cosine error or errors due to misalignment.

d. System installation. Discussion of how to install the measurement components in actual measurement applications. Consideration of possible combinations to split and direct the laser beam to the measurement location. Also discussed is how to route the laser beam to the measurement location with emphasis on minimizing possible measurement errors. This will include the effect of Abbe errors and thermal instabilities on the measurement process. Techniques of protecting the beam from disruptions such as thermal effects, cutting fluid, and chips which could interrupt the measurement are also discussed.

e. Alignment procedure. General rules for the actual alignment of the Laser Transducer System after it is installed on a machine are discussed. Different techniques of aligning the components, depending upon the installation and accuracy requirements are also covered. Specific examples include a 3-axis measurement application utilizing the linear interferometer and an X-Y stage application using plane mirror interferometers. Each example illustrates fundamental techniques which can be applied to most installations.

Remember that deciding how to physically mount the individual units on your equipment is only done once (provided it is done correctly). Therefore, be sure that you have examined all the factors that will affect your measurements. It is well worthwhile to spend extra time before mounting the equipment to minimize equipment downtime later.

1.4 Section III, System Electronics

The system electronics are covered as follows:

a. A brief description of the overall function of the system electronics.

b. HP-IB Interface Electronics.

c. Computer Interface Electronics

d. English/Metric Pulse Output Electronics.

e. 10781A Pulse Converter Electronics.

f. Theory of operation for each individual unit.

In this section you need only read the areas that directly pertain to your system.

1.5 Section IV, Programming

The programming section is also divided according to system configuration. However, some of the most useful information you will find in this section are the block diagrams that show the movement of data between units of the system. This movement is similar for all type systems and therefore each example can be studied to increase your overall system knowledge. The information is presented as follows:

a. A general discussion of the aims and methods of programming the Laser Transducer System.

b. A table of individual commands for each unit of the system that is programmable.

c. Commented programs and examples of measurements and data movement using the 9825A Calculator as the system controller and the 10745A HP-IB Interface.

d. Commented programs and examples of measurements and data movement using the 10746A Binary Interface. The 9825A Calculator is used as the system controller but the program illustrates how a computer could be used instead of the 9825A.

e. A general discussion with examples of data handling after the data has been transferred to the system controller.

f. A general discussion of how to debug (remove errors from) your program. Specific examples of common errors are given.

NOTE

> The operating procedures (other than initial turn on) for the Laser Transducer System are dependent on the programming or design of the system controller.

g. General operating instructions for a typical system and a brief explanation of the controls on applicable units.

1.6 Section V, Installation and Checkout

This section provides instructions for installing and checking your system to ensure correct operation. The procedures are step-by-step instructions for assembling a system and are divided as follows:

a. Preliminary checkout of individual units. For example, instructions are given on how to check the laser transducer head and receiver prior to mounting them on your equipment.

b. Physical installation of the laser transducer head, receiver, and optics. This procedure references Section II, LASER TRANSDUCER AND OPTICS, and the layout measurement paths you have prepared.

c. Recommended mounting and interconnection of electronics. Section V contains detailed information to install and interconnect the system. Details of the cable connectors are given in Appendix C. If the cables need to be fabricated, refer to Appendix E.

d. A system checkout procedure, including some simple programs, to verify that your system is operating correctly.

e. Any critical adjustments necessary to bring your system on-line (e.g., power supply adjustments).

1.7 Section VI, Troubleshooting

This section tells you what to do when your system fails in order to return it to proper operation in the shortest possible time. The troubleshooting information is presented in the following manner:

a. A general discussion of how to troubleshoot and repair the Laser Transducer System.

b. Troubleshooting tips for rapid fault isolation. This will tell you how to quickly locate a problem after your system has been operating.

c. A detailed troubleshooting procedure that is keyed to the system checkout procedure. By structuring the troubleshooting procedure in this manner it is possible to make valid assumptions of equipment condition at different points in the checkout procedure. For example, if the system controller has been checked and is functioning properly, it can be eliminated as a source of trouble at that time. This approach allows the use of the troubleshooting procedure during initial installation and checkout, and also if a problem can not be located after the system has been operational. The latter is done by disassembling your system and reperforming the installation and checkout procedure. One caution about the use of any troubleshooting procedure is that somewhere, sometime a trouble will occur that defies analysis by written procedures. At that time, the only solution is a knowledgeable, patient person tracking down the symptoms until each has been corrected.

1.8 HOW TO USE ALL OF THE MANUALS

The number and type of manuals supplied with your system is dependent upon the specific system. *Figure 1-2* is a family tree of the manuals supplied with each type of Laser Transducer System. To use this documentation effectively you must familiarize yourself with the contents of the individual manuals.

Every Laser Transducer System is supplied with this system level manual, a 5501A Laser Transducer Head unit manual, and a 10780A Receiver unit manual. As the family tree indicates, the 10700 series optics are covered in this manual. The remaining documentation is split into the following groups:

1. HP-IB Interface System manuals.
2. Computer Interface System manuals.
3. English/Metric Pulse Output System manuals.
4. 10781A Pulse Converter System manuals.

The important point to note about this division is that the information contained in these manuals provides both prerequisite, concurrent, and back-up information to the system manual. Unless all of the manuals are used effectively, you may encounter difficulty in installing, operating, and maintaining your system properly.

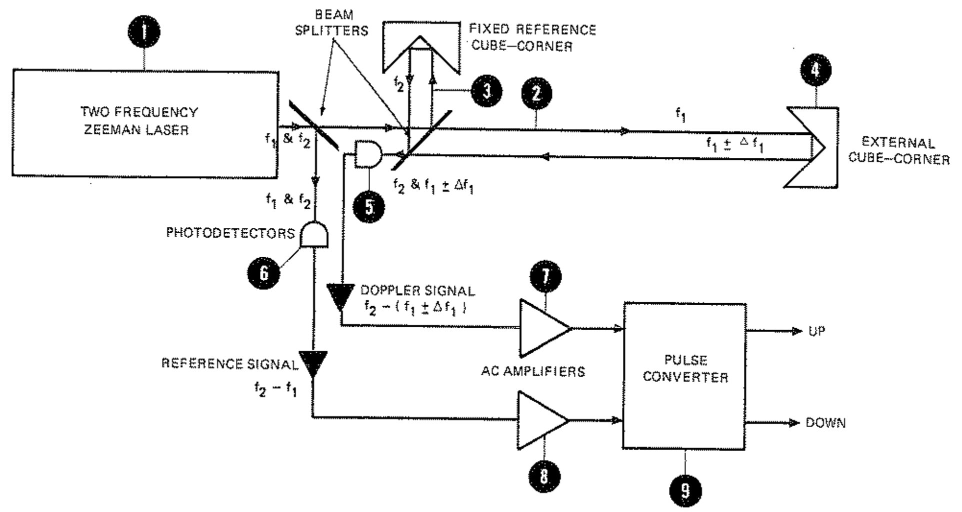
As an example, examine the additional manuals supplied with the HP-IB Interface System. First, you will receive all of the 9825A Calculator and Hewlett-Packard Interface Bus (HP-IB) manuals. Since the calculator and HP-IB control the system, the information contained in these manuals is a prerequisite to learning how to program your system correctly.

In this manual, Section IV, PROGRAMMING, provides the additional information necessary to program the Laser Transducer System. However, the programming information in this manual presupposes that you are familiar with the programming information contained in the calculator and HP-IB manuals. The same information is required for any other unit that acts as a system controller (e.g., an HP computer, some other computer, or a dedicated controller).

Next, you will receive all of the individual unit manuals for the equipment that make up your system. The information contained in these manuals provides the back-up information you will need if you desire to change your system configuration, increase your knowledge of the individual units, or troubleshoot these units beyond the level covered in this system manual.

During initial installation there are references to the unit manuals for addressing individual boards and installing them in the coupler. During operation, reference to the compensator manuals (either manual or automatic) is necessary to insure that you are properly compensating the system for atmospheric conditions.

In summary then, it is very important that you know where to find the specific information you need to efficiently use the Laser Transducer System. The only way to accomplish this objective is to understand the relationship between all of the manuals that are supplied with your system.



1. Laser generates light of two slightly different frequencies with opposite circular polarizations.
2. One of the two frequencies f_1, is optically separated and sent to the movable external cube-corner reflector.
3. The second frequency, f_2, is optically separated and sent to a fixed reflector and then rejoins f_1 at the beam splitter to produce an interference signal at about 2 MHz.
4. If the movable reflector moves, the returning beam frequency will be Doppler-shifted slightly up or down by Δf_1 depending on direction of motion.
5. Photodetector changes f_2 and $(f_1 \pm \Delta f_1)$ to electrical signal.
6. Photodetector changes reference beam, f_1 and f_2, to electrical signal.
7. AC amplifier separates measurement frequency difference signal $f_2 - (f_1 \pm \Delta f_1)$.
8. AC amplifier separates reference frequency difference signal $f_2 - f_1$.
9. Pulse converter extracts Δf_1 and outputs one pulse per quarter wavelength of motion.

Figure 1–3. Typical Laser Transducer System Block Diagram

1.11 TYPICAL APPLICATIONS AND MEASUREMENTS

Any machine with an accurate positioning requirement is a candidate for the Laser Transducer. Those with multiple axes such as numerically-controlled machine tools and coordinate measuring machines benefit especially from its multiaxis capability. NC machine tools, transfer machines, and other equipment having long axes can take advantage of the fact that, unlike other position transducers, a laser beam is the same price regardless of its length. At the other end of the size scale, two-axis machines with X-Y motion, used for integrated circuits manufacturing and photogrammetry, profit from the Laser Transducer's unique plane-mirror measurement technique. Many machines with an ultra-fine resolution requirement, such as the above X-Y stages and coordinate measuring machines, microscopes, grinders, dilatometers, and manometers can fully utilize quarter-wavelength-of-light or better resolution.

Three linear measurement techniques are available with the Laser Transducer: the 10702A Linear Interferometer for normal usage; the 10705A Single Beam Interferometer for non-contacting applications or usage when space is severely limited in the measurement path; and the 10706A Plane Mirror Interferometer.

The plane mirror interferometer technique is uniquely suited for monitoring the motion of X-Y stages. Measurements taken using this technique are immune to pitch or yaw of the moving stage as X and Y are measured in the same plane. The technique is also useful for many non-contacting applications.

Output formats are also varied. The Laser Transducer can be interfaced to virtually any mini-computer controller (including the HP Model 21MX Computer) and many "hardwired" controllers. Interfaces to HP Calculators are easily accomplished as well.

For readout, numeric displays are also available with the Laser Transducer System. Other capabilities include automatic compensation, the ability to monitor changing atmospheric conditions and provide wavelength corrections (due to the changing velocity-of-light) to the controller or displays. Included in this automatic compensation package is the additional capability to compensate for the thermal expansion and contraction of machine or workpiece.

1.12 CONFIGURING A 5501A LASER TRANSDUCER SYSTEM

Use the following information on configuring a 5501A Laser Transducer System to determine and record exactly what equipment is present in your system. You can then use that record to determine the specific information in this manual that is directly applicable to your system. For an overview of the various possible configurations see *Figure 1-1*.

a. LASER. All systems are based on one 5501A Laser Transducer. This instrument houses the laser source and its associated circuitry. It also produces the reference signal and provides diagnostics of the laser source (refer to *Table 1-2*).

b. CHOOSE ACCESSORIES FOR EACH AXIS OF MEASUREMENT (up to four axes). As illustrated in *Figure 1-1*, three accessories are required to be mounted on each machine axis; an interferometer, a reflector, and a 10780A Receiver. When the 10702A Linear Interferometer is used, the 10703A Retroreflector serves as its reflector. For the 10705A Single Beam Interferometer, the reflector may be either a flat reflective surface, or the 10704A Retroreflector. The 10706A Plane Mirror Interferometer is designed to be used in conjunction with high-quality plane mirror reflectors (refer to *Table 1-2*).

   The 10780A Receiver is a photodetector/preamplifier package which senses the laser beam and generates the measurement signal (refer to *Table 1-2*).

c. CHOOSE OPTICS TO DIRECT LASER BEAM TO MEASUREMENT The 10707A Beam Bender and 10700A/10701A Beam Splitters are designed to "pipe" a portion of the laser beam to each axis (refer to *Table 1-2*).

Table 1-2. Basic Measurement Components

REQUIREMENT	CONSIDERATIONS	EQUIPMENT
Laser Source	One per measurement system	5501A Laser Transducer
Interferometers, Retroreflectors, Receivers	How many axes of measurement?	10702A Linear Interferometer Option 001 Windows 10703A Retroreflector
	What types of Interferometers will be used?	
	Each Axis requires one Interferometer, one Receiver, and one Retroreflector. If the 10706A Plane Mirror Interferometer is used, no Retroreflector is needed.	10705A Single Beam Interferometer 10704A Retroreflector
	If it is required that the 10702A Linear Interferometer be a moving component, Option 001 Windows should be used. When using the 10705A Single Beam Interferometer, it must always be the fixed component. When using the Interferometer to bend one laser beam 90 degrees, the above restrictions do not apply.	10706A Plane Mirror Interferometer 10780A Receiver
Splitting and Bending Optics	The percentage of the laser beam directed to each axis is proportional to the length of the axis. ("Length of axis" is defined as distance from the 5501A Laser Transducer to the farthest position on the axis.)	10700A 33% Beam Splitter 10701A 50% Beam Splitter
	Draw a diagram of the paths of the laser beam, locating the position of Beam Splitters and Beam Benders.	10707A Beam Bender
Adjustable Mounts	Each optical component in the System has to be adjusted for System alignment.	
	The 10702A Linear Interferometer and 10706A Plane Mirror Interferometer use the 10711A Adjustable Mount. The 10700A and 10701A Beam Splitters, 10705A Single Beam Interferometer and the 10707A Beam Bender use the 10710A Adjustable Mount.	10710A Adjustable Mount 10711A Adjustable Mount

d. CHOOSE OUTPUT FORMAT. There are a number of output formats available for the 5501A Laser Transducer depending on the specific application:

1. HP-IB Interface Electronics, based on the HP 9825A Programmable Calculator and the HP Interface Bus, provide completely integrated measurement packages designed primarily for acquiring, displaying, and reducing measurement data. The HP-IB Interface Electronics allows simple application of the 5501A Laser Transducer to a wide variety of measurement oriented machines. A large number of options such as displays, additional memory, printers, and special calculator functions are available to tailor the measurement system for a specific application (refer to *Table 1-3*).

Table 1-3. *HP-IB Interface Electronics*

REQUIREMENT	CONSIDERATIONS	EQUIPMENT
Interface Bus System (HP-IB) Compatibility	How many axes of measurement? One 10740A Coupler can be used for up to four axes. Each axis requires one 10760A counter. Select number of 10760A's equal to number of axes. Each system requires only one 10745A Binary Interface and one 10755A compensation interface. The 10755A is an interface only. The compensator must be selected as automatic or manual as shown later.	(1) 10740A Coupler ( ) 10760A Counter(s) (Select from one to four per system) (1) 10745A HP-IB Interface (1) 10755A Compensation Interface ( ) 10783A Display (Select one to four per system) CABLES — Select one of 3 lengths and one per 10783 ( ) 10631A HP-IB Cable 0.91M (3 ft) ( ) 10631B HP-IB Cable 1.83M (6 ft) ( ) 10631C HP-IB Cable 3.66M (12 ft)

2. Computer Interface Electronics are available to interface the 5501A Laser Transducer system to virtually any digital processor or controller. Providing either an HP-IB interface or a digital interface with 32-bit binary information including displacement, system status, and compensation data, the Computer Interface Electronics are ideal for position control systems with the most demanding response requirements (refer to *Table 1-4*).

Table 1-4. Computer Interface Electronics

REQUIREMENT	CONSIDERATIONS	EQUIPMENT
Coupler	Houses and interconnects all circuit boards for Computer Interface Electronics. One required per measurement system.	10740A Coupler
Binary Interface	Utilized to provide transfer of commands and two-way transfer of data between all circuit cards housed in the 10740A Coupler and an external processor or controller. One required per measurement system.	10746A Binary Interface
Counter	Basic displacement input for Computer Interface Electronics. One required per measurement axis.	10760A Counter
Closed Loop Control Capability	Provides control functions for closed loop position feedback as well as displacement measurement capability. Requires 10746B Binary Interface and 10764B Fast Pulse Converter. One required per measurement axis.	10762A Comparator
Extended Resolution and High Measurement Velocity	Used in conjunction with 10762A Comparator to provide resolution extension along with high speed measurement capability. One 10764B Fast Pulse Converter will drive two 10762A Comparators.	10764B Fast Pulse Converter
Velocity of Light Compensation Input	Utilized to interface either 10756A Manual Compensator or 5510A Opt 010 Automatic Compensator. One required per measurement system.	10755A Compensation Interface
Manual Velocity or Light Compensation	Used in conjunction with 10755A Compensation Interface to provide thumbwheel input of velocity of light compensation data to the Interface Electronics	10756A Manual Compensator
Automatic Velocity of Light Compensation	Used in conjunction with 10755A Compensation Interface to automatically compute and input velocity of light compensation data to the Interface Electronics. Includes interconnecting cables 4.6m (15 ft.).	5510A Automatic Compensator Opt. 010 10563A Material Temperature Sensor
Display of Measurement Data	Utilized to provide numeric display of measurement data. Can be used only in conjunction with Hewlett-Packard Interface Bus(HP-IB). Interconnecting cable must be selected below.	10783A Numeric Display
Interconnecting Cable for 10783A Numeric Display	The interconnecting cables for the 10783A Numeric Display are available in 3 lengths: 10631A — 1m (3.28 ft) 10631B — 2m (6.56 ft) 10631C — 4m (13.12 ft)	10631A 10631B 10631C

3. English/Metric Pulse Output Electronics provide a universal interface for almost all numerical controls for machine tools. The English/Metric Pulse Output provides inch or metric value pulses over a wide range of resolutions (refer to *Table 1-5*).

Table 1-5. English/Metric Pulse Output Electronics

REQUIREMENT	CONSIDERATIONS	EQUIPMENT
English/Metric Interface System	How many axes of measurement? One 10740A can be used for up to four axes. Each axis requires one 10760A counter and one 10763A English/Metric output. The 10755A is an Interface only. The Compensator must be selected as either automatic or manual.	(1) 10740A Coupler ( ) 10760A Counter(s) (Select one to four per system) (1) 10761A Multiplier ( ) 10763A English/Metric ( ) Outputs (Select one to four per system) ( ) 10755A Compensation Interface

4. The 10781A Pulse Converter is the most basic output device for the Laser Transducer providing up-down or quadrature pulses of $\lambda/4$ value (refer to *Table 1-6*).

Table 1-6. 10781A Pulse Converter Electronics

REQUIREMENT	CONSIDERATIONS	EQUIPMENT
Pulse or Quadrature Signal Output	Provides output consisting ot up/down or phase quadrature pulses of one-quarter wavelength value. One required per measurement axis.	10781 Pulse Converter

Each of the output options receives the reference signal from the 5501A Laser Transducer and the measurement signal from the 10780A Receiver for each measurement axis.

e. POWER SUPPLIES. *Table 1-7* lists the available power supplies and current requirements.

Table 1-7. Power Supplies and Current Requirements

REQUIREMENT	CONSIDERATIONS	EQUIPMENT
115V Input	Two supplies; one to supply +5V, 60A; One to supply ±15V, 3A. ea. side. Both supplies include line cords.	(1) 10708A Power Supply Accessories
230V Input	Two supplies; one to supply +5V, 60A; One to supply ±15V, 3A ea. side. Both supplies include line cords.	(1) 10708B Power Supply Accessories

If it is desired to use power supplies other than those listed above, use the following table to determine the system current requirements.

CURRENT REQUIREMENTS

VOLTAGE	MODULES TO BE POWERED		CURRENT NEEDED
+15 Volts	5501A Laser Transducer	( ) × 0.6 Amps =	________ Amps
	10780A Receiver	( ) × 0.18 Amps =	________ Amps
	5510A Opt 010 Automatic Compensator	( ) × 0.2 Amps =	________ Amps
	10764B Fast Pulse Converter	( ) × 0.03 Amps =	________ Amps
	TOTAL FOR +15 VOLTS		Amps
-15 Volts	5501A Laser Transducer	( ) × 0.5 Amps =	________ Amps
	5510A Opt 010 Automatic Compensator	( ) × 0.2 Amps =	________ Amps
	TOTAL FOR -15 VOLTS		Amps
+5 Volts	10760A Counter	( ) × 1.8 Amps =	________ Amps
	10746A Binary Interface	( ) × 1.5 Amps =	________ Amps
	10755A Compensation Interface	( ) × 0.35 Amps =	________ Amps
	10756A Manual Compensator	( ) × 0.05 Amps =	________ Amps
	10781A Pulse Converter	( ) × 0.6 Amps =	________ Amps
	5510A Opt 010 Automatic Compensator	( ) × 1.1 Amps =	________ Amps
	10745A HP-IB Interface	( ) × 2.0 Amps =	________ Amps
	10783A Numeric Display	( ) × 1.2 Amps =	________ Amps
	10764B Fast Pulse Converter	( ) × 6.0 Amps =	________ Amps
	10762A Comparator	( ) × 1.9 Amps =	________ Amps
	10761A Multiplier	( ) × 1.8 Amps =	________ Amps
	10763A English/Metric Output	( ) × 1.0 Amps =	________ Amps
	TOTAL FOR +5 VOLTS		Amps

f. SELECT COMPENSATOR. For any of the systems choose either the manual or automatic Compensator as indicated below.

Table 1-8. Compensators

REQUIREMENT	CONSIDERATIONS	EQUIPMENT
Manual Compensator	If measurement is to be made in a controlled environment the 10756A will allow corrections of Data to standard operating conditions.	(1) 10756A Manual Compensator
Automatic Compensator	The Automatic Compensator is required if the environment is to change during the measurement. Option 010 is the cable to the 10755A Compensation Interface. At least one 10563A Material Temp Sensor must be ordered with the 5510A and 2 or 3 are optional.	(1) 5510A Automatic Compensator (1) Option 010 Cable ( ) 10563A Material Temp Sensors

section II

Laser and Optics

2.1 INTRODUCTION

This section provides the information necessary to determine the optimum layout of the 5501A Laser Transducer head, the 10780A Receiver, and the 10700 series Optics necessary to direct the laser beam from the laser head to the receiver. It is very important that you know and understand the material in this section **prior to** mounting these units. The information is organized as follows:

a. An overall discussion of what constitutes a basic measurement system. This includes only the optical portion of the Laser Transducer System. For information on the system electronics refer to Section III.

b. Measurement components. Detailed descriptions of the individual measurement components of the Laser Transducer System including dimensions, mounting, and installation information. Also discussed are the allowable measurement configurations for the optical components including interferometers, beam benders, and beam splitters.

c. Accuracy considerations. Deals with factors affecting the ultimate measuring accuracy of the Laser Transducer System. Centers on the effect of the environment under which the measurement is made along with techniques for compensating for these effects. Specific types of measurement errors, including the effect of thermal expansion of the part being measured or cut, are discussed. Consideration is also given to cosine error or errors due to misalignment.

d. System installation. Discussion of how to install the measurement components in actual measurement applications. Consideration of possible combinations to split and direct the laser beam to the measurement location. Also discussed is how to route the laser beam to the measurement location with emphasis on minimizing possible measurement errors. This will include the effect of Abbe errors and thermal instabilities on the measurement process. Techniques for protecting the beam from disruptions such as thermal effects, cutting fluid, and chips which could interrupt the measurement are also discussed.

e. Alignment procedure. General rules for the actual alignment of the Laser Transducer System after it is installed on a machine are discussed. Different techniques of aligning the components, depending upon the installation and accuracy requirements are also covered. Specific examples including a 3-axis measurement application utilizing the linear interferometer and an X-Y stage application using plane mirror interferometers illustrate fundamental techniques which can be applied to most installations.

2.2 OVERVIEW OF LASER AND OPTICS

The Laser Transducer System is a high accuracy, high resolution measuring system and improper installation or use can degrade measurement accuracy. An understanding of the basic measurement capabilities of the system along with the proper considerations of possible sources of errors prior to installation of the equipment will greatly minimize problems both during installation and during operation.

There are a wide variety of possible configurations for the laser and optics, but all multiaxis configurations have four basic parts in common:

a. A two-frequency laser source (5501A Laser Transducer).
b. A set of splitting and bending optics (10700 series).
c. A set of measurement optics (10700 series).
d. A set of receivers (10780A Receiver).

In addition, an adjustable mount (10710A) is available to facilitate the location and alignment of the splitting and bending optics and the single beam interferometer. Another adjustable mount (10711A) is available for the linear interferometer and the plane mirror interferometer.

2.3 FUNDAMENTAL MEASUREMENT CONCEPTS

To explain some of the basic measurement principles we will start with a single axis measurement system (*Figure 2-1*). The 5501A Laser Transducer (laser head) is the reference upon which all measurements are based. Also required is some type of interferometer/retroreflector combination. This can be the 10702A Linear Interferometer and 10703A Retroreflector; the 10705A Single Beam Interferometer and the 10704A Retroreflector; or the 10706A Plane Mirror Interferometer and a flat mirror (user supplied) as the retroreflector. The 10780A Receiver is the only other component required in the basic measurement system. The 10780A Receiver detects the displacement of either the interferometer or retroreflector with respect to each other and generates a measurement signal which is sent to the electronics. There the measurement signal is compared to the reference signal generated by the 5501A Laser Transducer. The comparison of the reference and measurement signals is done by the electronics in order to generate displacement information appropriate to the specific application. Refer to SECTION III for a description of the various system electronics configurations.

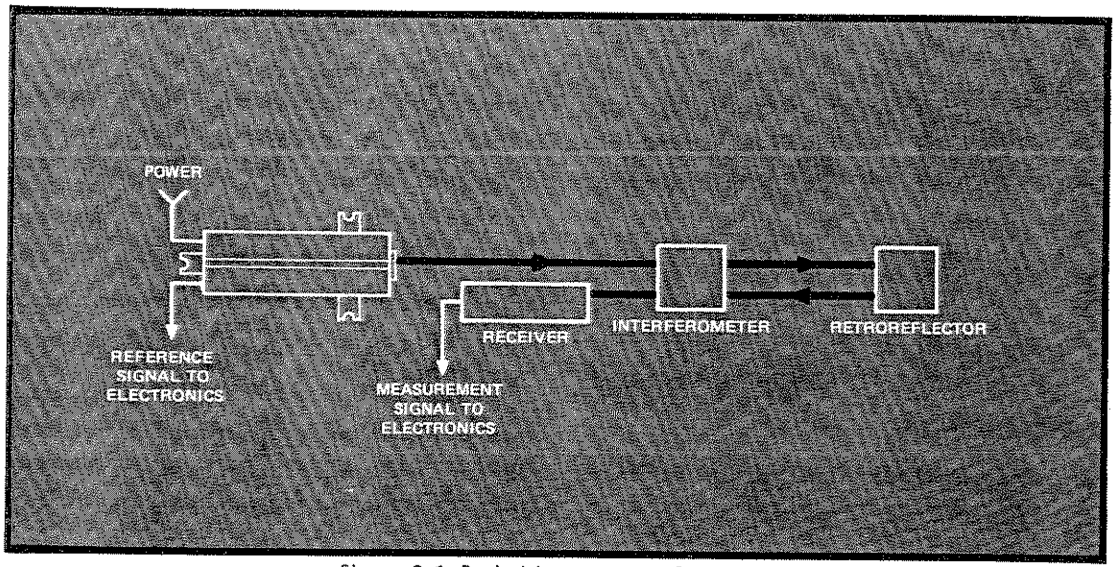


Figure 2-1. Basic Measurement System

One of the most important concepts which must be understood for successful application of the Laser Transducer System is that it measures only relative position change between the interferometer and the retroreflector. It does not measure absolute position. In addition, the only components sensitive to motion are the interferometer and the retroreflector (*Figure 2-2*). If the interferometer and retroreflector are fixed in position with respect to each other, there is no knowledge of the absolute distance between the components.

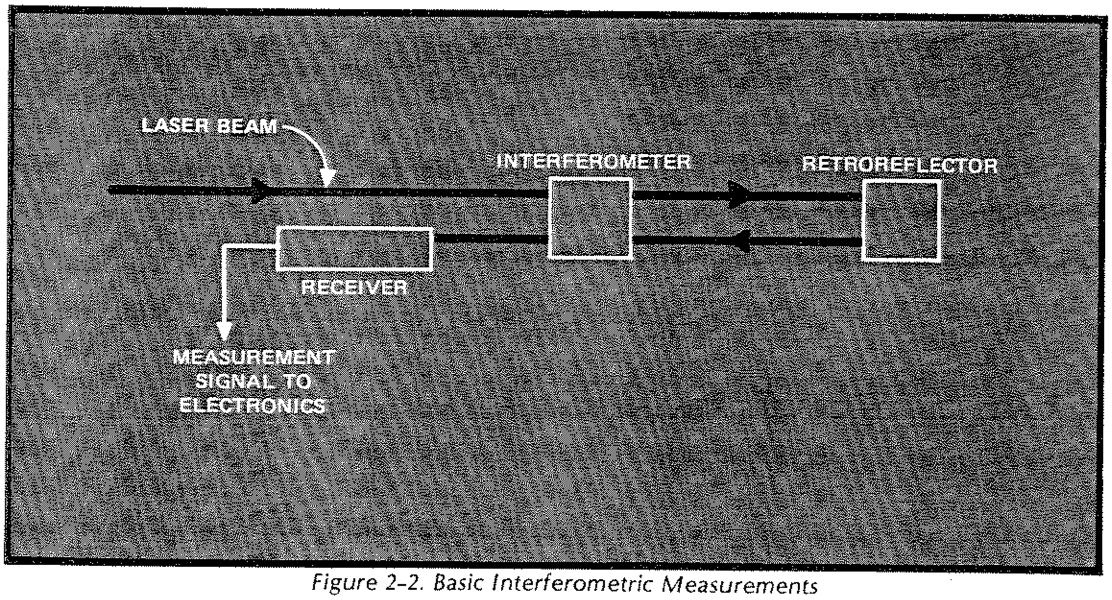


Figure 2-2. Basic Interferometric Measurements

In the measurement of relative position, it does not matter which component moves as long as one is fixed with respect to the other. If the interferometer is fixed and the retroreflector is the moving component (toward or away from the interferometer) only motion with respect to its original position is detected. Conversely, if the retroreflector is fixed the interferometer can be the moving component.

The measurement system is relatively insensitive to all other motions within limits which are covered in greater detail in following sections. The following brief summary of the different types of motion (see *Figure 2-3*) is intended only to familiarize you with their effect on a measurement application:

a. Motion of the receiver or laser head in a direction parallel to the measurement path (X) has no effect on the measurement.

b. Motion of the laser head, receiver, interferometer, or retroreflector in a direction lateral to the measurement path (Y or Z) has no effect on the measurement. The only restriction is that sufficient light returns to the receiver. In general, the maximum allowable lateral displacement is 2.5 mm (0.1 inch). Additional lateral movement will normally cause the laser beam to be displaced beyond the point where sufficient light is returned to the receiver.

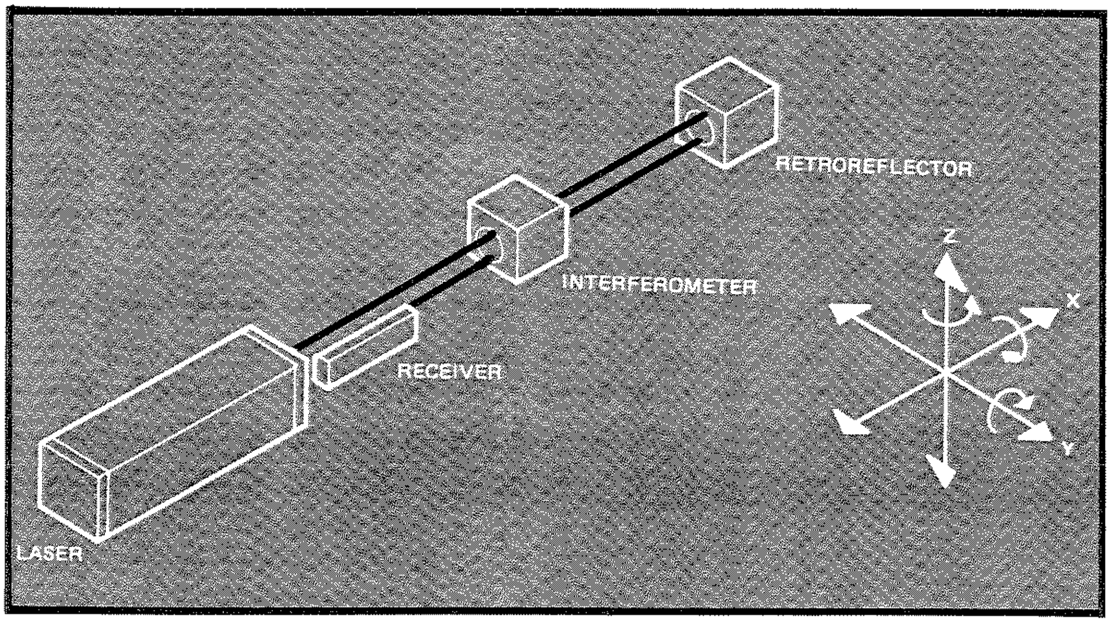


Figure 2-3. Allowable Component Motions

c. Angular motion of the laser head about the Z and Y axes has two effects:
    1. Introduces a measurement error (cosine error) which is discussed in the section on Accuracy Considerations.
    2. Can displace the laser beam enough so that insufficient light returns to operate the receiver.

NOTE

Angular motion of the laser head about the X axis is not allowed for reasons described in the section on Measurement Components.

d. Angular motion of the receiver about the X, Y, and Z axes has no effect on the measurement within certain limits (refer to Measurement Components).

e. Angular motions of the interferometer and retroreflector are dependent on the particular components and application. Refer to Measurement Components for limitations.

2.4 MULTIAXIS MEASUREMENT SYSTEMS

The system is designed to measure up to six independent 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 2–4*).

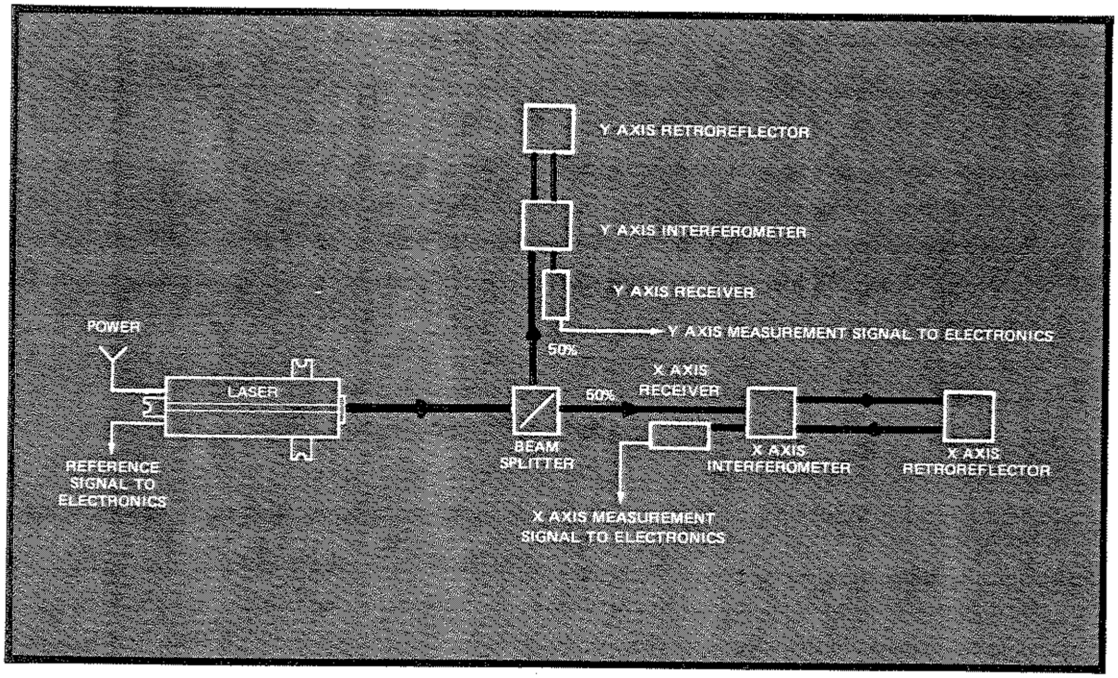


Figure 2–4. Multiaxis Measurement System

The multiaxis system is similar to the basic measurement system shown in *Figure 2–1* 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, retrorefectors, and receivers to provide up to six measurement axes.

2.5 MEASUREMENT COMPONENTS

The measurement components comprise that portion of the Laser Transducer System used to generate, direct, and detect the laser beam and consist of the following units:

a. 5501A Laser Transducer
b. 10780A Receiver
c. 10702A Linear Interferometer (and Option 001 Windows)
d. 10703A Retroreflector
e. 10704A Retroreflector
f. 10705A Single Beam Interferometer
g. 10706A Plane Mirror Interferometer
h. 10700A 33% Beam Splitter
i. 10701A 50% Beam Splitter
j. 10707A Beam Bender
k. 10710A Adjustable Mount
l. 10711A Adjustable Mount

2.6 Degrees of Freedom

Prior to covering the individual units a brief discussion of the degrees of freedom that an object (machine table, X-Y stage, etc.) can experience as it slides along a pair of ways will clarify some of the terminology (*Figure 2-5*). As the object moves linearly in the X-axis direction there are six degrees of motion which 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 experience 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. In total, there are six degrees of freedom of motion which will affect the final position of the object as we command it to move in the X direction. If one considers a typical 3-axis positioning system then there are 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.

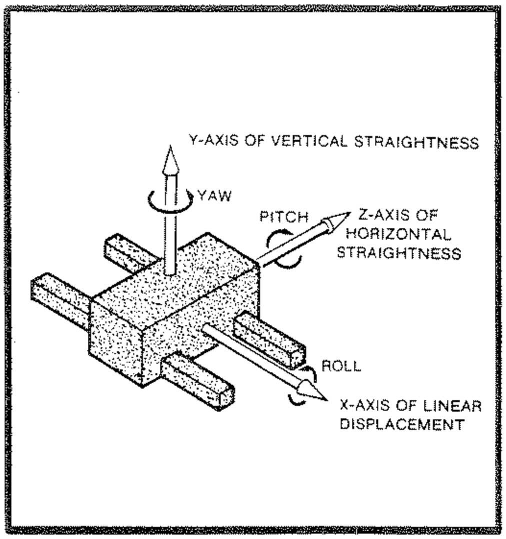


Figure 2-5. The Six Degrees of Freedom

2.7 General Considerations for Mounting Optics

When deciding where and how to mount the system's optics, keep the following points in mind:

a. Vacuum adhesive with low volatility sealant is used to hold the optical components.

b. Additional information including the method of calculating path loss to ensure that each axis has sufficient beam power is included in Accuracy Considerations.

c. If the laser beam has to go through a window (for example into a vacuum chamber) the window must meet the following requirements:

   1. A minimum window diameter of 25 mm (1 inch) with a minimum thickness of 8 mm (0.3 inch). Larger diameter windows must be proportionally thicker.
   2. A figure of transmission of $\lambda/20$ over 23 mm (0.9 inch).
   3. Parallelism of faces of ±2 minutes.
   4. Surface quality 60-40 per MIL-0-13830.
   5. But most important, be sure there is no strain in the glass.

2.8 5501A Laser Transducer

This paragraph covers only the laser beam orientation and mounting information for the laser head. Refer to SECTION III for the electronic theory of operation of the laser head.

The laser head must be positioned so that the beam entering the optical system will be orthogonal with the machine axes. This helps to eliminate cosine error, and can be accomplished with little difficulty (refer to cosine error and alignment procedure). The plane of the laser mounting feet must be roughly parallel (±3°) to either the bottom or sides of the optical component housings (most of which are cube shaped). This guarantees that the polarizing axes of the interferometers are oriented properly relative to the polarization vectors of the laser beam (*Figure 2-6*).

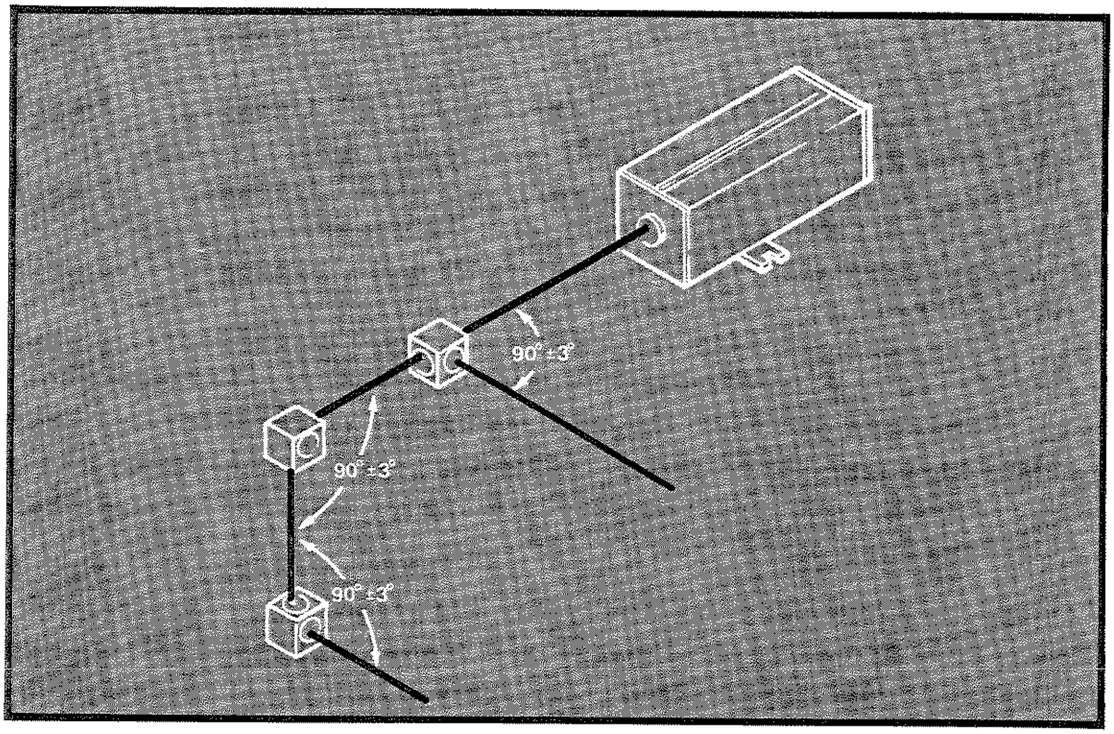


Figure 2-6. 5501A Laser Transducer Mounting

The laser output has two frequency components, one polarized vertically and one horizontally relative to the plane of the mounting feet. The interferometers work on the assumption that the beam entering them will be polarized vertically and horizontally relative to the interferometers mounting surfaces (*Figure 2-7*). It does not matter if the polarizations are reversed, only that one be vertical and one horizontal.

The laser can always be rotated in 90° increments about the beam axis (roll) without affecting the transducer performance. If the laser source is deviated in roll, (θ), from one of the four optimum positions, the desired signal in the receiver decreases, and an unwanted null signal starts to appear. To hold the effect on signal-to-noise ratio less than 1 dB (normally an acceptable amount) the laser source must be positioned in roll to within ±3° of one of the four optimum positions. At a θ deviation of 45° the usable signal at the receiver goes to zero.

The laser head dissipates 15 watts. Therefore, on small or very accurate machines care must be exercised in choosing a mounting location and a mounting method. Since the laser tunes itself automatically and continuously from the instant it is turned on (even from a cold start), it can be turned completely off whenever the machine is not being used for a fairly long period of time. This extends slightly the life of the laser tube but may also introduce thermal waves in the machine at start-up, depending on how it is mounted. A separate mounting plate with thermal isolators between the plate and the frame of the machine is generally a good approach. However, this plate must be very rigid to avoid resonance frequency oscillation which might cause a loss of information from a sudden acceleration or a beam displacement.

The displacement information is not affected by vibrations of the laser source or the receiver, but an offset of more than 2.5 mm (0.100 inch) will reduce the amount of light reaching the receiver and make the system more sensitive to other sources of attenuation.

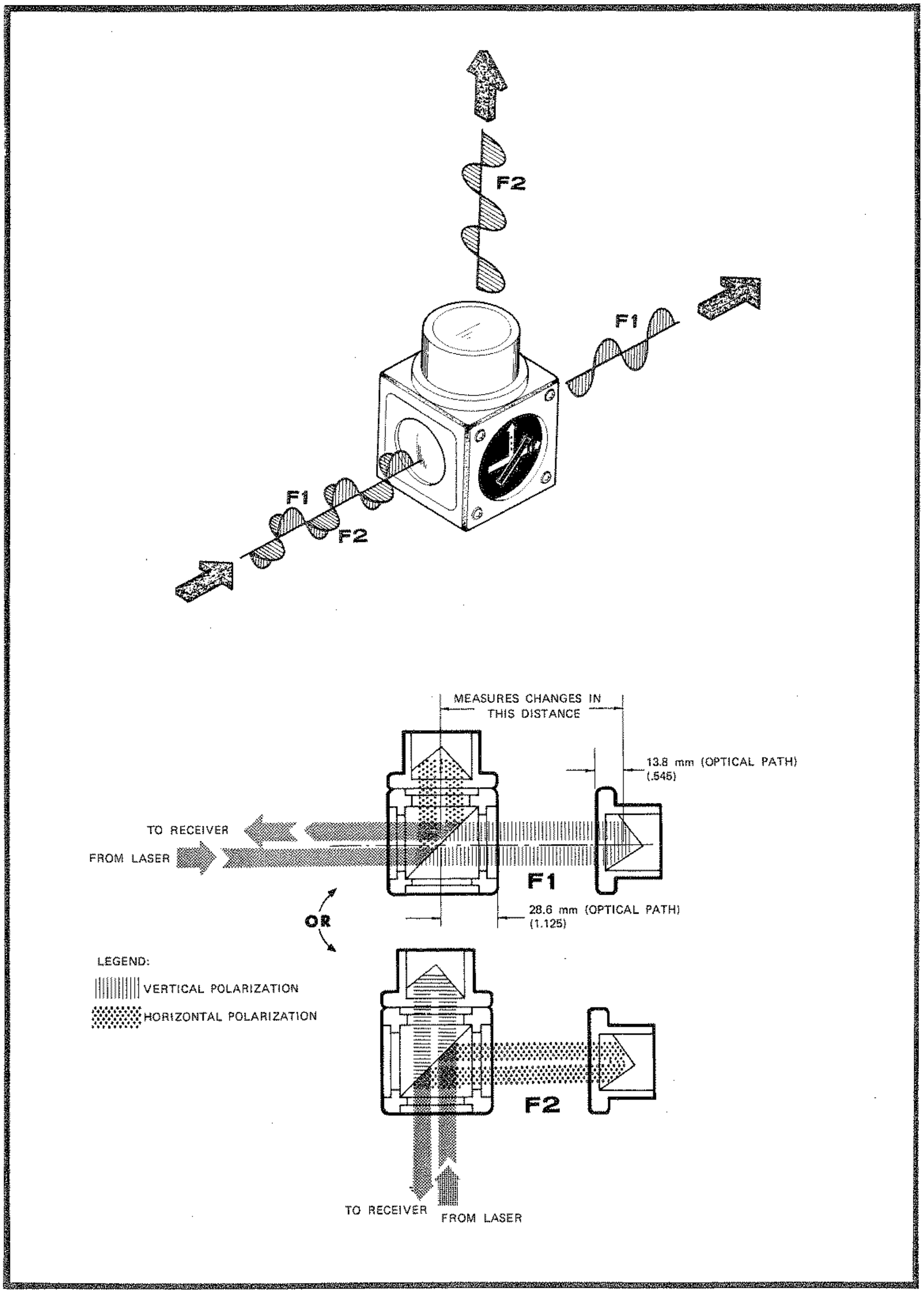
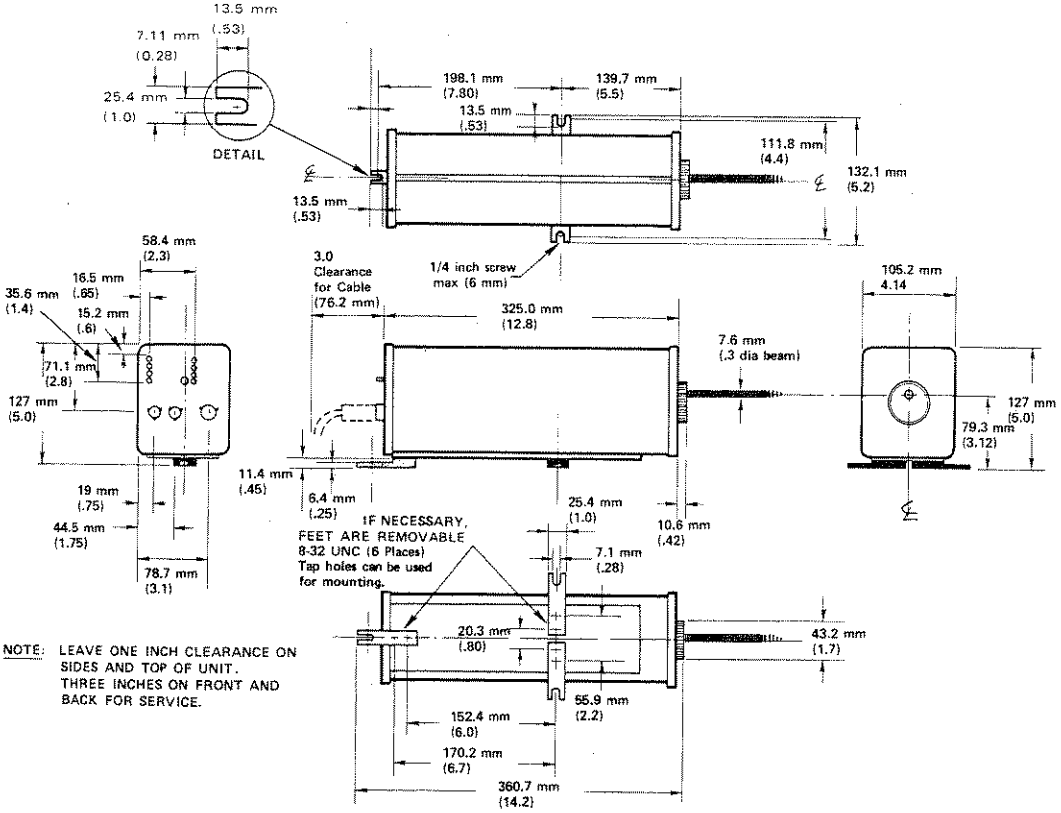


Figure 2-7. Beam Polarization

The laser head may be used upside down or on its side but must be fastened using the 3 feet. Or, if the feet are removed, use only the 8-32 UNC tapped holes under the bases (*Figure 2-8*).

a. Allow 50 mm (2 inches) clearance around the laser head for easy service.

b. To maintain good pointing stability it is good practice to use kinematic mounting principles. For example, a 10 arcsecond drift error in the pointing stability of the laser head causes a beam displacement of over 0.01 inch at the receiver if the cube-corner is at a distance of 100 feet.



NOTE: LEAVE ONE INCH CLEARANCE ON SIDES AND TOP OF UNIT. THREE INCHES ON FRONT AND BACK FOR SERVICE.

Figure 2-8. 5501A Laser Transducer Dimensions

2.9 Splitting and Bending Optics *(Figure 2-9)*

The splitting and bending optics consist of the following units:

a. 10700A 33% Beam Splitter
b. 10701A 50% Beam Splitter
c. 10707A Beam Bender

These 25 mm (1 inch) cubes are designed to allow a portion of the laser beam of the 5501A Laser Transducer to be directed along each measurement axis. Since they are to be mounted within a machine, they are designed for ease and flexibility in mounting and for durability.

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

The Model 10707A Beam Bender contains a 100% reflectance mirror which turns the direction of an incoming laser beam at a right angle. It is mandatory that only right-angle turns be used in routing the beam of the 5501A Laser Transducer within a machine.

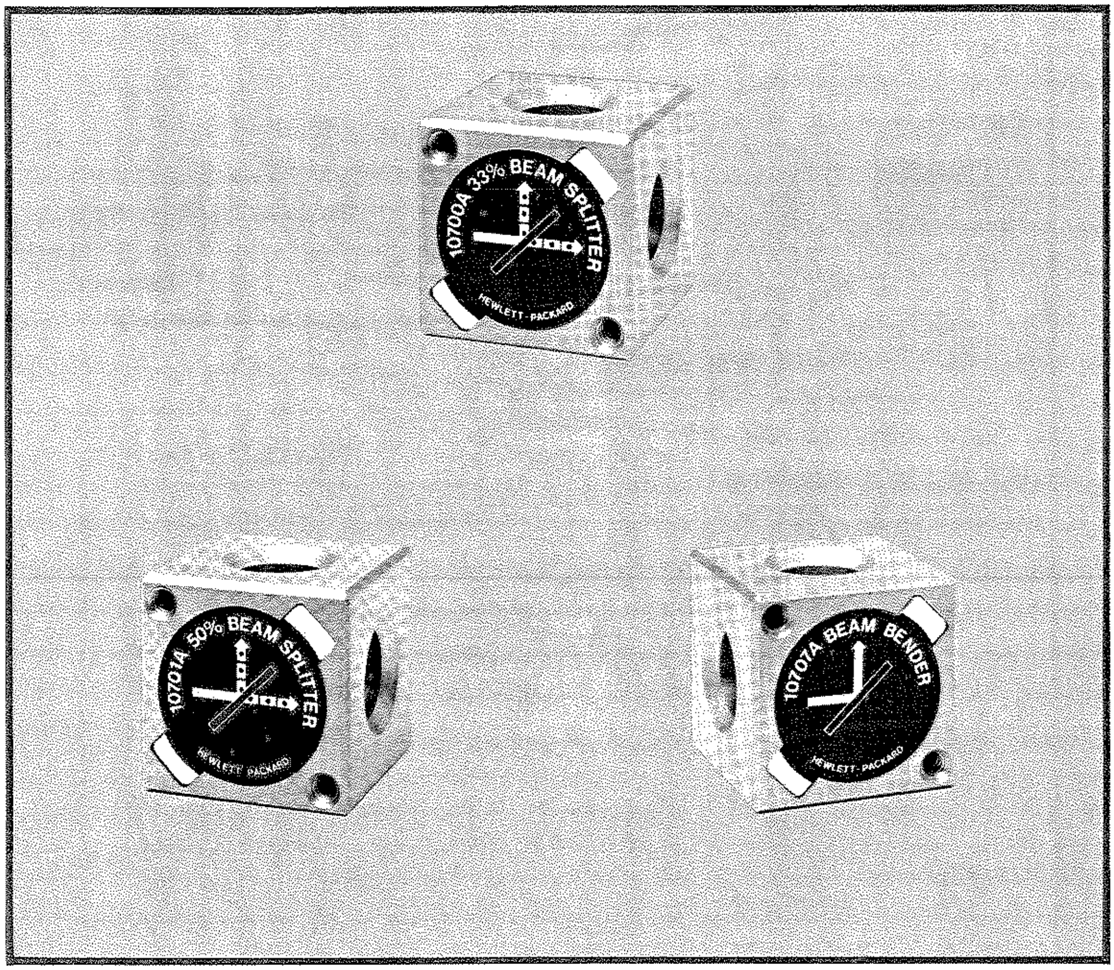


Figure 2-9. Splitting and Bending Optics

2.10 Measurement Optics

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

2.11 10702A LINEAR INTERFEROMETER AND 10703A RETROREFLECTOR (*Figure 2-10*). The 10702A Linear Interferometer is the lowest cost unit and is used whenever possible for that reason. The measurement retroreflector for this interferometer is the 10703A Retroreflector. Displacement is measured between the interferometer and the cube corner. Either one or both can move.

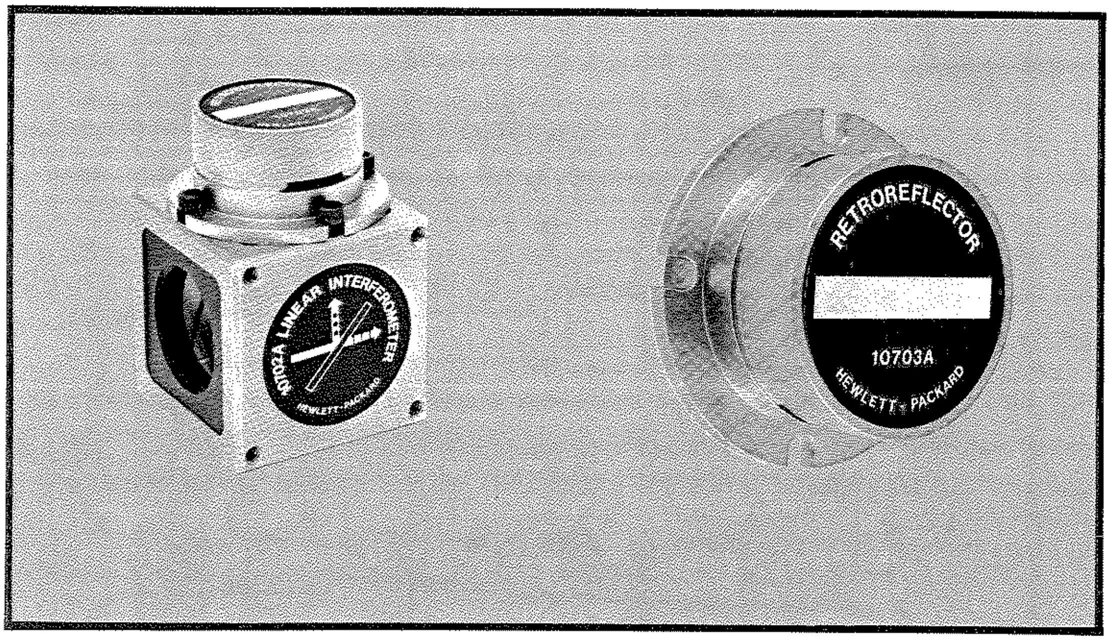


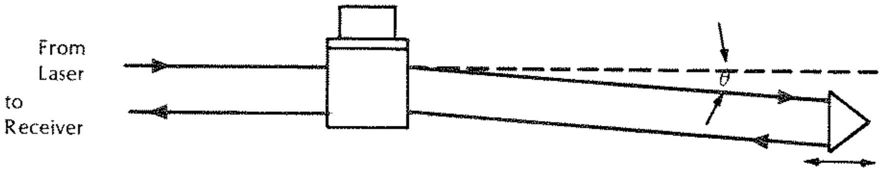
Figure 2-10. 10702A Linear Interferometer and 10703A Retroreflector

Normally, one 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 2-37*. Note that if this is a multiaxis installation each axis must be mechanically independent of the other. In other words, if the Y-axis moves, the X-axis must be unaffected, so that the X-axis retroreflector remains lined up with the X-axis laser beam.

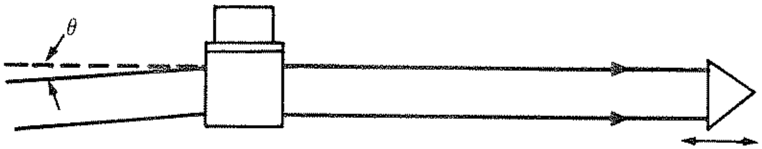
If the linear interferometer must move, the 10702A, Option 001, must be used. For a detailed explanation of why this option is required see *Figure 2-11*.

2.12 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 reflected to the reference cube corner mounted on the housing (*Figure 2-12*). The other frequency is transmitted to the 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, with one frequency including a Doppler frequency shift whenever the 10703A Retroreflector (or 10702A Linear Interferometer) moves.

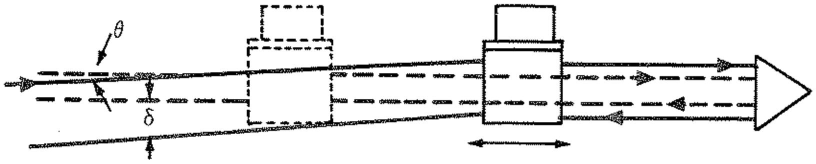
10702A LINEAR INTERFEROMETER
Option 001



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 20 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 2-11. 10702A Linear Interferometer with Option 001 Windows

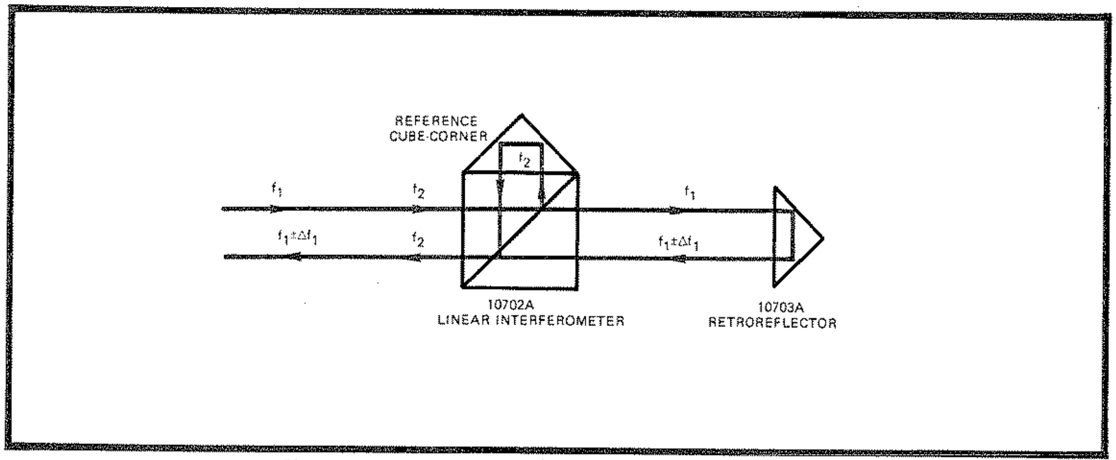


Figure 2-12. Linear Interferometer Laser Beam Path

2.13 10705A SINGLE BEAM INTERFEROMETER AND 10704A RETROREFLECTOR (*Figure 2-13*). A single beam interferometer is so called 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. This interferometer operates the same as the standard interferometer functionally but it 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 and the interferometer is smaller than the standard interferometer. One significant difference is that the receiver in this case is mounted at right angles to the measurement beam and the **interferometer cannot be moved.** A diagram of this type of interferometer is shown in *Figure 2-14*.

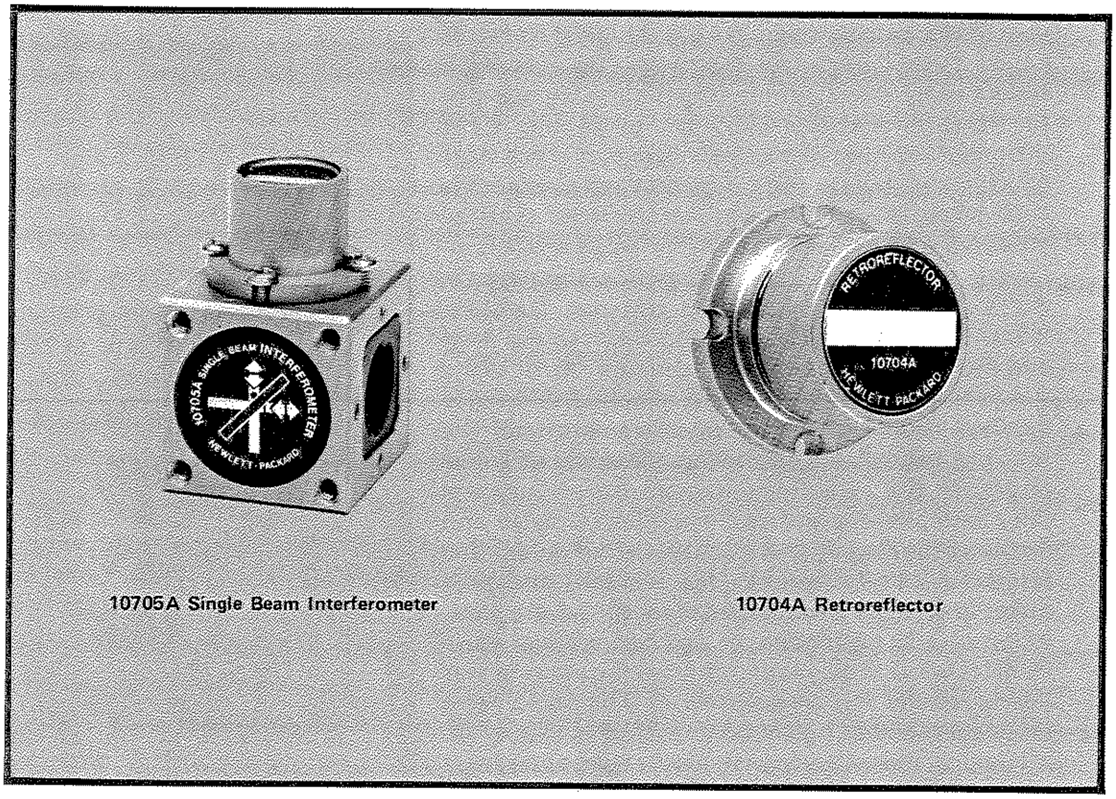


Figure 2-13. 10705A Single Beam Interferometer and 10704A Retroreflector

2.14 SINGLE BEAM INTERFEROMETER LASER BEAM PATH. A polarizing beam-splitter reflects f_2 to the reference cube corner and transmits f_1 to the 10704A Retroreflector or other surface whose displacement is being measured (*Figure 2-14*). 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 degrees. This causes f_2 to be transmitted and $f_1 \pm \Delta f$ to be reflected so that they are directed coaxially to the receiver along a path perpendicular to the measurement path.

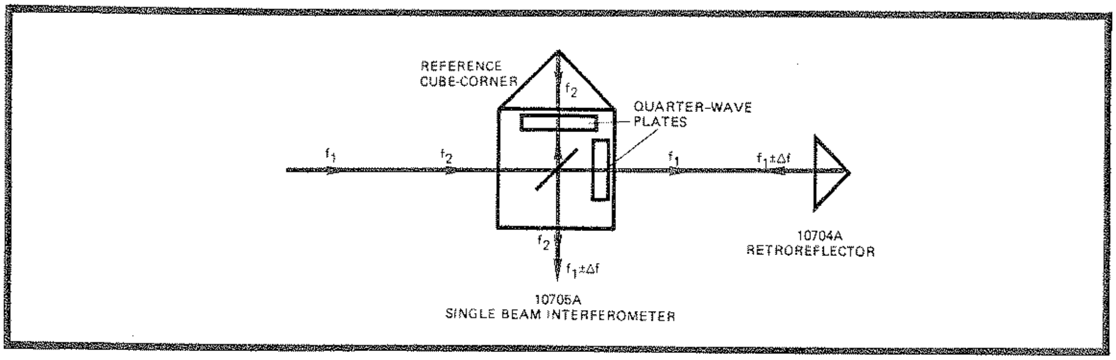


Figure 2-14. Single Beam Interferometer Laser Beam Path

2.15 10706A PLANE MIRROR INTERFEROMETER (*Figure 2-15*). The plane mirror interferometer has a unique feature in that the retroreflector can be a flat mirror and it has a particular advantage in that interference fringes can still be detected even if the measurement beam is not at a perfect right angle to the mirror. It is an advantage to use plane mirrors as retroreflectors because (in a two-axis system for example) the X retroreflector can be allowed to move in the Y direction without affecting the signal strength or the X measurement. Therefore both retroreflectors of a two-axis system can be mounted on the same moving part. This makes it very easy to eliminate Abbe offset on a two-axis system. If the measuring point is defined to be where the two axis beams cross, the measurement is essentially independent of yaw of the moving stage. Such a design is shown in *Figure 2-44*. Contrasting this system to a two-axis system using standard interferometers, we see that (if standard interferometers are used) the X-axis retroreflector must be mounted on a part of the stage which moves only in the X direction and never in the Y direction. Also, the Y-axis retroreflector must be mounted on a different part of the stage which is allowed to move only in the Y direction and never in the X direction. Therefore, the two-axis measurements cannot be made on the same part of the stage and there is by necessity some geometry error in the system if it is not perfectly rigid. Another difference between the plane mirror interferometer and the previous two types is that with a plane mirror interferometer the measurement beam travels between the interferometer and the retroreflector twice and therefore the resolution is twice that of the other interferometers. To be specific, the standard interferometer and single beam interferometer have a resolution of 0.16 micrometre (6 μinches) without electronic resolution extension, whereas the plane mirror interferometer has a resolution of 0.08 micrometre (3 μinches) without electronic resolution extension. All three of these interferometers are used to measure linear displacement.

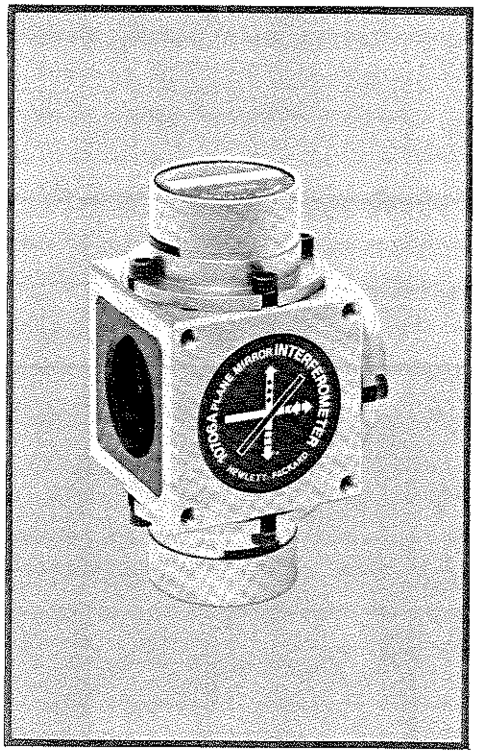


Figure 2-15. 10706A Plane Mirror Interferometer

2.16 PLANE MIRROR INTERFEROMETER LASER BEAM PATH (*Figure 2-16*). The beam entering the interferometer is split into f_1 and f_2, with f_2 returning to the receiver after retroreflection by the reference cube corner. As in the linear interferometer, f_1 is transmitted out to the plane retroreflector and is reflected back on itself (*Figure 2-16*). The quarter-waveplate causes the polarization of the return frequency to be rotated through 90 degrees so that $f_1 \pm \Delta f$ is reflected out a second time where it is Doppler shifted again. The polarization of $f_1 \pm 2\Delta f$ is rotated again through 90 degrees so it is now transmitted back of the receiver. Resolution doubling is inherent because of the double Doppler shift.

Any tilting of the plane reflector relative to the beam axis results only in an offset of the return, not in a tilt, since tilting of the first reflected beam is exactly compensated by the second reflection. See *Figure 2-23* for plane mirror specifications.

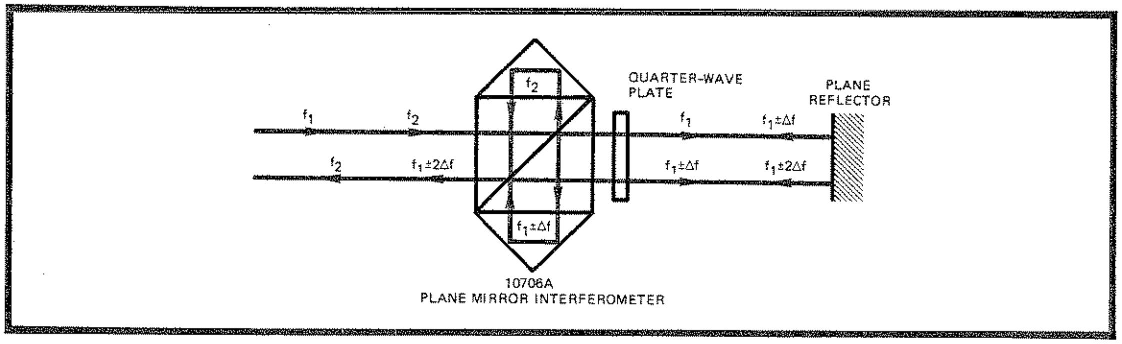


Figure 2-16. Plane Mirror Interferometer Laser Beam Path

2.16.1 10722A PLANE MIRROR CONVERTER (*Figure 2-16a*). The Plane Mirror Converter with an additional 10703A Retroreflector can be used to convert an HP 10702 Linear Interferometer to a 10706A Plane Mirror Interferometer. This configuration allows the 5501A Laser Measurement system to make measurements of axial displacement of a plane mirror. The stringent angular alignment requirements imposed by roof prisms of single-beam arrangements is eliminated. Due to the two reflections inherent in the Plane Mirror Interferometer, there is optical resolution doubling.

Figure 2-16a. 10722A Plane Mirror Converter

The 5501A Laser Transducer System can perform either single or dual axis plane mirror measurements. The dual axis option is particularly useful for X-Y stage applications. Typical measuring setups for single axis and dual axis measurements are shown in *Figures 2-16b* and *2-34*.

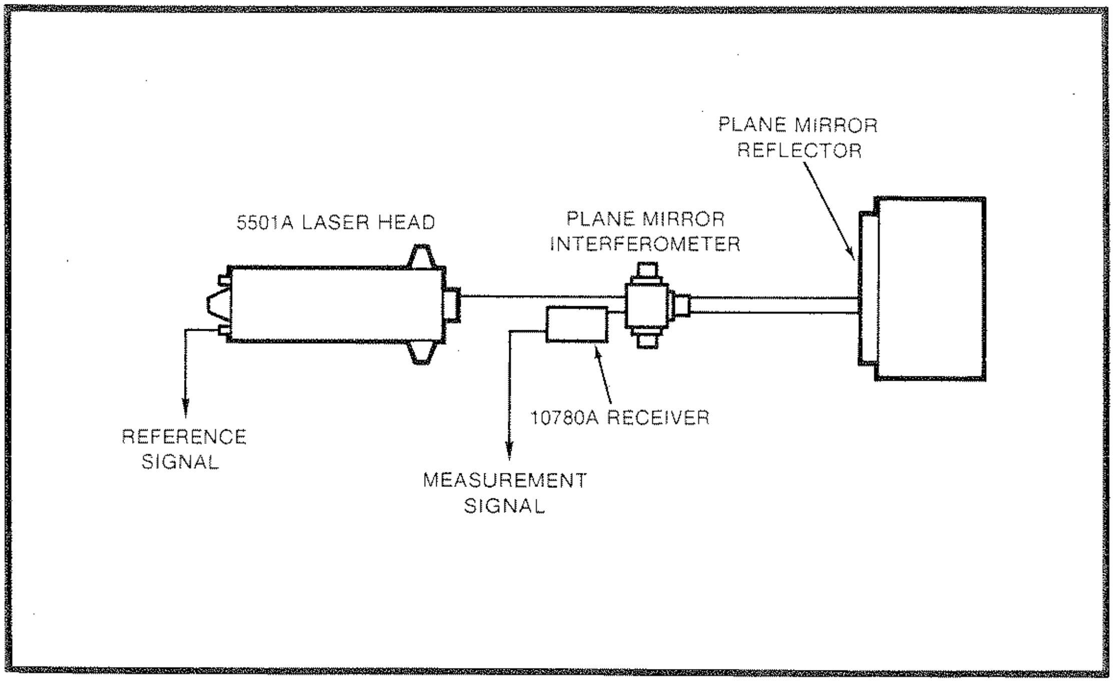


Figure 2-16b. Single Axis Measurements

2.17 10710A AND 10711A ADJUSTABLE MOUNTS (*Figure 2-17*). The 10710A and 10711A Adjustable Mounts provide a convenient means of mounting, aligning, and securely locking in position the optical accessories to the 5501A Laser Transducer System. Since both mounts allow approximately ±8° in the tilt adjustment and ±4° in the yaw adjustment, the need for custom fixturing is minimized on most installations. A unique feature of these mounts allows the component being adjusted to be rotated about its optical centerline providing simple, time-saving installations. The 10710A Adjustable Mount will accept the 10700A and 10701A Beam Splitters, the 10705A Single Beam Interferometer, and the 10707A Beam Bender. The 10711A Adjustable Mount will accept the 10702A Linear Interferometer and the 10706A Plane Mirror Interferometer. Mounting screws are provided to attach the optical components to the mount.

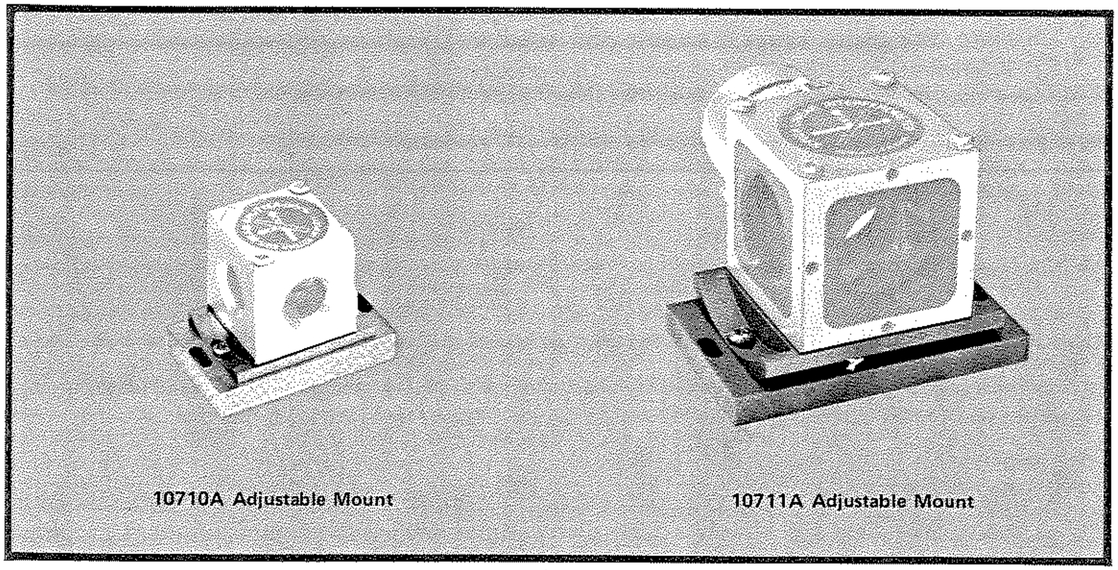


Figure 2-17. 10710A and 10711A Adjustable Mounts

The thickness of the 10711A mount is such that the beam centerline corresponds to the lower part of the 10701A or 10706A interferometers. To be in line with the center of the interferometer a spacer 6.4 mm (1/4 inch) thick has to be added to the laser head, or to be in line with the upper part, a 12.7 mm (1/2 inch) spacer is needed. Also remember as the beam goes through a beam splitter, the exit beam is slightly offset downward (or to the side if the beam is bent in the horizontal axis) by 0.8 mm (.03 inch). See *Figure 2-18.*

Both mounts are made of stainless steel 416. Its magnetic properties can be helpful at the design stage if magnetic clamps are used. However, in final installation, secure the mount with the provided screws.

2.18 SPECIFICATIONS OF INDIVIDUAL UNITS. The specifications for the individual units are contained in the following figures:

a. Splitting and Bending Optics (10700A, 10701A, and 10707A) Specifications, see *Figure 2-18.*
b. 10702A Linear Interferometer Specifications, see *Figure 2-19.*
c. 10703A Retroreflector Specifications, see *Figure 2-20.*
d. 10705A Single Beam Interferometer, see *Figure 2-21.*
e. 10704A Retroreflector Specifications, see *Figure 2-22.*
f. 10706A Plane Mirror Interferometer Specifications, see *Figure 2-23.*
g. 10710A and 10711A Adjustable Mounts Specifications, see *Figure 2-24.*

WEIGHT:
(All Models) 90 grams (3.2 ounces)
DIMENSIONS:
See dimensional drawings.

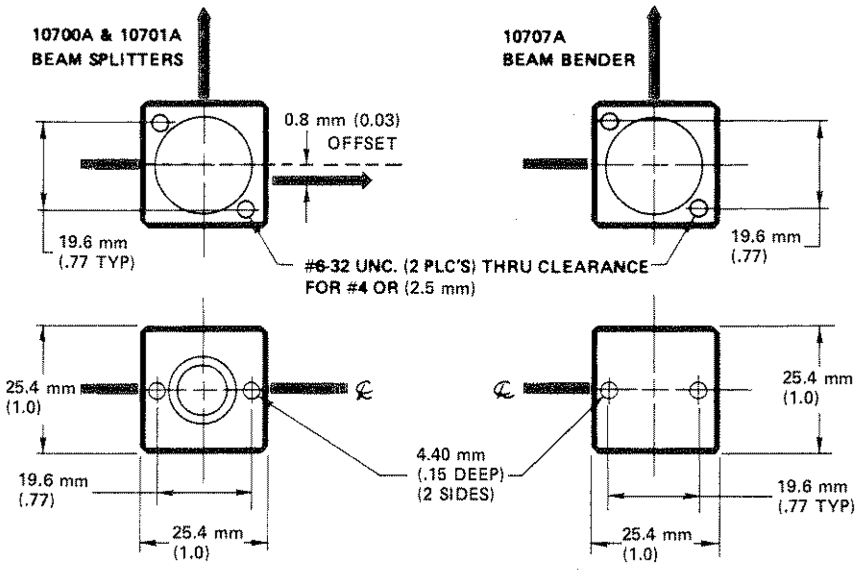


Figure 2-18. Splitting and Bending Optics (10700A, 10701A, and 10707A) Specifications

WEIGHT:

230 grams (8 ounces)

DIMENSIONS:

See dimensional drawing.

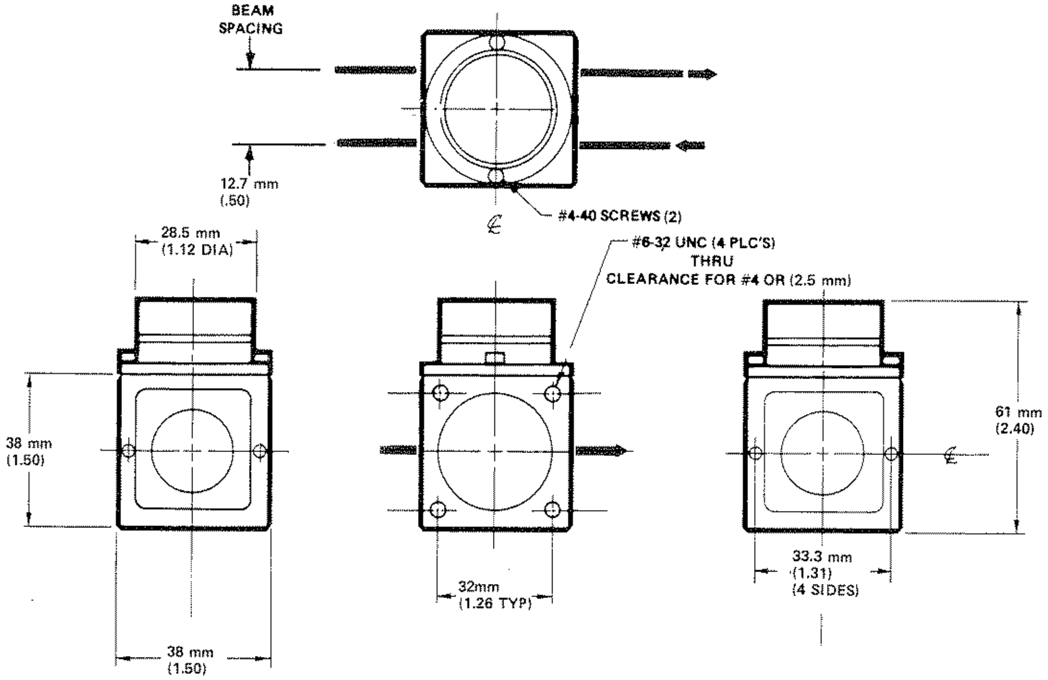


Figure 2–19. 10702A Linear Interferometer Specifications

WEIGHT:

45 grams (1.6 ounces)

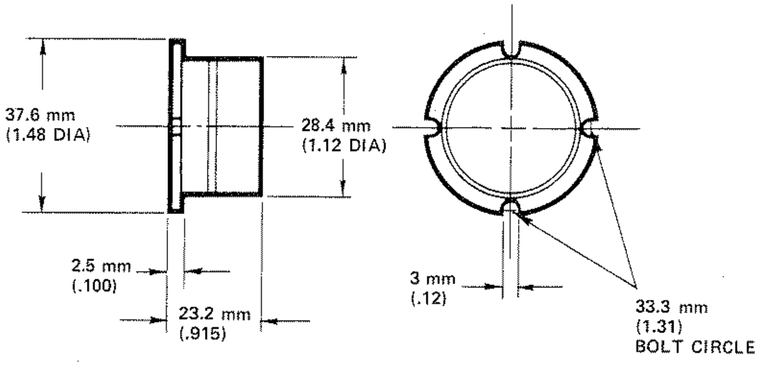


Figure 2–20. 10703A Retroreflector Specifications

WEIGHT:
90 grams (3.2 ounces)
DIMENSIONS:
See dimensional drawing.

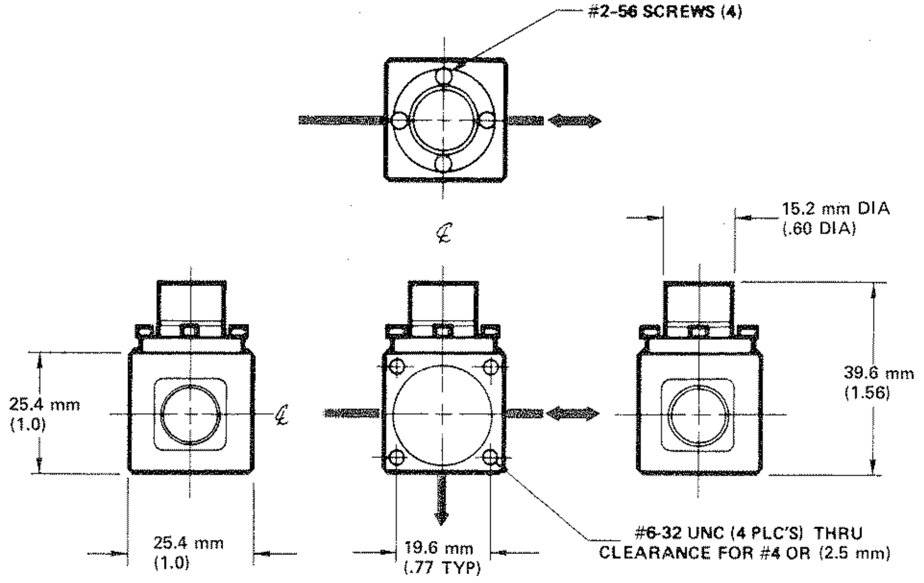


Figure 2-21. 10705A Single Beam Interferometer Specifications

WEIGHT:
23 grams (0.8 ounces)
DIMENSIONS:
See dimensional drawing.

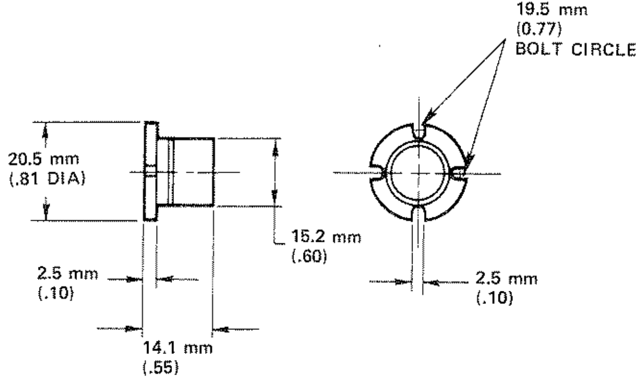


Figure 2-22. 10704A Retroreflector Specifications

WEIGHT:

11.2 ounces (316 grams)

DIMENSIONS:

See dimensional drawing.

REFLECTOR REQUIREMENTS:

Flatness: Must not deviate from a best-fit plane by more than 0.1 micrometre (3 microinches) over any 20 mm (0.8 inch) dimension.

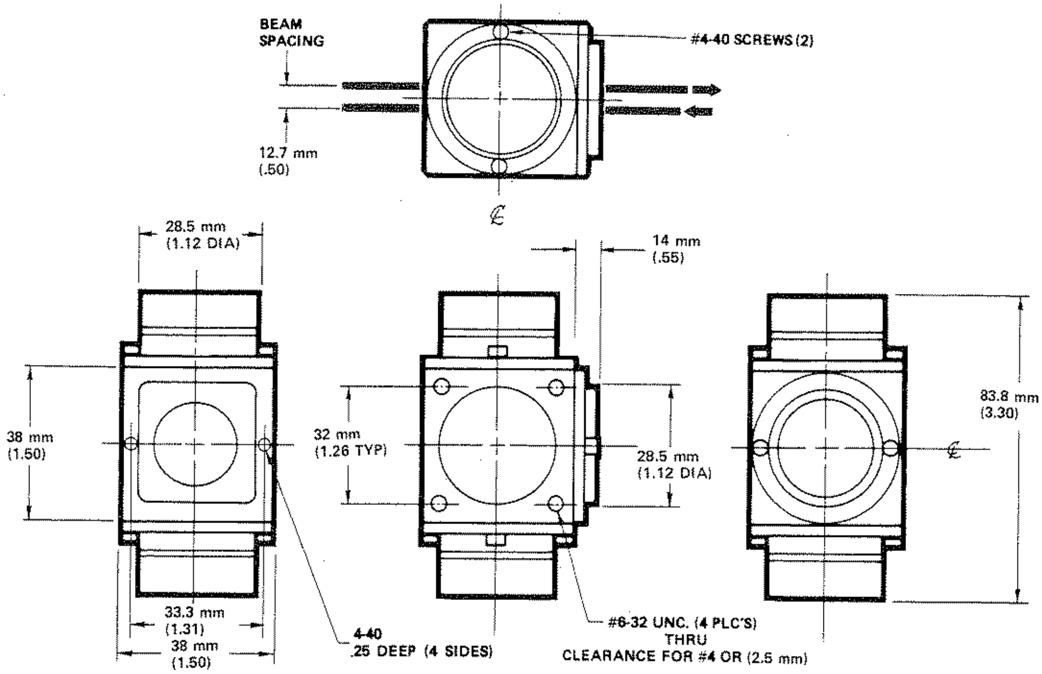
Surface Finish: Metal 0.1–0.3 microinch arithmetic average. Optical 80–40.

Maximum Angular Misalignment:

Depends on distance between interferometer and plane mirror. Typical values are:

±25 arc-minutes for 254 mm (10 inches)
±15 arc-minutes for 510 mm (20 inches)
±5 arc-minutes for 1270 mm (50 inches)

Reflectivity: 80% minimum recommended



NOTE

Plane mirror flatness will determine system accuracy for X-Y stage. For example if X axis mirror is out of flat by 20 microinches (0.5 micrometre) this will cause 20 microinch error in Y position.

Figure 2-23. 10706A Plane Mirror Interferometer Specifications

WEIGHT:

35 grams (1.2 ounces)

DIMENSIONS:

See dimensional drawing.

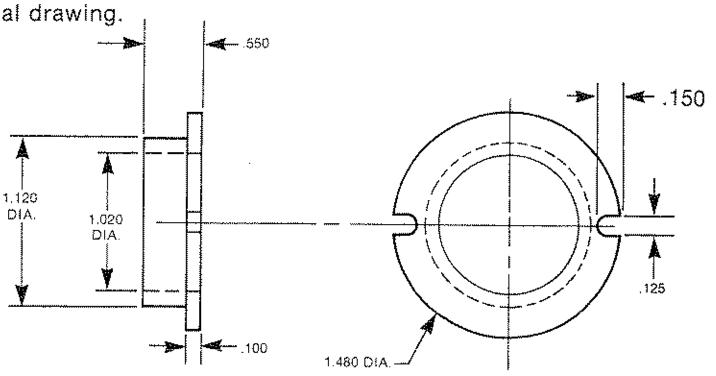


Figure 2-23a. Plane Mirror Converter Specifications

WEIGHT:

Model 10710A: 113 g (4 oz.)
Model 10711A: 198 g (7 oz.)

DIMENSIONS:

See dimensional drawings.

ADJUSTMENTS:

±8° Yaw
±4° Tilt

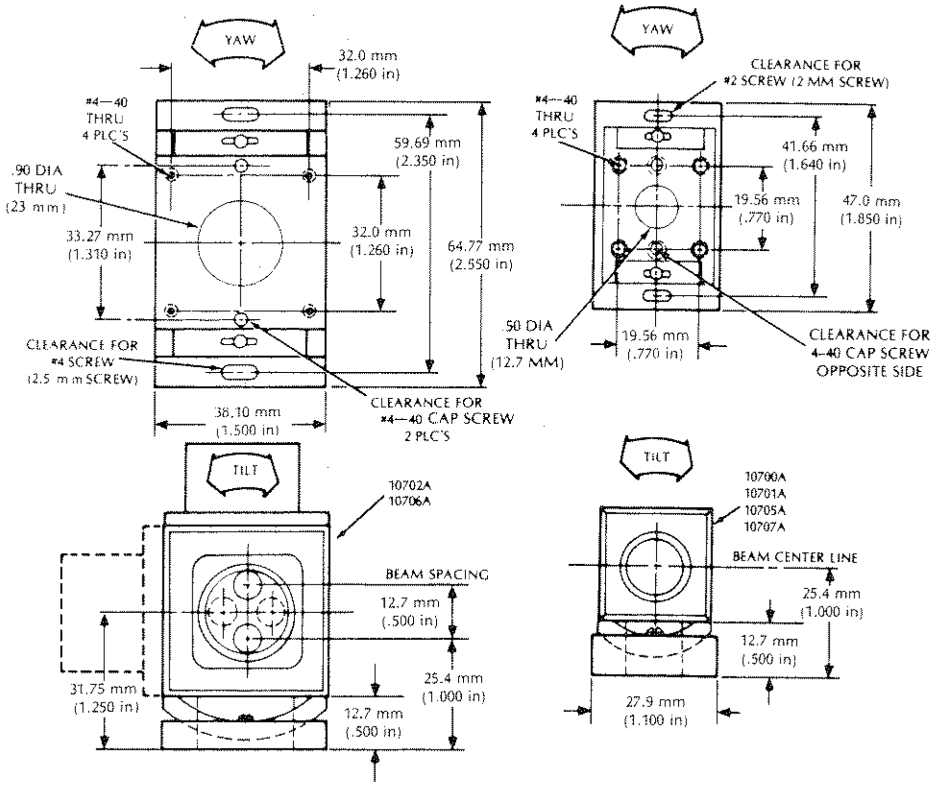


Figure 2-24. 10710A and 10711A Adjustable Mounts Specifications

2.19 Typical Mounting of Optics

The following figures show some methods of mounting the optics using the adjustable mounts:

a. *Figure 2-25* shows how to mount the splitting and bending optics or the single beam interferometer in the horizontal and vertical planes using the 10710A Adjustable Mount.

b. *Figure 2-26* shows how to mount the linear or the plane mirror interferometer in the horizontal plane using the 10711A Adjustable Mount.

c. *Figure 2-27* shows how to mount the linear or the plane mirror interferometer in the vertical plane using the 10711A Adjustable Mount.

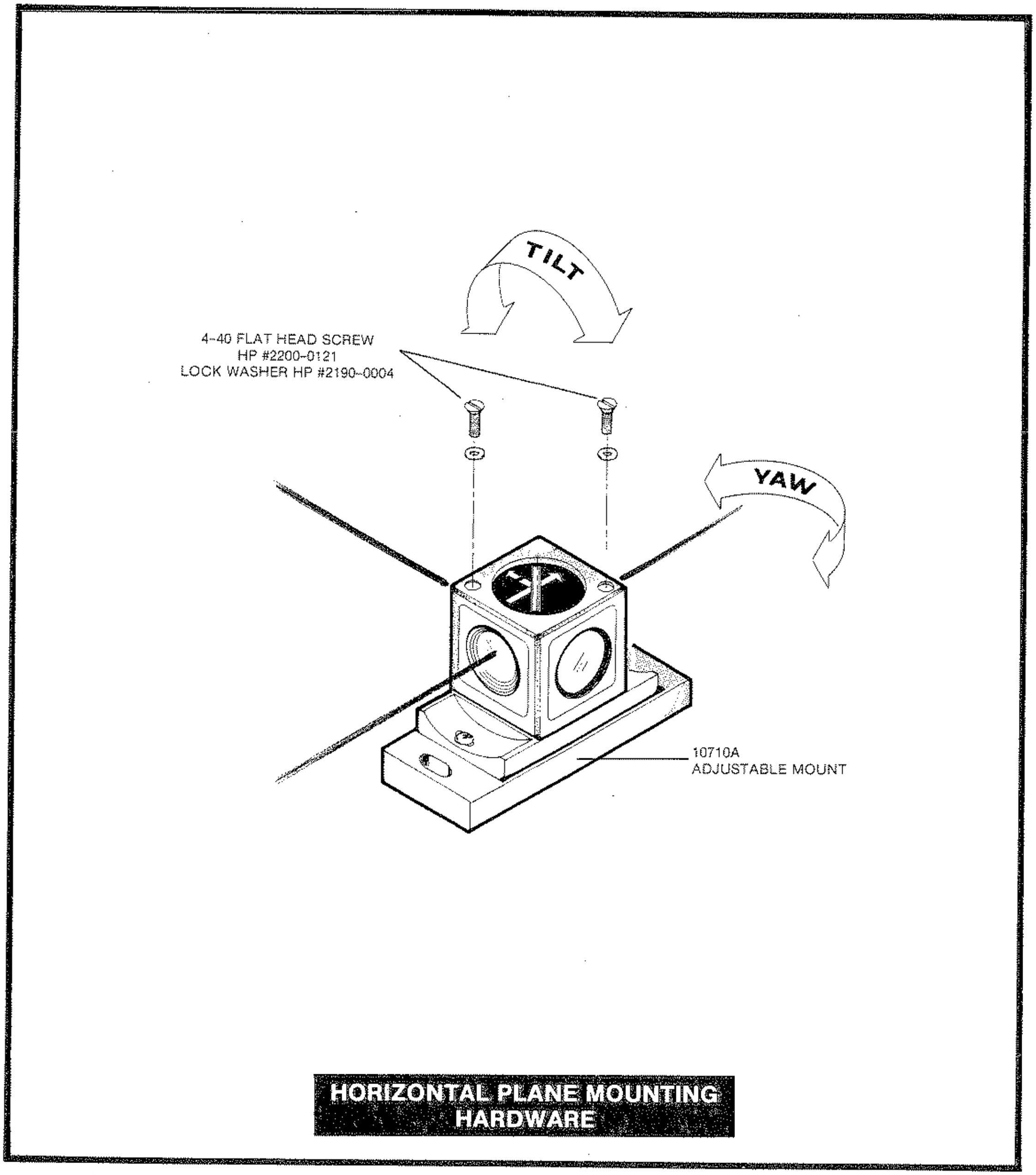
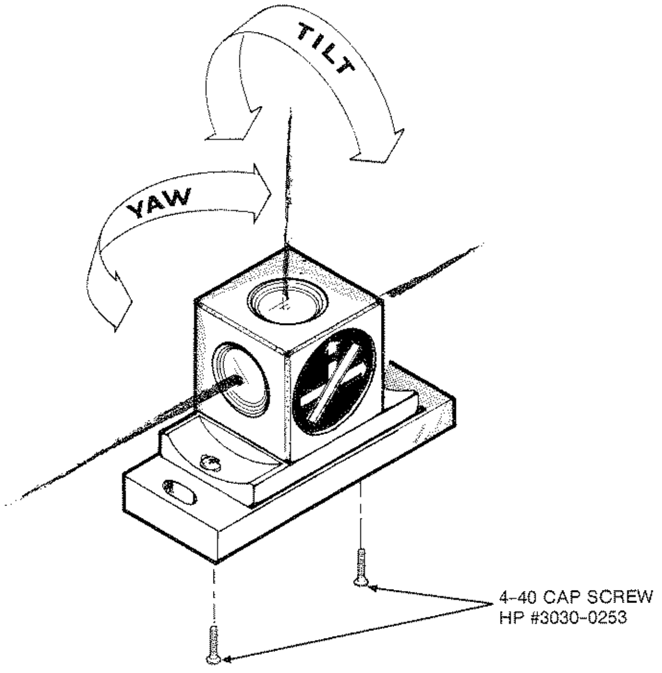
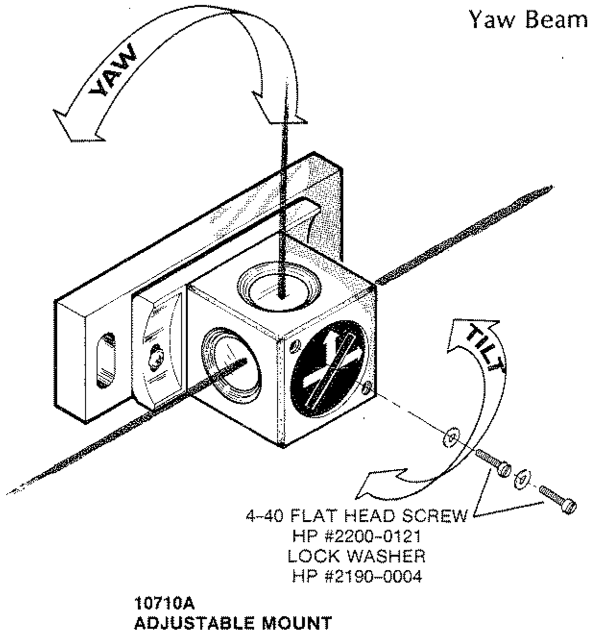


Figure 2-25. Horizontal and Vertical Plane Mounting Using the 10710A Adjustable Mount



NOTE

Yaw Beam Adjust Limited.



VERTICAL PLANE MOUNTING HARDWARE

Figure 2-25. Horizontal and Vertical Plane Mounting Using the 10710A Adjustable Mount (Cont'd)

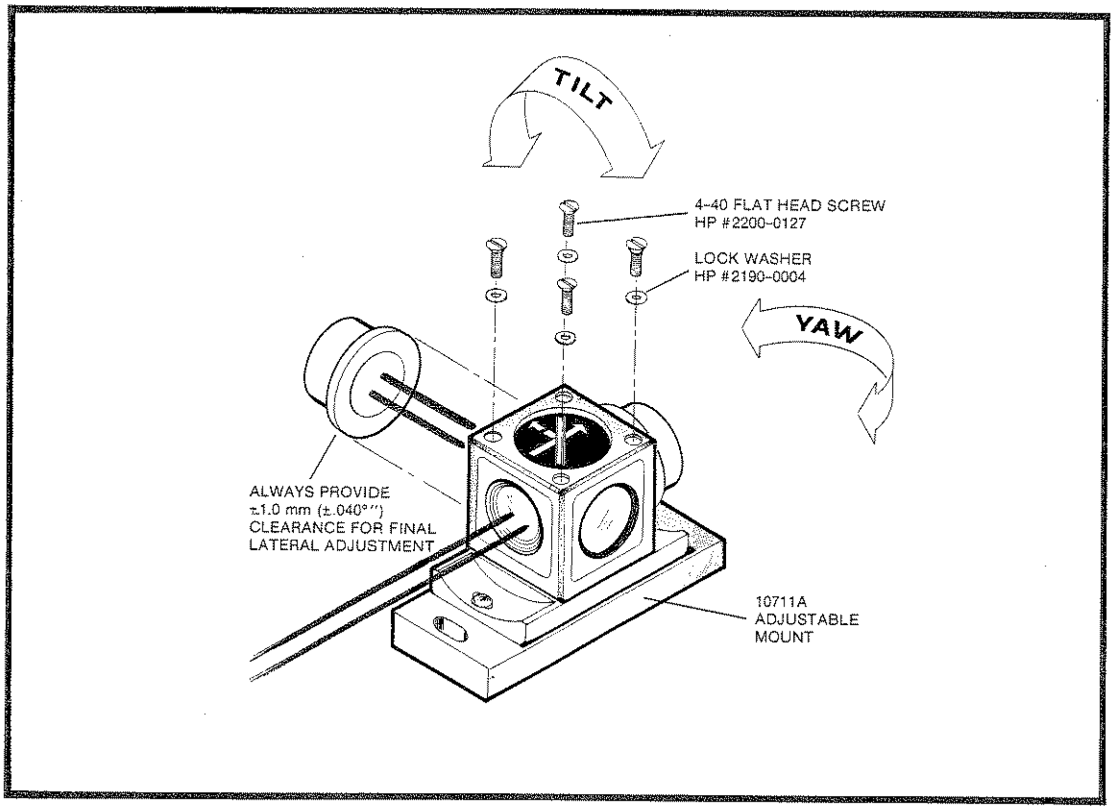


Figure 2-26. Horizontal Plane Mounting Using the 10711A Adjustable Mount

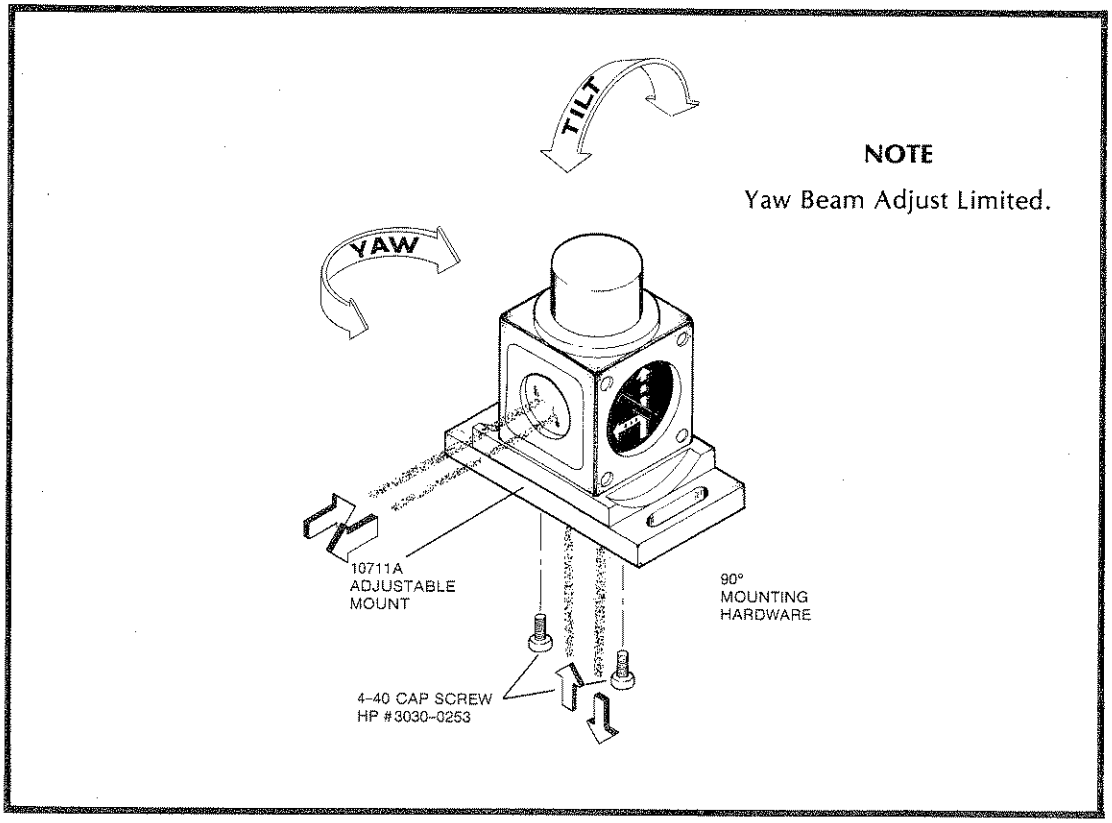


Figure 2-27. Vertical Plane Mounting Using the 10711A Adjustable Mount

2.20 10780A Receiver

Each axis of the Laser Transducer System has a receiver with a lens photodiode assembly in the front. It must be positioned so that the polarizing vectors of the laser beam are parallel or perpendicular to the line defined by the two mounting holes (within ±3°) as shown in *Figure 2-28.*

When mounting the receiver (see *Figure 2-28*) keep the following points in mind:

a. At a 45° position the signal will go to zero.

b. The receiver dissipates between 2 and 2.5 watts. Plastic pads keep an air gap around the receiver and also acts as thermal and electrical isolators.

c. Allow room for the cable to connect to the back connector of the receiver.

CAUTION

Use Nylon screw only (HP 2360-0369). The receiver housing must be electrically isolated from mounting fixture.

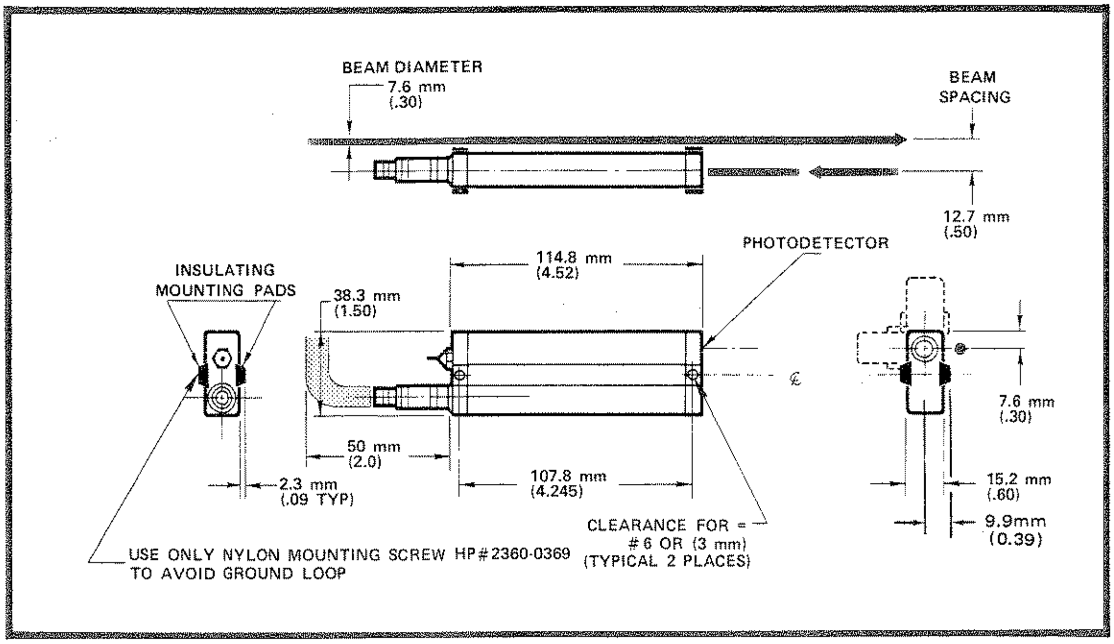


Figure 2-28. 10780A Receiver Dimensions

2.21 ACCURACY CONSIDERATIONS

To optimize the combined operation of the Laser Transducer System and the machine or measuring system on which it is mounted, it is necessary that you understand the factors that affect system accuracy. Only when all of these factors and their interrelationship is understood is it possible to predict the performance of a system. A summary of the major factors affecting accuracy are as follows:

a. Velocity of light compensation.
b. Deadpath error compensation.
c. Material temperature compensation.
d. Cosine error compensation.

2.22 Velocity of Light Compensation

The wavelength of the laser in a vacuum is known to better than 1 part per million. However, the wavelength in air is somewhat shorter than the vacuum wavelength because the velocity of light (VOL) in air is less than in a vacuum. In addition, the velocity of light in air is not constant but is a function of air composition, temperature, and barometric pressure. It is therefore necessary to accurately determine all of these factors in order to define the wavelength of the of the laser in air. Fortunately the composition of air is well known, and only the relative humidity needs to be measured in order to define air composition. Temperature and pressure, however, can also significantly affect the laser wavelength in air. As a general guide it can be stated that an error in wavelength of approximately one part per million is incurred for each error of 1°C in ambient temperature; 2.5 mm Hg. in absolute pressure, or 30% in relative humidity. For this reason the Laser Transducer System has provisions for determining barometric pressure, temperature, and relative humidity either via manual input (10756A Manual Compensator) or automatically using the 5510A Opt 010 Automatic Compensator.

Since the interferometer counts the number of wavelengths of motion traveled, the distance is calculated as follows:

❶ $$\text{distance} = (\text{wavelengths of motion}) \times \frac{\text{air wavelength}}{\text{vacuum wavelength}} \times (\text{vacuum wavelength})$$

Note that the air wavelength/vacuum wavelength ratio need not be known if the measurement is made in a vacuum rather than in air. Since the sole purpose of VOL compensation is to determine the air wavelength/vacuum wavelength ratio, obviously VOL compensation is not required for vacuum measurements and the previous relation reduces to:

❷ $$\text{distance (in vacuum)} = (\text{wavelengths of motion}) \times (\text{vacuum wavelength})$$

2.23 Deadpath Error Compensation

The previously defined relation ❶ is valid only if the air wavelength does not change during a measurement. If the air wavelength does change during a measurement, additional compensation must be made for deadpath error. In simple terms, deadpath error is an error introduced because of an uncompensated length of laser light between the interferometer and the retroreflector when the machine is at its 0 position as defined by the machine coordinate system. In *Figure 2-29*, the deadpath area of the laser measurement path is the distance between the interferometer and the 0 position of the machine (L_1). At this point the machine coordinate system indicates that the cube corner is at position L_2. Assuming there is no motion between the interferometer and retroreflector but environmental conditions surrounding the laser beam change, then the wavelength changes over the entire path (L_1+L_2). Since relation ❶ contains the term "wavelengths of motion" which involves only the distance L_2, it can make no correction for the wavelength change over L_1 and the interferometer causes a shift in the 0 position of the machine coordinate system. This is known as deadpath error and occurs whenever environmental conditions change during a measurement.

Deadpath error can be minimized in two ways:

a. By mechanically minimizing the distance L_1. This is done by mounting the interferometer as close to the retroreflector as possible when the machine is at 0 position as defined by its own coordinate system.

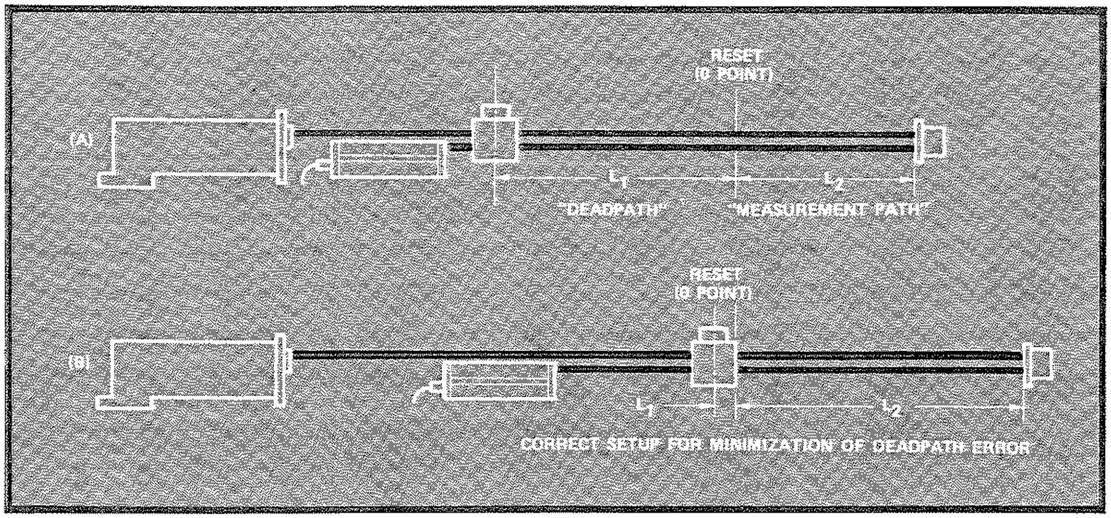


Figure 2-29. Deadpath Error Compensation

b. By correcting for the residual distance L_1 in software in the case of the Computer Interface Electronics and the Calculator Interface Electronics. Provisions are made for this correction in hardware in the English/Metric pulse output card. In this case relation ① is expanded to the more general relation:

③ $$\text{distance} = \left[(\text{wavelengths of deadpath} + \text{wavelengths of motion}) \times \frac{\text{air wavelength}}{\text{vacuum wavelength}} \times \text{vacuum wavelength}\right] - (\text{deadpath in inches or millimetres})$$

You must input the terms "wavelengths of deadpath" and "deadpath in inches or millimetres". These terms can be determined as follows:

$$\text{Quarter wavelengths of deadpath} = 1.61 \times 10^{5*} L_1 \text{ (if } L_1 \text{ is in inches)}$$

or

$$\text{Quarter wavelengths of deadpath} = 6.32 \times 10^{3*} L_1 \text{ (if } L_1 \text{ is in millimetres)}$$

$$\text{Deadpath in inches or millimetres} = L_1 \text{ in inches or millimetres}$$

The deadpath (L_1) need not be measured with high precision. The error in measuring L_1 simply shows up as an uncompensated deadpath (ΔL_1). For example, if the deadpath of a particular machine axis were 10.5 inches but was assumed to be 10 inches then this would result in 0.5 inches (the error in measuring L_1) of uncompensated deadpath. The resulting 0 shift that occurs if environmental conditions changed during a measurement would be:

$$0 \text{ shift} = \Delta L_1 \times \text{(change in air wavelength in parts per million)}$$

If atmospheric pressure changed by 0.1 in. Hg, this causes a 1 ppm change in laser wavelength and

$$0 \text{ shift} = 0.5 \text{ in.} \times 1 \text{ ppm} = 0.5 \times 10^{-6} \text{ in.}$$
$$(1 \text{ ppm} = 1 \times 10^{-6} \text{ in./in.} = 1 \times 10^{-6} \text{ mm/mm etc.})$$

The ability to correct for deadpath error in software does not eliminate the necessity of minimizing deadpath by proper location of the interferometer wherever possible. If the deadpath (L_1) is large compared to the distance traveled (L_2), then the predominant error is a 0 shift due to uncertainty in determining the change in air wavelength and this error cannot be eliminated in software.

2.24 Material Temperature Compensation

2.25 THERMAL EXPANSION OF THE PART. The previous section discussed compensation to eliminate errors due to a change in the laser wavelength. In addition, it is necessary to compensate for the expansion or contraction of the material of the part being machined or measured as the temperature changes. Strictly speaking, this problem is not related to the Laser Transducer System and occurs regardless of the position sensing transducer used on the machine. It is, however, of such prime importance that it must be understood by the user if he wishes to obtain optimum machine performance. *Figure 2-30* shows the relative effect of different errors.

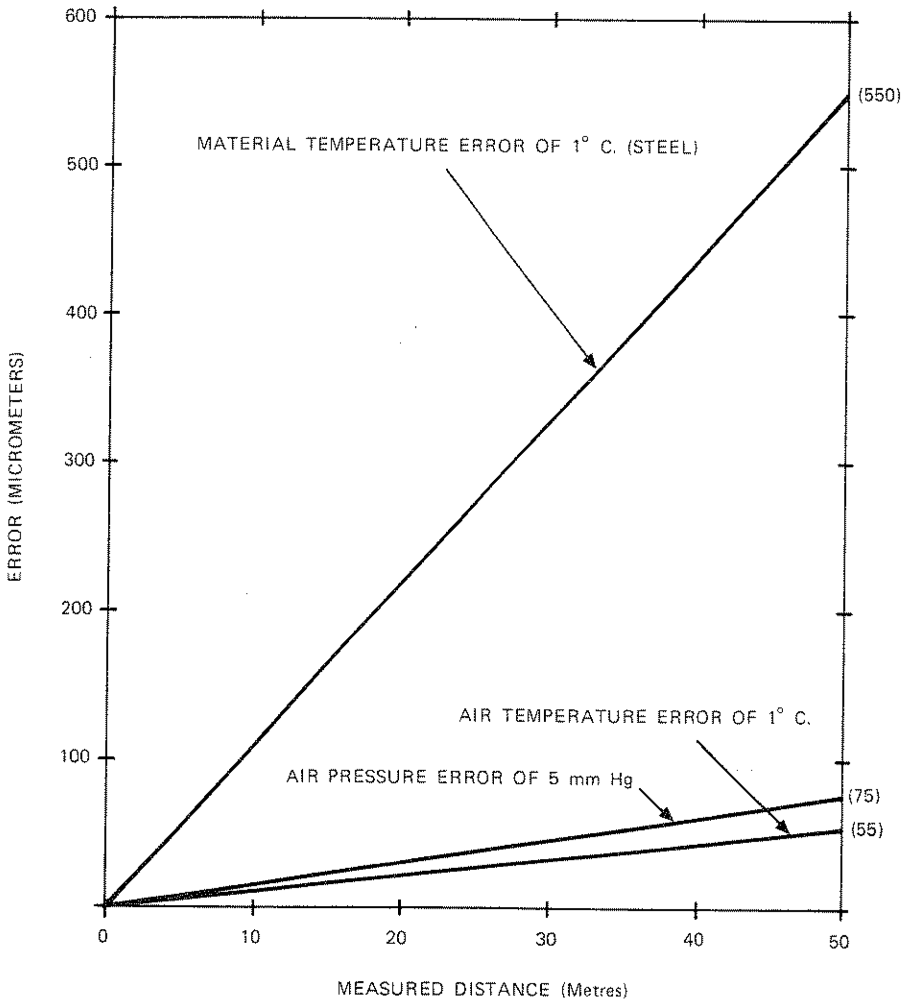


Figure 2-30. Relative Effect of Errors in Atmospheric and Material Temperature Factors

It is well known that the size of most physical objects changes with temperature. For this reason it was decided that physical length standards must always be measured or compared at a temperature of exactly 20°C (68°F). For example, a "1-inch" gage block is defined to be 1-inch long if (and only if) it is at 20°C. At any other temperature it will probably not be 1-inch long even though it is called a "1-inch" gage block. In addition, if three different "1-inch" gage blocks made of different materials are compared and found to be exactly the same length at 20°C they will not be the same length at any other temperature. For this reason the "true" size of a material object is commonly accepted as the size of the object at 20°C (68°F). In order to accurately machine or measure a part it is recommended that the part be at 20°C during the machining or measuring operation. If the path is not at 20°C its "true" size cannot be defined unless three things are known:

1. The temperature of the part.
2. The size of the part at that temperature.
3. The thermal coefficient of expansion of the part (refer to Appendix D).

The "true" (20°C) size of the part can then be determined using the following relation:

Let

L_O = the size of the part at 20°C (68°F)

L_T = the size of the part at Temperature T

ΔT = T - 20°C (68°F)

α = Coefficient of Expansion

then

④ $L_O = L_T (1 - \alpha \Delta T)$

This means that an additional compensation must be made for thermal expansion or contraction of the part whenever a laser-controlled machine is operated at a temperature other than 20°C (68°F). *Table 2-1* shows how to calculate the exact compensation factor, and *Table 2-2* shows how to calculate total compensation.

Table 2-1. Calculation of Exact Compensation Factor

A set of compensation factor charts is provided with the Laser Transducer System. However, the following formulas can be used to calculate the exact compensation factor to an accuracy of 0.1 ppm if desired:

T = Air Temperature	R = Relative Humidity in %
P = Air Pressure	C = Compensation thumbwheel setting, ppm (XXX.X)

$$C = \frac{10^{12}}{N + 10^{6}} - 999000$$

where N is given in English and Metric systems by:
English (T in degrees Fahrenheit, P in inches of mercury, R in %)

$$N = 9.74443P \times \left[\frac{1 + 10^{-6} P (26.7 - 0.187T)}{0.934915 + 0.0020388T}\right] - 1.089 \times 10^{-3} Re^{0.032015}$$

Metric (T in degrees Celsius, P in millimetres of mercury, R in %)

$$N = 0.3836391P \times \left[\frac{1 + 10^{-6} P (0.817 - 0.0133T)}{1 + 0.0036610T}\right] - 3.033 \times 10^{-3} Re^{0.057627}$$

Table 2-2. Calculation of Total Compensation

In each case C is then corrected for material temperature with:

$$\text{total } C = C - (TF - 68^{\circ}F) \times CEF.$$

or

$$\text{total } C = C - (TC - 20^{\circ}C) \times CEC.$$

where TF or TC = material temperature in °F or °C.
CEF or CEC = material coefficient of expansion in ppm/°F or ppm/°C.

2.26 OPERATION UNDER CHANGING TEMPERATURE CONDITIONS. It is very important to realize that material temperature compensation is completely accurate only under constant nonstandard conditions. Relation ④ can be used to compensate for thermal expansion of the part only if the part and the machine are at thermal equilibrium with their surroundings. Changing temperature can result in changing thermal gradients in both the machine and the part. In this case the primary machine errors are due to complex bending effects which distort machine geometry instead of simple thermal expansion. These effects are extremely difficult if not impossible to describe mathematically, and can certainly not be described by relation ④ . Bending effects can change the pitch, yaw, straightness, parallelism, and squareness of the machine slideways. The resulting errors are not a function of the positioning transducer used on the machine. Nor are they a function of material temperature. Therefore, if a machine is operated in a poor environment, its accuracy may be limited by its own geometry. In this case, the practical solution is to either improve the environment or make the machine less susceptible to environmental changes. There is no rule-of-thumb which can be used to estimate allowable temperature variation during a machining or measurement cycle to obtain a given tolerance. One can only predict that a given machine will be most accurate when operated in a constant temperature environment. If the machine environment is suspected to be poor it is best to run "drift tests" on the machine to determine environment affects on the machine tolerance.

2.27 WHERE TO SENSE MATERIAL TEMPERATURE. Even when a machine is operated at thermal equilibrium in a constant environment, different parts of the machine can be at different temperatures. In order to minimize errors, measure material temperature at a point as close to the workpiece as possible. For example, on a milling machine, if the workpiece is clamped to a table, measure the table temperature since the table is the closest available point to the workpiece. Since the table and the workpiece are in close contact, they will tend to come to the same temperature. Therefore, the table temperature will be indicative of the temperature of the workpiece. On turning machines this may not be possible since the workpiece is held in a rotating spindle. In cases like this, it is necessary to determine empirically which accessible machine member is the closest in temperature to the workpiece.

2.28 Cosine Error

Misalignment of the laser beam path to the axis of motion of the machine tool will result in an error between the measured distance and the actual distance traveled. This is referred to as cosine error because the magnitude of the error is proportional to the cosine of the angle of misalignment.

Cosine error can be visualized as shown in *Figure 2-31*. The laser beam consists of a number of plane-parallel, equally-spaced wavefronts. The separation between wavefronts is the laser wavelength which is approximately 25 microinches or 0.633 microns. Since the beam diameter is quite large compared to the wavelength, it has been shown large in *Figure 2-31*.

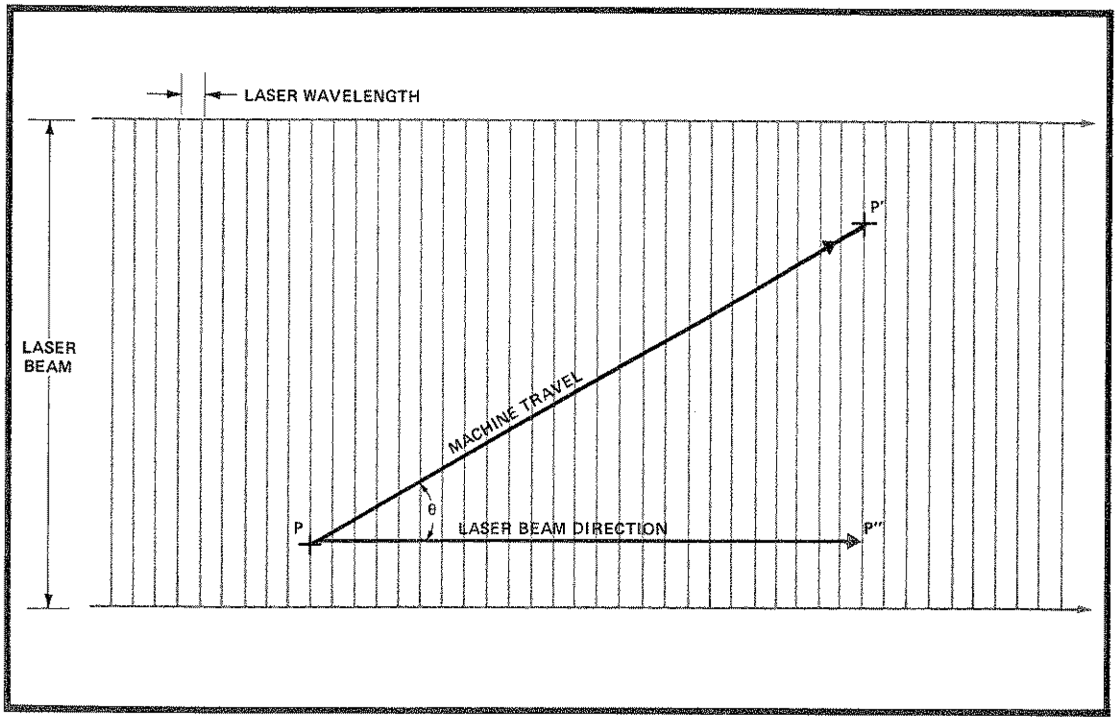


Figure 2-31. Cosine Error

These wavefronts can be thought of as lines on a conventional scale. As a point on the machine travels along the laser beam, the interferometer counts the number of wavefronts intercepted by the point during its travel. If the point travels along the path P-P′ as shown, the interferometer counts the number of wavefronts intercepted and measures the distance P-P″. In other words the interferometer measures the component of motion in the direction of the laser beam. Since

$$P\text{-}P'' = P\text{-}P' \cos\theta$$

(where θ = angle of misalignment between laser beam and machine axis of motion)

The error in parts per million would be:

$$\text{error} = (1 - \cos\theta) \times 10^6$$

It is obvious from *Figure 2-31* that the measured P-P″ is shorter than the actual distance traveled P-P′. Note that cosine error always causes the interferometer to read short of the actual distance traveled. *Table 2-3* shows some typical cosine errors for the angle θ.

Table 2-3. Angle θ Versus Cosine Error

θ		COSINE ERROR
(deg)	(rad)	
.001	1.7×10^{-5}	1.52×10^{-10}
.01	1.7×10^{-4}	1.52×10^{-8}
.08	1.4×10^{-3}	1.00×10^{-6}
.1	1.7×10^{-3}	1.52×10^{-6}
1	1.7×10^{-2}	1.52×10^{-4}

2.29 SYSTEM INSTALLATION

2.30 Multiple Measurement Axes

As previously discussed, the Laser Transducer System can measure up to six independent axes of displacement using one 5501A Laser Transducer head. When installing the laser head on a machine of any type, one of the prime considerations is how to direct the laser beam to the point on the machine where the measurement actually takes place. By using the proper combination of beam splitters, beam benders, and interferometers, the measurement axes can be established with a minimum number of components. The following figures illustrate several examples of how the laser beam can be routed for multiaxis measurement configurations.

In *Figure 2-32* a three-axis measurement configuration is shown with all components aligned in one plane. Note that any of the components (beam benders, beam splitters, or interferometers) could be rotated in increments of 90° to provide a three-dimensional configuration. Since the interferometers can also bend the laser beam through 90°, the number of components used can be minimized. A four-axis measurement configuration is shown in *Figure 2-33*. Again, any of the components can be rotated in 90° increments to direct the measurement axes into or out of the page.

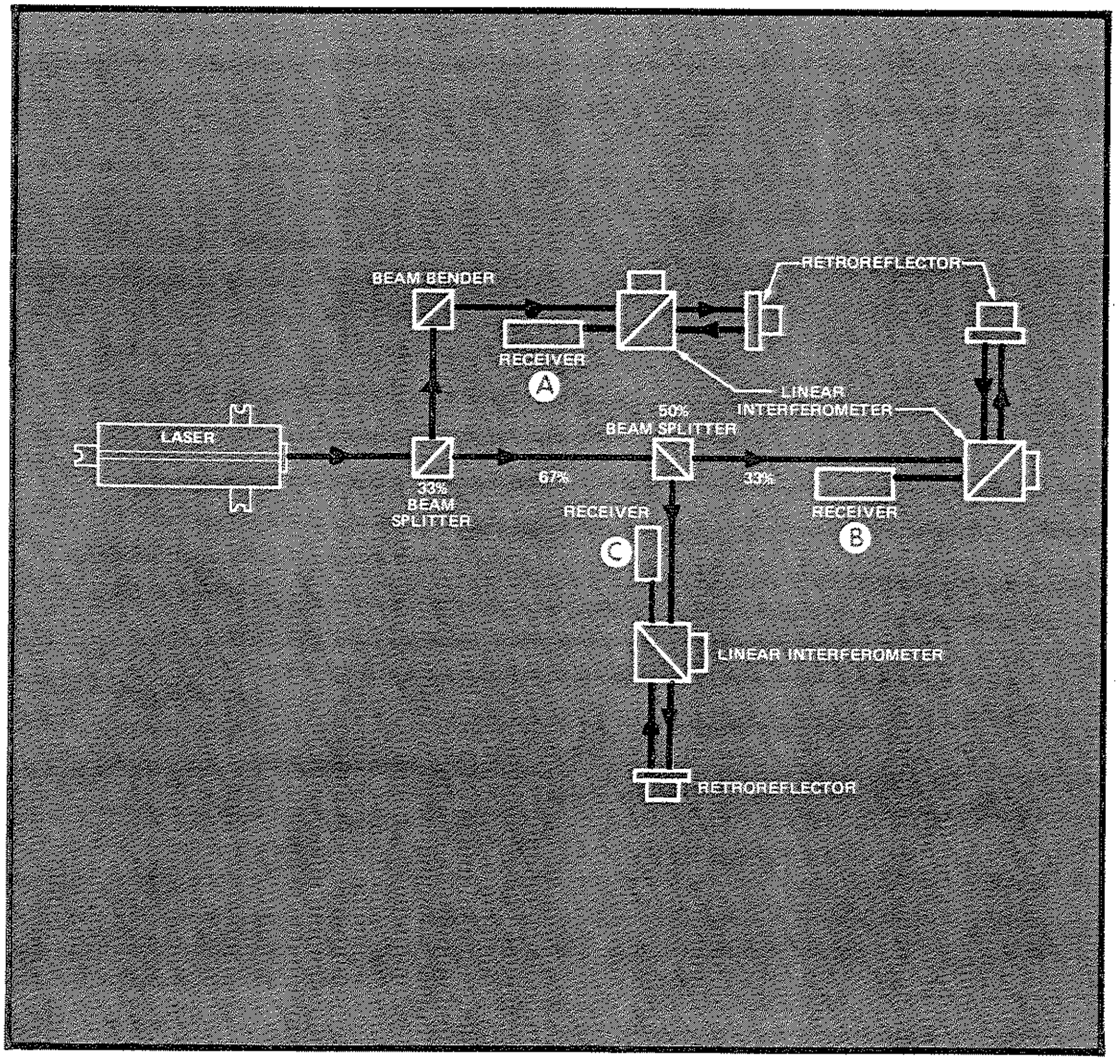


Figure 2-32. Three-Axis Configuration

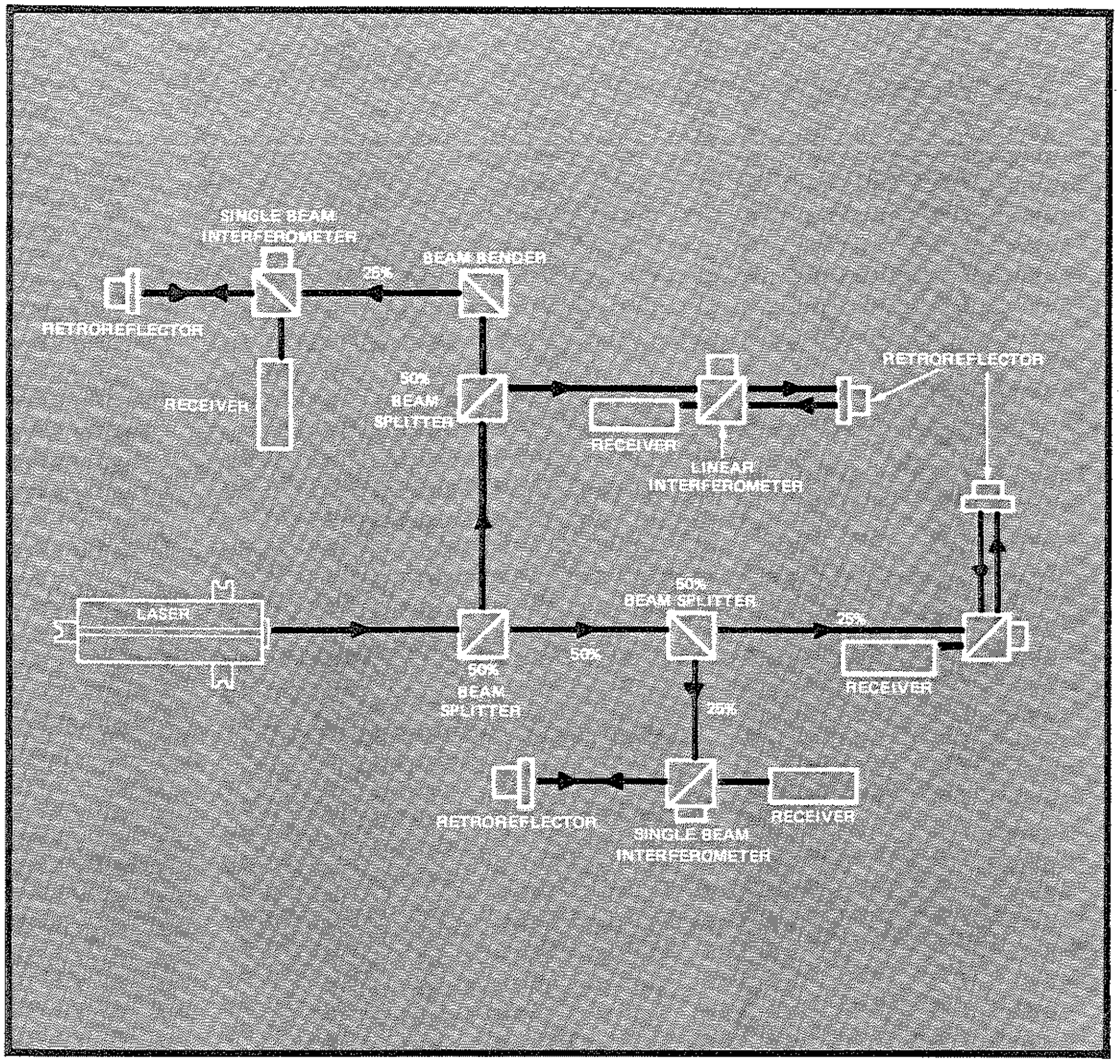


Figure 2-33. Four-Axis Configuration

NOTE

In a measurement application where the 10702A Linear Interferometer is the moving component and the 10703A Retroreflector is the fixed reference, the 10702A Linear Interferometer must have the Option 001 Windows to eliminate alignment errors. When using the 10705A Single Beam Interferoment along with the 10704A Retroreflector, the interferometer must be the fixed component with **only the retroreflector allowed to move**. For a detailed explanation, see *Figure 2-11*. If a right angle beam bend is made through the 10702A or 10705A Interferometers, the above does not apply.

In *Figure 2-34*, an X-Y stage measurement configuration utilizing the 10706A Plane Mirror Interferometer is illustrated. The X-Y stage has plane mirrors mounted at 90° to each other on the upper portion of the stage which serve as the retroreflectors for the plane mirror interferometer. The advantages of this configuration are discussed later in this section. The 10706A Plane Mirror Interferometer is used to bend the laser beam to the correct orientation.

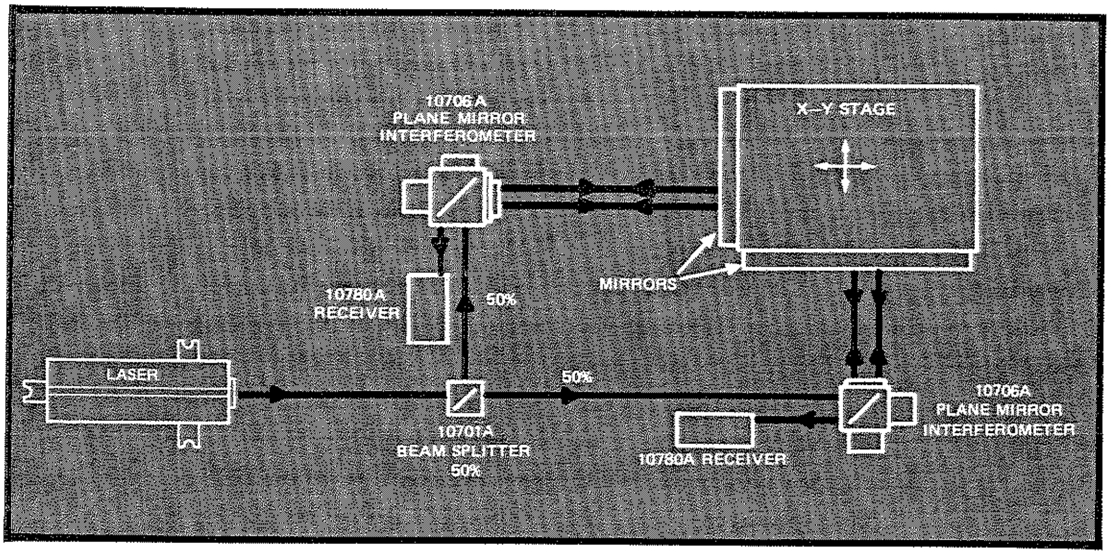


Figure 2-34. Two-Axis Plane Mirror Interferometer Configuration

In applications where the X-Y stage is installed in a vacuum chamber, the configuration in *Figure 2-34* may not be suitable. *Figure 2-35* shows a configuration where the laser beam can enter and exit the vacuum chamber through one window. This allows the receivers to remain outside the chamber and leaves only the optics inside. For window specifications, refer to the paragraph on General Considerations for Mounting Optics.

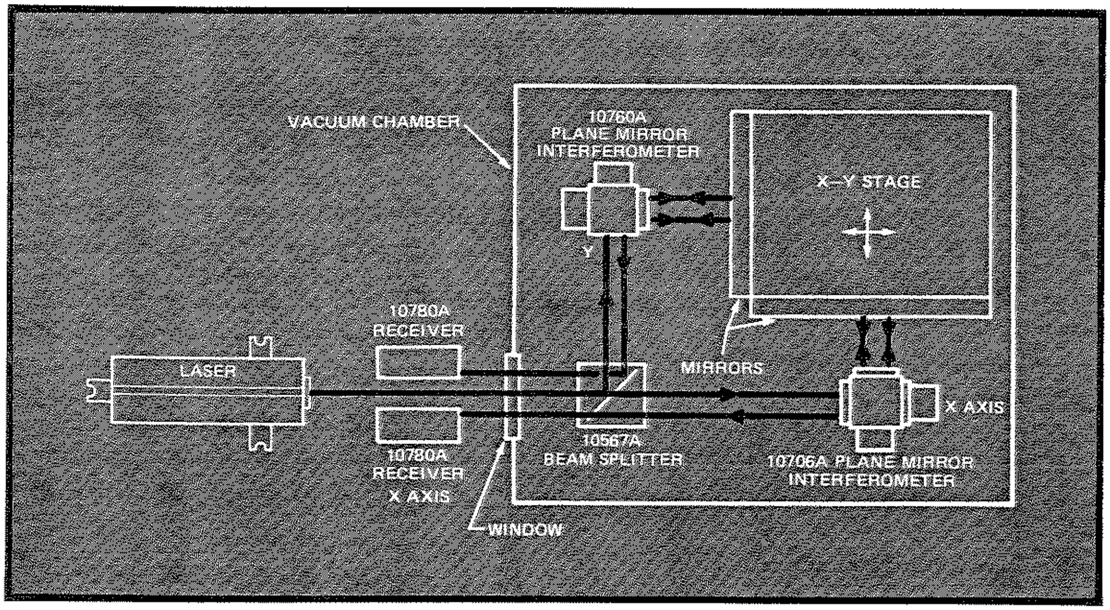


Figure 2-35. X-Y Stage Installed in a Vacuum Chamber

The configurations depicted above show typical multiaxis measurement applications and assume near equal length measurement paths. When dealing with unequal length measurement paths, consideration must be given to balancing the amount of light in each measurement leg. *Figure 2-36* shows a measurement configuration in which the distance BD is approximately three times the distance BC. In this case, it is better to use a 33% Beam Splitter than a 50% Beam Splitter even though the system is a two-axis configuration.

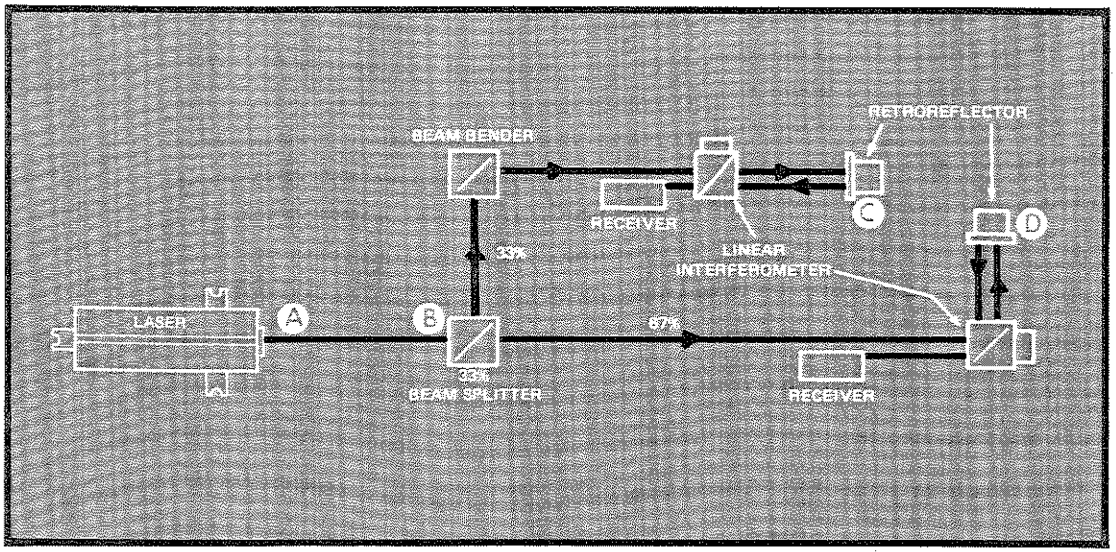


Figure 2-36. Two-Axis Measurement System with Unequal Measurement Paths

2.31 Beam Path Loss Computation

In general, multiaxis systems must be designed with sufficient safety margin in the power received by the 10780A Receiver. Computation of beam path loss is straightforward. The minimum output power of the laser head is 120 microwatts; most exceed this figure. The output power is relatively constant over the usable life of the tube and tends to drop off slightly toward the end. The minimum necessary power at the receiver is four microwatts. For a three-axis system, the power safety margin is 40 μW ÷ 4 μW or 10:1 on each axis.

Relating this to system configuration, the following considerations are important. Thirty-three percent Beam Splitters are not actually 33% but more on the order of 33% ±5%. The 10700 Series Beam Benders with dielectric coatings reflect 99% of the light. Some other beam benders (not supplied by HP) are only 80–95% reflective, and using more than one causes the losses to multiply. Cube-corners are typically 80% to 90% reflective. Dirt on the optics reduces the amount of light at the receiver. Poor alignment of the optics or the receiver reduces the amount of light detected by the receiver photodiode. This specifically includes misalignment of the optics causing the position of the beam at the receiver to wander as the object being measured runs down its travel. Fluctuations of the refractive index of air in the path of the interfering beams (which can be caused by local temperature differences) cause the laser beam to lose some of its coherence and could even break it for an instant. This is detected by the electronics which causes an error signal to be generated. The smaller the received signal safety margin, the more likely the fluctuations are to break the beam. Techniques of protecting the laser beam to minimize these fluctuations are discussed later in this section.

One thing that must be kept in mind when calculating the path loss in an axis of the laser is that the optics split the two frequency components of the laser beam into two separate paths for each axis and the losses are normally computed separately for each of the two components. Since the laser beam is detected by a mixing process and the result is proportional to the product of the powers of the two frequencies, the loss bookkeeping can be handled by calculating a transmission factor for each path. The overall transmission factor is then the product of all the individual transmission factors. The transmission factors refer to **usable signal** transmitted and **not** to light intensity.

The minimum power at the receiver must be four microwatts, and the guaranteed minimum power out of the laser is 120 microwatts, so the minimum allowable transmission factor is $(4/120)^2 = 0.0011$. Some typical transmission factors for transducer optical modules are as follows (these are worst-case numbers, which must be used for loss computation):

10700A	33% Beam Splitter 33% Side	0.08
10700A	33% Beam Splitter 67% Side	0.38
10701A	50% Beam Splitter each Side	0.19
10702A	Linear Interferometer†	1.00
10703A	Retroreflector	0.80
10704A	Retroreflector	0.80
10705A	Single-Beam Interferometer†	0.85
10707A	Beam Bender	1.00
10706A	Plane Mirror Interferometer*	0.54
10567A	Beam Splitter	0.19
10722A	Plane Mirror Converter	0.85

†This refers to the beam splitter only. The attached retroreflectors must be considered as a separate component (see example below).

*The plane mirror interferometer is listed as 10706A. This, however, consists of a 10581A, 10702A†, and two 10703A's. The transmission factor for this device would therefore be (1.00) × (0.80) × (0.80) × (0.85) = 0.54.

As an example, consider a typical installation with three axes (see *Figure 2-32*). Assume linear interferometers on each axis, good optical alignment, and comparable path lengths. Assume that the three axes have the following components:

Axis A: 10700A (33%), 10707A, 10702A, 10703A (2)
Axis B: 10700A (67%), 10701A, 10702A, 10703A (2)
Axis C: 10700A (67%), 10701A, 10702A, 10703A (2)

The transmission factors are, for each axis:

Axis A: $(0.08) \times (1.00) \times (1.00) \times (0.80) \times (0.80) = 0.0512$
Axis B: $(0.38) \times (0.19) \times (1.00) \times (0.80) \times (0.80) = 0.0462$
Axis C: $(0.38) \times (0.19) \times (1.00) \times (0.80) \times (0.80) = 0.0462$

Here, B and C are worst-case (net product is smallest) but still have a transmission factor 42 times greater than 0.0011. Therefore, these axes can operate with an additional transmission factor caused by dirt, misalignment, etc., of up to 1/42 = 0.024. (Note that the worst-case numbers for the beam splitters take into account the power division along each measurement axis.)

2.32 Installation Examples

The following examples illustrate the installation of a 5501A Laser Transducer System on a three-axis machine tool (*Figure 2-37*) and a three-axis measuring machine (*Figure 2-38*).

The three-axis machine tool installation (*Figure 2-37*) includes the 10702A Linear Interferometer and the 10703A Retroreflector. These measurement components were chosen because they are the least expensive and meet all measurement requirements.

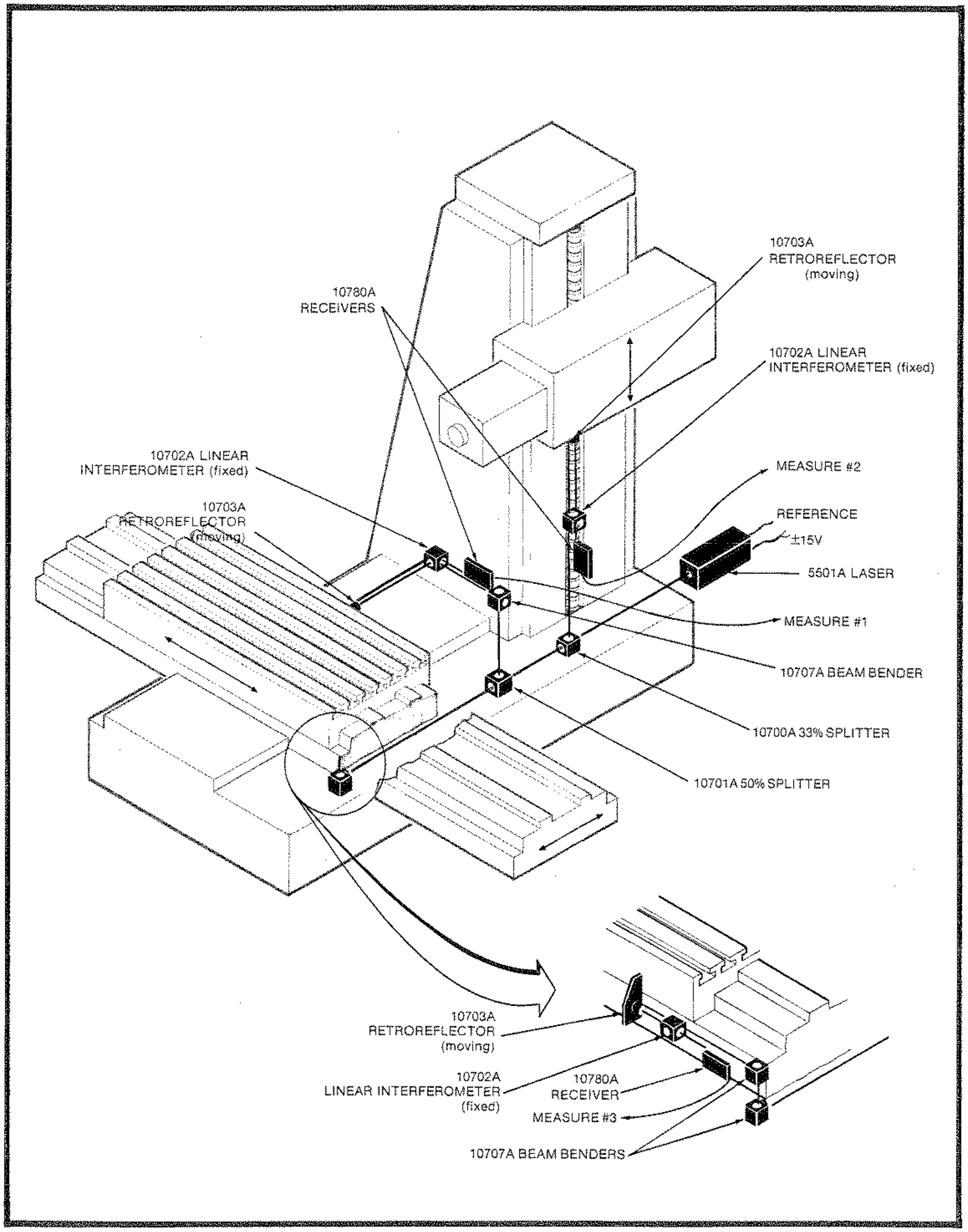


Figure 2-37. Three-Axis Machine Tool Installation

The three-axis measuring machine installation (*Figure 2-38*) includes the 10705A Single Beam Interferometer and the 10704A Retroreflector. These measurement components were chosen to eliminate any loss of travel because of limited space considerations. It was determined that the optimum installation position for the 5501A Laser Transducer head was at the top of the machine to minimize the optical path lengths.

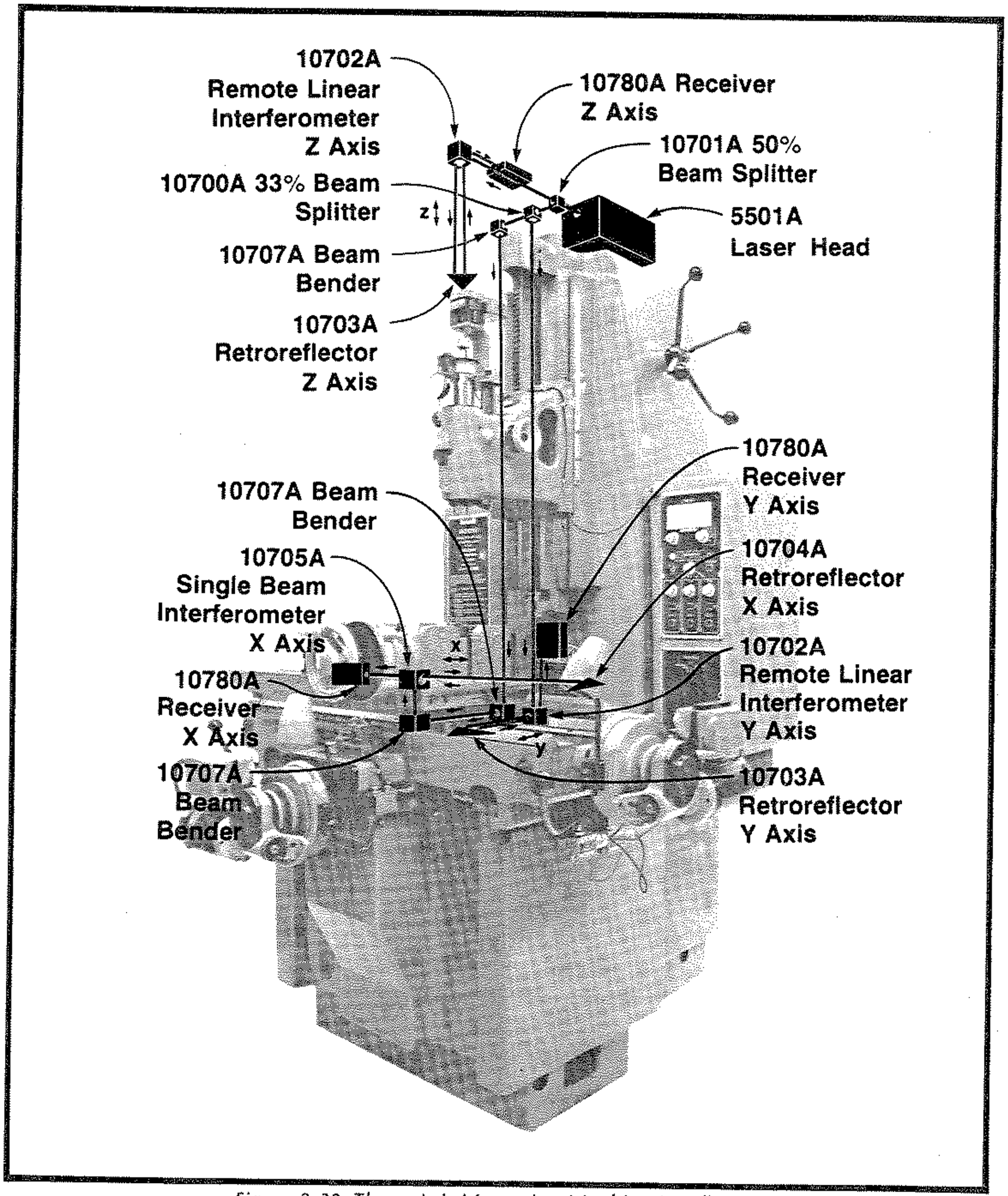


Figure 2-38. Three-Axis Measuring Machine Installation

Figure 2-39 shows the laser head installed on the top of the measuring machine on a single mounting plate (this approach simplifies and speeds the alignment procedure). The portion of the laser beam reflected by the first beam splitter is sent to a second beam splitter. The laser beam is again split into two portions. One portion is directed to the Y-optics and the other (using a beam bender) is directed to the X-optics.

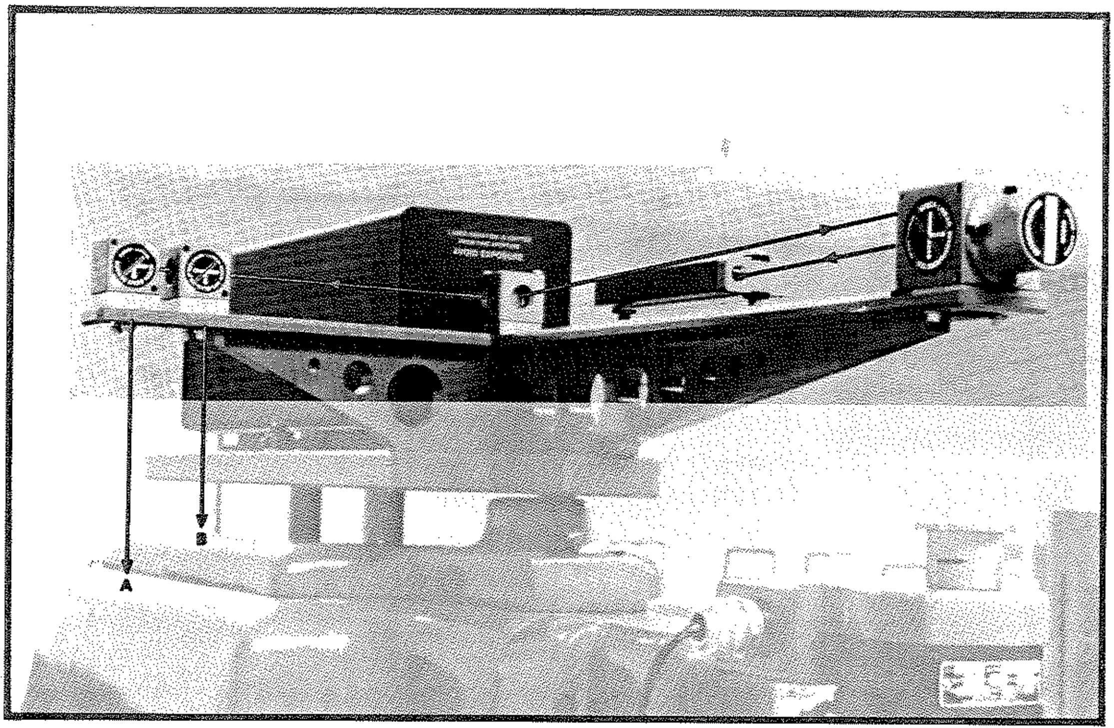


Figure 2-39. Laser Head Installation

In *Figure 2-40* one of the two parallel light beams reflected from above enters the fixed Y-axis linear interferometer. There the measurement beam is deflected 90° to the moving Y-axis retroreflector (shown in *Figure 2-41*) attached to the Y-axis machine slide. The other laser beam reflected from above enters a beam bender next to the interferometer where it is deflected to the X-axis measurement optics.

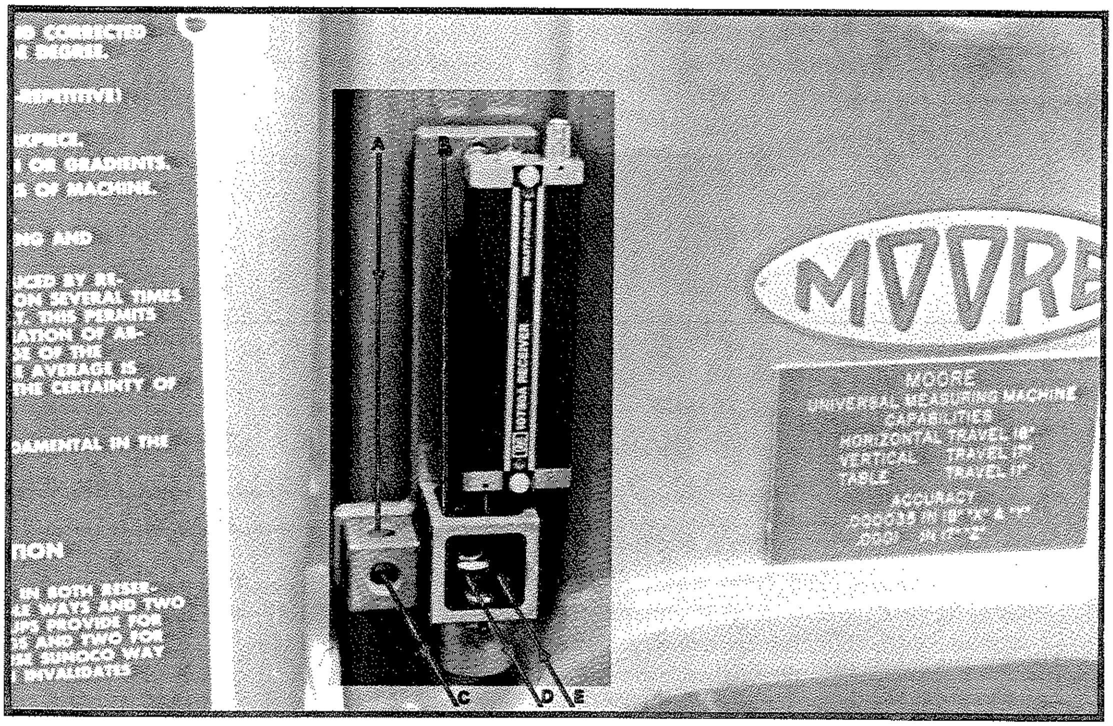


Figure 2-40. Y-Axis Installation

Figure 2-41 shows the Y-axis retroreflector and the X-axis measurement optics. All of the optics are mounted on a common bracket which is attached to the Y-axis. The laser beam reflected from the beam bender in *Figure 2-40* enters the beam bender shown below the single beam interferometer and is reflected vertically into the single beam interferometer. The measurement beam is then reflected horizontally along the X-axis to a retroreflector attached to the X-axis machine slide (not shown). Note the position of the X-axis receiver which is unique to the single beam interferometer.

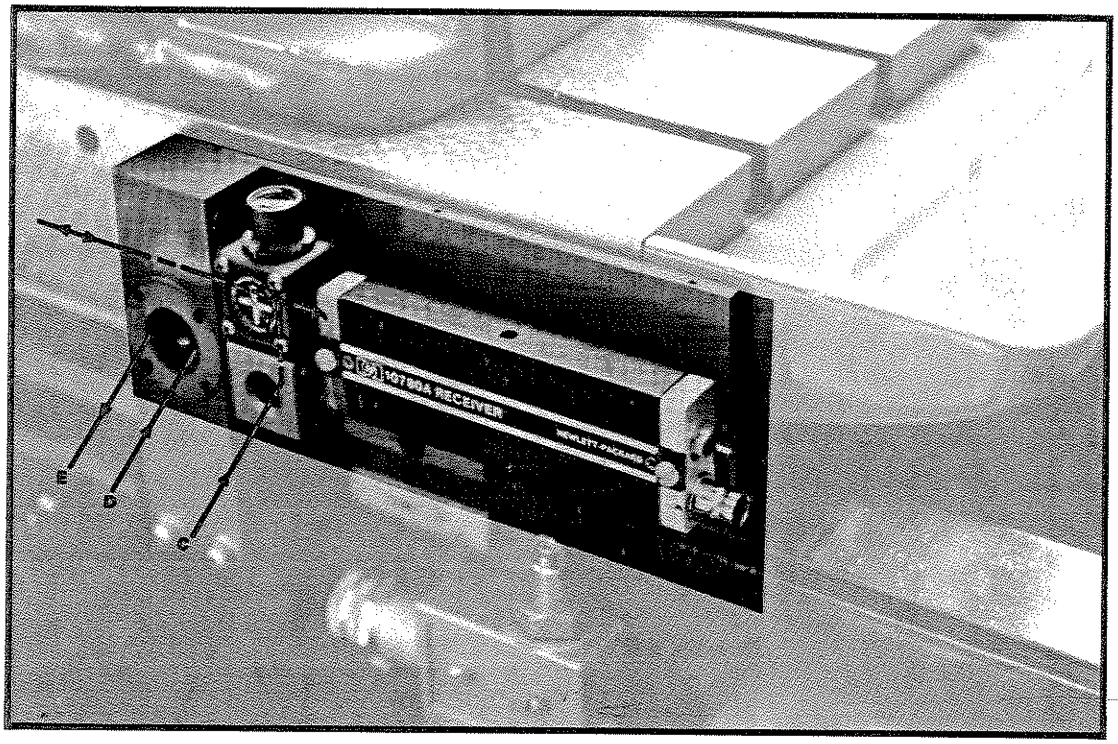


Figure 2-41. X-Axis Installation

2.33 MECHANICAL INSTALLATION CONSIDERATIONS

2.34 General

When determining how to install the Laser Transducer on a specific machine, a number of factors must be considered in addition to the method of dividing the laser beam into the appropriate number of measurement axis. Some of the more important points to consider are:

a. Selecting the measurement paths to minimize Abbe error.

b. Installing the interferometer and retroreflector to minimize deadpath errors.

c. Avoiding extreme thermal gradients near the measurement path which could disrupt the measurement or cause errors.

d. Providing protection for the laser beam where cutting fluid, chips, or air turbulance could interfere with the measurement.

In many cases it may not be possible to completely eliminate these sources of error but every effort should be made to minimize them. The following paragraphs discuss methods of installing the Laser Transducer System that maximize accuracy and measurement reliability.

2.35 Abbe Error

A very important advantage of the Laser Transducer System is that the Abbe error evident in almost all positioning systems is very easily reduced. Abbe error occurs when a displacement measurement is taken at a location which is offset from the displacement to be measured and the slideways which provide the displacement exhibit angular motion.

In *Figure 2-42A*, the measurement axis is coincident with the leadscrew centerline and is measuring a displacement of the carriage at the leadscrew. This figure illustrates the displacement error E which is generated at the tool tip due to angular motion θ of the carriage. *Figure 2-42B* shows the same carriage motion as *Figure 2-42A* but with the measurement axis coincident with the tool path. In this case the measurement system measures the actual displacement and there is no Abbe offset error. This is a general description of Abbe error and illustrates the requirement for minimizing angular error and placement of the measurement path.

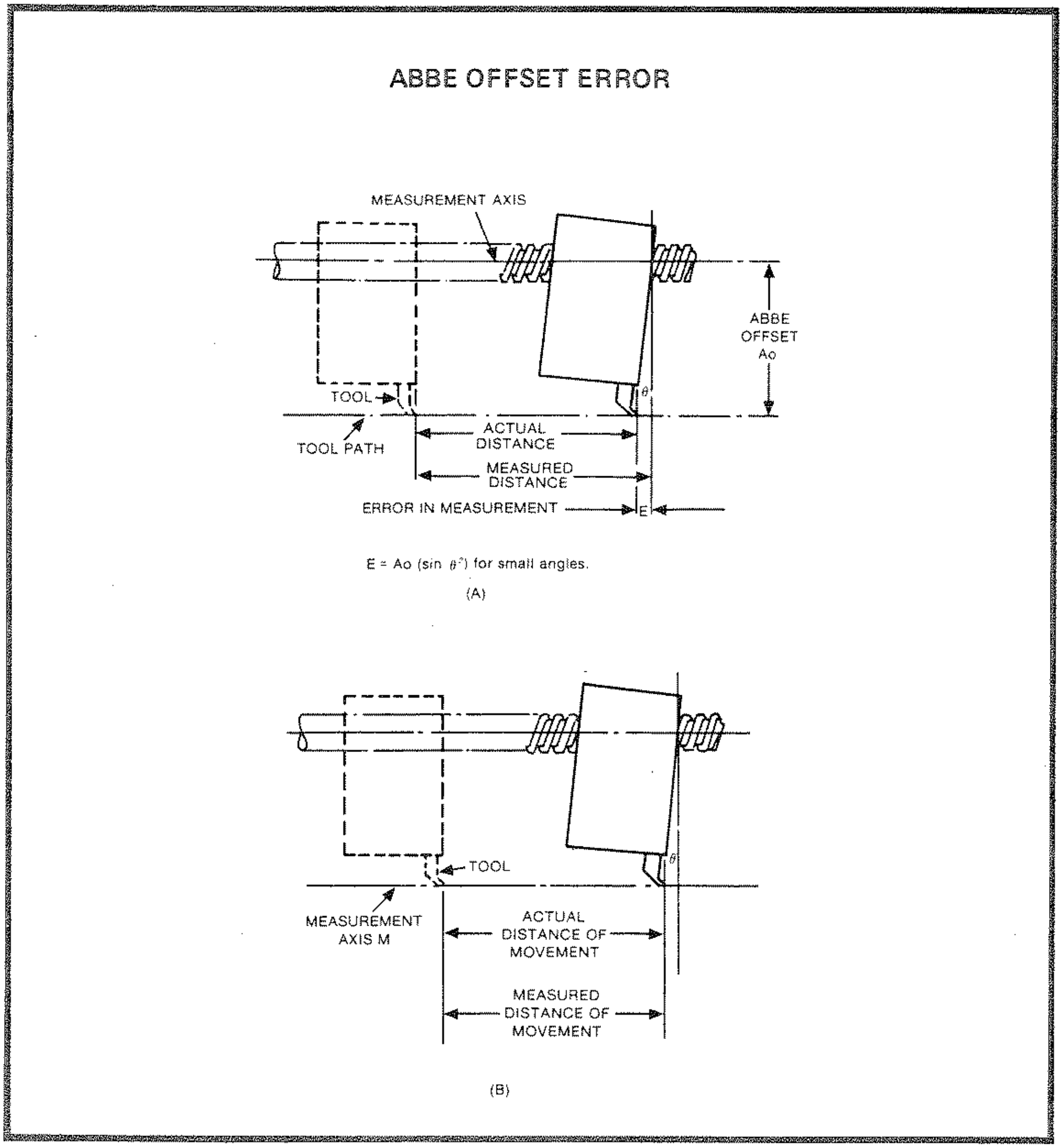


Figure 2-42. Abbe Offset Error

NOTE

> A rule of thumb which is helpful for approximating the error attributable to angular motion is that for each arcsecond of angular motion, the error introduced is approximately 0.1 microns per 20 mm of offset (5 microinches per inch of offset).

When considering a specific machine, make every effort to direct the measurement path as close as possible to the actual work area where the cutting or measurement process takes place. In *Figure 2-43* a machine slide is shown with the interferometer and retroreflector placed to minimize Abbe error. The measurement axis is placed at approximately the same level as the work table and is also measuring down the center of the machine slide.

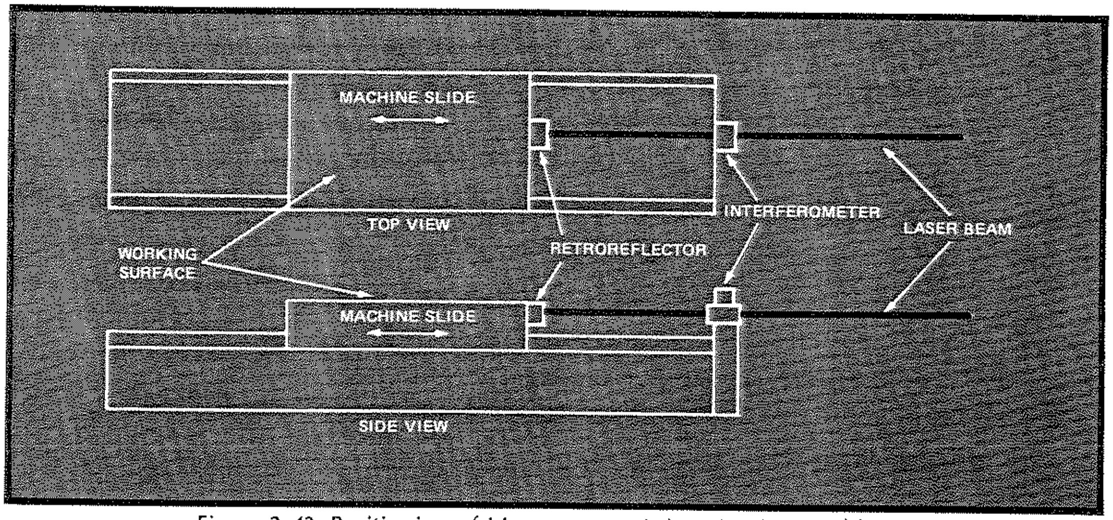


Figure 2-43. Positioning of Measurement Axis to Minimize Abbe Error

Although compromises must often be made because of mechanical interference or inaccessibility, the closer the measurement path of the Laser Transducer System is placed to the working surface, the smaller the measurement error is due to geometric inaccuracies of the machine.

With machines that exhibit small geometric errors, it may be adequate to mount the interferometer on the side of the machine slide and below the work surface without significantly affecting the measuring or cutting accuracy.

A special case where the Laser Transducer System can make a significant contribution to minimizing Abbe error is on high precision X-Y stages. Using the 10706A Plane Mirror Interferometer in conjunction with plane mirrors, mounted at 90° to each other on the top edges of the X-Y stage, a very accurate positioning system which almost completely eliminates Abbe error is achieved. *Figure 2-44* shows a typical installation for an X-Y stage. The principal advantage of this type of positioning system is that the measurement in both X and Y axes takes place at the work surface. If there are angular errors in the cross slides of the stage, any displacement of the work surface due to these errors is measured by the Laser Transducer System.

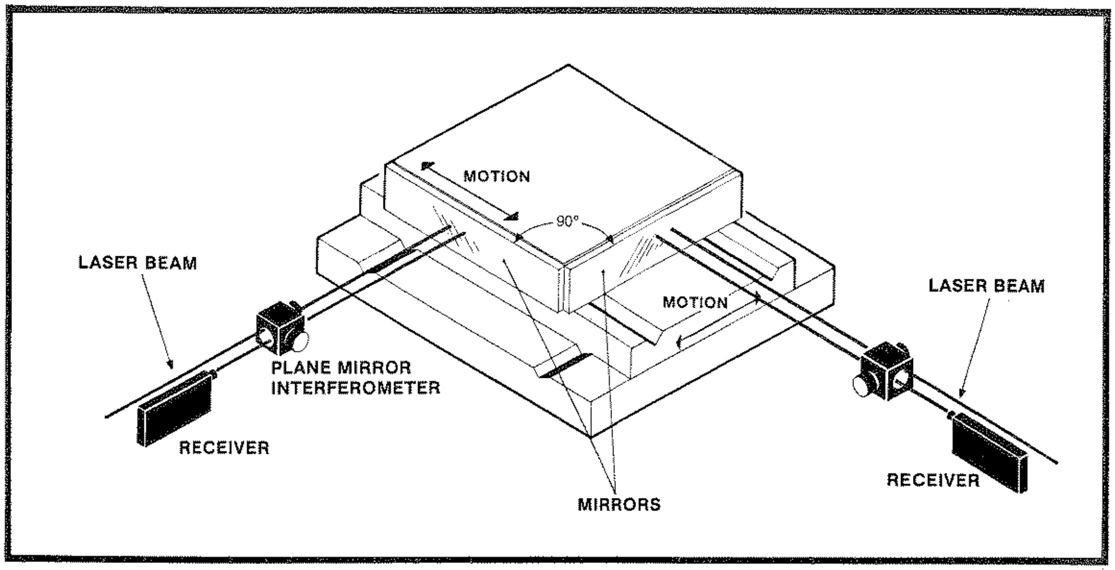


Figure 2-44. X-Y Stage Measurement with 10706A Plane Mirror Interferometer

In addition, if the mirrors are aligned at exactly 90° to each other, the orthogonality of the positioning system is determined by the mirrors and not the X-Y slides. *Figure 2-45* illustrates the actual measurement which takes place if there are any geometric errors in the X-Y stage.

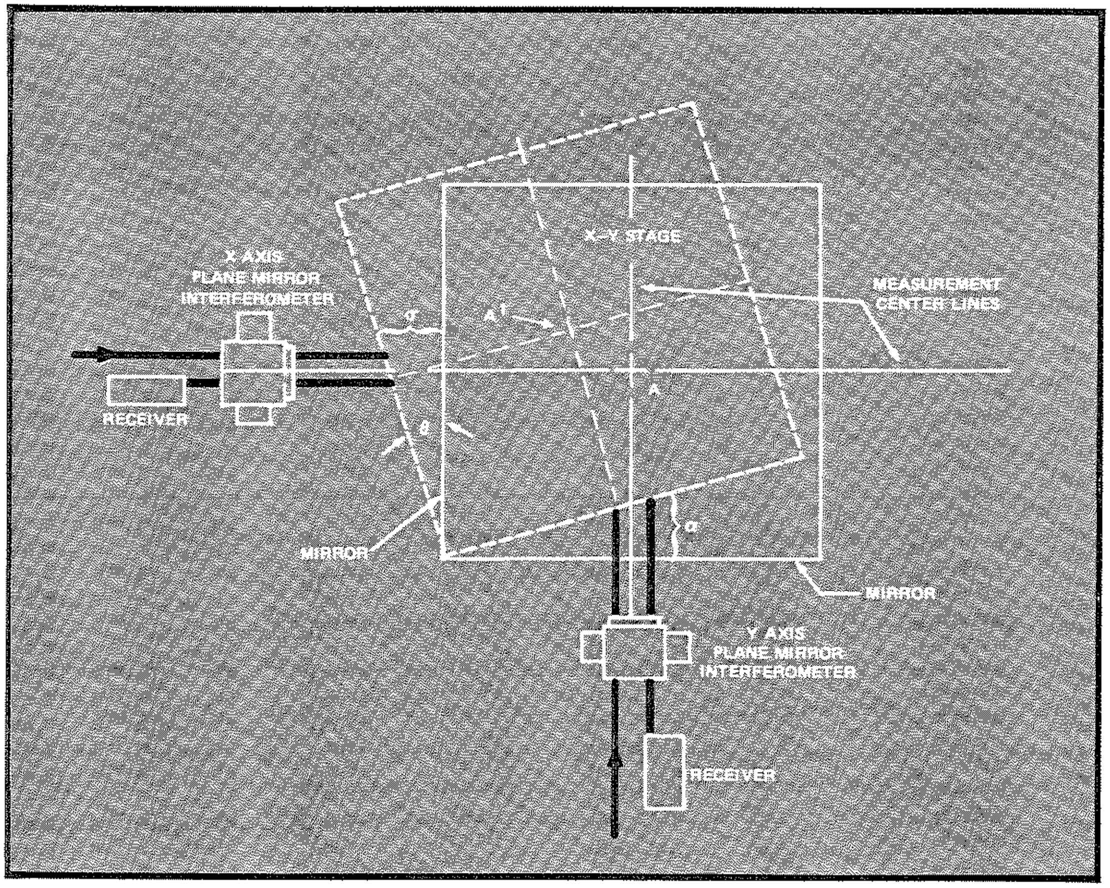


Figure 2-45. X-Y Stage Geometric Errors

If the 10706A Plane Mirror Interferometers are installed with their measurement centerlines intersecting on the axis of the fixed cutting tool, measuring probe, lens centerline, etc., (Point A), then X-Y position errors due to any yaw angle errors can be corrected. For example, if the X-Y stage undergoes an angular error θ, then the point of interest A is displaced to A'. Since this angular error also generates an X- and Y-axis position error of σ and α in the X and Y directions respectively, point A' can be moved back to point A which will be the correct position.

2.36 Deadpath Errors

When installing any displacement transducer in a positioning system, temperature effects causing thermal expansion of the system can be a significant source of error. When using the Laser Transducer System as a displacement measuring device, proper positioning of the interferometer and retroreflector can minimize this source of error. The error manifests itself primarily as a zero shift in the positioning system and is considered as a component of deadpath. The following information is concerned mainly with the installation aspects of this error source. A more detailed discussion of deadpath error is contained in Accuracy Considerations.

In general, when installing the interferometer and retroreflectors in a positioning system, make every effort to ensure that these components are almost in contact physically when the machine is at its coordinate system zero point. In *Figure 2-46* the interferometer and retroreflector are installed with the distance AB at a minimum when the saddle is at its closest point of travel to the machine table. In addition, place the fixed component of the measuring system (interferometer or retroreflector) as close as possible to the machine reference system. This helps compensate for thermal expansion.

If, because of interference or inaccessiblility, it is not possible to mount the interferometer and retroreflector in close proximity to each other, provision is made to compensate for this problem. The compensation is made in the interface electronics in conjunction with the controller.

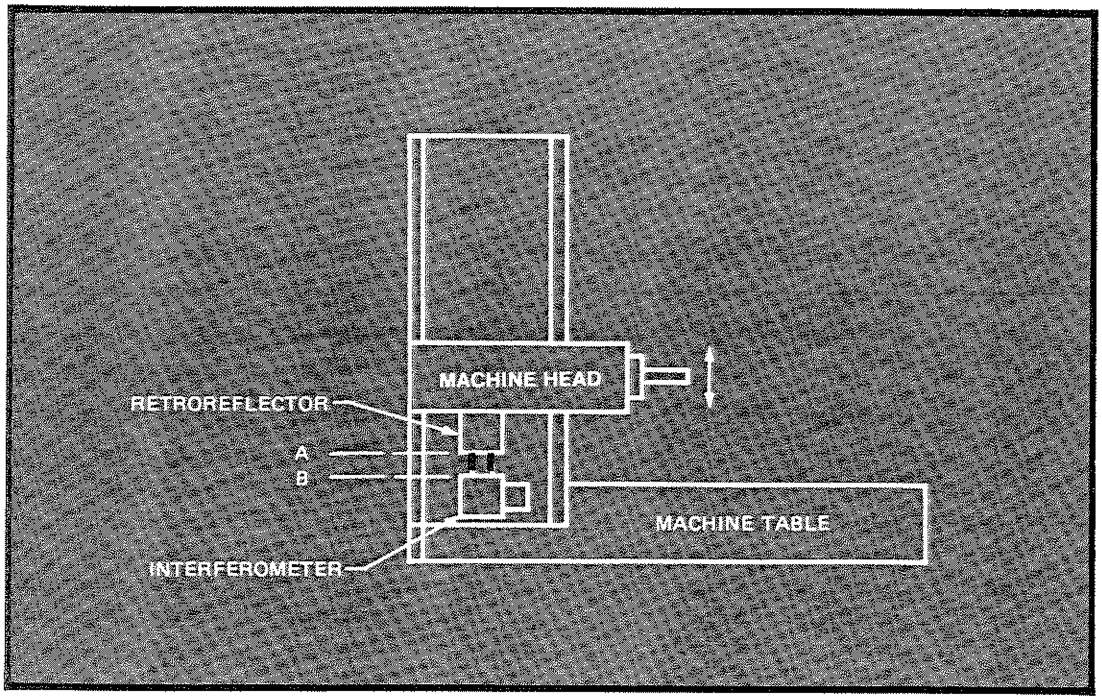


Figure 2-46. Installation of Optics for Minimum Deadpath

2.37 Air Turbulence

One of the most important factors to be considered during the installation of the Laser Transducer System is air turbulence. Air turbulence, or inhomogeneity of the air in the optical measuring path, is usually caused by variations in air temperature. The major effect of air turbulence is to reduce the amount of signal at the receiver. This reduction is due to either a physical deflection of the laser beam or a degradation of the coherence of the beam. If the air turbulence conditions become excessive, this could result in a complete loss of measurement signal. This loss of signal is detected by the interface electronics.

In uncontrolled environments such as a machine shop, the effects of air turbulence can be minimized by protecting the laser beam with covers of some type. Since this will undoubtedly be done anyway for protection against beam breakage caused by cutting fluid or metal chips, air turbulence effects will usually not be a significant installation factor in typical shop environments.

One application where serious consideration must be given to air turbulence is in temperature controlled environments. Although it would appear that such an environment would be ideal, temperature controlled areas often exhibit greater air turbulence than non-controlled areas. This turbulence is caused by a non-uniform air temperature resulting from the mixing of new air from the temperature control unit with existing air. Since air is a poor heat conductor, any attempt to change the temperature of the environment by heating and cooling the air causes non-uniform air temperature. On a long term basis, this provides good measurement conditions regarding thermal expansion effects. However, the short term fluctuations can cause measurement signal degradation in the Laser Transducer System.

Protection against air turbulence problems which occur in controlled environments depend largely on the specific application. For systems such as integrated circuit photomask cameras in small closely controlled rooms, it may be sufficient to provide constant air flow over the measurement paths. In other cases, such as measuring machines, protecting the laser beams with covers prevents air turbulence effects from interfering with the measurement.

One source of air turbulence which can affect not only the Laser Transducer System but also the accuracy of the machine itself is localized heat sources (e.g., motors, pumps, etc.) located on or near the machine. Make every effort to shield the measurement path from these types of heat sources. Note that a local heat source which can affect the Laser Transducer System enough to cause measurement signal loss also tends to degrade the geometric accuracy of the machine through warping or bending. Therefore, consideration should be given to thermally isolating the heat source from the machine as well as the measurement path.

2.38 Laser Beam and Optics Protection

In almost all positioning systems, some type of protection is generally provided for the protection of the displacement transducer whether it is a leadscrew, glass scale, or Laser Transducer System. This prevents metal chips or cutting fluid from interfering with the measurements. In the case of the Laser Transducer System, it can also provide additional protection against unintentional laser beam blockage and air turbulence problems. In addition, the optical components usually require protection to prevent contamination of the optical surfaces by oil or cutting fluid. In many applications which are "clean", no protection at all may be needed.

If protection of the laser beam and optical components is required, there are two general types; moving component protection and non-moving component protection. Since the 5501A Laser Transducer and 10780A Receiver are housed in NEMA-12 type enclosures, no protection for these devices is needed except in the most severe environments.

In many applications where the Laser Transducer is installed, the only moving components are the interferometer and retroreflector. Many of the beam splitters and beam benders are mounted in a stationary manner and only direct the laser beam to the measurement axes. In these cases it is only necessary to provide fixed tubing for the laser beam and some type of sealed enclosures for the optics. Since only one laser beam of approximately 7 mm (0.3 inch) is involved, relatively small diameter tubing can be used. Electric cable conduit for the laser beam and electrical junction boxes have proved successful for this type of protection.

Since either the interferometer or the retroreflector is moved during the measurement, protecting the laser beam and the moving components requires some type of telescoping cover or a cover of the type that is self-sealing. There are a wide variety of commercially available protective covers which are suitable for this purpose.

Figure 2–47 illustrates techniques for protecting the laser beam and optical components with different types of protective covering. Note that the cover for the retroreflector allows the retroreflector to be moved very close to the interferometer. This helps minimize the deadpath errors previously discussed.

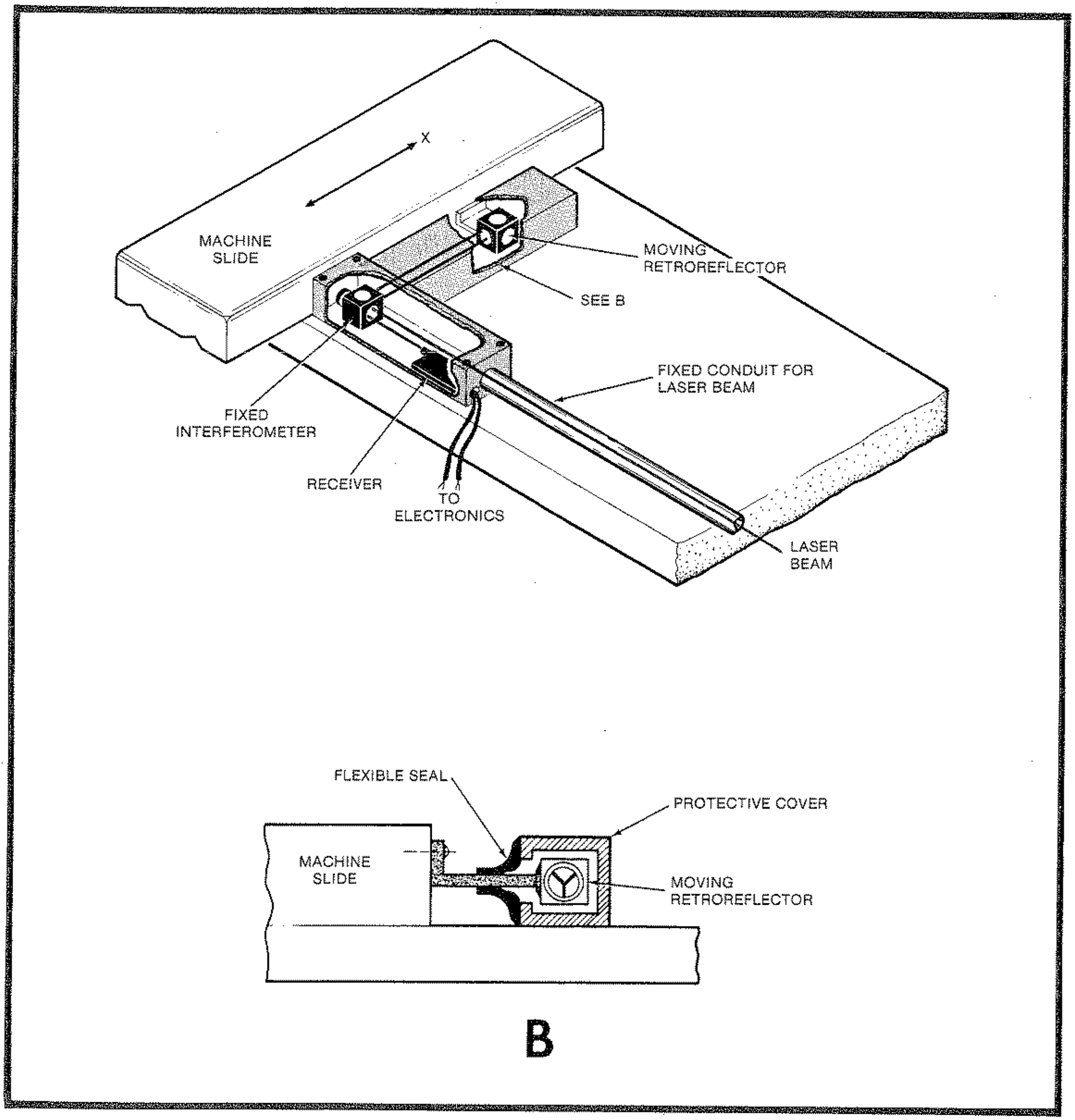


Figure 2–47. Protective Covers for Optics and Laser Beam

Figure 2-48 shows a different type of protective cover. Again, the mechanical arrangement allows the retroreflector to be in close proximity to the interferometer at the closest point of travel even though the telescoping cover is not entirely collapsible.

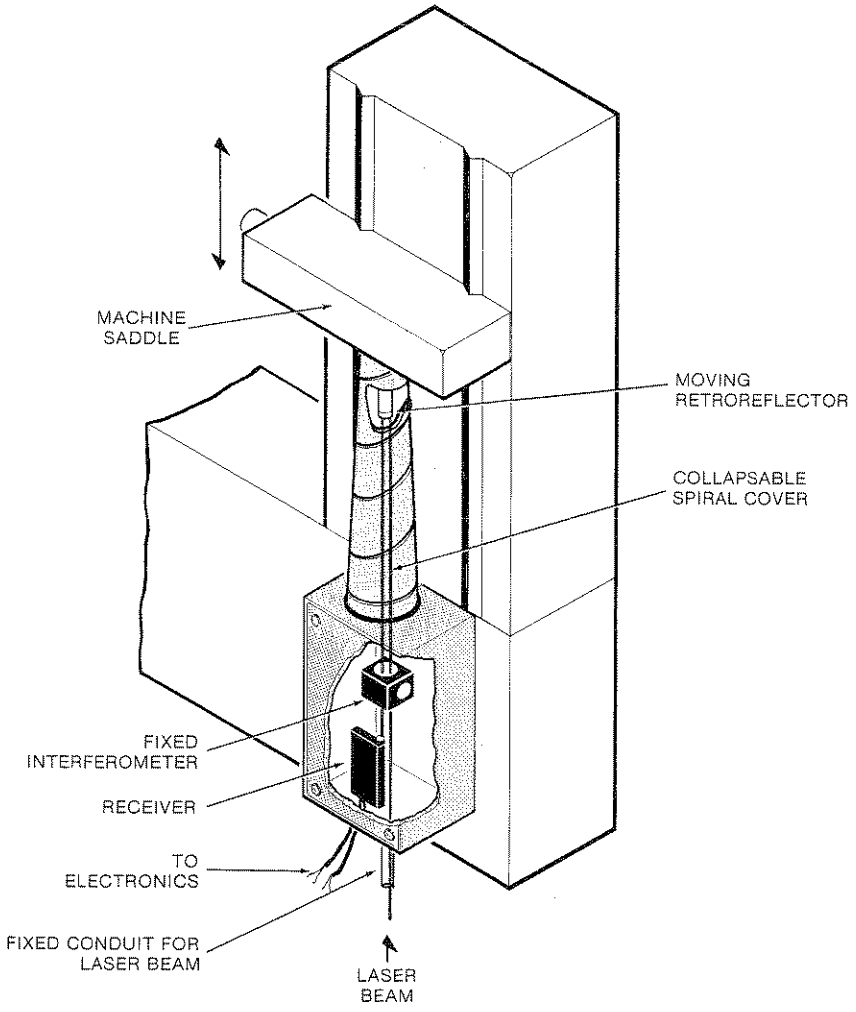


Figure 2-48. Collapsible Spiral Cover for Movable Retroreflector

2.39 ALIGNMENT PROCEDURES

2.40 General

When installing any displacement transducer in a positioning system, the transducer must be aligned to ensure correct operation and minimum measurement error. The two major objectives in aligning the Laser Transducer System are to maximize the measurement signal at the receiver to ensure reliable operation and to minimize cosine error. These objectives are generally accomplished simultaneously during the alignment process. Each measurement axis should be analyzed separately depending on the type of interferometer used and its relationship to the entire measurement system.

In general, the laser beam in the measurement is required to be parallel to the motion of travel to minimize cosine error and the optical components and receiver are required to have a specific spatial relationship to maximize the measurement signal. *Figure 2-49* shows a measurement axis where the laser beam is parallel to the mechanical motion of travel of the retroreflector and is optimized for maximum measurement signal.

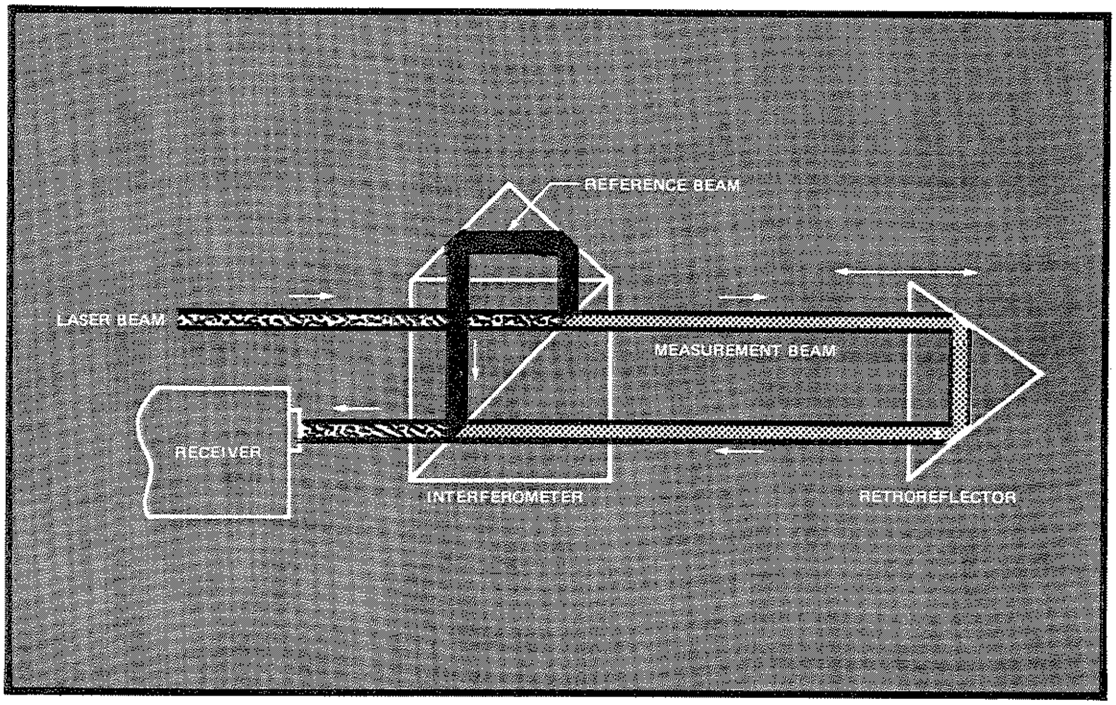


Figure 2-49. Optimum Alignment

For maximum signal, the interferometer and retroreflector are aligned laterally to each other such that the reference beam from the interferometer and the measurement beam from the retroreflector exactly overlap each other upon recombination. These recombined laser beams then enter the receiver in the center of the photodetector aperture. It is obvious from *Figure 2-49*, that if the recombined laser beams entering the receiver are not centered on the photodetector, measurement signal loss will occur. If either the interferometer or the retroreflector are misadjusted with respect to one another (*Figure 2-50*), then the reference and measurement beams no longer overlap completely and this results in a signal loss. The receiver photodetector only measures the overlapping portion of the laser beams.

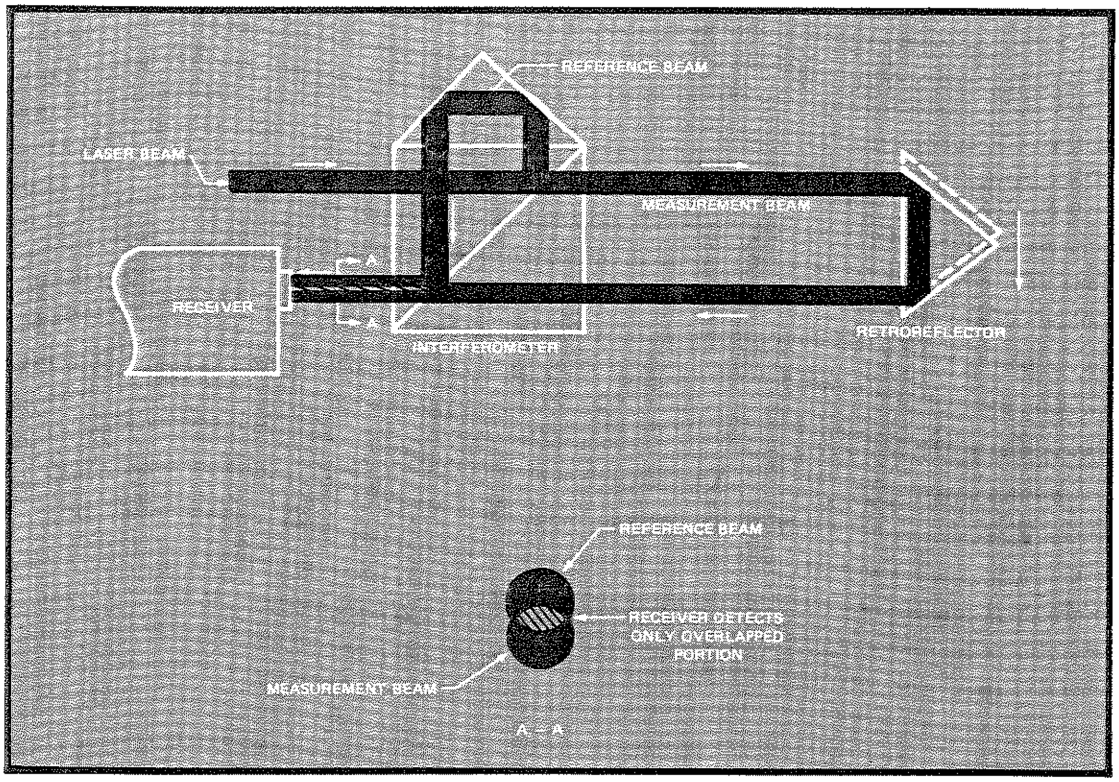


Figure 2-50. Effect of Optics Misalignment

A lateral offset of the interferometer has the same effect. Although a maximum offset of ±2.5 mm (±0.1 inch) is allowable, every effort must be made to optimize the laser beam overlap for maximum performance.

If the measurement beam is not angularly aligned parallel to the mechanical motion of travel of the retroreflector, there are two effects. First, a cosine error is included in the measurement of a magnitude directly related to the angle of misalignment. (For a complete description of cosine error refer to Accuracy Considerations.) Second, the angular misalignment also causes a displacement of the measurement beam with respect to the reference beam at recombination. This results in additional signal loss. *Figure 2-51* illustrates the result of angular misalignment.

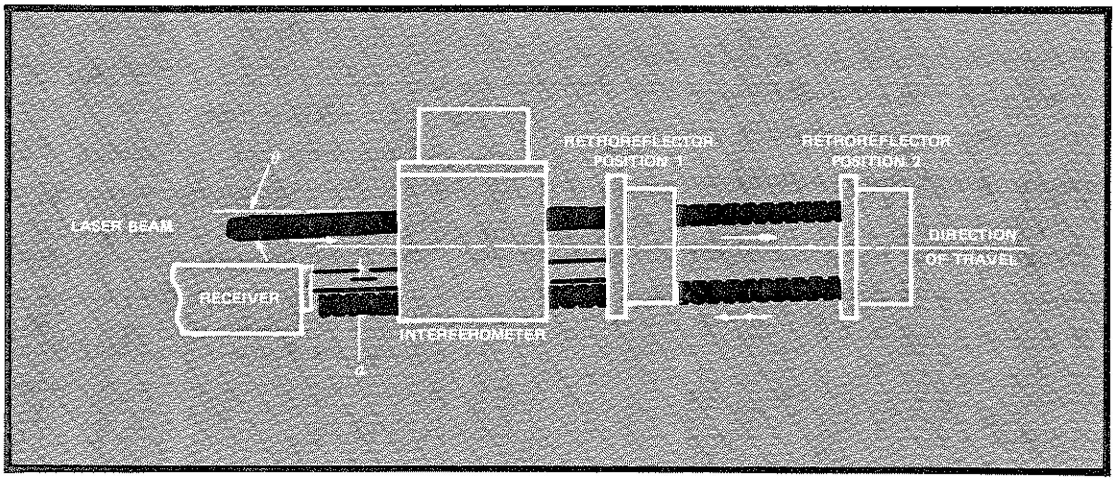


Figure 2-51. Effects of Angular Misalignment to the Direction of Travel

The cosine error is purely a function of the angle θ and the displacement α of the return measurement beam is a function of the angle θ and the distance traveled. In addition, a cube-corner retroreflector such as the 10703A or 10704A has the property of doubling the displacement of the laser beam (i.e., if the incoming laser beam to the retroreflector displaces 1 mm, the total separation between the incoming and outgoing beam is increased by 2 mm). Over short travel it is possible to maintain measurement signal even though there is considerable cosine error.

NOTE

> The presence of measurement signal through the total length of travel does not guarantee that the measurement axis is aligned for minimum cosine error. Also, any angular misalignment of the laser beam to the direction of travel causes a decrease in the measurement signal.

2.41 ALIGNMENT TECHNIQUES

There are two basic alignment techniques used with the Laser Transducer System: Visual alignment, which is a very satisfactory method in applications involving relatively long travel; and autoreflection, which is used for short travel applications and measurements where cosine error must be reduced to the absolute minimum possible. In general, regardless of the techniques used, alignments are performed with all optical components in place, **and since the alignment procedures require adjustment of the optical components, provisions must be made for this when the components are installed on the machine.**

2.42 Alignment Principles

Prior to beginning any alignment procedure, a basic understanding of what you are trying to accomplish will make the procedure easier to perform. The following information is intended as a concise summary of the various factors that affect the optical alignment of the Laser Transducer System. As you are performing the alignment procedure keep the following points in mind:

a. The laser beam is the measurement standard. In order to achieve maximum accuracy, the beam must remain parallel to the path of travel.

b. The angular direction of the beam can be changed by moving the laser head; using a beam splitter (reflected beam only); using a beam bender; or, using the interferometer to bend the beam.

c. The angular direction of the beam is not changed when using a retroreflector or for the transmitted beam going through a beam splitter or interferometer.

NOTE

> There is a 20-arcminute displacement of the beam when passing through the interferometer (see *Figure 2-11*).

d. To rough align the optics, you should start by aligning the laser head and the first moveable optical component. After this alignment is done move out one component at a time until the last component in that leg is aligned and the laser beam impinges on the receiver aperture.

e. The cube corners do not change the angular direction of the beam. However, they do displace the beam and reverse the direction. The laser beam remains parallel to its original path. In the case of the 10705A Single Beam Interferometer reference cube-corner and the 10704A Retroreflector the displacement is zero (i.e., the beam is reflected back on it's original path).

f. The interferometers are not sensitive to where on the aperture the laser beam comes in or goes out nor are they sensitive to the direction from which the beam is originated or reflected.

2.43 Alignment Tips

Understanding the following relationships between the movement of the retroreflector and the stationary interferometer will make it easier to decide how to align these two components in respect to each other. If the 10702A Linear Interferometer is the moving component, see *Figure 2-11* for an explanation of the Option 001 windows. If the 10705A Single Beam Interferometer is used it must be the stationary component. *Figure 2-52* shows a sequential relationship with the misalignment exaggerated for clarity. To initially align the components use the following sequence:

a. With the retroreflector as close as possible to the interferometer (position A of *Figure 2-52*), adjust any component (laser head, interferometer, or retroreflector) to get the small spots to overlap at the receiver (a receiver alignment target makes this adjustment easier).

b. Move retroreflector to position B and adjust the laser beam by angularly moving the laser beam until the small spots again overlap at the receiver.

NOTE

> As indicated by steps a and b, adjust the retroreflector to reduce alignment error when the distance between the components is small and adjust the laser beam when the distance is large.

c. Move the retroreflector back (position A″). If it does not align properly, move the retroreflector until the spots again overlap.

d. Move the retroreflector to position B′ and verify the system remains aligned. If necessary, repeat this procedure until you are certain that the optical leg being aligned remains aligned over the full path of travel.

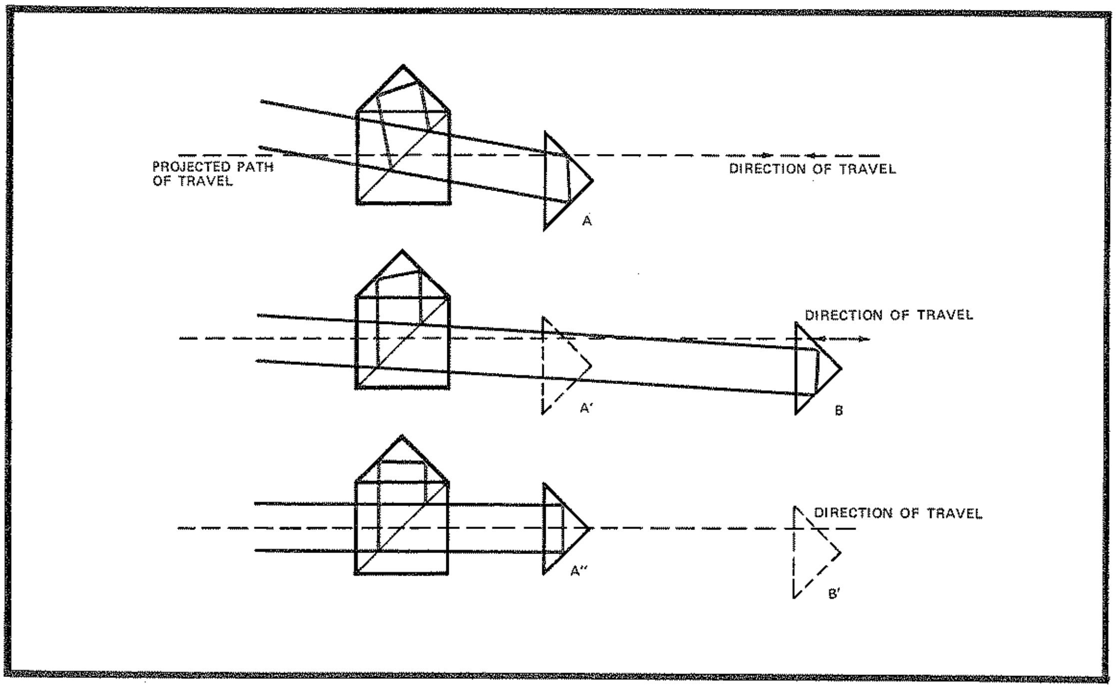


Figure 2-52. Alignment Tips

2.44 Visual Alignment Procedure

The visual alignment technique relies on the principle that if the measurement beam to the retroreflector is not parallel to the direction of travel, it is offset upon recombination with the reference beam of the interferometer (see *Figure 2-51*). When the interferometer and retroreflector are at the closest point to each other, the laser beam and optics are adjusted such that the reference and measurement beams completely overlap. When either the retroreflector or interferometer are moved along the measurement path, any angular misalignment causes a displacement of one laser beam with respect to the other which can be visually observed. Since the human eye can resolve a displacement of the beam of approximately 300 micrometres (0.01 inch) this technique can be applied for measurement travel of 0.5 metres (20 inches) or longer. For travel less than this, the sensitivity of this technique is normally not sufficient and autoreflection alignment should be used. The cosine error (E) in parts per million can be calculated from the following formula:

$$E = \frac{S^2}{8D^2}$$

Where D is the distance traveled in millimetres (inches) and S is the lateral offset of the returning beam in micrometres (thousandths of an inch). For example, if the distance traveled is 25 inches and this results in an offset of the return beam of 0.050 inches then:

$$E = \frac{(50)^2}{(8) \times (25)^2} = 0.5 \text{ parts per million or } 0.5 \text{ microinches error per inch of travel}$$

The techniques describing the two-axis visual alignment procedure can be followed for almost any measurement configuration. *Figure 2-53* is a typical measurement configuration which includes a linear interferometer and a single beam interferometer. In general, when the optical components are installed on the machine, their optical centerlines will be nominally in the correct relationship and only minor adjustments should be required.

When starting the adjustment procedure, one-axis at a time is adjusted. The first axis to be adjusted is the axis where any angular adjustment of the laser beam requires adjustment of the 5501A Laser Transducer (see X-axis, *Figure 2-53*). After angular adjustment, the laser head is locked down and any angular adjustment of the laser beam in the other measurement axes is accomplished by rotating the optical components. For visual alignment of the measurement system in *Figure 2-53*, perform the following procedure:

NOTE

Steps 1 through 10 constitute the X-axis visual alignment procedure.

1. Place the interferometer alignment target on the laser side of the X-axis interferometer and place the receiver alignment target on the receiver so that it is not in the laser beam (see *Figure 2-53c*, position 1). Place a piece of opaque material between the interferometer and the retroreflector.
2. With the retroreflector and interferometer at this closest point, adjust the laser head until the laser beam passes through the 50% Beam Splitter, enters one hole of the alignment target on the interferometer and exits the other to impinge on the receiver alignment target centered on the hole over the photodetector. A slight lateral adjustment of the interferometer or laser head may be required.
3. Remove the opaque material from between the retroreflector and interferometer and rotate the receiver alignment target to position 2 (see *Figure 2-53c*).
4. Adjust the retroreflector to center the return measurement beam on the receiver alignment target.

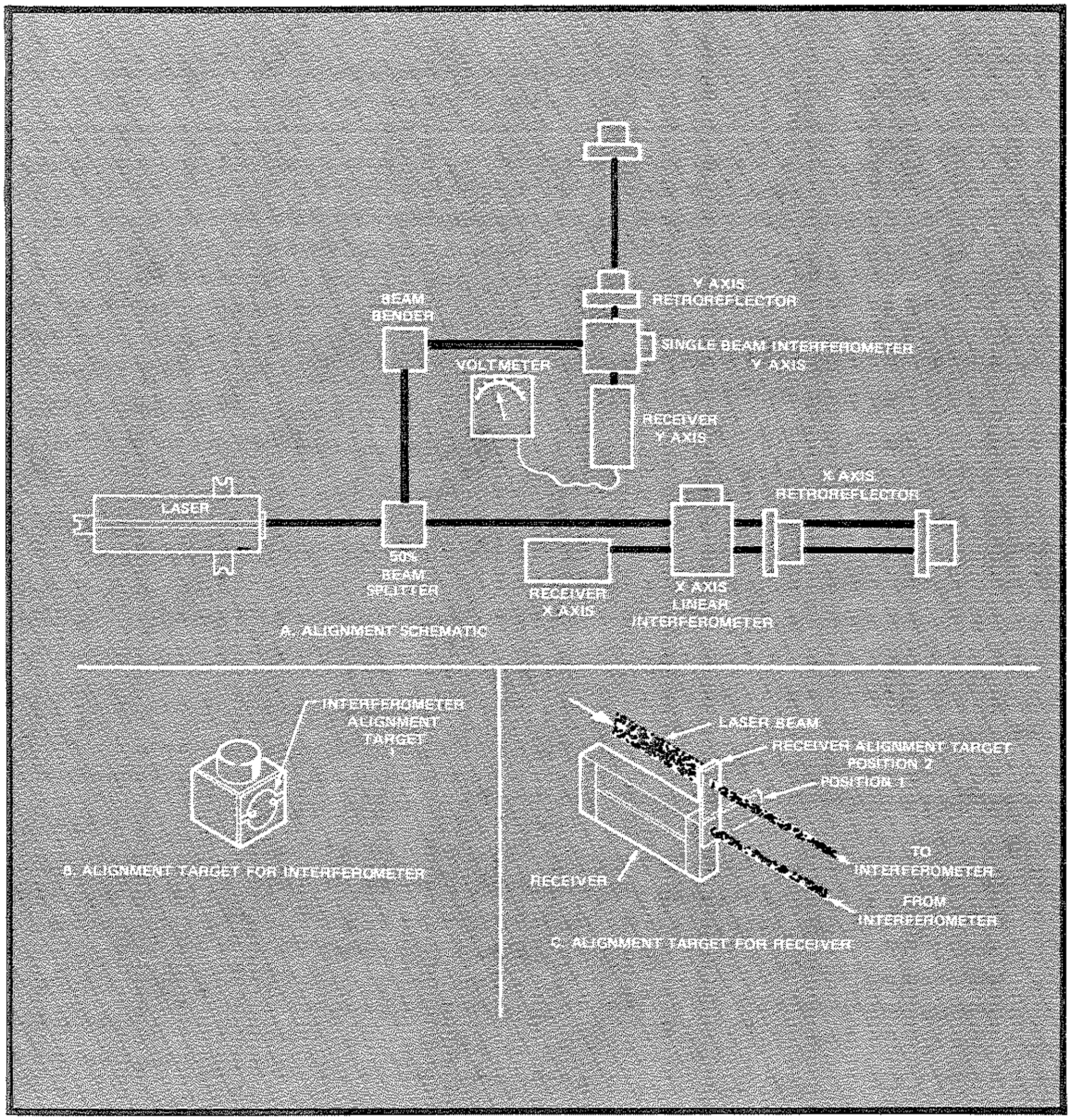


Figure 2-53. Visual Alignment

5. Traverse the retroreflector to its furthest point (at least 0.5 metres (20 inches)).
6. Adjust the laser head angularly to center the return beam on the receiver alignment target.
7. Return the retroreflector to the closest point to the interferometer.
8. Repeat steps 4 through 7 until the return beam is centered on the receiver alignment target at both ends of travel. An offset of 500 micrometres over a 0.5 metre travel is equal to a cosine error of 0.5 parts per million or 0.5 microns per metre of travel (0.5 microinches per inch).
9. If the reference beam returning from the interferometer is not centered on the receiver alignment target, adjust the interferometer until both the reference and measurement beams are centered.

NOTE

In Step 10, make sure the alignment is not disturbed.

10. Lock the laser head and X-axis optics down securely. Remove the receiver alignment target. Verify that the LED indicator on the receiver is illuminated and the voltage at the receiver test point is between 0.6 and 1.5 Vdc.

NOTE

Steps 11 through 20 constitute the Y-axis visual alignment procedure.

11. Place the alignment target on the Y-axis single beam interferometer and on the Y-axis receiver. Place a piece of opaque material between the single beam interferometer and the retroreflector.
12. Adjust the 50% beam splitter angularly until the reflected laser beam is centered in the beam bender entrance aperture. Slight lateral adjustments of the 50% beam splitter may be necessary to ensure there is no beam clipping. Lock down the 50% beam splitter securely.
13. Adjust the beam bender until the reflected beam is centered on the alignment target installed on the single beam interferometer. Lock the beam bender securely in place.
14. With the single beam interferometer and retroreflector at the closest point, adjust the single beam interferometer until the reference beam is centered on the receiver alignment target. Remove the opaque material.
15. Adjust the Y-axis retroreflector until the measurement beam is centered on the receiver alignment target.
16. Traverse the retroreflector to its furthest point of travel.
17. Angularly adjust the single beam interferometer to center the return beam from the retroreflector on the receiver alignment target. When adjusting the single beam interferometer angularly, it may also be necessary to make slight lateral adjustments to ensure that the reference beam from the single beam interferometer is also centered on the receiver alignment target.
18. Return the retroreflector to the closest point to the single beam interferometer.
19. Repeat steps 15 through 18 until the return beam from the retroreflector is centered on the receiver alignment target. Lock down the single beam interferometer securely making sure the alignment is not disturbed.
20. Remove the single beam alignment target and the receiver alignment target. Verify that the LED indicator on the receiver is illuminated and the voltage at the receiver test point is between 0.6 and 1.5 Vdc.

2.45 Autoreflection Alignment Procedure

The autoreflection alignment technique is used in short travel applications of less than 0.5 metre (20 inches). It is based on the principle of aligning a mirrored surface normal to the direction of travel and aligning the laser beam perpendicular to this mirrored surface (i.e., parallel to the direction of travel) to minimize cosine error. This technique is also used when it is necessary to make cosine error as small as possible regardless of travel distance.

Figure 2–54 shows a measurement setup similar to *Figure 2–53* except that the autoreflection technique is used for alignment.

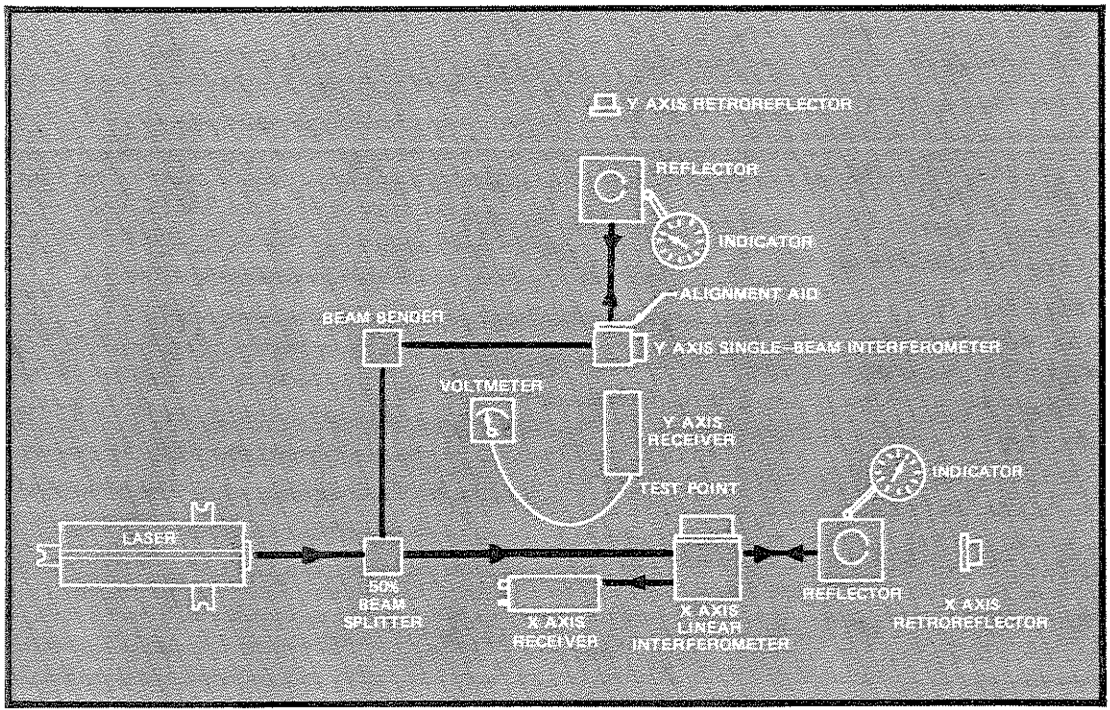


Figure 2-54. Autoreflection Alignment

For autoreflection alignment of the measurement system in *Figure 2-54*, perform the following procedure:

NOTE

Steps 1 through 11 constitute the X-axis autoreflection alignment procedure.

1. With all optical components in place, install the alignment targets on the interferometer and the receiver (*Figure 2-53c*, position 1). Place a piece of opaque material in front of the retroreflector.
2. With the laser beam passing through the 50% beam splitter, adjust the laser head and interferometer until the laser beam enters one hole of the alignment target and exits the other to impinge on the receiver alignment target centered on the hole over the photodetector.
3. Place a reflector* between the interferometer and retroreflector so that the measurement beam from the interferometer strikes its reflective surface. The reflector's sides must be perpendicular to its front face within stringent tolerances (<15 arcseconds).* Align the reflector with a precision indicator until its front surface is perpendicular to the direction of travel in both angular axes.
4. Turn the front turret of the laser head to select the small aperture.

**A typical reflector is the TRUE SQUARE manufactured by the Starret Co. This reflector, as well as other similar commercially available reflectors, have proved ideal for this application. Gage blocks (Jo-blocks) should not be used since their sides may or may not be perpendicular to their faces, depending on the technique of their manufacture.*

NOTE

If the distance between the laser head and the reflector is 0.5 metres (20 inches) or more, the formula given in the paragraph on Visual Alignment determines the cosine error based on the offset of the return beam at the laser head. For example, a distance between the laser head and reflector of 0.5 metres (20 inches) and an offset of the return beam at the small aperture of the laser of 500 micrometres (0.0202 inches) the cosine error is approximately 0.5 parts per million.

5. Adjust the laser head angularly until the return beam reflected from the reflector returns and is centered on the small aperture of the laser head. Slight lateral adjustments of the interferometer may be required to ensure that the reference beam from the interferometer is centered on the receiver alignment target.

NOTE

For high accuracy alignment and installations where there is less than 0.5 metre (20 inches) between the laser head and reflector, perform steps 6 through 8.

6. Remove the receiver alignment target and interferometer alignment target and rotate the turret of the laser head to select the large aperture.
7. With a fast responding voltmeter (preferably a meter type) attached to the receiver test point, angularly fine adjust the laser beam (laser head or interferometer, depending on axis) until a signal is received on the receiver. (The voltmeter will suddenly jump to some value greater than 0.25 volts.) This is a critical adjustment and may initially require great care to achieve the desired result.
8. Peak the voltmeter reading (which will be fluctuating) by fine adjusting the laser beam in both angular axes. This will align the laser beam to within ±15 arcseconds to the reflector surface. If the reflector surface is aligned to the direction of travel within ±15 arcseconds, the laser beam will be aligned to the direction of travel within ±30 arcseconds or approximately 0.04 parts per million. That is 0.04 micrometre per metre of travel (0.04 microinches per inch) of cosine error.
9. Lock down the laser head and interferometer securely. Make sure the alignment is not disturbed. Remove the reflector and the opaque material.
10. Adjust the retroreflector until the return measurement beam is centered on the receiver alignment target and overlaps the reference beam from the interferometer.
11. Remove the receiver alignment target and interferometer alignment target and rotate the turret on the laser head to the large aperture. Verify that the LED indicator on the receiver is illuminated and the voltage at the receiver test point is between 0.6 and 1.5 Vdc.

NOTE

Steps 12 through 21 constitute the Y-axis autoreflection alignment.

12. Adjust the 50% beam splitter angularly until the reflected laser beam is centered on the beam bender aperture. Slight lateral adjustments of the 50% beam splitter may be necessary to ensure there is no beam clipping. Lock down the 50% beam splitter securely.
13. Adjust the beam bender until the reflected beam is centered on the aperture of the single beam interferometer. The single beam interferometer alignment target can be used as an aid and then removed. Lock down the beam bender securely.
14. Place the receiver alignment target on the receiver and rotate the turret of the laser head to select the small aperture.

15. Place a reflector between the interferometer and the retroreflector so that the measurement beam from the interferometer strikes its reflective surface. Align the reflector with a precision indicator until its front surface is perpendicular to the direction of travel in both angular axes (<15 arcseconds).

16. Place alignment aid over output aperture of single beam interferometer as shown in Fig. 2-54. Edges of alignment aid must be parallel to sides of single beam interferometer housing. Adjust the single beam interferometer angularly until the return beam reflected from the reflector returns and is centered on the small aperture of the laser head. Slight lateral adjustments of the interferometer may be required to ensure that the reference beam from the interferometer is centered on the receiver alignment target. Do not adjust the laser head.

NOTE

> For high accuracy alignment and installations where there is less than 0.5 metre (20 inches) between the laser head and reflector, perform steps 17 through 19.

17. Remove the receiver alignment target and interferometer alignment target and rotate the turret of the laser head to select the large aperture.

18. With a fast responding voltmeter (preferably a meter type) attached to the receiver test point, angularly fine adjust the laser beam (laser head or interferometer, depending on axis) until a signal is received on the receiver. (The voltmeter will suddenly jump to some value greater than 0.25 volts.) This is a critical adjustment and may initially require great care to achieve the desired result.

19. Peak the voltmeter reading (which will be fluctuating) by fine adjusting the laser beam in both angular axes. This will align the laser beam to within ±15 arcseconds to the reflector surface. If the reflector surface is aligned to the direction of travel within ±15 arcseconds, the laser beam will be aligned to the direction of travel within ±30 arcseconds or approximately 0.04 parts per million. That is, 0.04 micrometre per metre of travel (0.04 microinches per inch) of cosine error.

20. Lock down the single beam interferometer securely making sure the alignment is not disturbed. Remove the reflector. Remove the alighment aid.

21. Remove the receiver alignment target and interferometer alignment target and rotate the turret on the laser head to the large aperture. Verify that the LED indicator on the receiver is illuminated and the voltage at the receiver test point is between 0.6 and 1.5 Vdc.

2.46 Plane Mirror Interferometer Alignment Procedure

This procedure covers specifically the alignment of the 10706A Plane Mirror Interferometer as applied to an X-Y positioning device using flat mirrors as retroreflectors. In this procedure it is assumed that the mirror surfaces are flat to within the tolerances required for operation of the plane mirror interferometer (refer to Measurement Components) and they have been aligned perpendicular to each other and perpendicular to their respective directions of travel. *Figure 2-55* illustrates the most common 2-axis plane mirror interferometer installation.

The alignment of the plane mirror interferometer is very similar to the autoreflection alignment technique previously described. In most cases, the accuracy demands of the X-Y positioning devices used, along with the relatively short travels encountered, dictate that the high accuracy alignment technique described in the autoreflection alignment procedure be used.

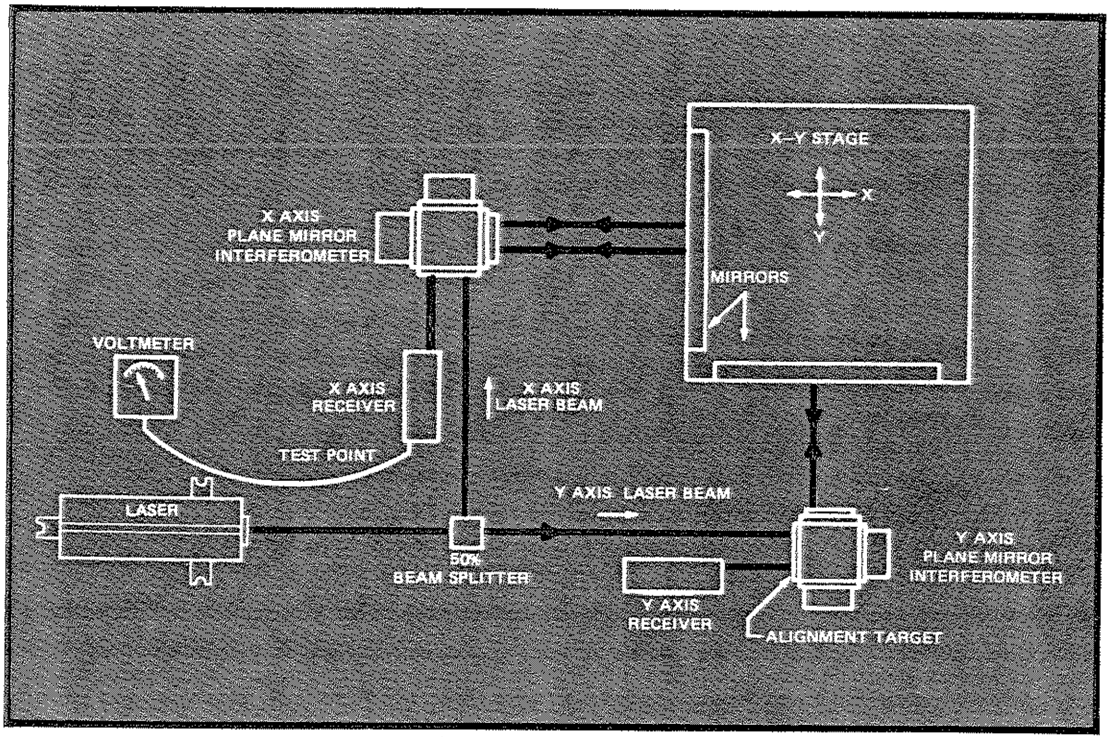


Figure 2-55. Plane Mirror Interferometer Alignment

NOTE

Steps 1 through 10 constitute the Y-axis alignment.

1. Place the interferometer alignment target on the laser side of the Y-axis plane mirror interferometer and the receiver alignment target on the receiver (*Figure 2-53c,* position 1). Place a piece of opaque material between the Y-axis plane mirror interferometer and the mirror.
2. Adjust the laser head until the laser beam passes through the 50% beam splitter, enters one hole of the interferometer alignment target and exits the other centered on the receiver alignment target. Lock down the laser head securely.
3. Select the small aperture of the front turret of the laser head and install the alignment aid on the output of the plane mirror interferometer in the correct orientation. Remove the opaque material from between the plane mirror interferometer and the mirror.
4. The laser beam will now exit the interferometer and be reflected by the mirror upon itself back into the interferometer. Angularly adjust the plane mirror interferometer until the beams reflected from the mirror returns through the plane mirror interferometer and back to the small aperture of the laser head. Slight lateral adjustments of the plane mirror interferometer may be required to ensure that the reference beam is still centered on the receiver alignment target. If the distance between the mirror and the laser head is at least 0.5 metres (20 inches) then the formula given in the section on Visual Alignment determines the cosine error based on the offset of the return beam at the laser head.

NOTE

For high accuracy alignment and installations where there is less than 0.5 metres (20 inches) between the laser and mirror, perform steps 5 through 7.

5. Remove the receiver alignment target and plane mirror interferometer alignment target and rotate the turret of the laser head to select the large aperture. Do not remove the plane mirror interferometer alignment aid on the output side of the plane mirror interferometer.
6. With a fast responding voltmeter (preferably a meter type) attached to the receiver test point, fine adjust the plane mirror interferometer angularly until a signal is received on the receiver. (The voltmeter will suddenly jump to some value greater than 0.25 volts.) This is a critical adjustment and may initially require great care to achieve the desired result.
7. Peak the voltmeter reading (which will be fluctuating) by fine adjusting the plane mirror interferometer in both angular axes. This aligns the laser beam to within ±15 arcseconds to the mirror. If the mirror has been aligned to the direction of travel within ±15 arcseconds, the laser beam will be aligned to the direction of travel within ±30 arcseconds, or approximately 0.04 parts per million. That is, 0.04 micrometre of travel (0.04 microinches per inch) of cosine error.
8. Lock down the plane mirror interferometer securely, making sure the alignment is not disturbed.
9. Remove the plane mirror interferometer alignment target and alignment aid. The reference beam and the measurement beam must be centered on the receiver alignment target.
10. Remove the receiver alignment aids and rotate the turret on the laser head to the large aperture. Verify that the LED indicator on the receiver is illuminated and the voltage at the receiver test point is between 0.6 and 1.5 Vdc.

NOTE

Steps 11 through 20 constitute the X-axis alignment.

11. With the laser head turret in the large aperture position, place the plane mirror interferometer alignment target on the laser head side of the X-axis plane mirror interferometer and the receiver alignment target on the receiver (*Figure 2-53c*, position 1). Place a piece of opaque material between the X-axis plane mirror interferometer and the mirror.
12. Angularly adjust the 50% beam splitter until the laser beam enters one hole of the plane mirror interferometer alignment target and exits the other centered on the receiver alignment target (do not adjust the laser head). Slight lateral adjustments of the 50% beam splitter may be necessary to ensure there is no beam clipping. Lock down the 50% beam splitter securely.
13. Select the small aperture on the front turret of the laser head and install the alignment aid on the output of the plane mirror interferometer in the correct orientation. Remove the opaque material from between the plane mirror interferometer and the mirror.

14. The laser beam now exits the interferometer and is reflected by the mirror back upon itself into the interferometer. Angularly adjust the plane mirror interferometer until the beam reflected from the mirror returns through the plane mirror interferometer and back to the small aperture of the laser head. Slight, lateral adjustments of the plane mirror interferometer may be required to ensure that the reference beam is still centered on the receiver alignment target. If the distance between the mirror and the laser head is at least 0.5 metres (20 inches) then the formula given in the section on Visual Alignment will determine the cosine error based on the offset of the return beam at the laser.

NOTE

For high accuracy alignment and installation where there is less than 0.5 metres (20 inches) between the laser and mirror, perform steps 15 through 17.

15. Remove the receiver alignment target and plane mirror interferometer alignment target and rotate the turret of the laser head to select the large aperture. Do not remove the plane mirror interferometer alignment aid on the output side of the plane mirror interferometer.
16. With a fast responding voltmeter (preferably a meter type) attached to the receiver test point, fine adjust the plane mirror interferometer angularly until a signal is received on the receiver. (The voltmeter will suddenly jump to some value greater than 0.25 volts.) This is a critical adjustment and may initially require great care to achieve the desired result.
17. Peak the voltmeter reading (which will be fluctuating) by fine adjusting the plane mirror interferometer in both angular axes. This aligns the laser beam to within ±15 arcseconds to the mirror. If the mirror has been aligned to the direction of travel within ±15 arcseconds, the laser beam will be aligned to the direction of travel within ±30 arcseconds, or approximately 0.04 parts per million. That is, 0.04 micrometre of travel (0.04 microinches per inch) of cosine error.
18. Lock down the plane mirror interferometer securely. Make sure the alignment is not disturbed.
19. Remove the plane mirror interferometer alignment target and alignment aid. The reference beam and the measurement beam must be centered on the receiver alignment target.
20. Remove the receiver alignment aids and rotate the turret on the laser head to the large aperture. Verify the LED indicator on the receiver is illuminated and the voltage at the receiver test point is between 0.6 and 1.5 Vdc.

section III

System Electronics

3.1 INTRODUCTION

This section contains the theory of operation of the Laser Transducer System electronics and of the individual units that make up the different systems. The optics are common to all systems and are covered in Section II.

The output electronics for the 5501A Laser Transducer System are available in a wide variety of configurations. General-purpose interface electronics include a universal binary interface for virtually any digital processor or controller; an HP-IB interface based on the Hewlett-Packard Interface Bus (HP-IB) and HP programmable calculators; and a universal English/Metric pulse output for most numerical controllers. A very basic quarter-wave pulse output is also available. Other electronic modules provide for manual or automatic velocity-of-light compensation and for the special needs of some closed-loop systems. The information is organized as follows:

a. Theory of operation of a simplified Laser Transducer System.
b. A functional description of each type of system.
c. Theory of operation of the individual units that make up the different systems.

After reading the simplified theory of operation and the functional description of the type system you have, read the theory of operation of the individual units that are contained in your system. You will find this information very helpful in both programming and troubleshooting your system.

3.2 SIMPLIFIED THEORY OF OPERATION

A low-power helium-neon laser (*Figure 3-1*) emits a coherent light beam composed of two slightly different optical frequencies, f_1 and f_2, of opposite circular polarizations. After conversion to orthogonal linear polarizations the beam is expanded and collimated, then directed to the reference beam-splitter where a small fraction of both frequencies is split off.

The split off portion of the beam is used both to generate a reference frequency and to provide an error signal to the laser cavity tuning system. The difference in amplitude of f_1 and f_2 is used for tuning while the difference in frequency between f_1 and f_2 (about 2 MHz) is used for the reference signal.

The major portion of the beam passes out of the 5501A Laser Transducer to an interferometer. All HP interferometers measure relative displacement of two reflectors by splitting the beam into f_1 and f_2, directing them to the two reflectors, and returning the resultant signals to a common point where they are made to interfere with each other. These combined beams are directed to a photodetector in the receiver.

Relative motion between the reflectors causes a Doppler shift in the difference frequency which is detected by the receiver. This Doppler shifted difference frequency ($f_1 - f_2 \pm \Delta f$) is the measurement signal.

Each output accessory (e.g., pulse converter, counter, etc.) receives the reference and measurement signals and compares them cycle-by-cycle in a dual output mixer. The mixer produces an appropriate up or down output pulse whenever one of the signals gets one-half cycle ahead of or behind the other. Each pulse corresponds to a reflector movement of one-quarter wave length of light. The pulses are accumulated in either a customer-supplied reversible counter or counters in one of the output accessories.

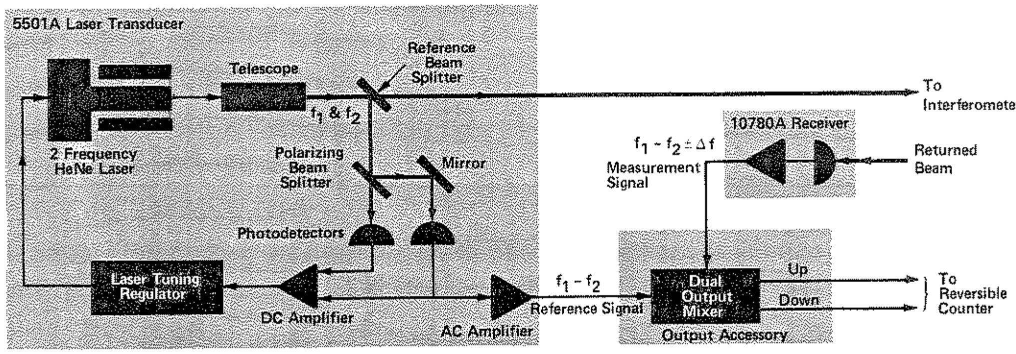


Figure 3-1. Simplified Block Diagram

3.3 FUNCTIONAL DESCRIPTIONS

The functional descriptions are subdivided as follows:

a. HP-IB Interface Electronics
b. Computer Interface Electronics.
c. English/Metric Pulse Output Electronics.
d. 10781A Pulse Converter Electronics.

3.4 HP-IB Interface Electronics

The HP-IB Interface Electronics *(Figure 3-2)* for the Laser Transducer System is an interface between the laser head and any digital controller compatible with Hewlett-Packard Interface Bus (HP-IB). A typical system contains the following electronic equipment:

a. One 9800 Series Calculator with HP-IB Interface.
b. One 5501A Laser Transducer.
c. Two 10780A Receivers.
d. One 10740A Coupler.
e. Two 10760A Counters.
f. One 10745A HP-IB Interface.
g. One 10755A Compensation Interface.
h. One 10756A Manual Compensator.
i. Two power supplies (±15V and +5V).

For additional capabilities the following can be selected:

a. Up to two additional measurement axes (10760A Counter and 10780A Receiver).
b. Automatic compensation (replace 10756A manual compensator with 5510A Opt 010 Automatic Compensator and 10563A Material Temperature Sensor).
c. Numeric displays (10783A).

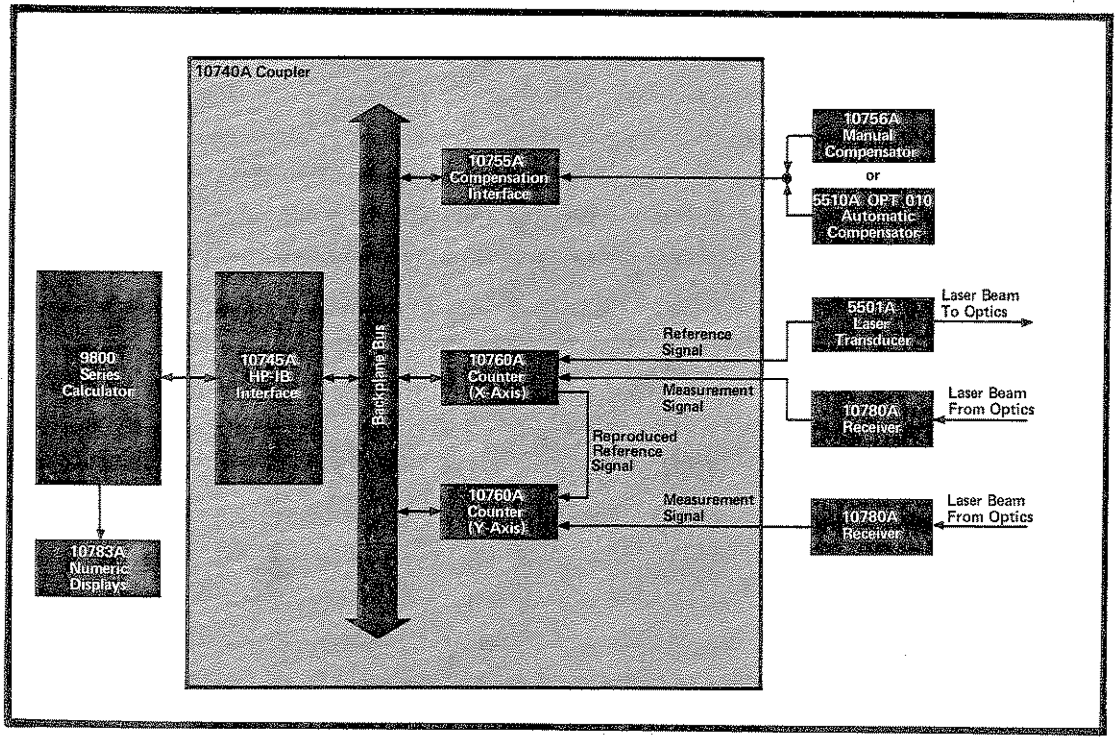


Figure 3-2. HP-IB Interface Electronics Block Diagram

The 9800 series calculator serves as a system controller (*Figure 3-2*). The reference and measurement signals from the laser head and receivers are compared continuously by the 10760A counters. These signals are approximately 2 MHz and are driven by line drivers to ensure noise immunity. Upon command from the calculator, the accumulated counts for each measurement axis can be sampled independently or simultaneously. Pulses are generated and accumulated in the counters only when movement has occurred. Refer to *Table 3-1* for typical system specifications.

The 10755A compensation interface is used with either the 10756A manual compensator or the 5510A Opt 010 automatic compensator. In typical installations the choice of manual or automatic compensation is determined by the stability of the ambient environment.

The 10783A numeric displays can be used to display the relative movement on each axis. The displays are interfaced to the 9800 series calculator via the HP-IB and receive and display information only on calculator command. (Refer to the individual unit theory of operation for additional information.)

Table 3-1. Typical HP-IB Interface Electronics System Specifications

Number of Measurement Axes: Up to 6 measurement axes, subject to optical configuration restrictions.

Measurement Resolution/Maximum Allowable Velocity: The measurement resolution and velocity depend on the type of interferometer used.

10702A Linear Interferometer
10705A Single Beam Interferometer

Resolution	**λ/4**	**λ/40**	**λ/24**
Maximum Velocity mm/sec (in/sec)	304(12)	30.4(1.2)	51(2)

10706A Plane Mirror Interferometer

Resolution	**λ/8**	**λ/80**	**λ/48**
Maximum Velocity mm/sec (in/sec)	152(6)	15.2(0.6)	25(1)

Measurement Accuracy: ±0.5 parts per million ±1 count in conjunction with the 5501A Laser Transducer.

Atmospheric and Material Temperature Compensation Input: Manual Compensation factor input (tables supplied); Automatic Compensator.

3.5 Computer Interface Electronics

The Computer Interface Electronics for the Laser Transducer System is designed to interface a wide variety of digital processors. The individual components are selected and assembled by the user for a specific measurement application.

The following discussion subdivides the Computer Interface Electronics into two typical types of systems; a 10760A Counter-based system and a 10762A Comparator-based system (closed-loop).

3.6 COUNTER-BASED SYSTEMS. A typical counter-based system (*Figure 3-3*) contains the following electronic equipment:

a. One system controller (calculator or mini-computer).
b. One 5501A Laser Transducer.
c. Two 10780A Receivers.
d. One 10740A Coupler.
e. Two 10760A Counters.
f. A system controller interface (typically a 10746A Binary Interface; however a 10745A HP-IB Interface can be used).
g. One 10755A Compensation Interface.
h. One 10756A Manual Compensator.
i. Two power supplies (±15V and +5V).

Additional capability can be selected by adding the following equipment:

a. Up to two additional measurement axes (10760A Counter and 10780A Receiver).
b. Automatic compensation (replace 10756A manual compensator with the 5510A Opt 010 Automatic Compensator and 10563A Material Temperature Sensor).
c. Numeric displays (10783A can be used only if the system controller is HP-IB compatible).

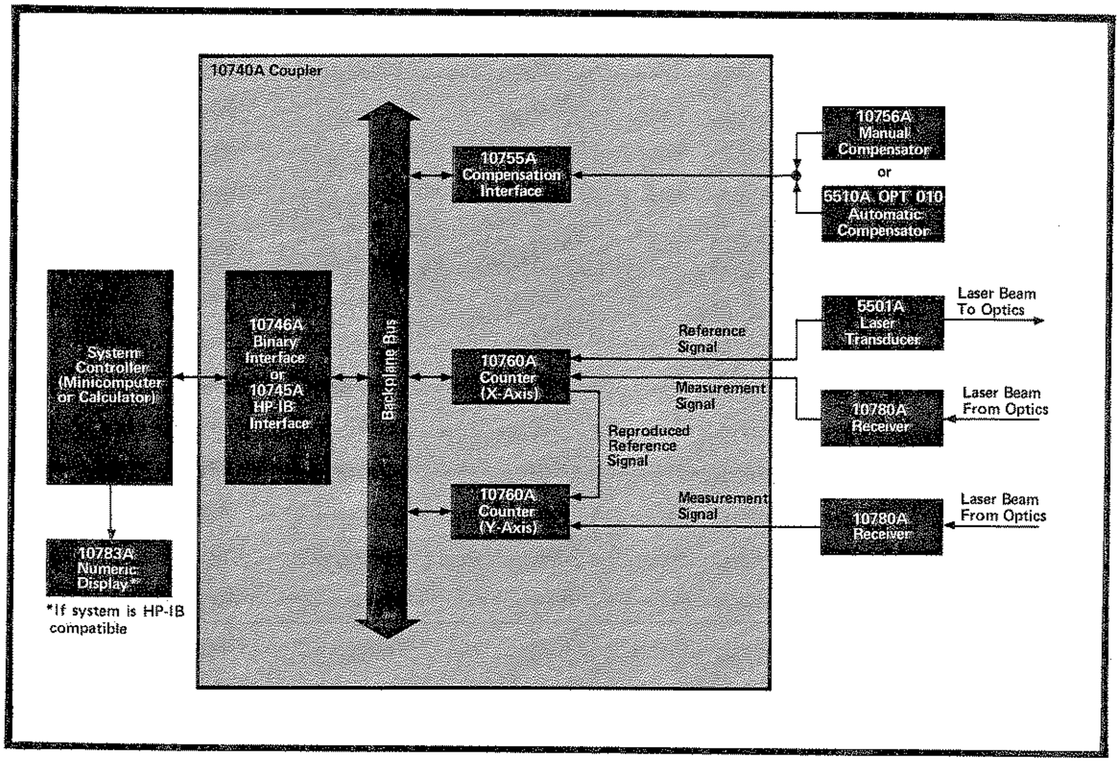


Figure 3-3. Counter-Based Computer Interface Electronics Block Diagram

This interface is used where high-speed position input to a computer based control system is desired. Since the output format can be either 8- or 16-bit words, the computer interface electronics are compatible with almost any digital processor. Refer to *Table 3-2* for typical specifications.

Upon command from the system controller (*Figure 3-3*), the contents of the 10760A Counters are sampled. This can be accomplished independently or simultaneously on the X- and Y-axis.

The 10755A Compensation Interface is used with either the 10756A Manual Compensator or the 5510A Opt 010 Automatic Compensator. In typical installations, the choice of manual or automatic compensation is determined by the stability of the ambient environment.

Table 3-2. Typical Counter-Based Computer Interface System Specifications

Number of Measurement Axes: Up to six 10760A counters may be used subject to optical configuration restrictions.

Measurement Resolution/Maximum Allowable Velocity: The measurement resolution and velocity depend on the type of interferometer used.

10702A Linear Interferometer
10705A Single Beam Interferometer

Resolution	**Normal $\lambda/4$**	**X10 $\lambda/40$**	**X6 $\lambda/24$**
Maximum Velocity mm/sec (in/sec)	304(12.0)	30.4(1.2)	51(2.0)

10706A Plane Mirror Interferometer

Resolution	**Normal $\lambda/8$**	**X10 $\lambda/80$**	**X6 $\lambda/48$**
Maximum Velocity mm/sec (in/sec)	152(6.0)	15.2(0.6)	25(1.0)

Measurement Accuracy: ±0.5 parts per million ±1 count measurement resolution in conjunction with 5501A Laser Transducer.

10760A Counter Output: The contents of the 28-bit counter on the 10760A along with four status bits are available for transfer to the system controller via the 10746A Binary Interface:

Format: 32-bit word; 28-bit position word with four status bits which allow detecting measurement or reference signal errors, counter overflow, and decimal point. Can be transferred to system controller as two 16-bit words or four 8-bit bytes.

Output Rate: Nine individual operations at typically one microsecond each are required to transfer two 32-bit words (two axes of measurement data) to the system controller using the two 16-bit word format in conjunction with the 10746A Binary Interface.

Atmospheric and Material Temperature Compensation Input: Transferred to the system controller as a 28-bit word from the 10755A Compensation Interface via the 10746A Binary Interface. Can be transferred as either two 16-bit words or four 8-bit bytes. Two types of inputs are available:
Manual – 10756A Manual Compensator for thumbwheel input (tables supplied)
Automatic – 5510A Opt 010 Automatic Compensator and 10563A Material Temperature Sensor.

System Control Functions: Input from system controller via 10746A Binary Interface.

Reset: Initializes all interface electronics. Presets 10760A counters to 160 counts.

Sample: Places counter contents of 10760A in output buffer for transfer to system controller. Can be initiated either externally (TTL level signal) or by the system controller.

3.7 COMPARATOR-BASED (CLOSED-LOOP) SYSTEMS. A special case of laser transducer applications occurs in certain comparator-based (closed-loop) systems, such as that shown in *Figure 3-4*. The system controller sends the laser transducer system a digital representation of the destination of the object under control. The transducer system then takes over the task of measuring the object's position on a real-time basis, comparing it with the desired position, controlling the drive motor, and indicating when the object under control has arrived at its destination.

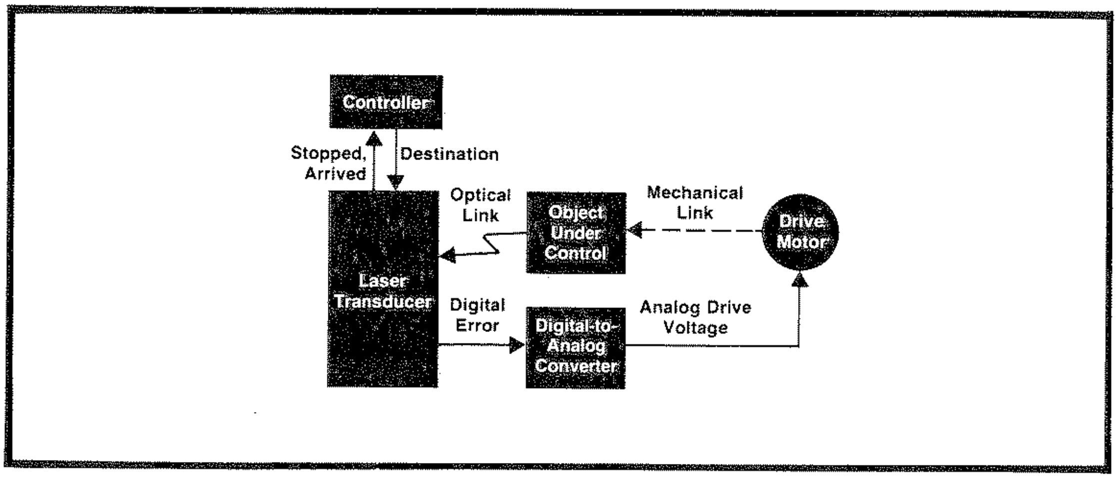


Figure 3-4. Comparator-Based (Closed-Loop) System Simplified Block Diagram

A typical comparator-based system (*Figure 3-5*) contains the following electronic equipment:

a. A system controller (calculator or mini-computer).
b. A 5501A Laser Transducer.
c. Two 10780A Receivers.
d. A 10740A Coupler.
e. Two 10762A Comparators.
f. A 10764B Fast Pulse Converter.
g. 10746A Binary Interface.
h. A 10755A Compensation Interface.
i. A 10756A Manual Compensator.
j. Two power supplies (±15V and +5V).

Additional capability can be selected by adding the following electronic equipment:

a. Provide additional measurement axis (10762A Comparator and 10764B Fast Pulse Converter. Note that each axis uses only one-half of the 10764B Fast Pulse Converter. Therefore, two additional axes would require only one additional fast pulse converter).

b. Automatic compensation (replace 10756A Manual Compensator with the 5510A Opt 010 Automatic Compensator and 10563A Material Temperature Sensor).

This interface is used for applications where high-speed control functions are required. The 10764B Fast Pulse Converter *(Figure 3-5)* operates in conjunction with two 10762A comparators. The 10764B provides up/down position counts to the two 10762A comparators and allows resolution extension by factors of from 1 to 6 and 8 and 10 with high allowable slew rates. Refer to *Table 3-3* for typical specifications.

The 10755A Compensation Interface is used with either the 10756A Manual Compensator or the 5510A Opt 010 Automatic Compensator. In typical installations, the choice of manual or automatic compensation is determined by the stability of the ambient environment.

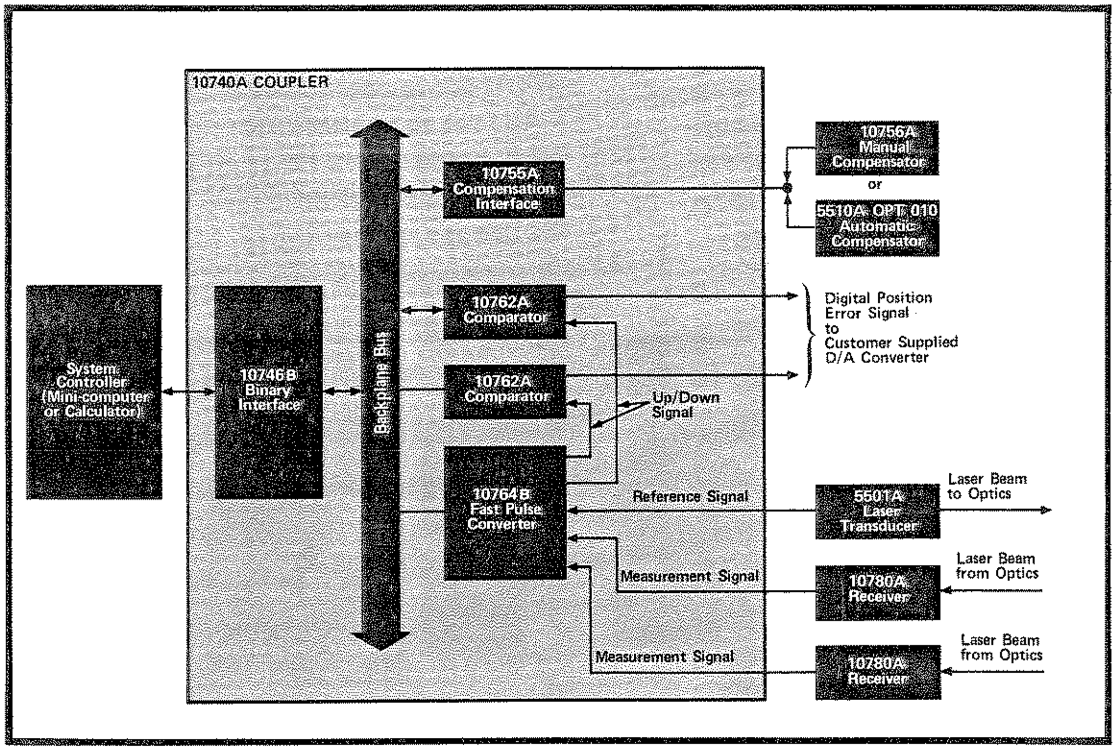


Figure 3-5. Comparator-Based Computer Interface Electronics Block Diagram

Table 3-3. Typical Comparator-Based Computer Interface System Specifications

Number of Measurement Axes: Up to 4 measurement axes, subject to optical configuration restrictions.

10764B FAST PULSE CONVERTER

Input Requirements:

Reference Signal: Compatible with 5501A Laser Transducer.

Measurement Signal: Compatible with 10780A Receiver. (The 10764B is a two-axis device and will accept inputs from two 10780A Receivers.)

Maximum Acceleration: 19.6 m/s^2 or 6 ft/s^2 (2 g's).

Resolution/Maximum Allowable Velocity: The 10764B provides the capability for increasing the measurement resolution. The allowable resolution and maximum measurement velocity depends on the type of interferometer used.

10706A Plane Mirror Interferometer

Resolution	**$\lambda/8$**	**$\lambda/16$**	**$\lambda/24$**	**$\lambda/32$**	**$\lambda/40$**	**$\lambda/48$**	**$\lambda/64$**	**$\lambda/80$**	**$\lambda/120$**
Maximum Velocity mm/sec (inches/sec)	152 (6.0)	152 (6.0)	152 (6.0)	142 (5.5)	114 (4.4)	95 (3.7)	71 (2.7)	57 (2.2)	36 (1.4)

10702A Linear Interferometer
10705A Single Beam Interferometer

Resolution	**$\lambda/4$**	**$\lambda/8$**	**$\lambda/12$**	**$\lambda/16$**	**$\lambda/20$**	**$\lambda/24$**	**$\lambda/32$**	**$\lambda/40$**	**$\lambda/60$**
Maximum Velocity mm/sec (inches/sec)	304 (12.0)	304 (12.0)	304 (12.0)	285 (11.2)	228 (9.0)	190 (7.4)	142 (5.5)	114 (4.4)	71 (2.8)

Output: Compatible with 10762A Comparator. Up/Down pulses: TTL differential line driver output. Pulse width 67 ±10 nanosecond, maximum 9 MHz. The 10764B Fast Pulse Converter will drive two 10762A Comparators. Coaxial interconnection cables for 10762A Comparators are supplied.

Table 3-3. Typical Comparator-Based Computer Interface System Specifications (Continued)

Error Check:

External: TTL level signals are available when Reference or Measurement errors are detected.

System Controller: An error code is available to the system controller via the 10746A Binary Interface for Reference or Measurement errors.

10762A COMPARATOR

Input Signal: Up/down or Phase-quadrature (A–Quad–B) Pulses. Minimum 50 nanosecond pulse width, maximum 10 MHz.

Measurement Accuracy: ±0.5 PPM ±1 count in conjunction with 5501A Laser Transducer and 10764B Fast Pulse Converter. ±2 counts if hysteresis circuit selected.

Destination and Tolerance: Input from system controllers via 10764B Binary Interface. The digital difference output is automatically forced to a Null or zero difference when the destination and tolerance are loaded.

Format: 32-bit word. Four tolerance bits (±15 counts) and 28 position bits can be transferred from system controller as either two 16-bit words or four 8-bit bytes.

Input Rate: Nine individual operations at typically 1 microsecond each are required to transfer two 32-bit words from the system controller to two 10762A Comparators using the two 16-bit word format in conjunction with the 10746A Binary Interface.

Digital Difference Output: Available at card edge connector.

Format: 28-bit TTL level. Sign-magnitude; binary negative-true representation. Twenty-four most-significant bits can be wired-OR'ed for variable linearity.

Response: One microsecond typical for constant velocity; 2 microseconds typical under acceleration conditions; relative to motion detected by the interferometer.

Null Output: Occurs when the 28-bit counter agrees with the 28-bit destination within the four tolerance bits (±15 counts). This signal is available both externally at the card edge connector and to the system controller via the 10746A Binary Interface.

External Null Output: TTL level change, active low.

Response: 1.1 microsecond typical for constant velocity; 2.1 microseconds typical under acceleration conditions; relative to motion detected by the interferometer.

System Null: Available to system controller when all 10762A Comparators are at a null condition.

Zero Speed Output: Occurs when no counts have entered the Up/Down Counter within 17 msec (variable from 1 to 100 msec); TTL level change, active high.

Reset: Initializes Up/Down counter at 160 counts. Can be initiated either externally or by the system controller via the 10746B Binary Interface. Reset also activates a Forced Null condition on the Digital Difference Output.

External: TTL level change, active low. Reset condition will be maintained until returned to the high state.

System Controller: The counter on a specific 10762A Comparator can be reset or all 10762A Comparator Counters in the system can be reset simultaneously under program control.

Sample: Places Up/Down counter contents in output buffer for transfer to system controller. Also releases the forced Null on the digital difference output after loading destination and tolerance. Can be initiated either externally or by the system controller via the 10746A Binary Interface.

External: TTL level change; active low. Minimum 40 nanosecond pulse width.

Table 3-3. Typical Comparator-Based Computer Interface System Specifications (Continued)

System Controller: The counter on a specific 10762A Comparator can be sampled or all 10762A Comparator counters can be sampled simultaneously under program control.

External Forced Null: TTL level change, active low; forces the digital difference output to zero difference regardless of the actual difference and the Null Output to a low state. The External Forced Null will be maintained until returned to the high state.

Forced Zero Speed: TTL level change, active low; forces the Zero Speed Output to a high state regardless of actual conditions. The Forced Zero Speed condition will be maintained for the duration of the Zero Speed time constant after being returned to the high state.

Counter Output: The contents of the 28-bit counter of the 10762A Comparator along with 4 status bits from both the 10762A Comparator and the 10764B Fast Pulse Converter are available for transfer to the system controller via the 10746A Binary Interface.

Format: 32-bit word; 28-bit position word with 4 status bits which allow detecting measurement or reference signal errors, counter overflow, system Null and decimal point. Can be transferred to system controller as two 16-bit words or four 8-bit bytes.

Output Rate: Nine individual operations at typically 1 microsecond each are required to transfer two 32-bit words to the system controller from two 10762A Comparators using the two 16-bit word format in conjunction with the 10746A Binary Interface.

Atmospheric and Material Temperature Compensation Input: Manual Compensation factor input standard (Tables supplied); Automatic Compensator.

3.8 English/Metric Pulse Output Electronics

The English/Metric Pulse Output Electronics *(Figure 3-6)* is an interface configured for two axes of measurement providing micrometre or microinch value pulses. A typical system contains the following electronic equipment:

a. A 5501A Laser Transducer.
b. Two 10780A Receivers.
c. A 10740A Coupler.
d. Two 10760A Counters.
e. A 10761A Multiplier.
f. Two 10763A English/Metric Pulse Output Cards.
g. A 10755A Compensation Interface.
h. A 10756A Manual Compensator.
i. Two power supplies (±15V and +5V).

Equipment can be selected to provide the following additional capabilities:

a. Up to two additional measurement axis (10760A Counter and 10763A English/Metric Pulse Output).

b. Automatic compensation (replace 10756A Manual Compensator with 5510A Opt 010 Automatic Compensators and 10563A Material Temperature Sensor).

The English/Metric Pulse Output Electronics (*Figure 3-6*) provide a universal interface for almost all numerical controls for machine tools. Refer to *Table 3-4* for typical system specifications.

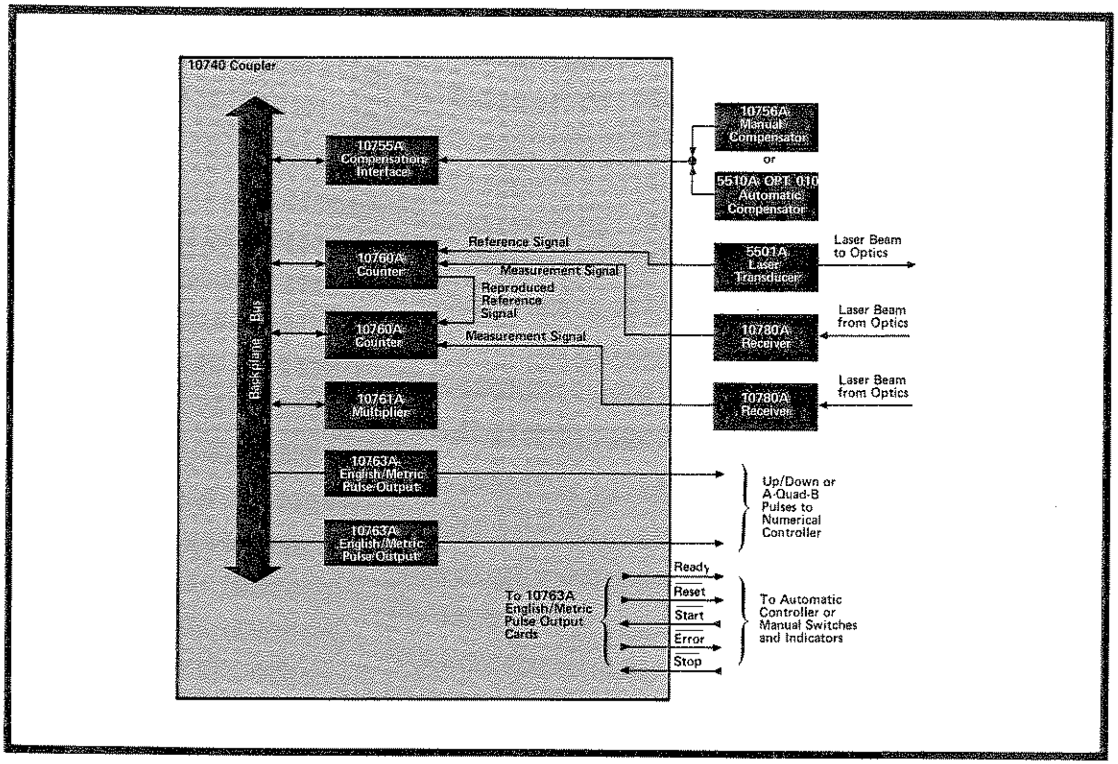


Figure 3-6. English/Metric Pulse Output Electronics Block Diagram

The English/Metric Pulse Output Electronics converts the basic wavelength value pulses from the laser head and receivers to compensated English or Metric value up/down or phase-quadrature (A-Quad-B) pulses. This conversion is done in real time to provide electrical interchangeability of the Laser Transducer with a variety of conventional incremental scales and encoders.

The 10763A English/Metric Pulse Output cards are the system controllers for the coupler backplane. They issue instructions to the 10760A Counters, the 10761A Multiplier, and the 10755A Compensation Interface. These cards convert the incoming reference and measurement signals into compensated displacement information. The 10763A English/Metric Pulse Output cards use this data to generate up/down or A-Quad-B signals representing total change in position. When there is more than one axis, the 10761A Multiplier is shared by each of the pulse output cards. Control of the backplane is transferred from one pulse output card to the next in a regular sequence that is set during initial configuration.

The following control functions are available on the control connector of the output cable from the English/Metric Pulse Output card:

a. Start. Initiates system operation and automatically initializes all circuit cards.
b. Error. A signal is available for error indication from any of the measurement axes.
c. Ready. Indicates pulse output has been enabled on this axis.
d. Stop. Halts pulse output and all system operation.
e. Reset. Slaved to 10740A Coupler Bus reset. Intended to reset external pulse counting device.

The 10755A Compensation Interface is used with either the 10756A Manual Compensator or the 5510A Opt 010 Automatic Compensator. In typical installations, the choice of manual or automatic compensation is determined by the stability of the ambient environment. Refer to the individual unit theory of operation for additional information.

Table 3-4. Typical Specifications for English/Metric Pulse Output System

Output Format: Phase Quadrature (A-Quad-B) or Up/Down Pulses; TTL differential line driver output, 100 nanosecond pulse width.

Maximum Output Rate: 1.6 MHz

Number of Measurement Axes: 1 to 4.

Output Resolution:
Metric Normal. 0.1 micrometre to 25 micrometre in 0.1 micrometre increments.
English Normal. 10 microinch to 2500 microinch in 10 microinch increments.
Metric Extended. 0.01 micrometre to 2.5 micrometre in 0.01 micrometre increments.
English Extended. 1 microinch to 250 microinch in 1 microinch increments.

Maximum Measuring Velocity:

NORMAL RESOLUTION

Interferometer	10702A, 10705A		10706A	
Resolution	0.1 micrometre	all other	0.1 micrometre	all other
Maximum Velocity mm/sec (in/sec)	0.15(6)	0.3(12)	0.15(6)	0.15(6)

EXTENDED RESOLUTION

Interferometer	10702A, 10705A		10706A	
Resolution	0.01 micrometre	all other	0.01 micrometre	all other
Maximum Velocity mm/sec (in/sec)	0.015(0.6)	0.03(1.2)	0.015(0.6)	0.015(0.6)

Measurement Accuracy: ±0.5 parts per million ±1 count output resolution ±1 count measurement resolution in conjunction with the 5501A Laser Transducer System. Measurement resolution depends on the type of interferometer used and if extended resolution is selected.

Measurement Response Time: 11 microseconds per axis; relative to motion detected by the interferometer.

Atmospheric and Material Temperature Compensation:
Manual thumbwheel input (tables supplied).
or Automatic Compensation.

Control Functions: Available at control connector (mate supplied).
Start. Initializes measurement system.
Stop. Halts measurement signal output.
Error Output: TTL level error signal from any measurement axis.
A variety of troubleshooting signals are also available at the control connector.

3.9 10781A Pulse Converter

The 10781A Pulse Converter is the simplest method of getting useful information from the Laser Transducer to external equipment. A typical system contains the following electronic equipment:

a. A 5501A Laser Transducer.
b. Two 10780A Receivers.
c. Two 10781A Pulse Converters.
d. Two power supplies (±15V and +5V).

The 10781A Pulse Converter (*Figure 3–7*) converts the measurement and reference signals to pulses that can be counted by an external counter. The output consists of up/down or A-Quad-B pulses of 1/4-wave length value. Refer to the unit manual for additional information and specifications.

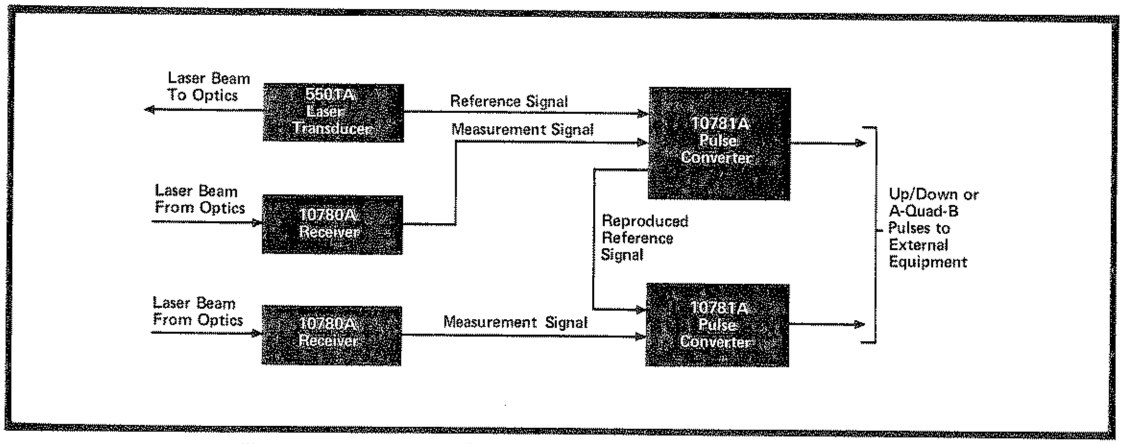


Figure 3–7. 10781A Pulse Converter Electronics Block Diagram

3.10 DETAILED THEORY OF OPERATION

The detailed theory of operation is subdivided as follows:

a. 5501A Laser Transducer.
b. 10780A Receiver.
c. 10740A Coupler.
d. 10745A HP-IB Interface.
e. 10746A Binary Interface.
f. 10760A Counter.
g. 10762A Comparator.
h. 10764B Fast Pulse Converter.
i. 10761A Multiplier.
j. 10781A Pulse Converter.
k. 10763A English/Metric Pulse Output.
l. 10755A Compensation Interface.
m. 10756A Manual Compensator.
n. 5510A Opt 010 Automatic Compensator.
o. 10783A Numeric Display.
p. 5501A Power Supplies.

3.11 5501A Laser Transducer

The 5501A Laser Transducer (laser head) is the source of the laser light for the system. The laser head package meets the NEMA-12 standard for industrial packages. *Figure 3–8* is the laser head block diagram.

The laser tube has the advantages of very long life-time, instant-on service, and automatic tuning. It is a two-frequency laser source; that is, the laser beam contains two components at slightly different frequencies, polarized at right angles to each other. The frequency split is about 2 x 10^6 Hz, compared to the laser frequency of some 10^{14} Hz, and is produced by an axial magnetic field which causes Zeeman splitting in the energy levels of the laser medium (helium-neon gas).

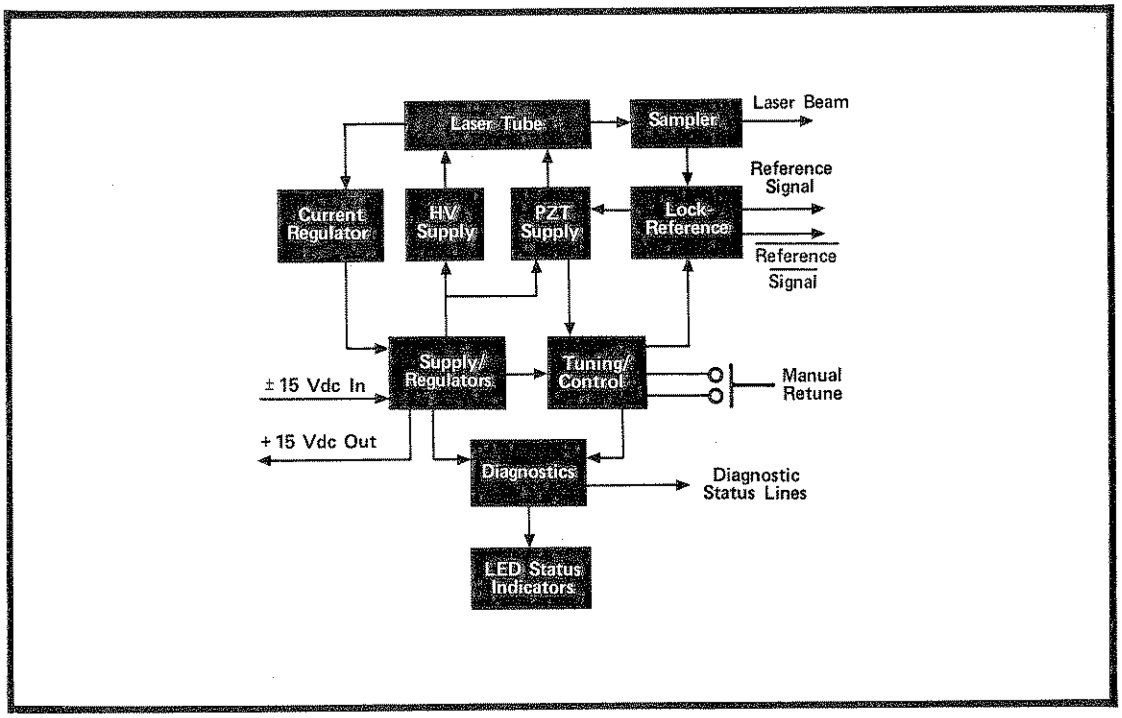


Figure 3–8. 5501A Laser Transducer Block Diagram

The laser system measures displacements by looking at the Doppler shift induced by the motion of the displacements. Both frequencies of laser light come from the laser head to the interferometer, where they are separated optically. One of the two frequency components is directed to the object whose motion is being measured. There it is reflected by a mirror or retroreflector (cube-corner) and returned to the interferometer. The effect of the motion is to cause a Doppler shift in the frequency of the reflected component. The two laser light components now differ in frequency by the original frequency split plus or minus the Doppler frequency shift. By integrating the total positive and negative excursions in the difference frequency, the system can find the net displacement in wave lengths of laser light.

The primary advantage of the two-frequency "ac" measurement system is its large dynamic range. For example, in the laser transducer system, the nominal output power is 120 microwatts, but the power returned to the laser receiver can be as low as four microwatts and the laser will continue to operate the system. The 5501A Laser Transducer System takes advantage of this wide dynamic range by moving the receiver from inside the laser head, where space considerations would limit the number of receivers, to the outside world. As a result, a single laser head can drive up to six linear measurement axes. Furthermore, the remote receivers can be mounted wherever most convenient; the laser light need not be returned to the laser head.

The laser head provides TTL-logic-level diagnostic signals that indicate the status of its auto-tune circuit and supply voltages to the system controller. Eight rear-panel light-emitting diodes give the same information in visible form. A RETUNE pushbutton provides for manual tuning whenever the laser exceeds its auto-tune range. The same function can also be commanded by an external controller.

For additional information and schematics, refer to the 5501A Laser Transducer Operating and Service Manual.

3.12 10780A Receiver

The 10780A Receiver (*Figure 3-9*) converts the Doppler-shifted laser light into electrical signals that can be processed by the rest of the laser system. The receiver contains a photodetector, an amplifier and level translator, a line driver, a level sensor (comparator), and local voltage regulators.

A lens on the front end of the receiver focuses the laser light onto the active chip of a silicon PIN photodiode. Between the lens and the diode is a small piece of polarizing material oriented at 45 degrees to the horizontal and vertical axes of the receiver. When the receiver is mounted properly—vertical axis parallel or perpendicular to the axes of the laser head—the polarizer passes one-half the incident power from each of the two incoming orthogonally polarized components of the received laser beam. The resulting power on the photodiode chip is an amplitude-modulated sine wave; its frequency is the Doppler-shifted split frequency, and its amplitude is proportional to the product of the incident powers of the two orthogonal components. The photodiode generates an ac current, which is converted to an ac voltage at a frequency of 100 kHz to 5 MHz.

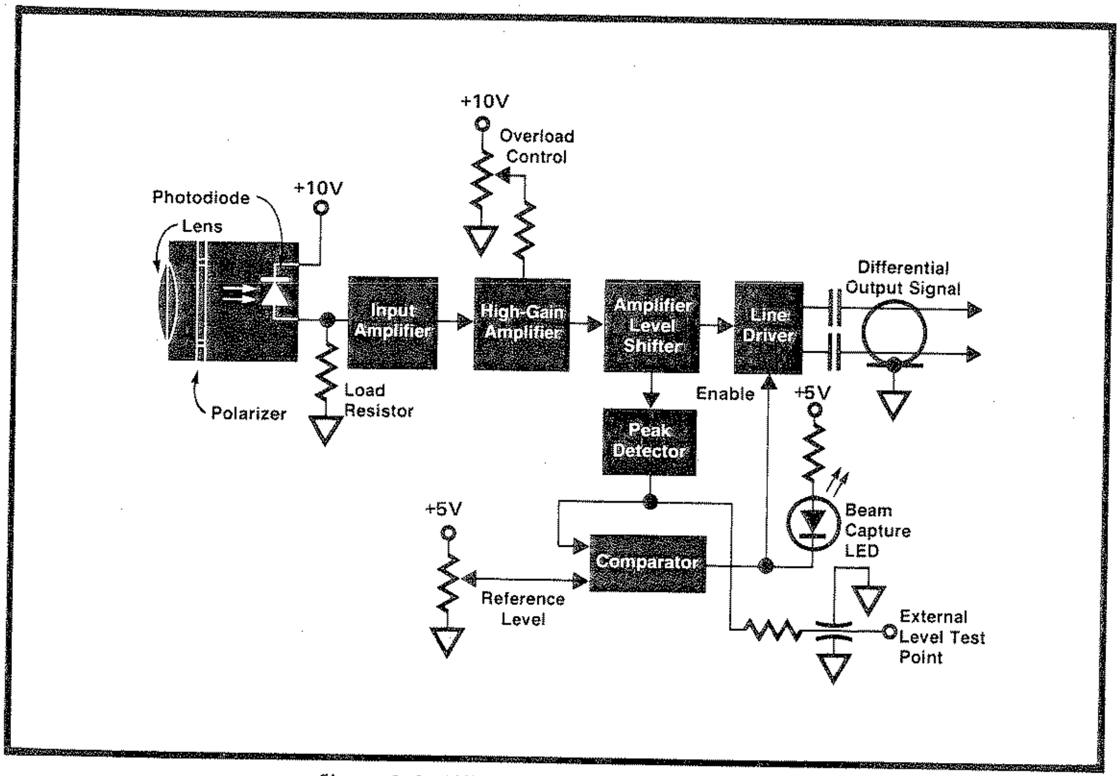


Figure 3-9. 10780A Receiver Block Diagram

The detected signal voltage goes through a stage of impedance transformation, two stages of voltage gain, and a stage of level translation. The result, a TTL-level signal, goes to a TTL differential line driver, which is ac-coupled to the rest of the 5501A system by a shielded twisted-pair cable. The output of the line driver is a differential square wave at the Doppler-shifted split frequency (measurement signal).

The level sensor (comparator) disables the line driver unless the incident laser power is four microwatts or more.

The receiver enclosure is designed to meet NEMA-12 standards for industrial packages. The receiver is mounted by its two aluminum end caps. Four plastic spacers (part of the end caps) separate the receiver case from its mounting plate and allow full air circulation around the receiver to carry away the heat it generates (nominally two watts). By using Nylon mounting screws, the entire receiver is electrically isolated from its mounting plates breaking any ground loops. This can be important when there are large electrical transients in the dc power lines or large ac ground currents running through a machine.

For additional information and schematics, refer to the 10780A Receiver Operating and Service Manual.

3.13 10740A Coupler

The 10740A Coupler serves as a housing and communications facility for the other electronic modules of the Laser Transducer System. *Figure 3-10* shows the inputs and outputs to the different modules. Electrical interconection of the modules is provided by the 86-pin connectors on the coupler's printed circuit backplane. The other system modules are plugged into the backplane connectors. The coupler has no internal power supplies, but supplies power to the modules from external power supplies connected to a barrier strip on its rear panel. Three dc voltages are required: +5V, +15V, and -15V. (The ±15V is required only if the 5510A Opt 010 Automatic Compensator is used in place of the 10756A Manual Compensator or if the system includes 10764B Fast Pulse Converter.

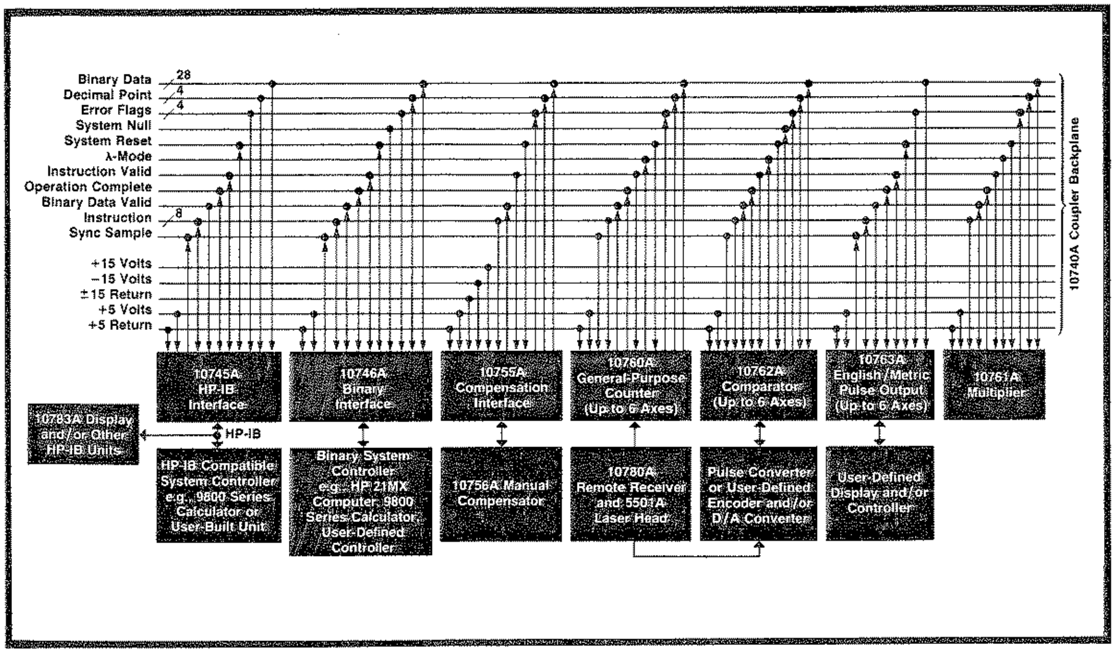


Figure 3-10. 10740A Coupler Backplane Signals

Numerical data is transferred between cards over a 28-bit parallel data bus on the coupler backplane. Binary coding is used. A four-bit-wide bus carries decimal point position information, and another four-bit bus carries error flags that indicate the existence of conditions that might make the data invalid. Associated with the data, decimal point, and error flag lines is a status line called Binary Data Valid (BDAV).

Instructions are sent from card to card over an eight-bit-wide instruction bus and two status lines called Instruction Valid (INSV) and Operation Complete (OPC). Instructions consist of two parts: a four-bit alpha address and a four-bit numeric command. Each card in the system has its own address, fixed in some cases and selectable by means of jumpers or switches in others. The modules and their addresses are:

Module	**Address**
10745A HP-IB Interface	O
10746A Binary I/O	P
10755A Compensation Interface	V
10760A General-Purpose Counter	X,Y,Z,A,B, or C
10761A Multiplier	M
10762A Comparator	X,Y,Z,A,B, or C
10763A English/Metric Pulse Output	X,Y,Z,A,B, or C
10764B Fast Pulse Converter	X,Y,Z,A,B, or C

In general, a particular numeric command always has the same meaning. However, different modules respond differently to the same command. An important concept here is that of implied talkers and listeners.

One way to handle communications in a bus-oriented system is to address one module as talker and one or more modules as listeners. This requires two modes of operation, one for addressing and one for data transfer.

For example, we can make the instruction lines separate from the data lines and agree that all modules will continuously monitor the instruction lines, looking for and reacting to only those instructions that concern them and ignoring those that do not. This means that a particular instruction will have any of several meanings, depending upon a particular card's point of view.

As an example, consider the instruction "2X". The address portion is "X", which could designate an X-axis counter card in the system. From the point of view of the X-axis counter the instruction "2X" means that it should enable its data output buffers, its decimal point position code drivers, and its error flag drivers to the 10740A backplane and set the Binary Data Valid line true. To a 10745A HP-IB Interface card it means load this information into your data register, decimal point code register, and error flag register, and issue a service request (SRQ) if there has been an error. To a 10761A Multiplier, however, it says take the data being output, multiply it by the laser light wavelength corrected for changes in the index of refraction of air, and store the result. The X-axis counter card was the implied talker and the multiplier and I/O card were the implied listeners. It was not necessary to address the counter as a talker or the I/O and multiplier as listeners.

There are four lines on the 10740A backplane that are dedicated to particular functions and always have the same meaning. Two are nonaddressed commands and two are status lines. System Reset is the command to initialize to some starting condition. This command is generated by the interface modules during power-up; it can also be sent by the system controller. Synchronous Sample is the command to take present displacement information and load it into output buffers. It is used to get a simultaneous sample from all axes. λ-Mode is a status code from counters and comparators, indicating to the multiplier card whether quarter-wave (λ/4) or eighth-wave (λ/8) resolution is being used in the system. System Null is a status code from comparators, indicating the system has arrived at the required destination. For additional information and schematics, refer to the 10740A Coupler Operating and Service Manual.

3.14 10745A HP-IB Interface

The 10745A HP-IB Interface is an appropriate laser transducer input/output (I/O) module for any system controller that is compatible with the HP Interface Bus (IEEE Standard 488-1975). Such controllers include Hewlett-Packard Models 9815A, 9820A, 9821A, 9825A, 9830A, 9835A, and 9845A Calculators, HP 2100 Series Computers with the 59310B I/O card, or any HP-IB compatible user-built controller. *Figure 3-11* is a block diagram of the HP-IB card.

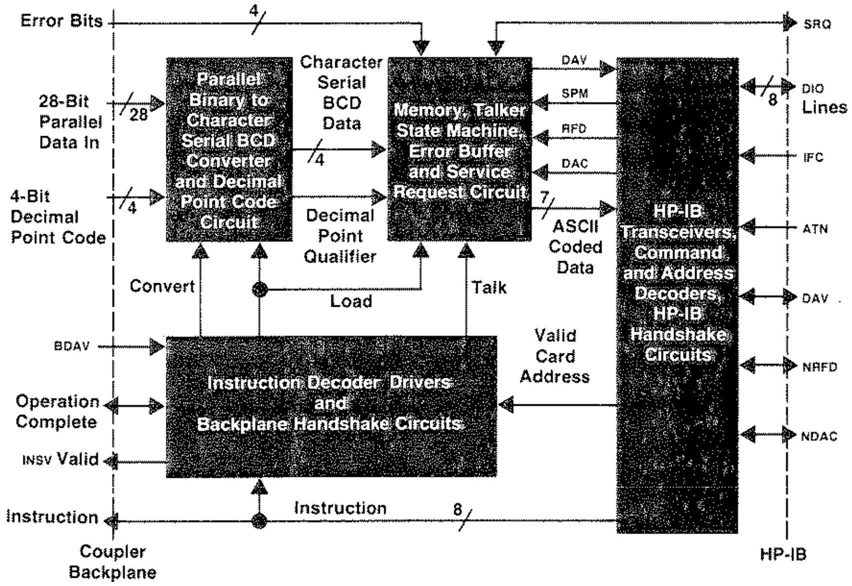


Figure 3-11. 10745A HP-IB Interface Block Diagram

The HP-IB card can operate as either a talker or a listener on the HP-IB. As a talker, it has two modes of operation. First, when addressed to talk, it outputs a string of nine ASCII (American Standard Code for Information Interchange) numeric digits followed by ASCII carriage return (CR) and line feed (LF) codes. A decimal point, also in ASCII, can occur anywhere in the string of digits.

The HP-IB card's second mode of operation as a talker is related to the service request capability and the serial poll mode. When an error in the laser transducer system is noted by any card, the card involved stores the occurrence in a buffer. When that card is instructed to output its data, it also outputs the contents of its error buffer. This error information is loaded into an error register on the HP-IB card and can only be cleared with a reset command. The presence of the error condition causes the HP-IB line called SRQ to be set true. The controller should be programmed so that, when it recognizes this condition, it executes a serial poll, that is, it untalks and unlistens everything on the bus, then addresses itself to listen and sends the universal command SPE (Serial Poll Enable). Then it begins polling devices on the HP-IB capable of responding to SPE by sequentially addressing them to talk. Responding to serial poll, the HP-IB card outputs an eight-bit status byte. The controller takes the decimal value of the status byte and examines it to see if bit 6, the service request bit, is set or not. If it is, bits 0 through 3 are examined to see what combination of errors has occurred. The controller may then send a reset command to clear the error register of the HP-IB card.

As a listener, the HP-IB card receives a four-bit-wide command and a four-bit-wide address and combines them into an eight-bit-wide instruction that is sent out over the instruction bus on the backplane of the coupler. Each time its address buffer is loaded, the HP-IB card sets a backplane line called Instruction Valid (INSV) to the true state to inform cards in the coupler to look at this instruction. Whenever INSV is true, the HP-IB card will not allow new data to be loaded into its command and address buffers. It sets the HP-IB Not Ready for Data (NRFD) line low whenever INSV is true and it is addressed to listen. This informs the talker on the HP-IB that the HP-IB card is not ready for data.

There are two algorithmic state machines (ASM) on the HP-IB card. They operate essentially independently but because they share some common circuits they do not operate simultaneously. One ASM controls the binary-to-BCD converter and the other controls the talker function.

Whenever an output instruction for another card occurs on the coupler's instruction bus, the HP-IB card takes the binary data, the decimal point position code, and the error flags that are put on the backplane as a result of the instruction and loads this information into its input data register, its decimal point register, and its error bit register, respectively. Then if a conversion instruction occurs, the conversion flip-flop is set and a signal is sent to the coupler backplane indicating that the instruction need not be held. The output of the conversion flip-flop is logically ANDed with a signal from the talker ASM signifying that it is not presently talking. The result is a qualifier input to the converter-control state machine. When this qualifier goes true, the converter-control state machine starts through its sequence of clocking the binary-to-BCD converter and loading its output into a random-access memory. Once started, it proceeds on its own until the conversion is complete, at which time it clears the conversion flip-flop.

The binary-to-BCD converter takes the 28-bit binary word in the input data register and, each time it receives a clock pulse, outputs a four-bit BCD character. This conversion takes place least-significant bit first to most-significant bit last. The 28-bit binary word translates a nine-character BCD word and therefore it takes nine clock pulses to complete the conversion.

Before clocking the converter each time, the converter-control ASM checks to see if the RAM address counter output agrees with the decimal point position code stored in the decimal point register. If it does, the converter is not clocked but the RAM address counter is advanced one. This leaves a space in the data string for the decimal point.

The converter-control ASM is clocked by a two-phase clock with a frequency of 3.33 MHz ±20%. Thus the time required for a complete conversion of the 28-bit parallel binary number to a nine-character BCD number with decimal point information is between 7 μs and 10.5 μs. The typical value is 8.4 μs. To date, there is no controller that can call for a conversion and issue a second command before the conversion is finished. But just in case one is built, the converter-control ASM and the talker ASM are interlocked so they will not try to operate simultaneously. In addition, the HP-IB card will hold up a data transfer on the bakcplane until it finishes converting the number. To take the converted data in the RAM and transfer it to the controller, all that is necessary is for the controller to address itself to listen and the HP-IB card to talk, and put the HP-IB into the data mode (ATN false). When this happens the talker ASM takes the four-bit-wide BCD data in the RAM, adds to it three additional bits to make it seven-bit ASCII, and outputs it on the HP-IB. The talker ASM monitors the NRFD line and the NDAC line on the HP-IB and drives the DAV line in accordance with the rules of the HP-IB. For additional information and schematics, refer to the 10745A HP-IB Interface Operating and Service Manual.

3.15 10746A Binary Interface

The 10746A Binary Interface (*Figure 3–12*) is the appropriate input/output (I/O) interface for a wide variety of computers and controllers that require an 8- or 16-bit binary interface.

The binary interface transmits data to the controller in the form of two 16-bit binary words. There are 16 lines for data output, so all 16 bits may be transmitted in parallel. Alternatively, only 8 lines may be used and the data sent as four 8-bit words. Data from the controller is sent to the interface card in the same format, using either the same lines or a separate set of tri-state buffered lines that are turned off during data output from the card.

Instructions come into the binary I/O card in the form of eight-bit words on the same lines as data.

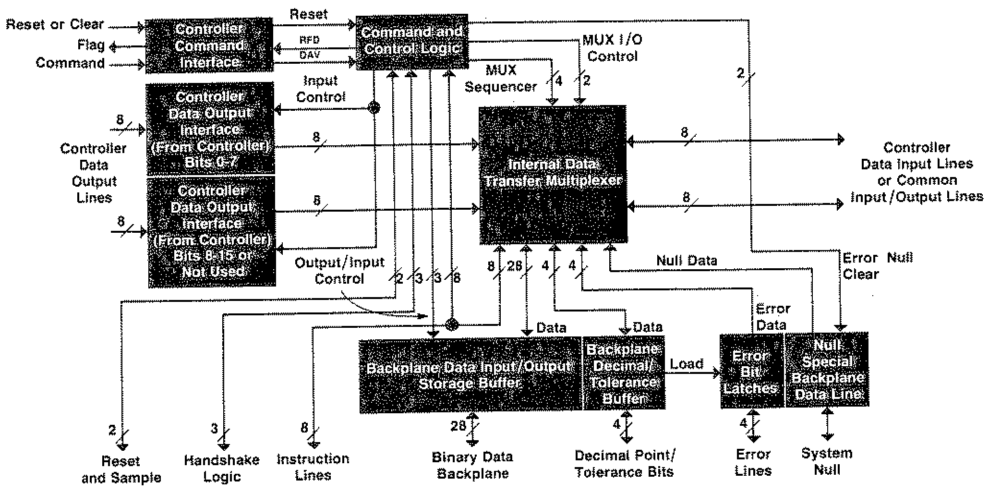


Figure 3–12. 10746A Binary Interface Block Diagram

The transfer of an instruction or data word is controlled by a command line, which indicates to the I/O card that the bit pattern on the input lines is valid information, and a flag line, which indicates to the controller that the data bits have been accepted. When data is transferred to the controller the flag line indicates valid information and the command line indicates data accepted, a convention common to many I/O structures.

Because instructions and data share the same lines, the I/O structure has two modes of operation, called command mode and data mode. In the command mode, information from the controller is clocked into an instruction register and placed on the system backplane as an instruction to all the cards in the system, including the binary I/O card. The binary I/O card's control logic then interprets the instruction from the backplane and performs the required operation (if any). Once the instruction is clocked into the instruction buffer the controller is free to set up the next instruction even though the transducer system may not have completed execution of the preceding one. This allows operation with a fast controller in an interrupt environment.

There is a 36-bit data register on the binary interface card: 28 bits are used for binary data, four bits are used as a decimal point location buffer, and four bits are used as error status buffers. This register has two separate tri-state I/O ports, one for backplane input/output, and one for controller input/output.

When an instruction is received from the backplane to transfer data to or from the controller, the control logic switches to the data mode. In the case of data input from the controller, the data register is sequenced by the control logic so that each time valid data is available, that data is clocked into part of the data register. If the card has been set (jumper selectable) for 16-bit words, the first 16 bits of data are loaded into the upper bits of the register with the four most-significant bits being the decimal point location code. The next 16-bit word is loaded into the remaining half of the data register and the control logic immediately switches back to the command mode (error status bits cannot be loaded from the controller). If the card has been set for 8-bit words, the first word is placed in the upper portion of the data register and again the four most-significant bits are the decimal point location. Then three more data words are accepted and placed in successively lower bit locations with the last word in the least-significant eight bits. The control logic switches immediately back to the command mode after the fourth word.

If data is to be sent to the controller, the sequence is the same except that the control logic sequences the data register to put data onto the interface lines, most-significant word first. If an error has been detected, the upper four bits (decimal point bits) of the transmitted data contain all ones to indicate that an error is being transmitted and the four status bits replace the data in the next four bits. This allows the same sequence to be used for error transmission as for regular data transmission.

A jumper-selectable data-mode-only configuration causes the binary interface to ignore commands from the controller. It will still transfer data, however, so it can be used as an I/O device for some peripheral other than the system controller. For additional information and schematics, refer to the 10746A Binary Interface Operating and Service Manual.

3.16 10760A Counter

The 10760A Counter is a general-purpose counter consisting of line drivers and receivers, a resolution extender, a pulse converter, and a reversible counter (see *Figure 3-13*).

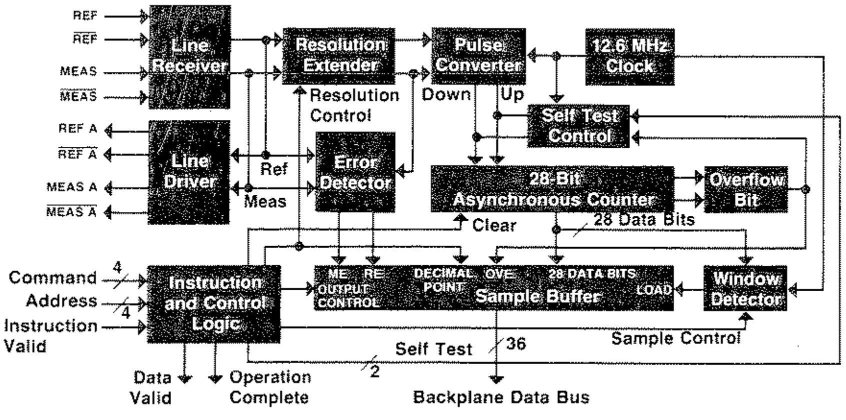


Figure 3-13. 10760A Counter Block Diagram

The line receivers accept two differential RF signals, one from the laser source (reference signal), and one from the remote receiver (measurement signal), and convert them to TTL signals. The input signals are then amplified by the line drivers for use by other cards in the system. For example, the reference signal must be sent to each counter card and must be daisy-chained because the line impedance matching requirement and available line driving power do not allow parallel connection. The measurement signal is also reproduced, and may be used for other signal processing, such as differential measurement using one measurement signal at the reference input.

The resolution extension circuit allows a user to select normal resolution of 0.16 micrometre (6 microinch) or extended resolution of 0.016 micrometre (0.6 microinch) under program control. The only drawback of the resolution extender is the 1.2-inch-per-second slew rate limitation imposed when resolution extension is in use. This is more than compensated for by the real time extenstion in resolution and resulting increase in positioning accuracy.

After the measurement signal has been resolution extended (or not, depending upon program control), the measurement and reference signals are converted to displacement information in the form of up/down pulses, which are fed to a counter. This is done by the pulse converter circuit.

The next functional block on the counter card is a 28-bit binary counter that counts the up/down pulses from the converter to give total displacement information. The delay between a position change on the measurement axis and a change in the counter is on the order of 0.4 microseconds depending on the length of cable between the receiver and the counter card.

In addition to these signal processing blocks, the counter card also has several control and error functions. The error circuits constantly monitor the status of the counter and the conditions of the reference and measurement signals at the input to the pulse converter. If the reference signal is interrupted for more than 6 microseconds a reference error bit is set. If the measurement signal is interrupted or becomes invalid because of excessive slew rate, a measurement error bit is set. The error circuits monitor the frequencies of the two signals and set the respective error bit if prescribed limits are exceeded.

The counter status error bit is set whenever the counter chain overflows or underflows. This error is recoverable, that is, it can be corrected by moving the retroreflector in the direction opposite to that which caused the overflow or underflow until the condition is reversed. Thus no counter information is lost. This is not the case for reference or measurement signal errors. Should one of these occur, the measurement axis must be returned to some gage point to redefine the zero point.

The control circuits interpret system instructions and cause the counter to perform the required operation. Test functions are included on the counter card to allow the system controller to check the operation of the counter chain and error bits, the output buffer, and the pulse converter clock. For additional information and schematics, refer to the 10760A Counter Operating and Service Manual.

3.17 10762A Comparator

In a comparator system, the 10762A Comparator cards, one for each axis, replace the general-purpose counter cards. A compensation interface card, a binary I/O card, and a fast pulse converter complete the electronics package in the 10740A Coupler. Also required for each axis are an external digital-to-analog (D/A) converter (not supplied with the system).

Figure 3-14 is a block diagram of the comparator card. The heart of the comparator is a 28-bit parallel subtracter with a built-in null decoder for the upper 24 bits. This circuit receives from the I/O card a 28-bit digital representation of the object's destination along one axis and stores this information. It also receives and stores a four-bit tolerance code representing the degree of precision required in positioning the object.

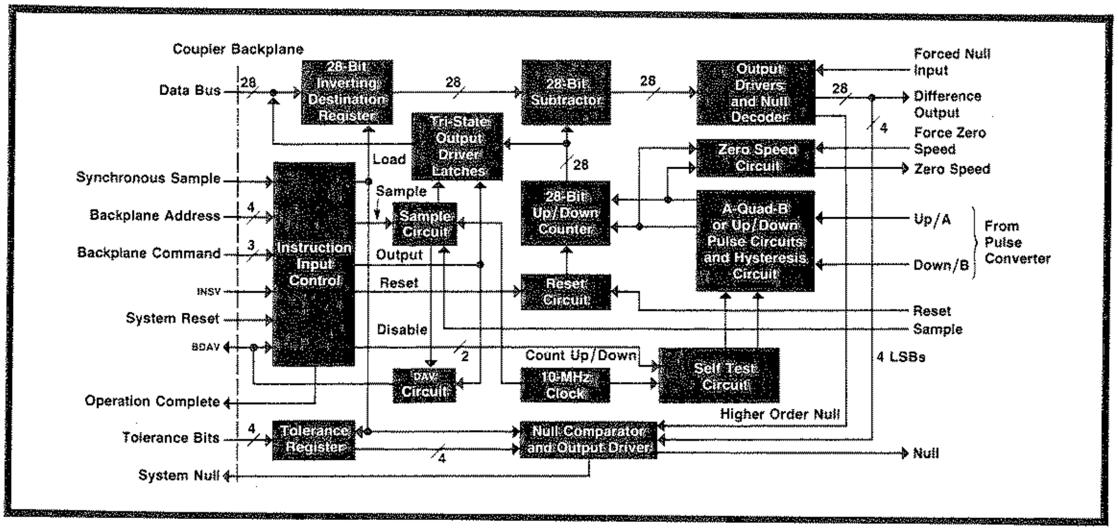


Figure 3-14. 10762A Comparator Block Diagram

The act of loading the tolerance register and the destination register causes the digital output to be forced to a null or zero difference regardless of the actual difference. This prevents the servo stage from taking off in some uncontrolled manner as soon as the destination register of the first comparator is loaded, and allows time for the comparators associated with the other axes to be loaded before allowing the system to move. However, this does not prevent the subtracter from working. As soon as the destination register is loaded, the comparator card begins to calculate the difference between the contents of a 28-bit-wide up/down counter and the contents of the destination register. The difference appears at the input of the output-driver/null-decoders.

To start the system moving, either a synchronous sample command or an addressed sample instruction can be given. In addition to taking the present contents of the up/down counter and loading it into the comparator's output buffer, these commands release the forced null that was applied to the null decoder when the destination register was loaded. The digital difference in sign and magnitude form then appears at the output of the comparator and is sent to the external D/A converter.

Under the influence of the drive voltage from the D/A converter the object begins to move toward the desired location. This movement is sensed by the laser transducer and translated by the pulse converter into up or down pulses. Fed into the comparator, these pulses cause the contents of the up/down counter to change in a direction that brings it closer to the value stored in the destination register. As this happens the digital difference between the desired location and the actual position is continuously fed out to the D/A converter to drive the object closer to the desired location. When the upper 24 bits of the up/down counter agree with the upper 24 bits of the destination register, the output of a four-bit comparator comparing the lower four bits of the difference output to the four-bit tolerance in the tolerance register is examined. When the difference output is within the tolerance a null signal is issued both to the outside world and to the coupler backplane. This null is wired on the backplane with the same output from other comparators. This system null goes true only when all axes in the system have achieved their desired locations within their individual tolerances. For additional information and schematics, refer to the 10762A Comparator Operating and Service Manual.

NOTE

See 10764B manual for differences between 10764A and 10764B cards. Power supply requirements, jumpers/switches, and operating temperatures are different.

3.18 10764B Fast Pulse Converter

The 10764B Fast Pulse Converter is used in a comparator-based computer interface system in conjunction with a comparator card to increase the measurement resolution and velocity of the Laser Transducer System. Refer to *Table 3-3* typical comparator-based computer interface specifications for allowable resolution and maximum velocity specifications for specific interferometers.

The fast pulse converter *(Figure 3-15)* provides a means of converting the reference and measurement signals from two axes to pulses that can be counted by the comparator card. The reference and measurement signals are applied to signal reception and isolation circuits. These circuits contain photo-isolation devices which convert the differential input signal pairs to single-ended signals with ECL logic levels. Additional immunity to external noise is obtained by applying these signals to Schmitt trigger circuits.

The resolution selection circuits allows resolution extension of the system by factors of 1 through 15. The pulse generation circuits compare the input signals (derived from the incoming reference and measurement signals) with respect to frequency and outputs a pulse for each 1/2 cycle difference between the reference and measurement signals. If the reference signal frequency is higher, pulses occur on the down-pulse line; if the measurement signal frequency is higher, pulses occur on the up-pulse line.

Error detect circuits monitor the incoming reference and measurement signals for extreme frequency. If the frequency deviates from its nominal value by greater than preset limits, an error signal is generated. The only instructions that the fast pulse converter responds to are reset error bits and output error bits.

For additional information and schematics, refer to the 10746B Fast Pulse Converter Operating and Service Manual.

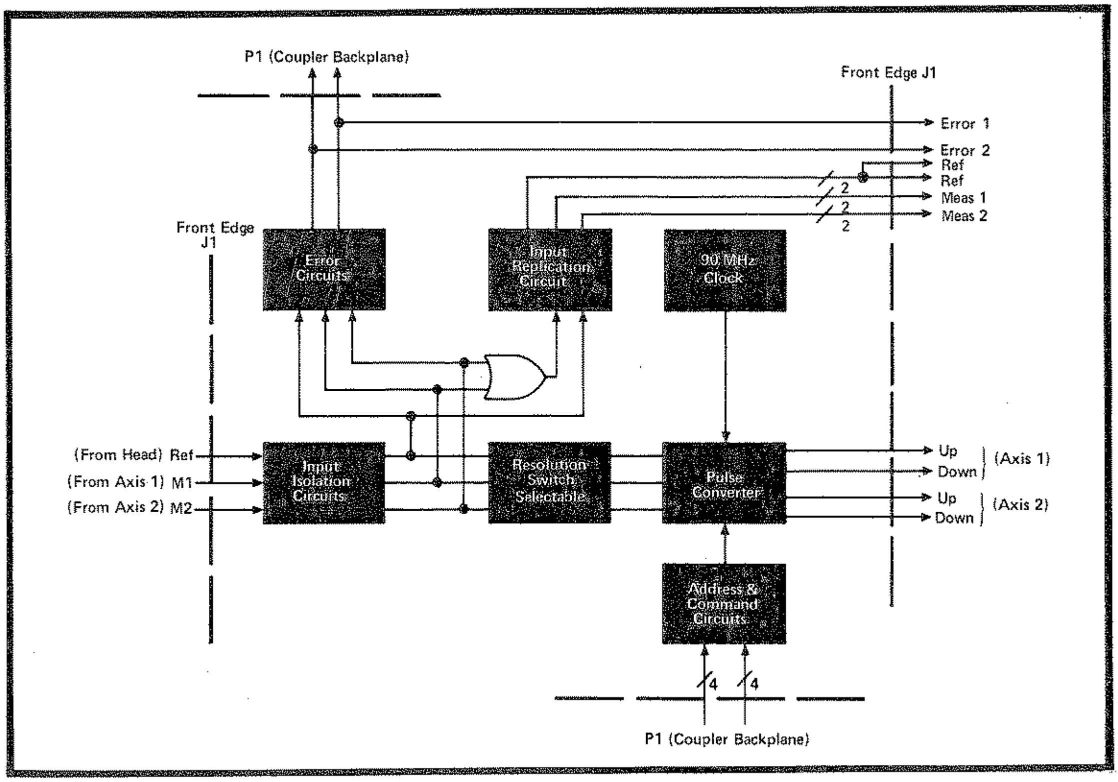


Figure 3-15. 10764A Fast Pulse Converter Block Diagram

3.19 10761A Multiplier

The 10761A Multiplier card is used only with the English/Metric system. Its main purpose is to perform the conversion of uncompensated fringe (quarter-wave) displacement data to either metric units (in millimetres) or English units (in inches) for output to a controller.

Figure 3–16 is a block diagram of the multiplier card. The input buffer accepts and holds data available from the coupler backplane. This may be velocity-of-light information from a compensation interface card (described later), displacement information from a counter card, or any other applicable backplane data. The next part of the multiplier is a group of AND gates used as data control for the magnitude data stored in the input buffer. These gates control the add-shift/shift- only function (multiplication is accomplished by repeated shifting and adding). From here the data goes to the adder-shifter section of the card. The inputs to the adder are the outputs of the AND gates and the output of the accumulator. The resulting addition is fed back to the inputs of the accumulator, which is a 29-bit register. The 29th bit is an overflow bit used to indicate that the result of multiplication has a magnitude greater than 28 bits. The multiplier register is a shift register that can be loaded from the accumulator or from a constants ROM (read-only-memory) which contains all the conversion constants for the multiplier. This shift register's least significant bit controls the input buffer AND gates.

Besides the main adder there is a four-bit decimal point adder that handles the conversion of the decimal point code for the appropriate measurement units. These circuits are directed by the control logic, which interprets backplane instructions and controls the execution of indicated operations. The control logic has a 10 MHz clock, which allows a complete multiplication in less than 5 microseconds.

Instructions recognized by the binary multiplier card include reset, English units, metric units, velocity-of-light (VOL) output, counter output, and multiplier output. The VOL output in-

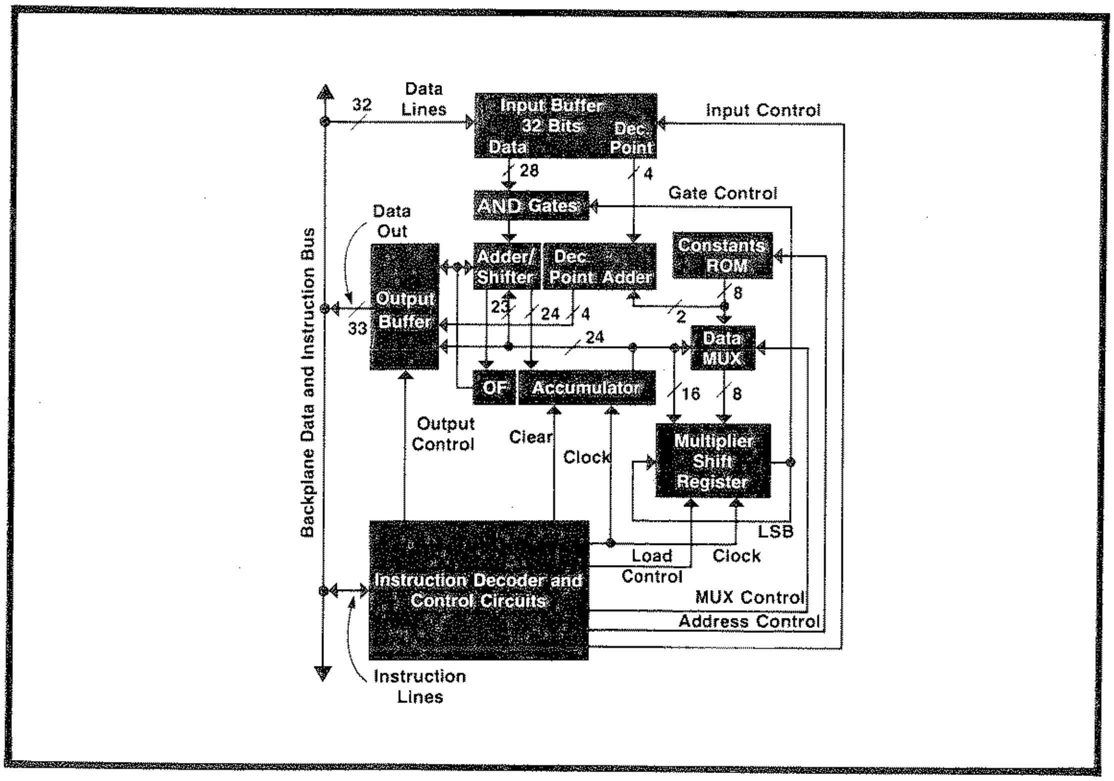


Figure 3–16. 10761A Multiplier Block Diagram

struction is interpreted by the multiplier card as an input operation. The VOL data is loaded into the buffer and then multiplied by the preselected units constant from the constants ROM. The product is stored in the shift register for future use. This result represents a compensated units-conversion number for converting fringe displacement data from the counter cards to the preselected unit of measure. For additional information and schematics, refer to the 10761A Multiplier Operating and Service Manual.

3.20 10781A Pulse Converter

The 10781A Pulse Converter (*Figure 3-17*) is a quarter-rack size electronic module for 5501A Laser Transducer systems which accepts the REF (reference) and MEAS (measurement signals and outputs displacement information in pulse or A-Quad-B format. The A-Quad-B output is designed to interface to some hardwired controllers and other closed-loop systems which contain reversible counters.

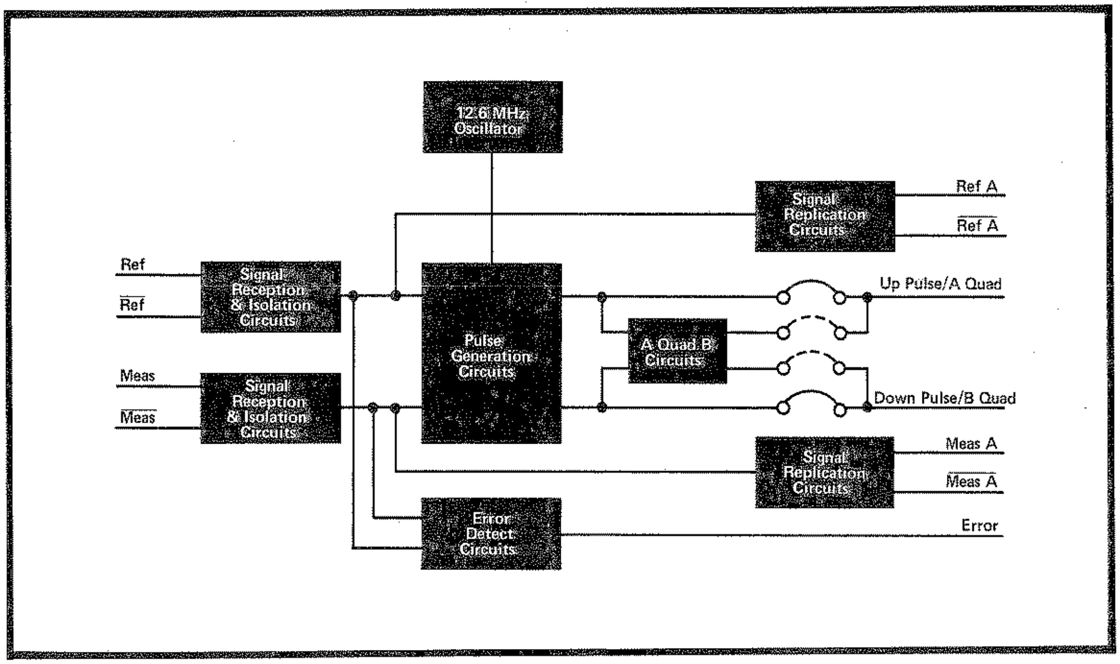


Figure 3-17. 10781A Pulse Converter Block Diagram

Resolution of 10781A Pulse Converter output is one-quarter wavelength (approximately 6.23×10^{-6} inches). If desired, pulse pairs may be generated to create an apparent resolution of 1/8 wavelength. A pair of jumper wires allows selection of either up and down pulses or A-Quad-B format output; another jumper wire allows the pulse output to be disabled in the event of an error detection on the axis being monitored (error trip). The pulse converter is designed to provide a simple method of converting the reference and measurement signals to pulses that can be counted by a user's counting electronics.

The reference and measurement signals are applied to signal reception and isolation circuits. These circuits contain photo-isolation devices which convert the differential input signal pairs to single-ended signals with TTL logic levels. Additional immunity to external noise is obtained by applying these signals to Schmitt trigger circuits.

The pulse generation circuits compare the two input signals (derived from the incoming reference and measurement signals) with respect to frequency. The outputs from these circuits are 40 ns pulses (one pulse represents 1/2 cycle difference between the reference and measurement signals). If the reference signal frequency is higher, pulses occur on the down-pulse line; if the measurement signal frequency is higher, pulses occur on the up-pulse line.

Error detect circuits monitor the incoming reference and measurement signals for extreme frequency excursions. If the frequency deviates from its nominal value by greater than preset limits, a panel light illuminates and the two input signals are inhibited from passing to the pulse generation circuits. These extreme frequency excursions occur when the system optical devices are moved at too rapid a rate.

For additional information and schematics, refer to the 10781A Pulse Converter Operating and Service Manual.

3.21 10763A English/Metric Pulse Output

The 10763A English/Metric Pulse Output card is the system controller for the coupler backplane. It issues instructions to the counter, multiplier, and compensation cards, which converts the incoming reference and measurement signals into compensated displacement information in the form of a 28-bit binary number on the backplane. The pulse output card uses this data to generate up-down or A-Quad-B signals representing total change in position. *Figure 3–18* is a block diagram of the 10763A.

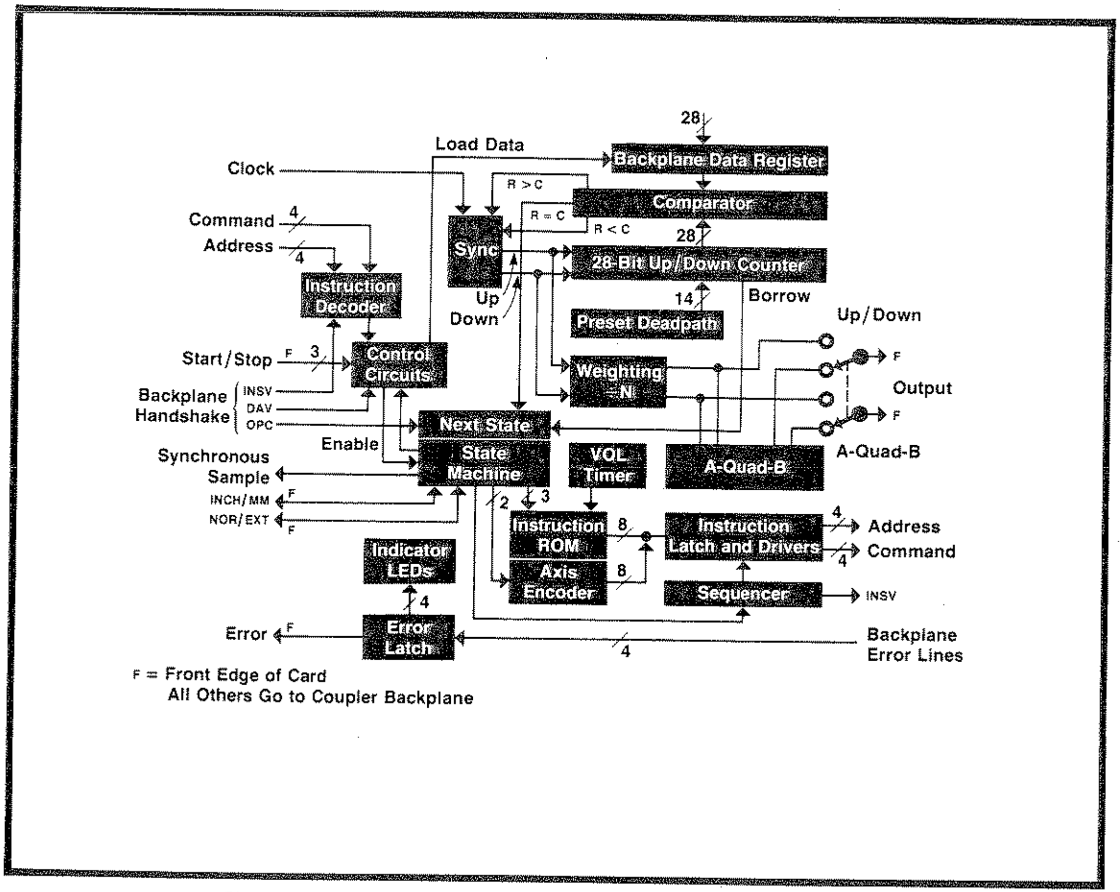


Figure 3-18. 10763A English/Metric Pulse Output Block Diagram

The heart of the pulse output card is a 28-bit comparator, which compares the 28 bits of backplane displacement information with the contents of a 28-bit up-down counter. Should the displacement number increase, the comparator enables up counts into the up-down counter until its contents are equal to the displacement. These up counts (or down counts for a negative displacement) each represent 0.1 micrometre (10 microinches in the case of English units). These same count pulses are routed through a divide-by-N counter that allows the scaling factor to be selected by the user, so that each output pulse can represent any even 10th micrometre from 0.1 to 25.6 micrometres (or 10 to 2560 microinches). A quadrature coding circuit allows the user to select A-Quad-B output coding instead of the weighted up and down pulses. The A-Quad-B output consists of two square waves in quadrature, with up/down information supplied by their relative phase: wave A lags wave B for an upward displacement and vice versa.

An algorithmic state machine (ASM) controls the internal functions of the card and generates the proper sequence of backplane instructions: synchronous sample; counter card output; multiplier card output; and return. If there are two, three, or more axes, the multiplier card is shared by the several pulse output cards, and control of the backplane is transferred from one pulse output card to the next in a regular sequence that is set during initial configuration.

A feature of the pulse output card is its ability to enter a preset number into the general-purpose counter card. This is used to allow for environmental compensation of the deadpath of the measurement axis. Deadpath is measured during machine installation and converted to a code that is entered into switches on the pulse output card. During initialization, the contents of these switches are preset into the up-down counter portion of the pulse output card. At the proper time in the initialization sequence, the pulse output card sends a count up instruction to its assigned counter card. When the pulse output card counts down to zero, it stops the counter, which now contains the deadpath, measured in quarter-wave fringe counts.

It is necessary to preset the pulse output card to a displacement count equivalent to the fringe count in the counter. This is easily done by causing the counter to output to the multiplier, and the multiplier to convert the fringe count to a compensated deadpath displacement and output it to the pulse output card. The pulse output card clocks this displacement into its 28-bit data register, and begins a special up count to equalize the up-down counter and the data register. During this time no pulses are sent to the external controller. When the special up count is complete the normal displacement data transfer begins. Should environmental conditions change, the new compensation factor will operate on both the measured displacement and the preset deadpath. This additional accuracy can be useful in some installations where physical limitations make it impossible to reduce the deadpath to the desired absolute minimum.

During each data transfer the pulse output card currently in control of the backplane looks at the four error lines on the backplane. Should one of these be true, an error latch is set and an LED lamp is lighted on the pulse output card to show which card has the error state and what kind of error it is. A user option allows the system to ignore errors on axes not currently being used, or to shut down the axis at the first error on any axis in use, or any combination. Each pulse output card has an ERROR status line brought out to the front of the card; these may be looked at individually for each axis or wire-ORed together. A backplane reset resets the error latch.

The pulse output card also allows the user to select slow or fast maximum output pulse rate, and normal or extended resolution (x6 or x10) for each axis individually.

Because each axis does a complete data input to pulse output cycle in approximately 11 microseconds (33 μs for a three-axis system) the output pulses are a real-time measure of the displacement. For additional information and schematic, refer to the 10763A English/Metric Pulse Output Operating and Service Manual.

3.22 10755A Compensation Interface

Changing environmental conditions that result in a change in the index of refraction of air cause a change in the velocity of light and therefore in the wavelength of laser light. Accurate measurements require compensation for this effect.

The 10755A Compensation Interface Card (*Figure 3-19*) places the required compensation factor on the coupler backplane when commanded by the system controller. Most coupler-based systems will include one compensation interface card.

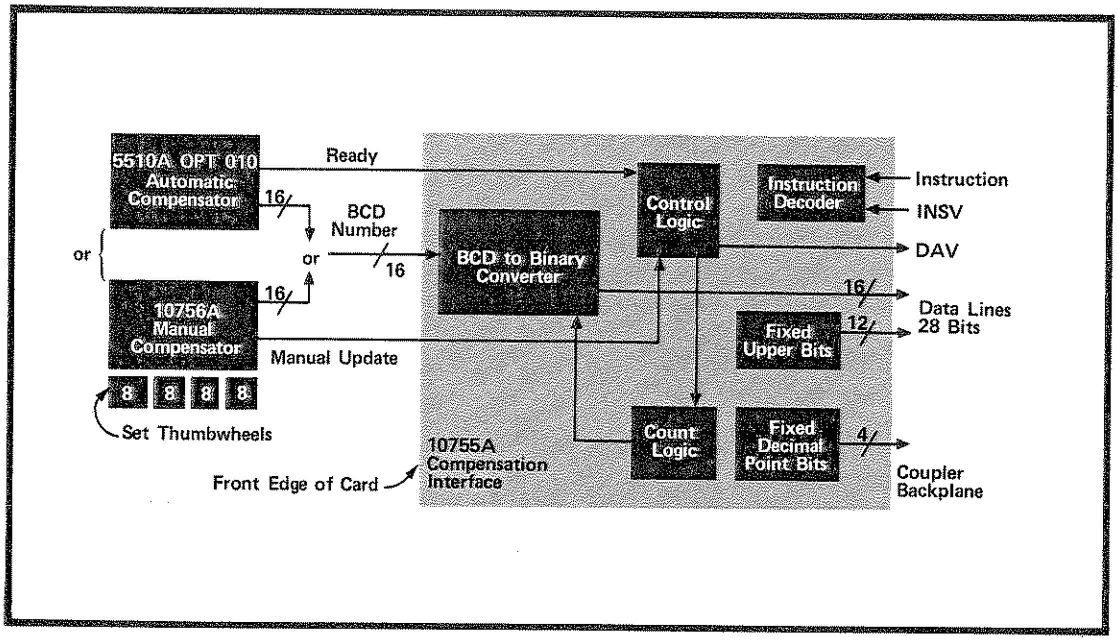


Figure 3-19. 10755A Compensation Interface Block Diagram

The compensation interface gets the compensation factor either from the 5510A Opt 010 Automatic Compensator, a separate unit, or from the 10756A Manual Compensation module, which plugs into the coupler. The automatic compensator measures the temperature, pressure, and humidity of air and computes the index of refraction of air, n, and the compensation factor, 1/n, which is between 1.0000000 and 0.9990000 for all earth-type atmospheres. Because only the four-least-significant digits change, the compensator presents only these digits to the compensation interface card in binary-coded-decimal format on 16 parallel lines. The compensation interface converts the data to a form usable by the laser transducer system and outputs it to the coupler backplane when commanded to do so.

In typical installation (workshops, laboratories, machine shops, etc.) the compensation factor can change over a period as short as a few minutes. The 5510A Opt 010 Automatic Compensator can compute a new number as often as twice each second. Where the environment is closely controlled, such as in metrology labs, the compensation factor changes very little during a day, and the data can be entered instead from a 10756A Manual Compensation module. This module presents the compensation factor, computed from a formula or derived from tables in a handbook, to the compensation interface in BCD bit-parallel, digit-parallel format identical to that of the 5510A Opt 010. A small cutout in the front panel of the coupler allows access to the thumbwheel switches that set the number, and an update pushbutton tells the compensation interface that a new number has been entered and should now be converted into the proper format for the backplane.

The 10755A Compensation Interface Card recognizes two instructions, output and update. Update comes from the coupler backplane, from the manual module's pushbutton, during system reset, and after each output to the backplane.

When an update command occurs the interface card waits for the completion of the next compensator computation cycle. It then presets four BCD down-counters with the 16 bits from the compensator. At the same time it presets four binary up-counters with a 16-bit word representing the least-significant 16 bits of the binary represenation of 9990000. The BCD down-counters are then clocked down toward zero, and simultaneously the binary up-counters are counted up. When the BCD counters reach zero, the binary counters hold a binary representation of the lower 16 bits of a binary representation of the compensation factor.

Operation with the manual compensation module proceeds in similar fashion.

In addition to compensating for the variable speed of light, the use of the compensation factor allows the operator to correct for thermal expansion of the part being measured or worked. All dimensions are normally referenced to their values at 20.0°C (68.0°F); at higher temperatures they measure longer or shorter than this, depending on whether the part has a positive or negative coefficient of thermal expansion. The 5510A Opt 010 Automatic Compensator has a special thermal probe for sensing part temperature. The coefficient of thermal expansion is entered on the front of the unit through a set of thumbwheel switches. The compensator does the required computation automatically and modifies the compensation factor accordingly. The same principle can be applied when using the 10756A Manual Compensation module.

A special check mode of the automatic compensator causes it to output the measured values of pressure, temperature, and humidity. These numbers can be placed on the backplane by the compensation interface, and can be accessed by the system controller for setup or system checkout. For additional information and schematics, refer to the 10755A Compensation Interface Operating and Service Manual.

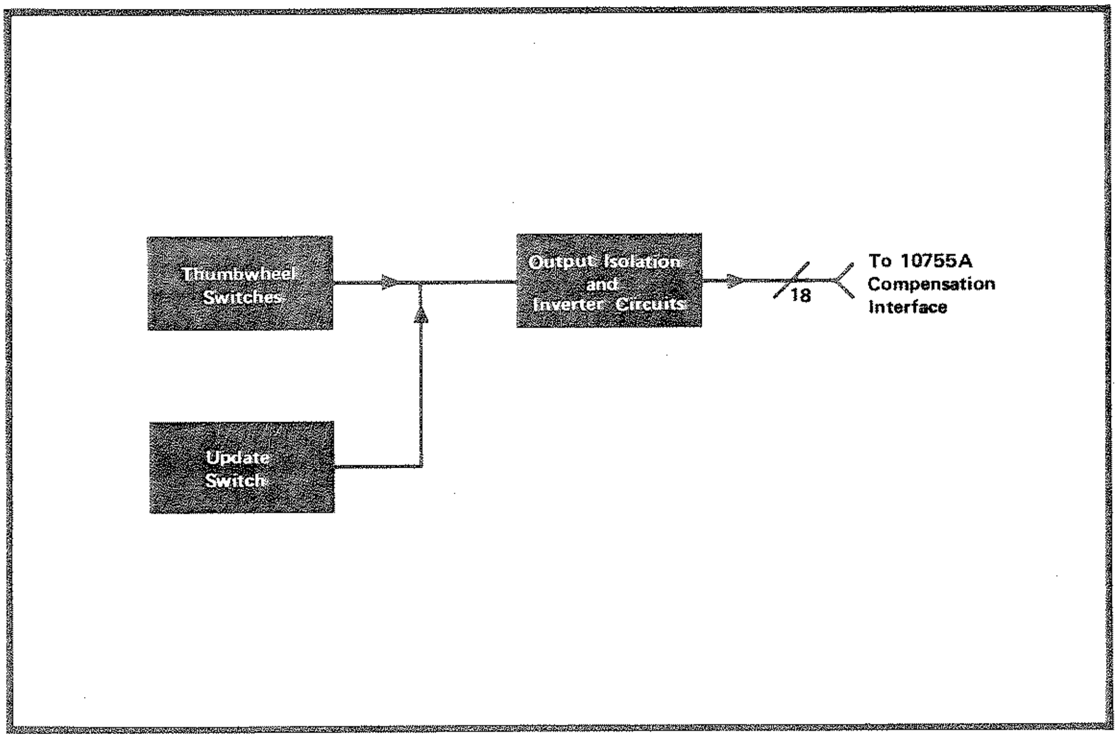


Figure 3-20. 10756A Manual Compensator

3.23 10756A Manual Compensator

The 10756A Manual Compensator is a small panel and circuit board unit (*Figure 3-20*) designed to plug directly on the 10755A Compensation Interface. The 10756A has four thumbwheel operated switches that allow the calculated compensation factor number to be set. The four BCD bits from each switch are then inverted and applied to the 10755A Compensation Interface. For additional information and schematics, refer to the 10756A Manual Compensator Operating and Service Manual.

3.24 5510A Opt 010 Automatic Compensator and 10563A Material Temperature Sensor

The 5510A Opt 010 Automatic Compensator itself is identical to the standard 5510A Automatic Compensator. The difference in models is that when used in the 5501A Laser Transducer System, the following cable changes are made:

a. Delete the 562A-16 Cable.

b. Add the 59995-61082 Interface Cable between the 5510A and the 10755A Compensation Interface;

c. Add the 10740-60005 Power Cable between the 10740A Coupler and the ±15V power supply.

Overall, the 5510A Opt 010 Automatic Compensator makes atmospheric measurements and the 10563A Material Temperature Sensor makes material temperature measurements and supplies four BCD compensation digits to the 10755A Compensation Interface. For operating instructions refer to Section IV, Programming and Operation. For additional information and schematics refer to the HP 5510A Operating and Service Manual.

3.25 10783A Numeric Display

The 10783A Numeric Display provides the laser transducer system with digital display of single or multiple-axis displacement data. It is driven from the Hewlett-Packard Interface Bus in either the "Listen Always" mode or the "Addressable" mode.

Fourteen 7-segment LED indicators with left-hand decimal points allow ample capacity for displaying more than one axis of data. Six axis identifiers (A, B, C, X, Y, Z) are supplied with each display module and may be inserted into the specially designed front panel. As an example, one 10783A can display six digits with sign and decimal point for the X-axis and five digits with sign and decimal point for the Y-axis, with a space between the two numbers. The "X" and "Y" identifiers can be placed in the front panel below the appropriate digits.

The characters that can be displayed are the digits 0 to 9, a minus sign, the letter E and the decimal point. Front panel indicators include an ON light indicating when the 10783A is "Addressed" and an overflow light that indicates when more than 14 characters have been received. In an overflow condition, the 14-least-significant digits are displayed. In addition to these indicators, there is a lamp test switch for checking all segments and indicators not already energized.

Flicker-free output is obtained by employing both input and output data storage. The display digits are strobed at a constant rate independent of input data transfer rate.

3.26 5501A Power Supply Options

The 5501A Laser Transducer Systems require a ±15V Power Supply and a +5V Power Supply. The Hewlett-Packard power supplies that can be used with the system are 62000 series power supplies with an LED indicator added as required by FED, REGIST., July 31, 1975, Vol. IV-0-148, part 2.

The 5501A power supply options all contain overcurrent, overtemperature, overvoltage, reverse voltage, and remote sensing protection.

Table 3-6 lists the power supplies available. For additional information and schematics, refer to the applicable Operating and Service Manual.

Table 3-5. Power Supplies Available for 5501A Laser Transducer System

HP Model No.	Description	Input Voltage
10708A	62215E ±15V Power Supply and 62605L ±5V Power Supply	115V
10708B	62215E ±15V Power Supply and 62605L +5V Power Supply	230V

section IV
Programming and Operation

4.1 INTRODUCTION

This section provides the information necessary to program and operate your system. It is organized as follows:

a. A general discussion of the objectives and methods of programming the Laser Transducer System. This includes a general system operating discussion from the viewpoint of the system programming requirements.

b. A table of individual commands for each unit of the system that is programmable. Instruction formats for both ASCII characters and the decimal equivalent of the binary command are included.

c. Commented programs and examples of measurements and data movement using the 9825A Calculator as the system controller and the 10745A HP-IB Interface to the Laser Transducer System.

d. Commented programs and examples of measurements and data movement using the 10746A Binary Interface. The 9825A Calculator is used as the system controller but the program illustrates how a computer could be used instead of the 9825A.

e. A general discussion with examples of data handling after the data has been transferred to the system controller.

f. A general discussion of how to debug (remove errors from) your program.

NOTE

The operating procedures (other than initial turn on) for the Laser Transducer System are dependent on the programming and design of the system controller.

g. Initial turn on, general operating instructions for a typical system, and brief explanations of the controls and indicators on the receiver, the laser head, the numeric displays, and the 5510A OPT 010 Automatic Compensator.

4.2 PROGRAMMING OBJECTIVES AND METHODS

The objective of programming is to obtain the defined results from the system under control. The methods of programming are dependent on the requirements of the system controller and the capabilities of the system under control. Therefore, in order to effectively program the Laser Transducer System you must understand and be able to use the following information:

a. LANGUAGE OF THE SYSTEM CONTROLLER. For example, when the HP 9825A Calculator is used as the system controller the operating and control manuals supplied with the calculator contain complete descriptions and examples of the commands and syntax used with the 9825A. Note that since the Laser Transducer System also requires the 98213A I/O ROM and the 98034A HP-IB Interface, you must also familiarize yourself with the additional commands and capabilities of these units. Separate operating and programming manuals provide this information. If any other unit is used as the system controller (e.g., a computer or other calculator), you must have a complete understanding of the capabilities and limitations of its control language.

b. OPERATION OF THE LASER TRANSDUCER SYSTEM. Prior to attempting to program the system you should be familiar with the information in Sections II and III that applies to your system. In addition there are general discussions of system operation from programming viewpoint contained in this section.

c. Finally, you must know the specific addresses and commands that make up the instructions that are applicable to the units in your system. This information is contained in *Tables 4-2* through *4-11.*

After you have reviewed this information, study the commented programs and illustrations in this section to gain the necessary insight into information flow within the Laser Transducer System. These programs are written using the 9825A as a system controller. However, the illustrated examples of data flow apply to any system containing the specified units.

4.3 GENERAL SYSTEM OPERATING DESCRIPTION

Most laser transducer systems are based on the 10740A Coupler (with associated plug-in modules) and a calculator or computer which is used as the system controller and data processor. The plug-in modules interface the various laser system components to the coupler backplane bus, and the coupler backplane bus carries all signals (data and control) between the plug-in modules.

Basically, a counter-based laser transducer system operates as follows. Displacement information, which is updated continuously in an operating system, is transferred, upon command, from the counters on the 10760A Counter plug-in module to the coupler backplane bus. This data is then transferred from the bus to the system controller for later processing. Next, velocity-of-light compensation data is transferred to the controller. The controller then manipulates the data (using its processing capabilities) so that the raw data represents meaningful displacement data. The controller then outputs the data to a printer or display unit or compares the data to predetermined limits or setpoints for automatic machine positioning applications.

One of the two plug-in modules (either the binary interface or the HP-IB interface, depending upon specific application) is used to interface the coupler backplane to the controller/processor. The controller commands the system, via the selected interface card, to perform each function necessary to make a measurement. The controller does this by issuing instructions that contain four bits of module address information and four bits of module command information. Each module in the coupler recognizes its unique address and responds to commands associated with that address. Additionally, some modules automatically respond to commands sent to other modules. For example, when a counter card is instructed to output measurement data to the coupler backplane bus, the HP-IB interface card automatically inputs that data and holds it until instructed to output the data to the controller (or other device connected to the HP-IB). This feature allows faster processing of data with fewer instructions.

The following programming information describes the coupler backplane instruction set that is available to control operation of a laser measurement system. Additionally, sample programs are supplied to demonstrate the sequence of operations required to control the system. This information and a thorough understanding of the system controller characteristics will allow you to generate programs for your specific measurement application.

4.4 Sample Outline for a Three-Axis Counter-Based System

The following steps outline the general programming requirements for a simple three-axis counter-based system:

OPERATION	RESULT
a. Backplane Reset	Initializes all cards. Presets counters to 160.
b. Output Compensation	Puts compensation data on backplane which is accepted by 10745A HP-IB Interface.
c. Format Data	10745A HP-IB Interface converts binary data to BCD and stores in RAM.
d. Read into Calculator	Compensation data stored in Calculator.
e. Backplane Sample	Samples all counters simultaneously. Puts counter contents in output buffer.
f. Output X-Axis Data	Puts X-axis data on backplane which is accepted by 10745A HP-IB Interface.
g. Format Data	10745A HP-IB Interface converts binary data to BCD and stores in RAM.

8. Each card releases (allows to go high) OPC as soon as it is able.

NOTE

In step 6 this card may drive $\overline{\text{DAV}}$ low at the same time or before it lets OPC go high. However the card in step 7 may not let OPC go high until it has accepted the backplane information. OPC remains low until all cards have released it.

9. When all cards have released OPC, $\overline{\text{INSV}}$ is returned high to terminate instruction.
10. $\overline{\text{DAV}}$ goes high if an output was involved. $\overline{\text{DAV}}$ remains high if no output was involved. OPC is driven low by all cards.
11. Sequence starts over at step 1.

4.8 HP-IB BASED SYSTEM PROGRAMMING

HP-IB based transducer systems are supplied with the 9825A Calculator (for information on other HP calculators, see Appendix A). The calculator systems include an HP-IB interface module and appropriate ROM modules. The calculator documentation includes information for these devices.

Tables 4–2 through *4–11* show the instructions that can be issued to the laser system to control system operation. These instructions are issued from the calculator via the HP-IB interface module to the 10740A Coupler backplane bus. Instructions consist of a numeric command and an alphabetical address (e.g., 2X causes the 10760A Counter card that has its address jumper in the X position to output its last sample to the coupler backplane bus). The instructions must be sequenced in the order that will cause the desired operations.

NOTE

In all programming instructions, 0 is zero and O is the letter O.

Instructions can be combined in one calculator program step. An example of this is the instruction sequence 1O2X3O. From the tables it can be seen that the 1O instruction generates a backplane sample command, the 2X instruction causes the X-axis counter card to output its sampled data and causes the HP-IB interface card to input that data, and the 3O instruction causes the HP-IB interface card to convert that data to BCD and prepare to send the data to the calculator upon receipt of further program statements.

Because the displacement data contained in the 10760A Counter cards (and, consequently, the data sent to the calculator) is in units of $\frac{1}{4}$ wavelengths of the laser light, the calculator must convert this to a useable unit of measure — either inches or millimetres. Additionally, the counters are preset to 160 counts so the effects of vibration do not cause the counters to underflow. The calculator, therefore, must also subtract 160 counts from the displacement data prior to converting the data to inches or millimetres. One last data-manipulation requirement must be satisfied by the calculator program: the displacement data must be multiplied by the velocity-of-light compensation factor. The following formula demonstrates the procedure for conversion of input counts from the 10760A Counter to compensated inches or millimetres. For accurate measurements, the formula must be included in all calculator programs. Subsequent samples show how this is done.

FORMULA: $X = (D - 160)(K)(C)$

Where: X is compensated inches or millimeters of displacement data,
D is uncompensated counts from the 10760A Counter card,
K is the inch or millimeter conversion factor (6.23023×10^{-6} for inches and 1.58248×10^{-4} for millimetres),
C is the velocity-of-light compensation factor from the manual or automatic compensator.

NOTE

If the system is operated in the "X10" extended resolution mode, the formula must be changed to subtract 16 counts instead of the 160 counts specified above.

4.9 COMPUTER-BASED SYSTEM PROGRAMMING

Several different configurations of laser transducer systems can be controlled by a digital computer. The following discussion refers specifically to a system using the 10740A Coupler and the 10746A Binary Interface.

The binary interface module allows a digital computer to control the laser transducer system if the computer has its own input/output circuits or has other means for accomplishing the following:

a. It must send a "command" signal to the binary interface module to start each functional operation.

b. It must accept a "flag" signal from the binary interface module. The "flag" signal signifies completion of a function by the binary interface module.

c. It must have a set of data lines to allow passage of binary data to and from the binary interface module.

The data lines between the binary interface module and the computer can be separated into input and output lines, or can use common input/output lines. In either case, only one operation can take place at a time. Data words can consist of either 8 or 16 bits; 12-bit computers must use 8-bit words and pack them, if desired, by software means.

The general sequence for a computer-controlled operation is as follows:

a. The computer outputs an instruction to a register on the computer output interface circuit assembly.

b. The computer sends a "command" signal to the 10746A Binary Interface. The "command" signal causes the 10746A to accept the instruction and perform the associated function.

c. The 10746A returns a "flag" signal to the computer to indicate acceptance of the instruction.

d. The computer can now proceed to other program steps. For example, the steps required to input data from its interface register if the original instruction specified a data transfer from the 10746A to the computer.

If the "command" signal is removed by the computer, the "flag" signal from the 10746A will be immediately reset. The signal therefore, should not be removed until all flag-dependent transfers have been completed.

In the "command" mode, the 10746A treats all computer outputs as commands. If a command from the computer instructs the 10746A to go to the "data" mode, the 10746A treats the next two 16-bit words (or four 8-bit words, if jumper selected) as data. The most-significant word must be transferred first.

Two instructions cause "data" mode operation. These instructions initiate computer data outputs and computer data inputs. At the end of a data transfer, the 10746A returns to the "command" mode.

If the 10746A is in "command" mode, all instructions sent by the computer are passed on to the 10740A Coupler backplane. The instructions are also examined simultaneously by the 10746A to determine if they require specific responses by the 10746A.

Use *Tables 4-2* through *4-11* to organize the operating sequence necessary to provide desired system operation. For example, *Table 4-3* shows that an 0P instruction generates a backplane reset signal and clears the error-bit buffer on the 10746A Binary Interface. To generate this instruction from the computer, output the binary equivalent of the decimal number shown for 0P in *Table 4-3* (decimal 255 or binary 11111111) for a negative-true interface card. The 10746A Binary Interface uses positive-true logic. The decimal instructions in *Tables 4-2* through *4-11* show the decimal negative-true logic value in black and the positive-true logic in red.

Table 4-2. 10745A HP-IB Interface Instructions

BACKPLANE CARD ADDRESS IS O		
ADDRESSED INSTRUCTIONS		
HP-IB Instruction	**Response**	**Decimal Instruction**
0O	Generate system reset, clear error-bit buffers and initialize all state machines	15 **240**
*0$\overline{O}$	Clear error bit buffer	——
1O	Generate simultaneous sample command	14 **241**
2O	Handshake and do nothing	13 **242**
*2$\overline{O}$	Load HP-IB data buffer and handshake in response to BP-DAV	——
3O	Convert data stored in data buffer from binary to BCD and store in RAM. Output according to HP-IB rules	12 **243**
?O	Do nothing. This instruction causes HP-IB to drive instruction lines passive - high	0 **255**
NONADDRESSED INSTRUCTIONS		
System Reset	Same as 0O instruction	
Sample	Do nothing	

*2$\overline{O}$ means CMD 2 and any card address except O

Table 4-3. 10746A Binary I/O Interface Instructions

BACKPLANE CARD ADDRESS IS P		
ADDRESSED INSTRUCTIONS		
HP-IB Instruction	**Response**	**Decimal Instruction**
**0P	Generate backplane reset and clear error bit buffer	255 **0**
*$\overline{0P}$	Clear error bit buffer	——
1P	Generate simultaneous sample command	254 **1**
2P	Output data to backplane data bus from I/O buffer	253 **2**
*2$\overline{P}$	Load data from backplane data bus into I/O buffer	——
3P	Sends data and/or error bits to computer from I/O buffer	252 **3**
*3$\overline{P}$	Load addressed card with data via backplane data lines	——
4P	Load Data into 10746A I/O buffer	251 **4**
All Other Instructions	Do Nothing	——
NONADDRESSED INSTRUCTIONS		
System Reset	Same as 0P instruction	——
Sample	Do Nothing	——

*$\overline{0P}$ means CMD 0 and any card address except P.

**For 16-bit mode, three sequential 0P commands are required; for 8-bit mode, five sequential 0P commands are required.

Table 4-4. 10755A Compensation Interface

BACKPLANE CARD ADDRESS IS V		
ADDRESSED INSTRUCTIONS		
HP-IB Instruction	**Response**	**Decimal Instruction**
0V	Initialize state machine and take new reading	159 **96**
*2V	Output VOL compensation information to BP data bus and start new measurement	157 **98**
All Other Instructions	Handshake immediately and do nothing	——
NONADDRESSED INSTRUCTIONS		
System Reset	Same as 0V	——
Sample	Do Nothing	——

*This is the compensation number for the last time a 2V or 0V was given. Therefore, if a 2V command is given every 15 minutes, the compensation value is 15 minutes old.

Table 4-5. 10760A Counter Instructions

BACKPLANE ADDRESS IS SELECTABLE, MAY BE X, Y, Z, A, B, OR C (Mutually Exclusive)		
ADDRESSED INSTRUCTIONS		
HP-IB Instruction	**Response**	**Decimal Instruction**
*0X	Preset counter to 160, clear error bits, and set normal resolution	See *Table 4-11* instruction is address-dependent
1X	Load contents of counter into output data buffer	
2X	Output last sample, decimal point, and error bits to BP Data Bus	
4X	Count DOWN	
5X	Go to normal resolution mode, preset counter, clear error bits. Does not clear HP-IB error bits	
6X	Go to extended resolution mode, preset counter, clear error bits	
7X	Count UP	
NONADDRESSED INSTRUCTIONS		
System Reset	Preset counter to 160, clear error bits, and set normal resolution	——
Sample	Load contents of counter into output data buffer	——

*Address "X" is used in this table as an example, To have instruction apply to another counter card replace "X" with that card's address.

Table 4-6. 10761A Multiplier Instructions

BACKPLANE CARD ADDRESS IS M		
ADDRESSED INSTRUCTIONS		
HP-IB Instruction	**Response**	**Decimal Instruction**
0M	Reset multiplier and set up λ/4 multiplication mode.	47 **208**
2V	Accept VOL number and do conversion constant correction	157 **98**
2 ABC XYZP	Accept Displacement number and perform conversion	Refer to *Table 4-11*
2M	Output conversion results to backplane	45 **210**
3M	Accept user generated conversion constant from binary I/O card	44 **211**
3V	Accept user generated VOL compensation numbers from binary I/O card	156 **99**
4M	Clear registers, go to mm units and set multiplier constant for non-VOL system – mm mode, clear error bit	43 **212**
6M	Clear registers, go to inches units and set multiplier constant for non-VOL system – inches mode, clear error bit	41 **214**
All Other Instructions	Do Nothing	——
NONADDRESSED INSTRUCTIONS		
System Reset	Same as 0M	——
Sample	Do Nothing	——

Table 4-7. 10762A Comparator Instructions

BACKPLANE ADDRESS IS SELECTABLE, MAY BE X, Y, Z, A, B, OR C (Mutually Exclusive)		
ADDRESSED INSTRUCTIONS		
HP-IB Instruction	**Response**	**Decimal Instruction**
*0X	Preset count register to 160 counts, force digital difference output to null, clear OVFL-BUFFER, terminate self-check (if in progress)	Refer to *Table 4-11* as instruction is address-dependent
1X	Load contents of counter into output buffer as soon as there is a window wide enough to insure that a count is not propagating through the count chain	
2X	Output contents of output buffer to backplane data bus, output λ mode ($\lambda/4$ or $\lambda/8$), output decimal point code, output contents of OVFL-ERROR buffer. Data valid signal goes true only if sample circuit is not in the process of taking a sample	
3X	Load destination register with 28-bit number and tolerance register with 4-bit number on 10740A backplane when binary $\overline{\text{DAV}}$ goes true. X is implied Listener — 10746A implied Talker	
4X	Disable UP/A and DWN/B inputs and count down at 10 MHz. (Terminates with a reset, or an underflow in count register)	
5X	NOP	
6X	NOP	
7X	Disable UP/A and DWN/B inputs and count up at 10 MHz. (Terminates with reset or an overflow in count register)	
NONADDRESSED INSTRUCTIONS		
System Reset	Same as 0X instruction	——
Sample	Same as 1X instruction	——

*"X" used as an example of the address in this table. To make instruction apply to another comparator simply replace "X" with that card's address.

Table 4-8. 10764B Fast Pulse Converter Instructions

BACKPLANE ADDRESS IS SELECTABLE, MAY BE X, Y, Z, A, B, OR C (Mutually Exclusive)		
ADDRESSED INSTRUCTIONS		
HP-IB Instruction	**Response**	**Decimal Instruction**
*0X	Reset error bits and samples resolution switches	Refer to *Table 4-11* as instruction is address-dependent
2X	Output contents of buffer register error bits to backplane data bus	
NONADDRESSED INSTRUCTIONS		
System Reset	Same as 0X instruction	——

*"X" used as an example of the address in this table. To make instructions apply to another fast pulse converter simply replace "X" with that card's address.

At least two reset pulses are required after power on or resolution change.

Table 4-9. 10763A Responses to Instructions

<table>
<tr><th colspan="3">BACKPLANE ADDRESS IS SELECTABLE, MAY BE X, Y, Z, A, B, OR C (Mutually Exclusive)</th></tr>
<tr><th colspan="3">ADDRESSED INSTRUCTIONS</th></tr>
<tr><th>HP-IB Instruction</th><th>Response</th><th>Decimal Instruction</th></tr>
<tr><td>*3X</td><td>Accepts control of coupler bus from previous 10763A controller</td><td>See Table 4-11 as instruction is address dependent</td></tr>
</table>

*In a multiaxis system one 10763A is in control until it updates its displacement data and then it passes control to the next 10763A.

Table 4-10. Possible Instructions by 10763A English/Metric Pulse Output

<table>
<tr><th colspan="4">BACKPLANE ADDRESS IS SELECTABLE, MAY BE X, Y, Z, A, B, OR C (Mutually Exclusive)</th></tr>
<tr><th colspan="4">ADDRESSED INSTRUCTIONS</th></tr>
<tr><th>HP-IB Instruction</th><th>To</th><th>Response</th><th>Decimal Instruction</th></tr>
<tr><td>5X</td><td>10760A</td><td>Set normal resolution</td><td>N/A</td></tr>
<tr><td>6X</td><td>10760A</td><td>Set extended resolution</td><td>N/A</td></tr>
<tr><td>4M</td><td>10761A</td><td>Select millimeter conversion factor</td><td>N/A</td></tr>
<tr><td>6M</td><td>10761A</td><td>Select inch conversion factor</td><td>N/A</td></tr>
<tr><td>2V</td><td>10755A</td><td>Output most recent data</td><td>N/A</td></tr>
<tr><td>7X</td><td>10760A</td><td>Count up</td><td>N/A</td></tr>
<tr><td>1X</td><td>10760A</td><td>Load count in output buffer</td><td>N/A</td></tr>
<tr><td>2X</td><td>10760A</td><td>Output count to coupler bus</td><td>N/A</td></tr>
<tr><td>2M</td><td>10761A</td><td>Output product to coupler bus</td><td>N/A</td></tr>
<tr><td>*3Y</td><td>*Next 10763A</td><td>Accepts control of coupler bus</td><td>N/A</td></tr>
<tr><th colspan="4">NONADDRESSED COMMANDS</th></tr>
<tr><td>System Reset</td><td>All Units on Bus</td><td>Returns all units to original RESET condition</td><td>N/A</td></tr>
<tr><td>Sample</td><td>10760A only respondent</td><td>Loads count in output buffer</td><td>N/A</td></tr>
</table>

*In a multiaxis system one 10763A is in control until it updates its displacement data and then it passes control to the next 10763A.

Table 4-11. Instruction Set Conversion from Alphanumeric to Decimal

NOTE

The numbers shown in black are negative-true logic interface cards. The numbers shown in **red** are for positive-true cards. The 10746A Binary Interface is a positive-true card. If you are in doubt as to which numbers to use, the easiest way to determine the polarity of your I/O card is to program a simple command and note the system response.

Address Command	A	B	C	M	O	P	V	X	Y	Z
0	239 **16**	223 **32**	207 **48**	47 **208**	15 **240**	255 **0**	159 **96**	127 **128**	111 **144**	95 **160**
1	238 **17**	222 **33**	206 **49**	—	14 **241**	254 **1**	—	126 **129**	110 **145**	94 **161**
2	237 **18**	221 **34**	205 **50**	45 **210**	13 **242**	253 **2**	157 **98**	125 **130**	109 **146**	93 **162**
3	—	—	—	44 **211**	12 **243**	252 **3**	156 **99**	124 **131**	108 **147**	92 **163**
4	235 **20**	219 **36**	203 **52**	—	—	251 **4**	—	123 **132**	107 **148**	91 **164**
5	234 **21**	218 **37**	202 **53**	—	—	—	—	122 **133**	106 **149**	90 **165**
6	233 **22**	217 **38**	201 **54**	41 **214**	—	—	—	121 **134**	105 **150**	89 **166**
7	232 **23**	216 **39**	200 **55**	—	—	—	—	120 **135**	104 **151**	88 **167**

4.10 TYPICAL PROGRAMS

Two typical programs (*Tables 4–12* and *4–13*) are provided to illustrate how to program the 10745A HP-IB Interface and the 10746A Binary Interface respectively. Both programs are commented. Reference is made in these programs to data movement figures to further illustrate the data flow within the Laser Transducer System. In these figures each specific instruction and the associated data movement is shown in red. Note that the decimal instructions used in the binary interface program are positive-true values. *Table 4–14* lists the Binary Interface Typical Program Variables. The sequence of drawings in *Figure 4–2* assumes that you will go to a subroutine the first time it is referenced to determine its function.

Table 4-12. 10745A HP-IB Interface Typical Program using HP 9825A Calculator

PROGRAM	COMMENT
0: clr 7; rem 7	Send Device Clear to all devices on the HP-IB. Send Remote Enable to all devices on the HP-IB.
1: wrt 709, "0O6X"	Send to 10745A. 7 = Select Code of 98034A.HP-IB Interface. 09 = Address of 10745A. 0O = System Initialization via HP-IB. 6X = Set X-axis to extended resolution. See *Figures 4–1A* and *B*.
2: wrt 709, "2V3O"	Send to 10745A. 2V = transfer VOL number. 3O = Setup to output VOL to HP-IB. See *Figures 4–1C* and *D*.
3: red 709,C	VOL transferred via HP-IB to variable C.
4: 0→E	Set loop counter for compensation update to 0.
5: "loop": E+1→E; if E=10; gto -3	Increment loop counter. If 10 times through loop go read in new compensation value.
6: wrt 709, "1O2X3O"	Send to 10745A. 1O = sample X, Y axis via HP-IB. 2X = Transfer X to 10745A. 3O = set up to output X to HP-IB. See *Figures 4–1E,F,* and *G*.

Table 4-12. 10745A HP-IB Interface Typical (Cont'd)

PROGRAM	COMMENT
7: red 709,X	X transferred via HP-IB to variable X
8: if rds (7)<128; gto +2	If no device on HP-IB is requesting service, skip the next line.
9: 0→A;gsb "status"	A=0 for X-Axis. Go find out if 10745A is requesting service.
10: (X-16)*6.23023e-6*C→X	-16 is the subtract preset for extended resolution. X6.23023e-6 is the conversion of λ/4 to microinches C compensates for VOL + Material Temperature.
11: fmt 1,f12.6	Format No. 1. Fixed point 12 characters wide, 6 digits to the right of the decimal.
12: wrt 717.1,X	Send X to X-Display. Format 1 is used. 7 = select code of 98034A 17 = address of 10783A X-Display. See *Figure 4-1H*.
13: wrt 709, "2Y3O"	Send to 10745 via HP-IB. 2Y = transfer to 10745A via HP-IB. 3O = set up to output Y to HP-IB. See *Figure 4-1I* and *J*.
14: red 709,Y	Y transferred via HP-IB to variable Y.
15: if rds(7)<128;gto +2	If no device on HP-IB is requesting service skip the next line.
16: 1→A;gsb "status"	A=1 for Y-Axis to find out if 10745A is requesting service.
17: (Y-160)*6.23023e-6*C→Y	-160 is the subtract preset for normal resolution.
18: wrt 718.1,Y	Send Y to Y-display. Format 1 is used. 7 = select code of 98034A 18 = address of 10783A Y-Display. See *Figure 4-1K*.
19: gto "loop"	Go to top of display "loop"
20: "status":rds(709)→B	Get status byte from 10745A.
21: if B>=64;gsb "check"	If bit 6 set then 10745A has requested status. Go check what kind of error.
22: wrt 709, "0P"	Send to 10745A. 0P = clear error bits on 10745A via HP-IB. See *Figure 4-1L*.
23: ret	subroutine "status" return statement.
24: "check":B-112→B	Clear Bits 6,5,4.
25: if B>=8;gsb "ovf"	If Bit 3 is set, go to subroutine "ovf"
26: if B>=4:prt "VOL OUT OF RANGE";B-4→B; 0→D	If Bit 2 is set, VOL error irrecoverable.
27: if B>=2; prt "MEAS ERROR";B-2→B;0→D	If Bit 1 is set, MEAS error 0→D is irrecoverable error.
28: if B=1;prt"REF ERROR" ;0→D	If Bit 0 is set, reference error 0→D is irrecoverable error.
29: if D=1;ret	If D=1 then the only error is an overflow which is recoverable.
30: if A=0;prt"X-AXIS ERROR"	
31: if A=1;prt"Y-AXIS ERROR"	
32: dsp "GO TO GAGE";stp	Display "GO TO GAGE" and stop.
33: gto 0	When CONTINUE is pressed the program restarts at the beginning of the program.
34: "ovf":B-8→B;1→D	1→D. Perhaps recoverable error. Clear Bit 3.
35: if A=0;X-2↑28/10→X	X-Axis complement all bits of X and Add 1.
36: if A=1;Y-2↑28→Y	Y-Axis complement all bits of Y and Add 1.
37: ret	
38: end *19613	

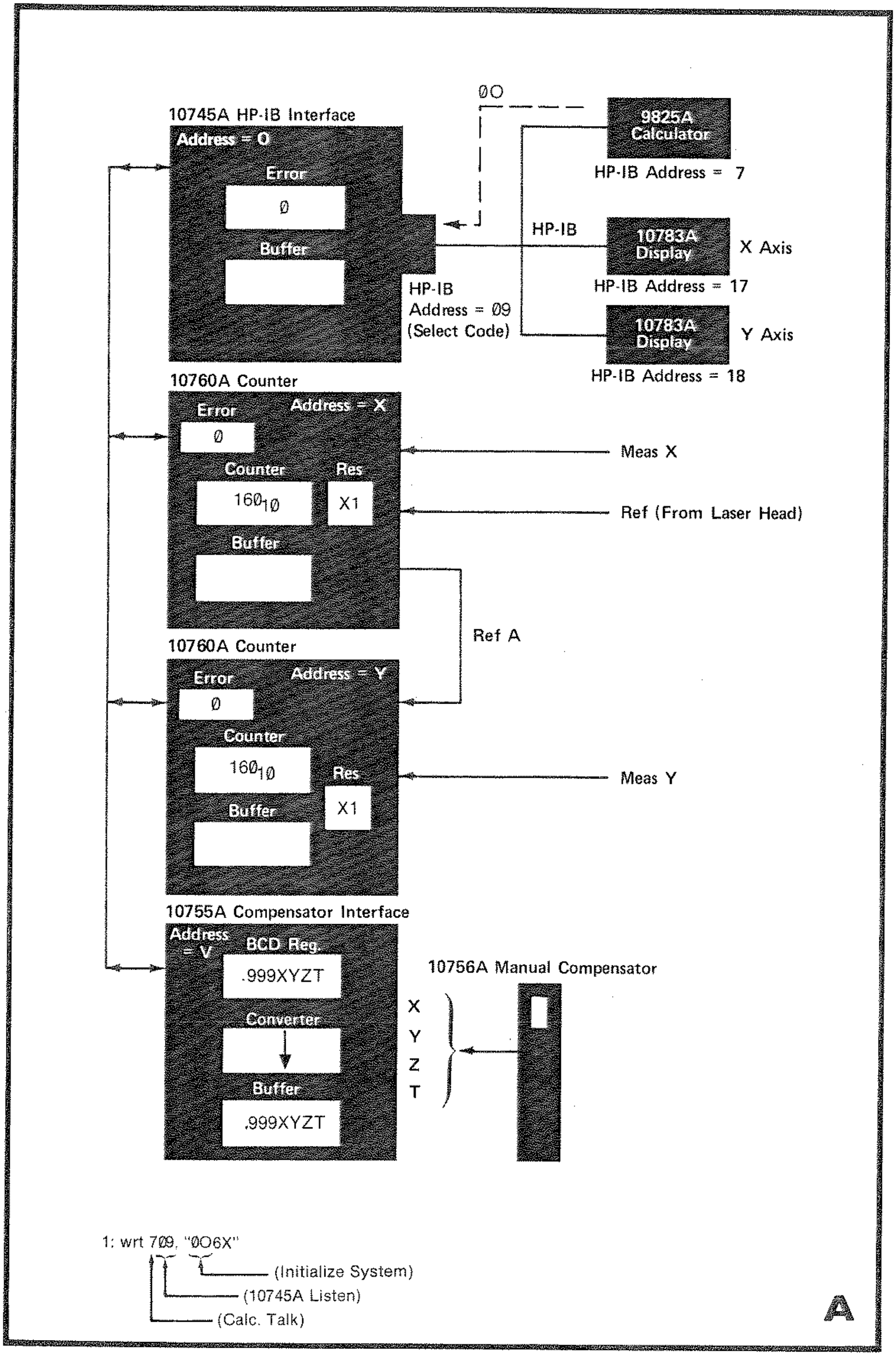
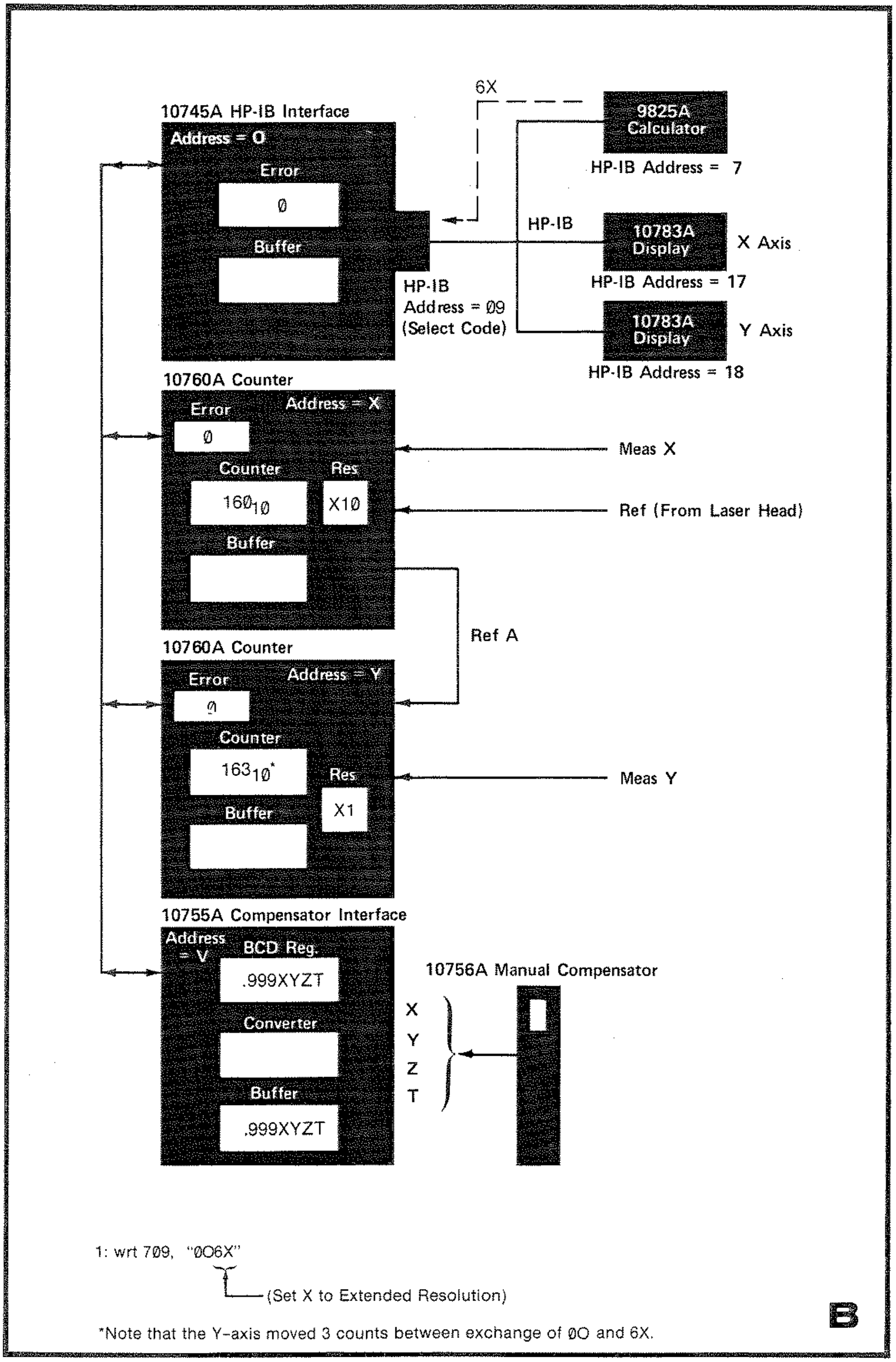


Figure 4-1. Counter-Based System Data Flow

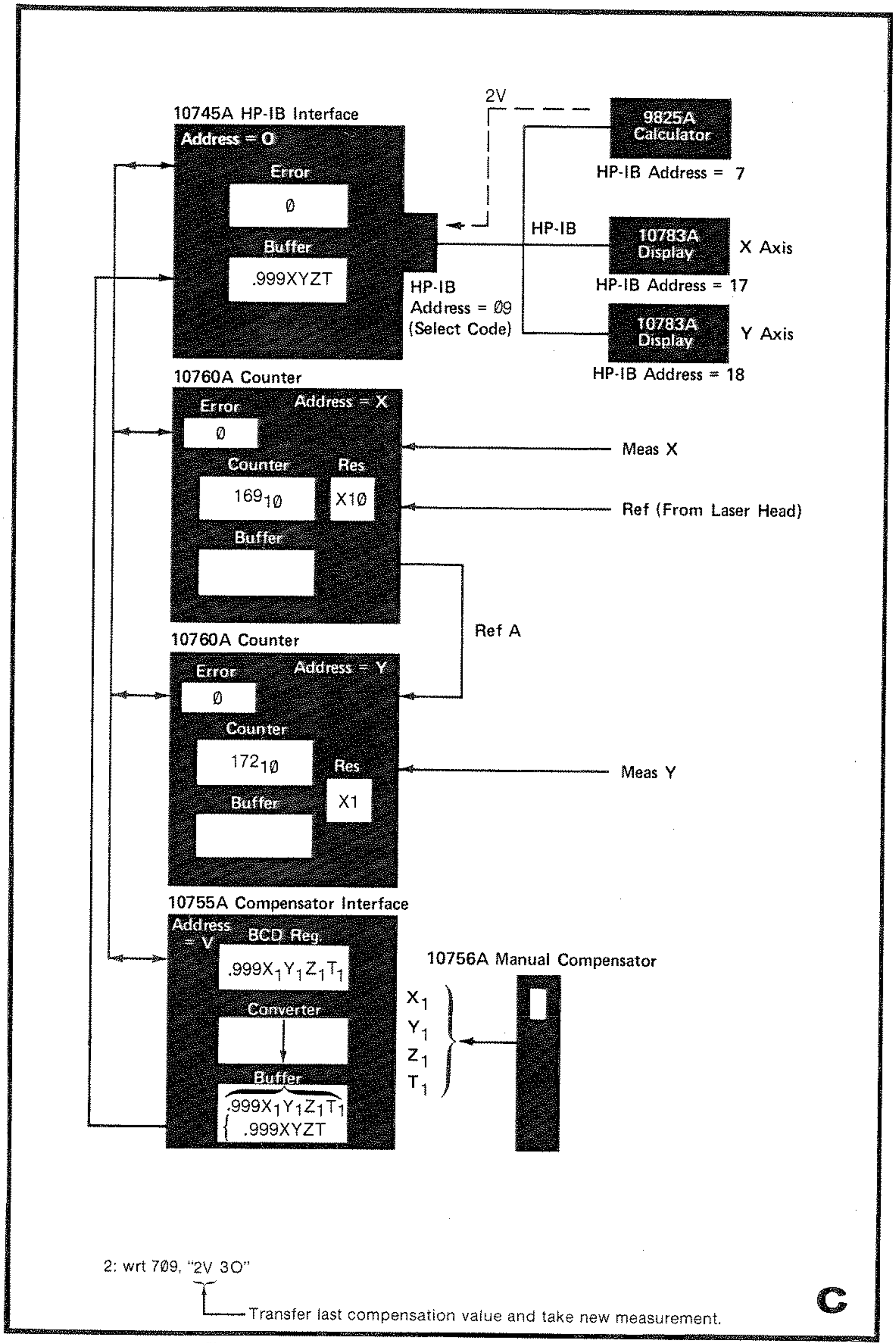


1: wrt 709, "0O6X"

(Set X to Extended Resolution)

*Note that the Y-axis moved 3 counts between exchange of 0O and 6X.

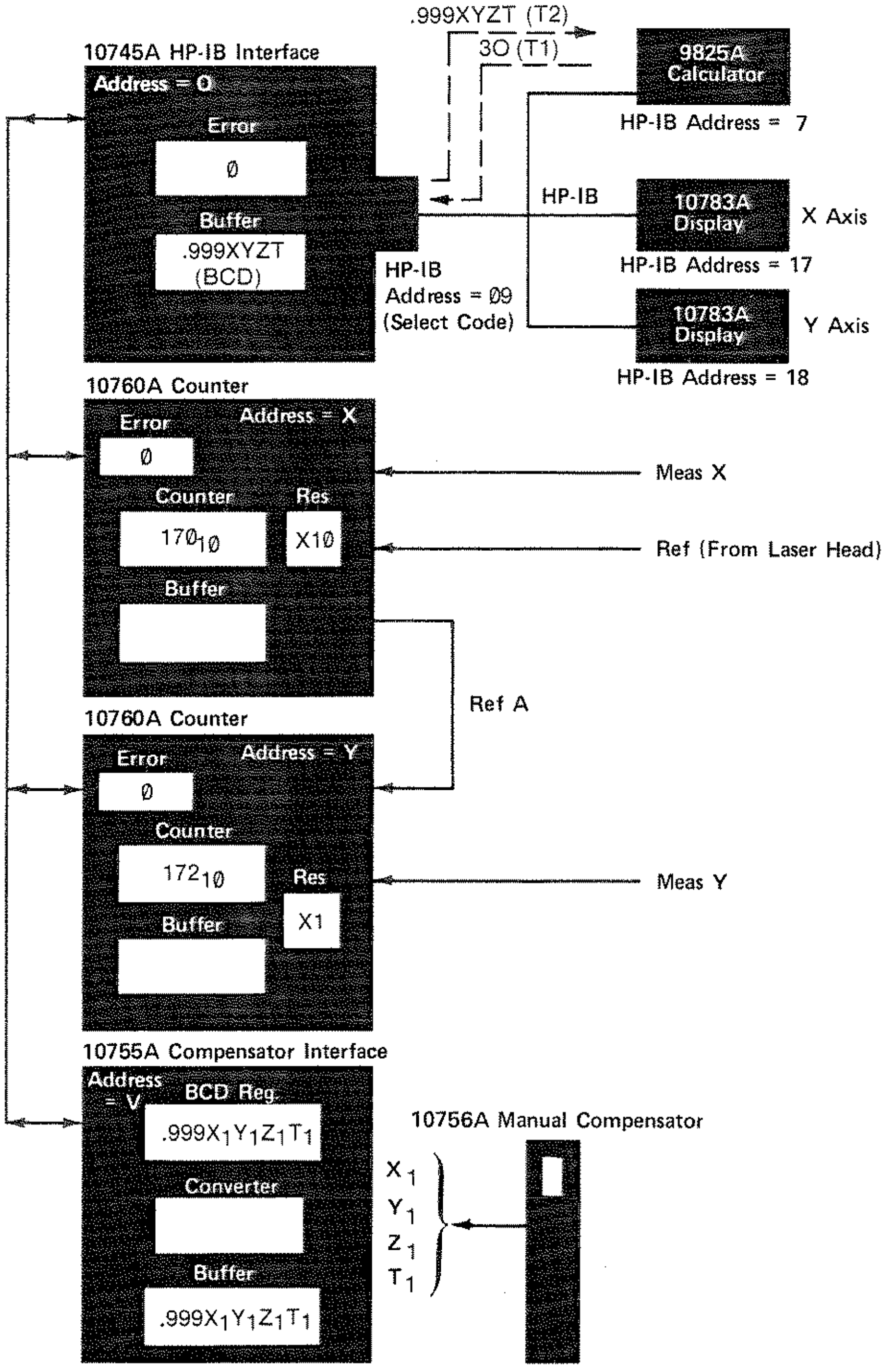
Figure 4-1. Counter-Based System Data Flow (Continued)



```
2: wrt 709, "2V 3O"
```

Transfer last compensation value and take new measurement.

Figure 4–1. Counter-Based System Data Flow (Continued)



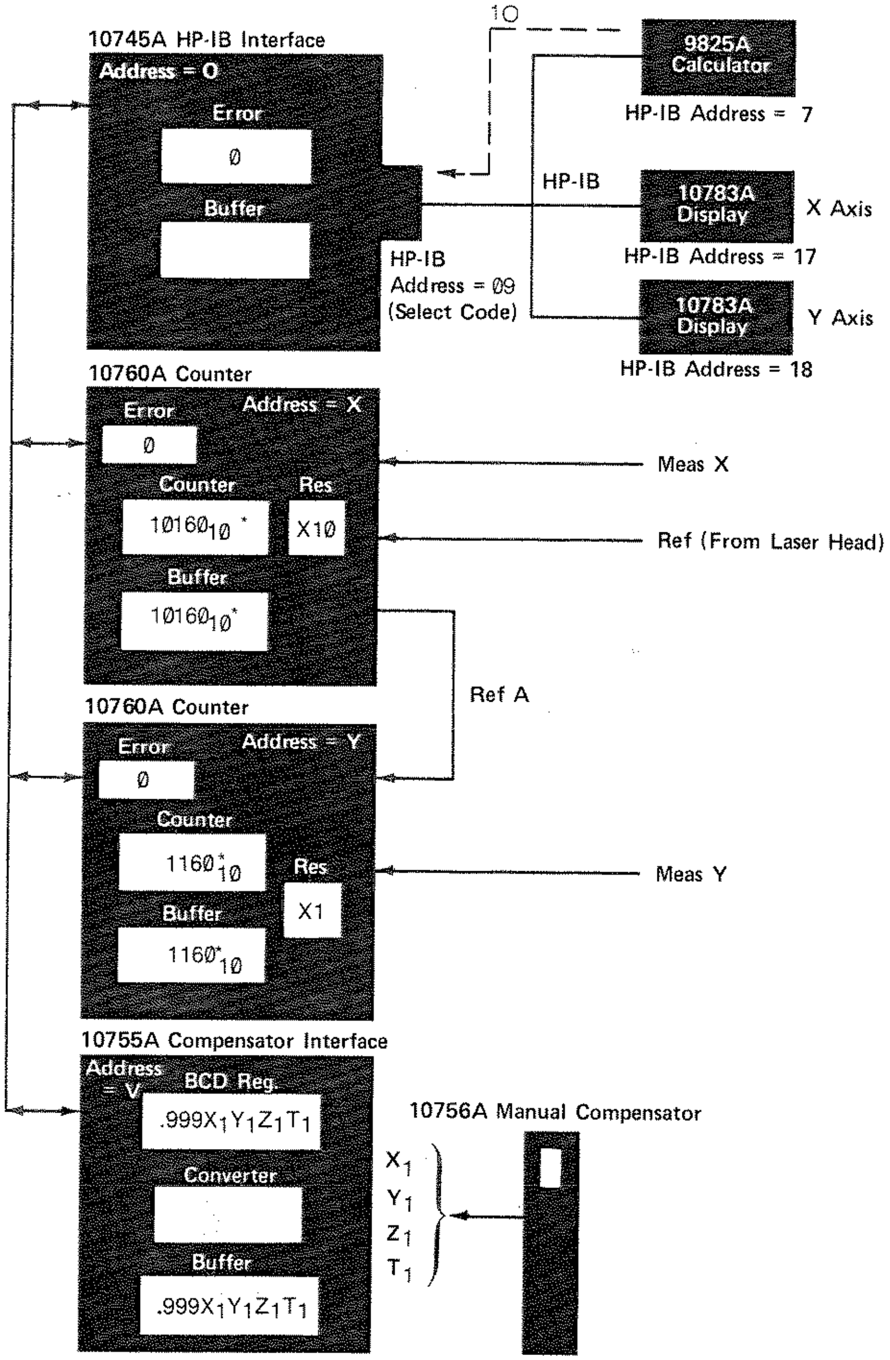
2: wrt 709, "2V3O"
Convert from binary to BCD and prepare to output. (T1)

3: red 709, C
output buffer contents to calculator and store in variable C (T2)

*T1 - convert to BCD
*T2 - ready to output

D

Figure 4-1. Counter-Based System Data Flow (Continued)

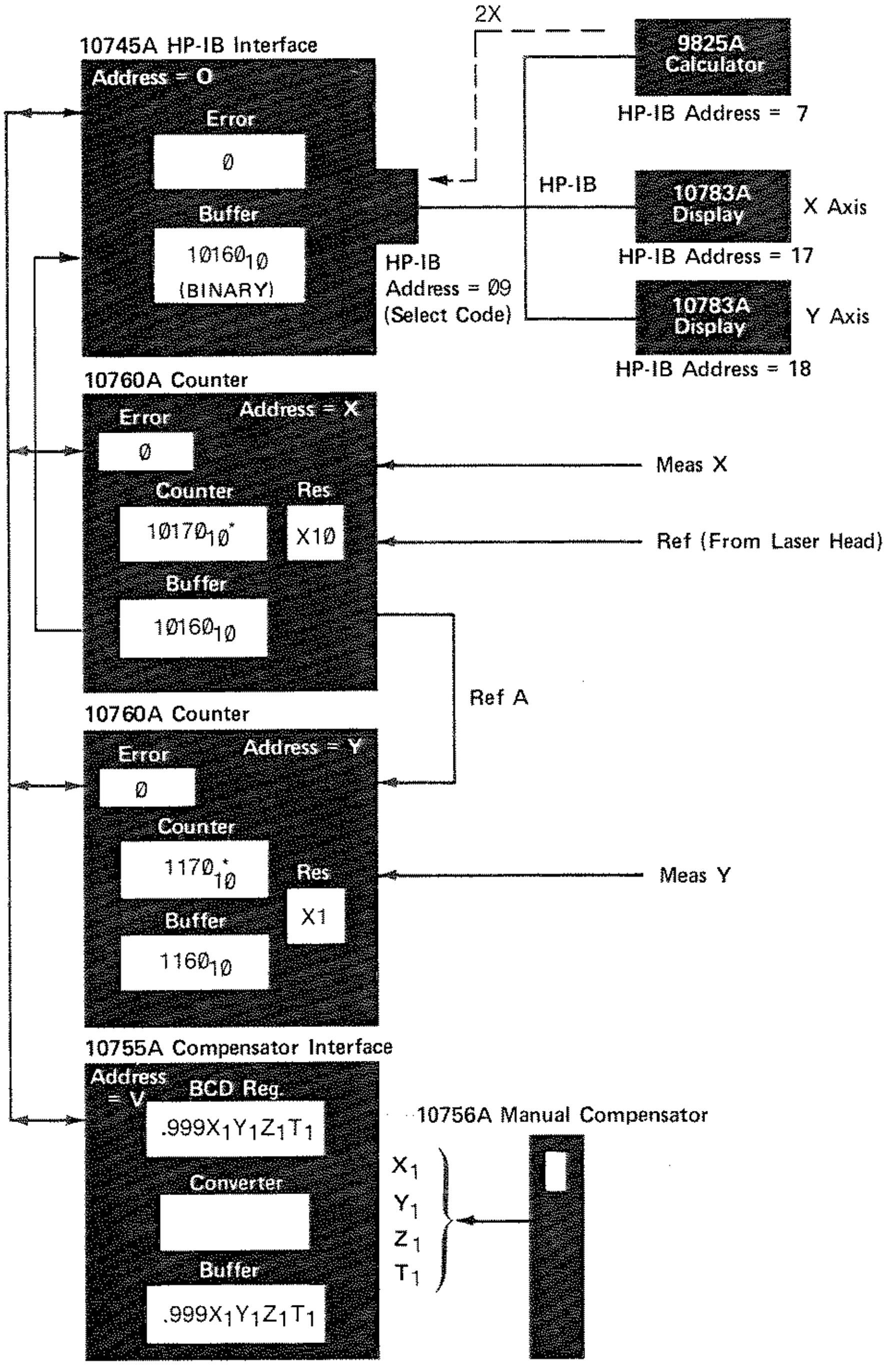


6: wrt 709, "1O2X3O"

Sample all counters simultaneously

Prior to 1O instruction both X and Y moved identical distance.
X axis in X10 mode gives 10 times the counts into the counter.

Figure 4–1. Counter-Based System Data Flow (Continued)



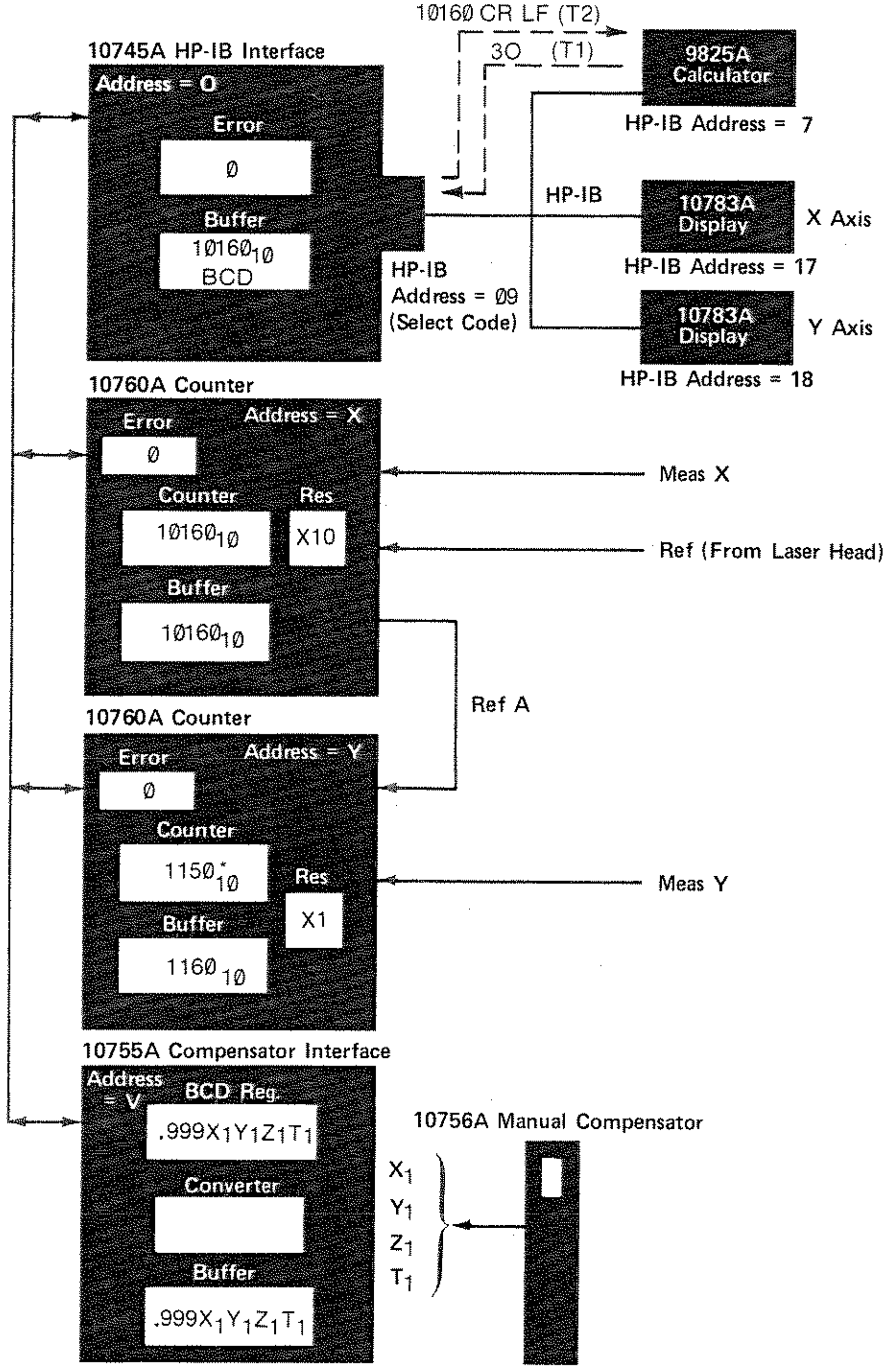
6: wrt 709, "1O 2X3O"

$\underbrace{2X}$ Transfer X buffer data to HP-IB Interface

*X has moved 1 count and Y 10 counts between execution of 1O and 2X.

F

Figure 4-1. Counter-Based System Data Flow (Continued)

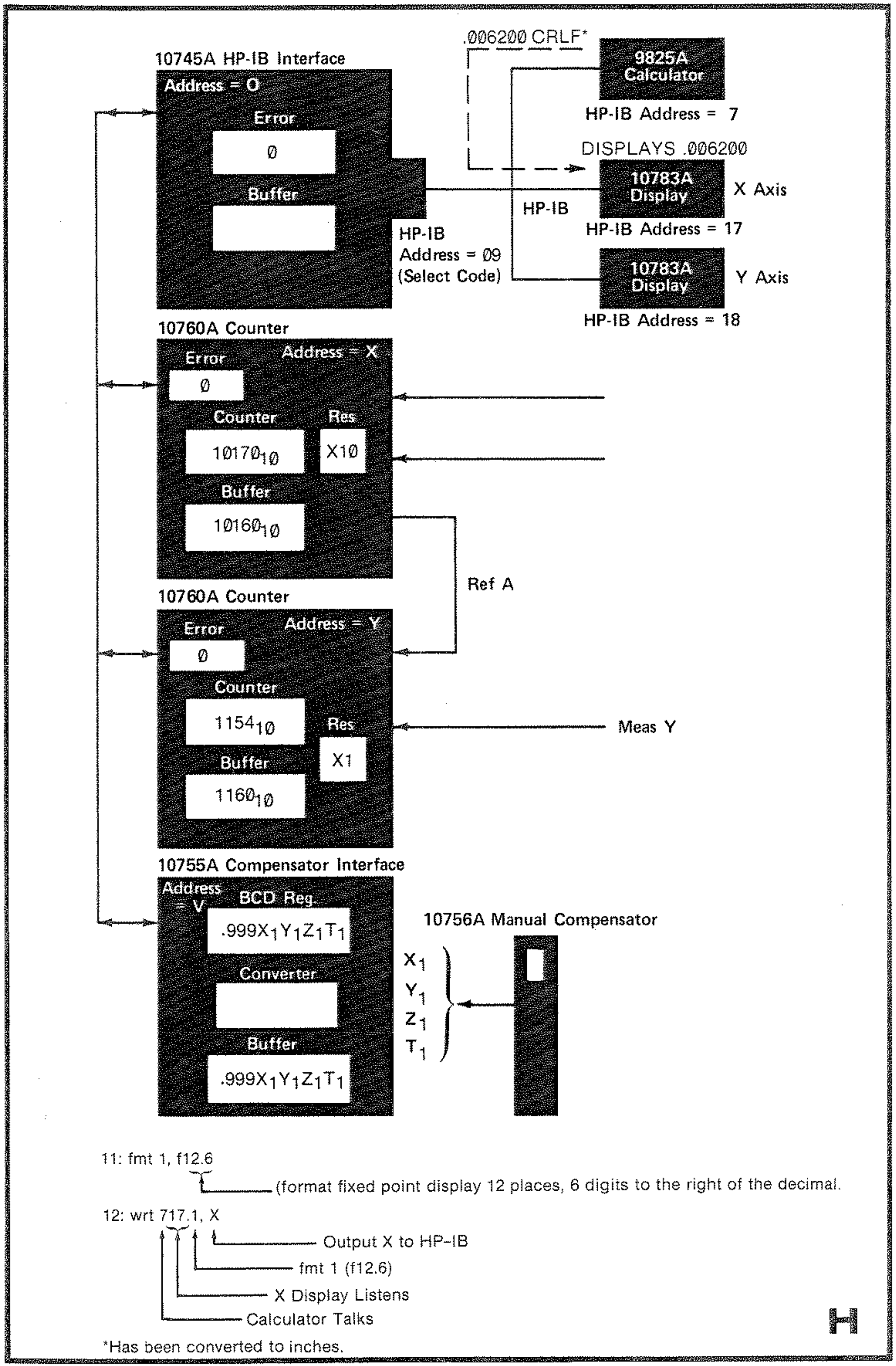


```
6: wrt 709, "102X30"
                 └──── (Convert to BCD and prepare to output)
7: red 709, X
            └──── (output to calculator and store in variable X)
```

*Continues to change but does not change buffer information.

G

Figure 4-1. Counter-Based System Data Flow (Continued)



```
11: fmt 1, f12.6
              (format fixed point display 12 places, 6 digits to the right of the decimal.
12: wrt 717.1, X
                 Output X to HP-IB
                 fmt 1 (f12.6)
                 X Display Listens
                 Calculator Talks
```

*Has been converted to inches.

Figure 4–1. Counter-Based System Data Flow (Continued)

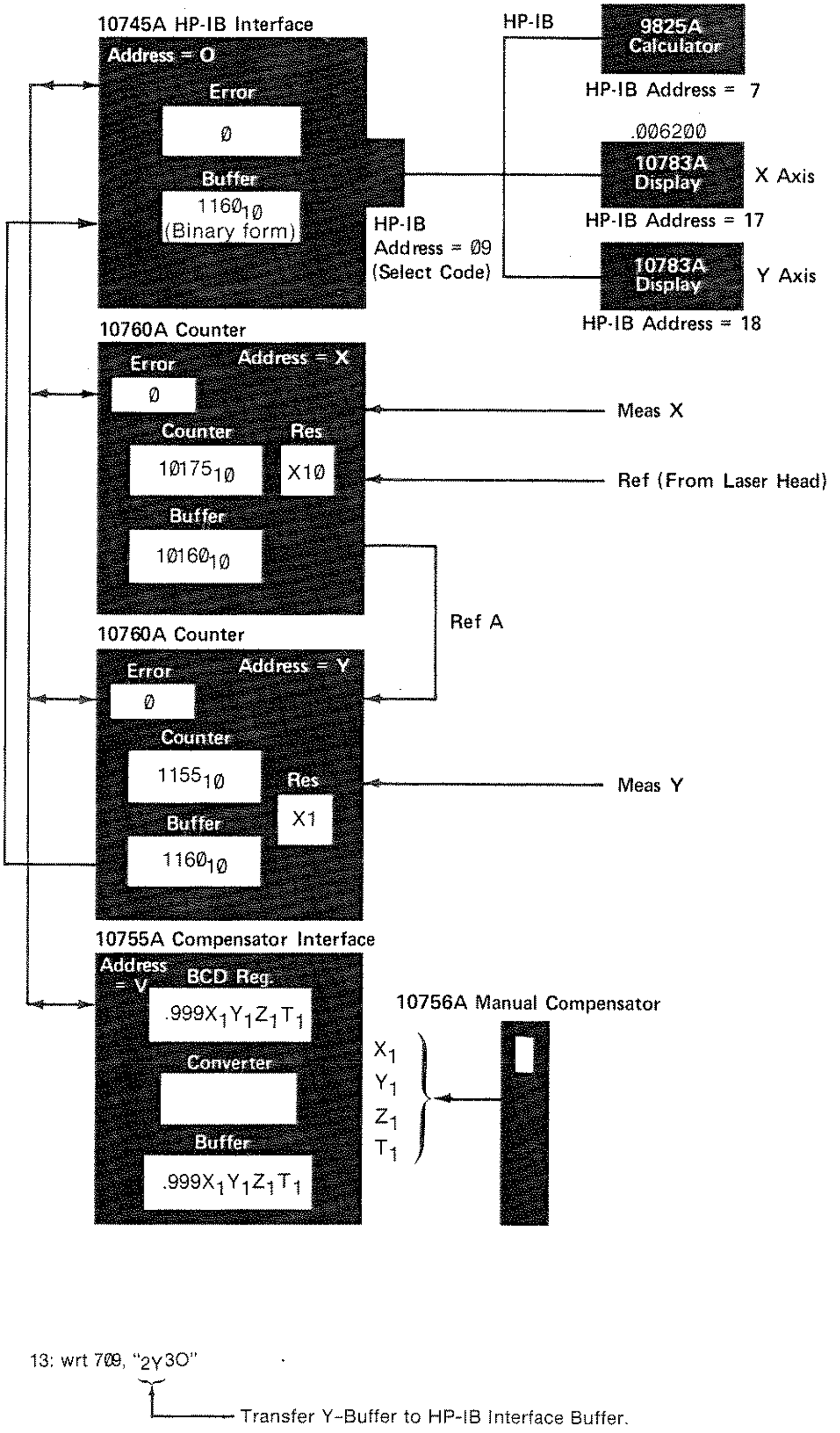
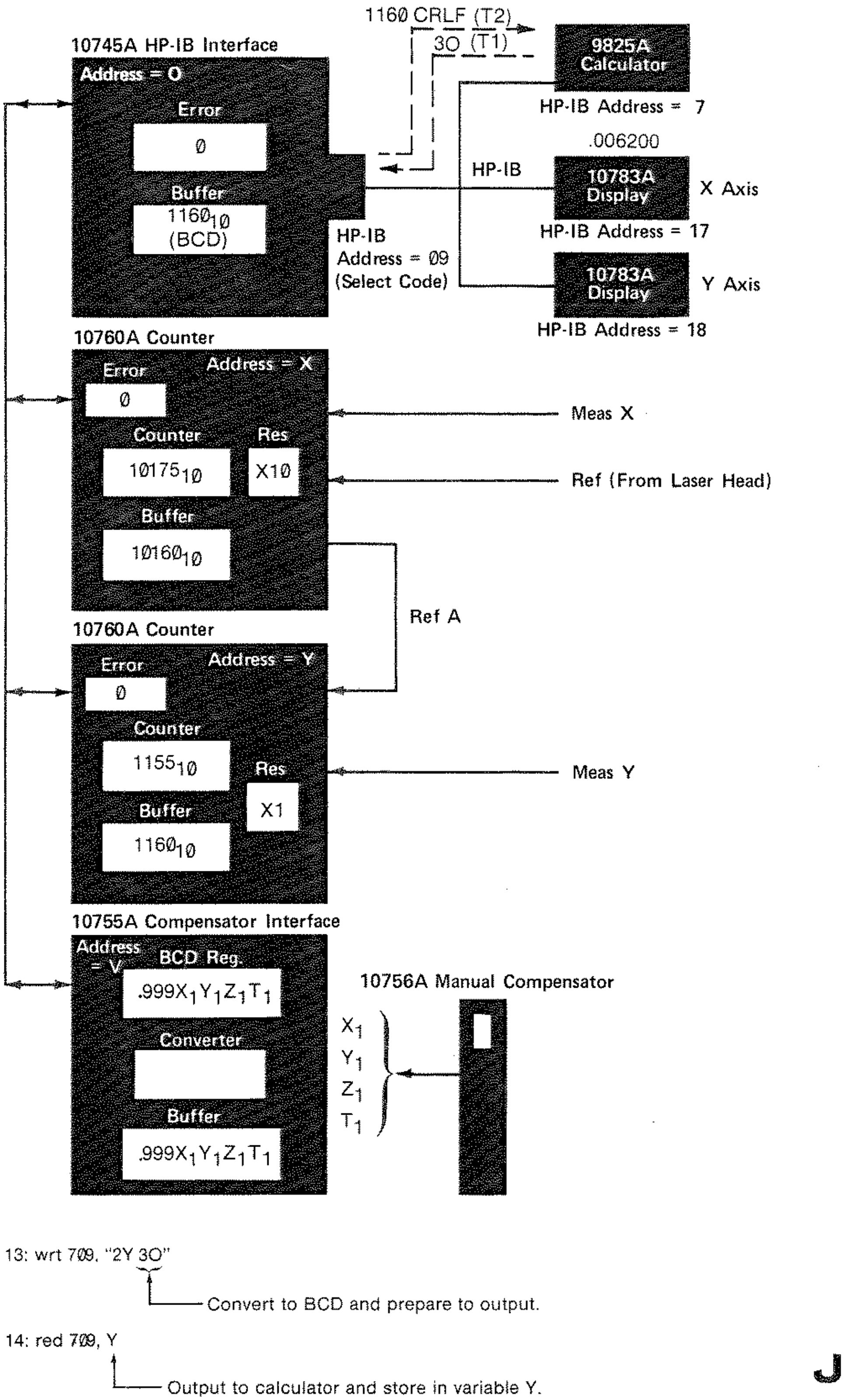


Figure 4-1. Counter-Based System Data Flow (Continued)



13: wrt 709, "2Y 3O"

Convert to BCD and prepare to output.

14: red 709, Y

Output to calculator and store in variable Y.

Figure 4-1. Counter-Based System Data Flow (Continued)

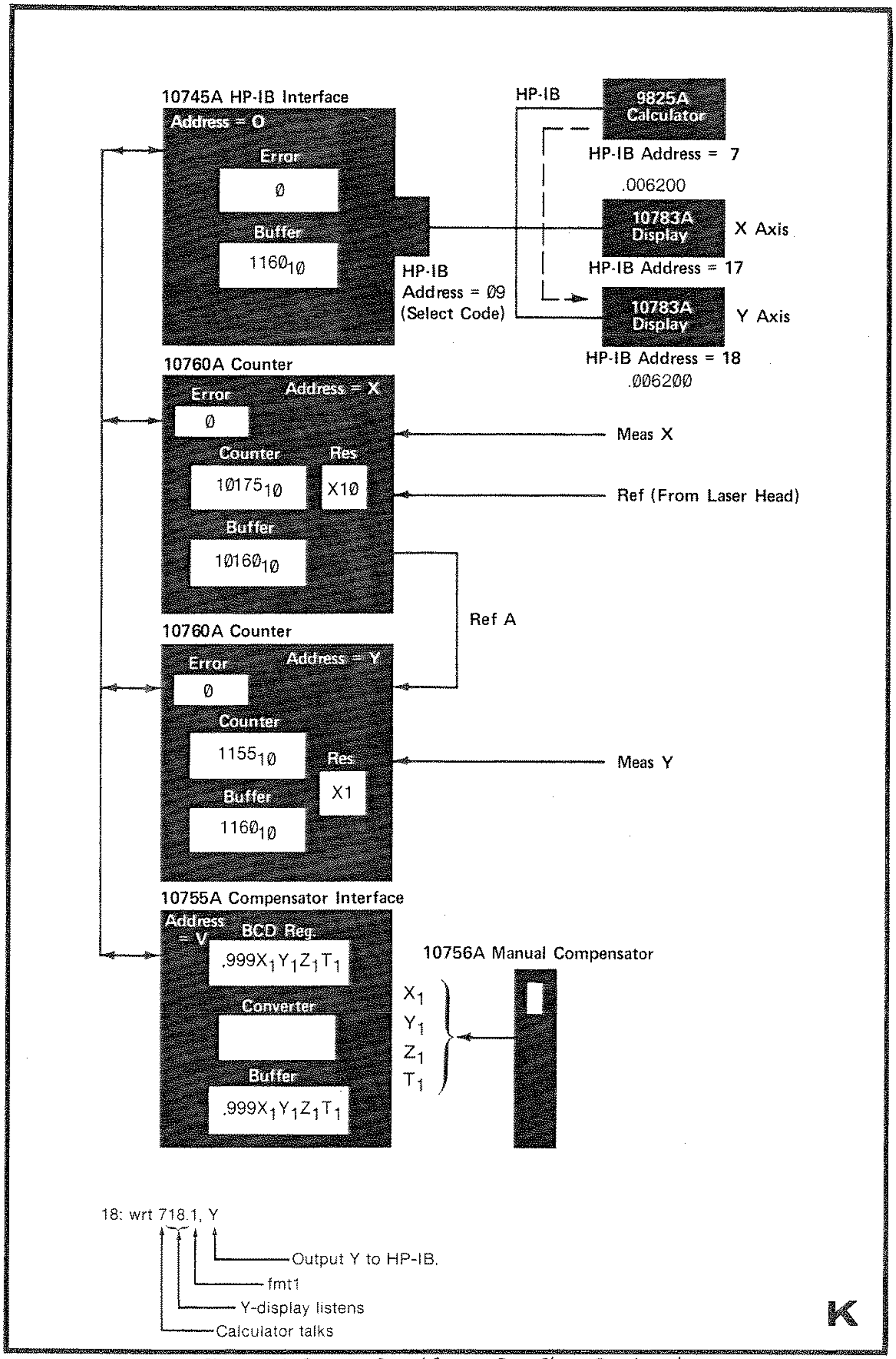
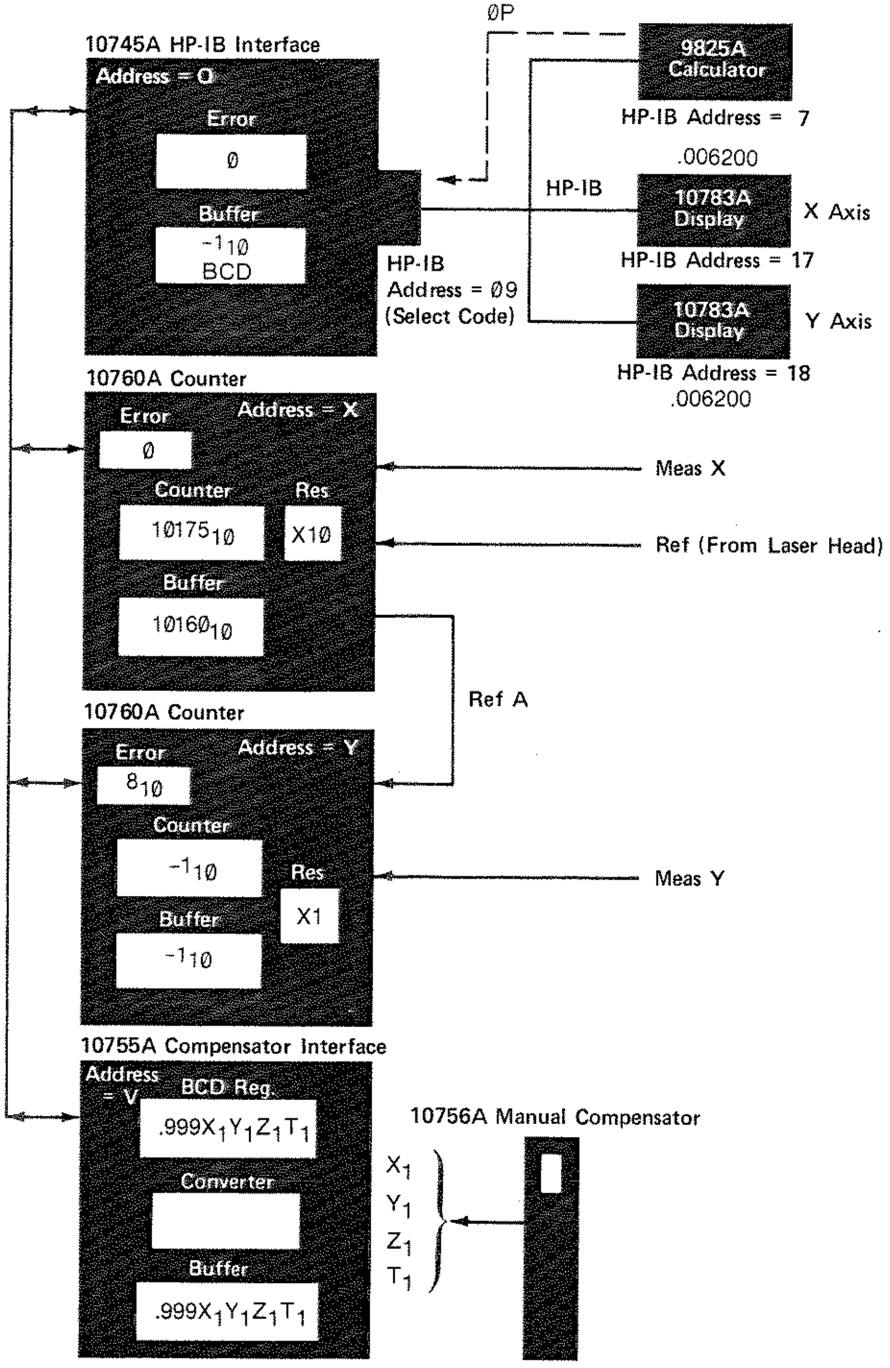


Figure 4-1. Counter-Based System Data Flow (Continued)



In this example error is over flow only.

```
22: wrt 7Ø9, "ØP"
```

Clear HP-IB error bits without resetting entire system. This way no displacement information is lost.

Figure 4-1. Counter-Based System Data Flow (Continued)

Table 4-13. 10746A Binary Interface Typical Program

PROGRAM	COMMENT
0: wtb 2, 0,0,0,98,3	000 = 0P,0P,0P. Guarantees System Reset. 98 = 2V = sample compensation reading 3 = 3P = prepare to output See *Figures 4-2A, B, and C.*
1: gsb "in"	"in" is a subroutine which inputs the number and places it in variable B. Refer to step 32.
2: B→C	C = Compensation Number.
3: ent "X TOLERANCE IN MICRONS?", r1	r1 = X Tolerance (refer to *Table 4-14*). No safeguards are provided.
4: ent "Y TOLERANCE IN MICRONS?",r2	r2 = Y Tolerance
5: "newdest":0→X;ent "X DESTINATION IN MM?",X	Top of Loop. X is X-Axis destination in millimetres 0 is default value.
6: 0→Y;ent "Y DESTINATION IN MM?",Y	Y is Y-Axis destination in millimetres. 0 is default value.
7: "comp":wtb 2, 98,3	98 = 2V = sample compensation reading. 3 = 3P = prepare to output. See *Figures 4-2B* and C.
8: gsb "in"	"in" inputs the number and places it in variable B. Refer to step 32.
9: B→C	C = Compensation Number.
10: X→A;gsb "cnv"	"cnv" converts X to fringes. Refer to step 38.
11: A→X	X = destination in fringes.
12: Y→A;gsb "cnv"	"cnv" converts Y to fringes. Refer to step 38.
13: A→Y	Y = Destination in fringes.
14: int(r1/1.58248e-1) *2↑28+X→A	Add X-tolerance in fringes to X-desination bits 28-31.
15: gsb "out"	Output to 10746A Card. Refer to step 39.
16: wtb 2,131	131 = 3X = transfer to X-destination register. See *Figure 4-2H.*
17: int(r2/1.58248e-1) *2↑28+Y→A	Add Y-tolerance in fringes to Y-destination bits 28-31.
18: gsb "out"	Output to 10746A Card.
19: wtb 2,147	147 = 3Y = transfer to Y-destination register. See *Figure 4-2I.*
20: "newsample":wtb 2,1,130,3	1 = 1P = sample X and Y to compare X,Y location with X-Y destination. 1P releases difference signals. 130 = 2X = transfer from X comparator to 10746A Binary Interface. 3 = 3P = prepare to transfer to calculator. See *Figure 4-2J,K,* and *L.*
21: 0→F	F = 0 for X-Axis.
22: gsb "in"	Subroutine to input the number from the 10746A Card.
23: B→r3	Store the X-location in r3.
24: wtb 2,146,3	146 = 2Y = transfer Y to 10746A. See *Figure 4-2M.* 3 = 3P = prepare to transfer to calculator. See *Figure 4-2N, O.*

Table 4-13. *10746A Binary Interface Typical Program (Cont'd)*

PROGRAM	COMMENT
25: 1→F	F = 1 for Y-Axis.
26: gsb "in"	Subroutine to input the number from the 10746A Card.
27: B→r4	Store the Y-location in r4.
28: fmt 1,2f10.0,f10.7	X format fixed 0 places to right of decimal. Y format. C Compensation format. Fixed 7 places to right of decimal.
29: wrt .1,r3-160,r4-160,C	Display raw counts.
30: if abs(X-r3)<=r1/(.158*C) and abs (Y-r4)<=r2/ (.158*C) gto "newdest"	If X and Y are within tolerance, get anothe destination; if not, resample. This could also be done by checking for system null. The error checking subroutine ("er") picks this up as an error, but drops out of the routine for system null.
31: gto "newsample"	Sample again.
32: "in":rdb(2)→B; if B<0;65536+B→B	Reads in bits 31-16. Complements if negative.* See *Figure 4-2D*.
33: if B>=61440;gto "er"	If bits 31-28 are all 1's go to error checking routine. Refer to step 45.
34: rdb(2)→G;ifG<0; 65536+G→G	Read in bits 15-0. Complements if negative. See *Figure 4-2E*.
35: int (B/4096)→D	D contains bits 31-28 decimal point information.
36: B-4096*D→B	B = Bits 27-16
37: (65536*B+G) *tn↑(2-D)→B;ret	B*2↑16 + bits 15-0. 2-D applies decimal point.
38: "cnv":A/(1.58248e-4*C) +160→A;ret	Subroutine to convert destination to fringes and add preset (160).
39: "out":wtb 2,4	"out" is a subroutine to output a 32-bit number in 2's complement form from two 16-bit words in positive-true form. 4=4P=load data into 10746A I/O buffer. See *Figure 4-2F*.
40: int (A/65536)→B; if B>32767;B-65536→B	B is bits 31-16
41: wtb 2,B	Output bits 31-16 to 10746A. See *Figure 4-2G*.
42: A-65536*int(A/65536)→B; if B>32767;B-65536→B	B is bits 15-0. Convert to 2's complement.
43: wtb 2,B	Output bits 15-0 to 10746A. See *Figure 4-2G* from step 15.
44: ret	Output is completed. Transfer command needs to be given.
45: "er":int(B/256)- 240→B;15-B→B	B = Bits 31-16. Initially -240 clears bits 31-28 which indicates an error. Bits 27-24 need to be complemented by subtracting from 15.
46: if B>=8;prt "vol error"; B-8→B;0→D	If Bit 27, Vol error clear bit 27.

*Range of 9825 16 bit words = +32,767 to -32,768.

Table 4–13. 10746A Binary Interface Typical Program (Cont'd)

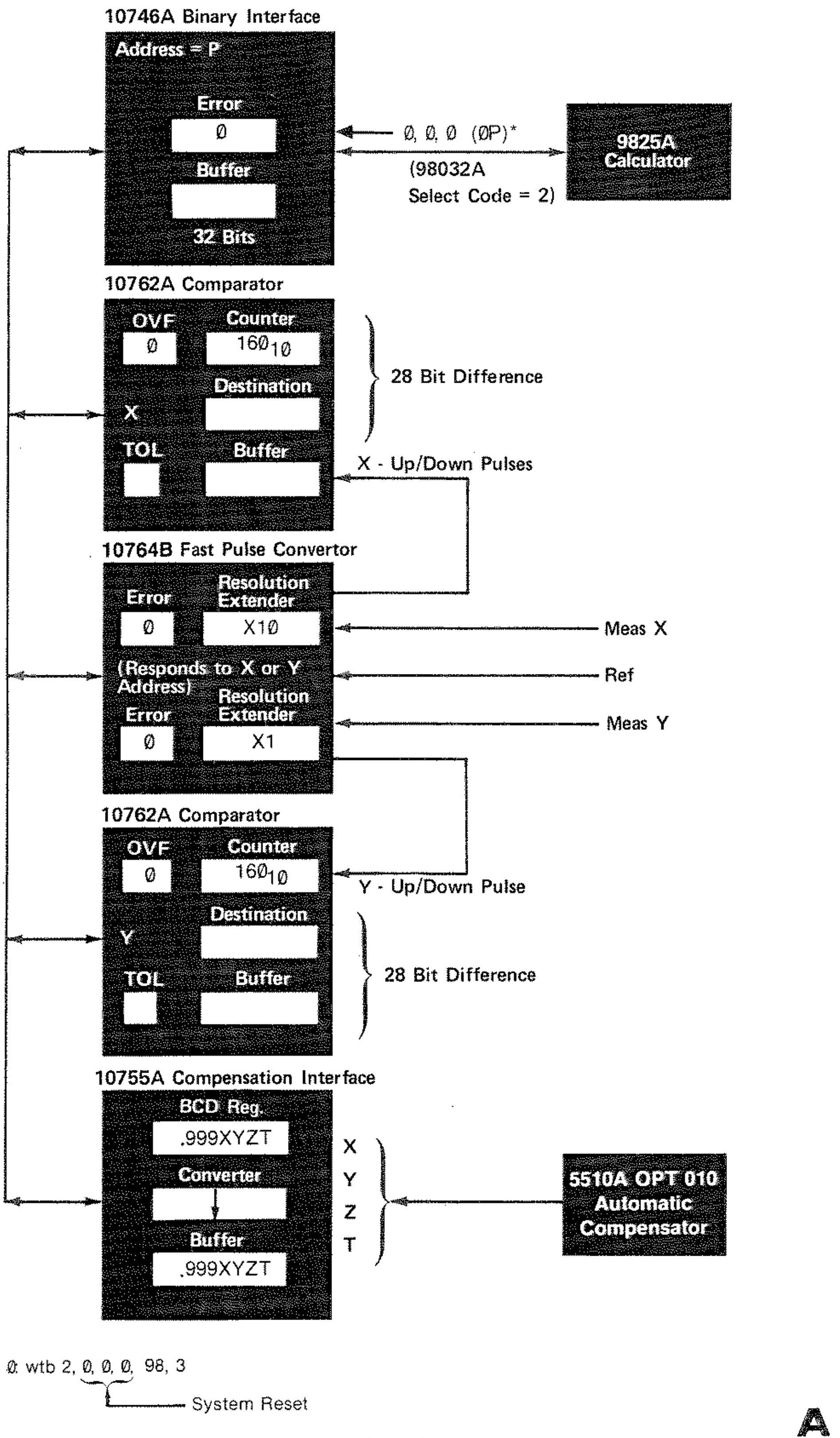
PROGRAM	COMMENT
47: if B>=4;B-4→B;1→D	If Bit 26, D=1 as possible recoverable error. Clear Bit 26.
48: if B>=2;prt "ref error";* 0→D	If Bit 25, D=0 as irrecoverable error. Clear bit 25.*
49: if B=1;prt "meas error"; 0→D	If Bit 24, D = 0 as irrecoverable error. Print "meas error".
50: if D=0;gto"prterr"	go to "prterr" if irrecoverable error. Refer to step 61.
51: rdb(2)→B	Overflow only. Read in bits 15-0 to complete previous 3P command.
52: wtb2,240,3	240 = 0O = clears error bits on 10746A so 28 bits of data can be transferred with 3P command. 3 = 3P = prepare to transfer.
53: rdb(2)→B; if B<0; 65536+B→B	Read in bits 31-16. Complements if negative.
54: rdb(2)→G;ifG<0; 65536+G→G	Reads in bits 15-0. Complements if negative.
55: int(B/4096)→D	D contains bits 31-28 decimal point information.
56: B-4096*D→B	B = Bits 27-16.
57: (65536*B+G)*tn↑(2-D)→B	B*2↑16 + Bits 15-0. 2-D applies decimal point.
58: if F=0 and B–160#0; B–2↑28→B	Correct for overflow. (Really underflow).
59: if F=1 and B–160#0; B–2↑28→B	Correct for overflow. (Really underflow).
60: ret	
61: "prterr":ifF=0; prt "X-AXIS ERROR"	
62: if F=1; prt "Y-AXIS ERROR"	
63: dsp "go to gage";stp	Irrecoverable error, so stop and go to gage.
64: gto 0	
65: end	

*It should be noted when a reference error occurs both measure and error signals will also go true. In this example X and Y will both show a measure error although no measure error has occurred.

If using a 5510A Automatic Compensator, a 0V(96) command must be sent to guarantee update of data. (This should be done at beginning of program.)

Table 4–14. Binary Interface Typical Program Variables

VARIABLE	CONTENTS
rl	X Tolerance in Microns
r2	Y Tolerance in Microns
X	X Destination in MM or Fringes
Y	Y Destination in MM or Fringes
C	Compensation Number for VOL and Material Temperature
r3	Current X Location in Fringes
r4	Current Y Location in Fringes



*HP-IB COMMANDS SHOWN IN PARENTHESIS.

Figure 4-2. Comparator-Based System Data Flow

Table 4–13. 10746A Binary Interface Typical Program (Cont'd)

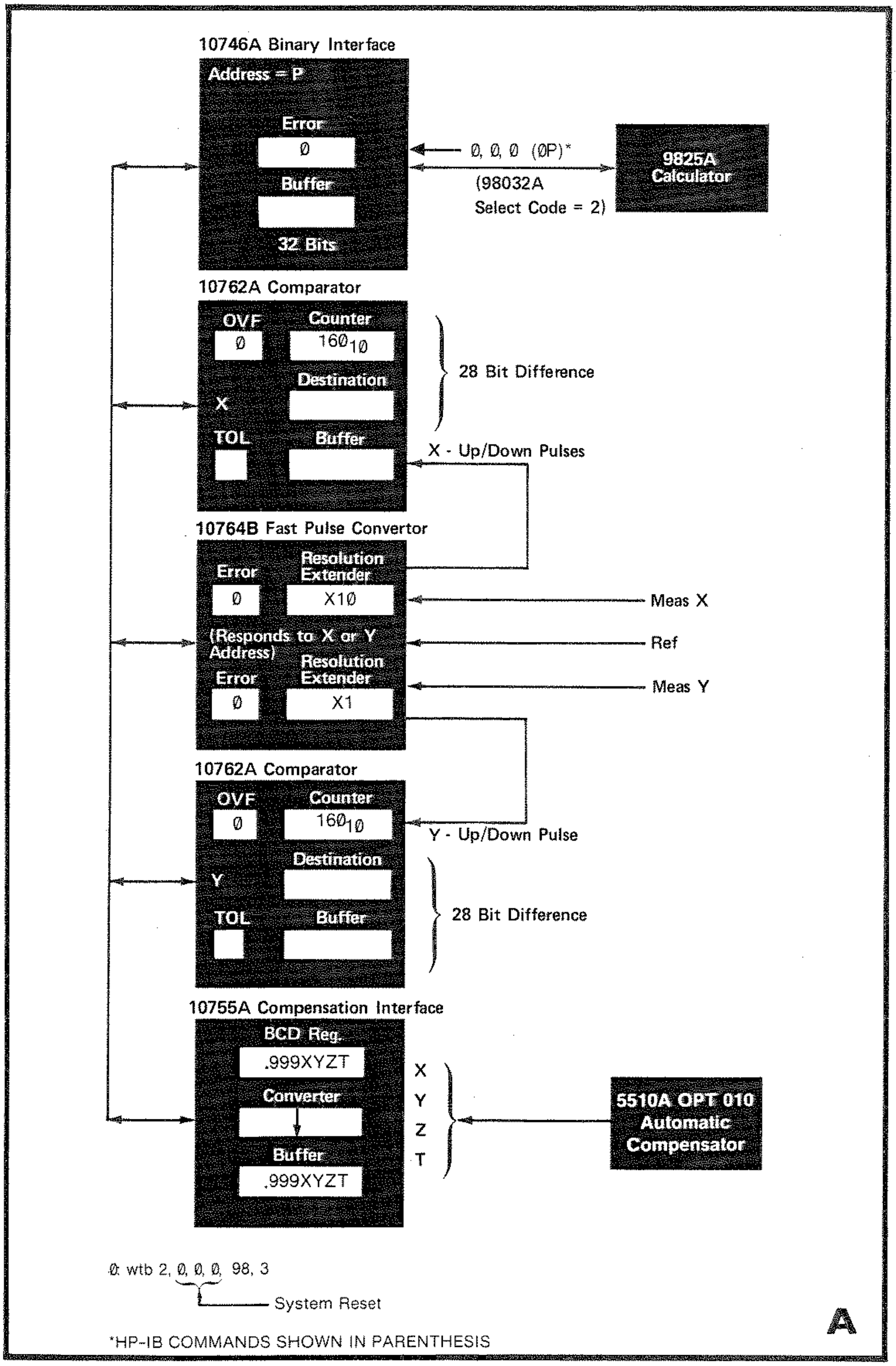
PROGRAM	COMMENT
47: if B>=4;B-4→B;1→D	If Bit 26, D=1 as possible recoverable error. Clear Bit 26.
48: if B>=2;prt "ref error";* 0→D	If Bit 25, D=0 as irrecoverable error. Clear bit 25.*
49: if B=1;prt "meas error"; 0→D	If Bit 24, D = 0 as irrecoverable error. Print "meas error".
50: if D=0;gto"prterr"	go to "prterr" if irrecoverable error. Refer to step 61.
51: rdb(2)→B	Overflow only. Read in bits 15-0 to complete previous 3P command.
52: wtb2,240,3	240 = 0O = clears error bits on 10746A so 28 bits of data can be transferred with 3P command. 3 = 3P = prepare to transfer.
53: rdb(2)→B; if B<0; 65536+B→B	Read in bits 31-16. Complements if negative.
54: rdb(2)→G;ifG<0; 65536+G→G	Reads in bits 15–0. Complements if negative.
55: int(B/4096)→D	D contains bits 31-28 decimal point information.
56: B-4096*D→B	B = Bits 27-16.
57: (65536*B+G)*tn↑(2-D)→B	B*2↑16 + Bits 15-0. 2-D applies decimal point.
58: if F=0 and B–160#0; B–2↑28→B	Correct for overflow. (Really underflow).
59: if F=1 and B–160#0; B–2↑28→B	Correct for overflow. (Really underflow).
60: ret	
61: "prterr":ifF=0; prt "X-AXIS ERROR"	
62: if F=1; prt "Y-AXIS ERROR"	
63: dsp "go to gage";stp	Irrecoverable error, so stop and go to gage.
64: gto 0	
65: end	

**It should be noted when a reference error occurs both measure and error signals will also go true. In this example X and Y will both show a measure error although no measure error has occurred.*

If using a 5510A Automatic Compensator, a 0V(96) command must be sent to guarantee update of data. (This should be done at beginning of program.)

Table 4–14. Binary Interface Typical Program Variables

VARIABLE	CONTENTS
rl	X Tolerance in Microns
r2	Y Tolerance in Microns
X	X Destination in MM or Fringes
Y	Y Destination in MM or Fringes
C	Compensation Number for VOL and Material Temperature
r3	Current X Location in Fringes
r4	Current Y Location in Fringes



*HP-IB COMMANDS SHOWN IN PARENTHESIS

Figure 4-2. Comparator-Based System Data Flow

Table 4-13. 10746A Binary Interface Typical Program (Cont'd)

PROGRAM	COMMENT
47: if B>=4;B-4→B;1→D	If Bit 26, D=1 as possible recoverable error. Clear Bit 26.
48: if B>=2;prt "ref error";* 0→D	If Bit 25, D=0 as irrecoverable error. Clear bit 25.*
49: if B=1;prt "meas error"; 0→D	If Bit 24, D = 0 as irrecoverable error. Print "meas error".
50: if D=0;gto"prterr"	go to "prterr" if irrecoverable error. Refer to step 61.
51: rdb(2)→B	Overflow only. Read in bits 15-0 to complete previous 3P command.
52: wtb2,240,3	240 = 0O = clears error bits on 10746A so 28 bits of data can be transferred with 3P command. 3 = 3P = prepare to transfer.
53: rdb(2)→B; if B<0; 65536+B→B	Read in bits 31-16. Complements if negative.
54: rdb(2)→G;ifG<0; 65536+G→G	Reads in bits 15-0. Complements if negative.
55: int(B/4096)→D	D contains bits 31-28 decimal point information.
56: B-4096*D→B	B = Bits 27-16.
57: (65536*B+G)*tn↑(2-D)→B	B*2↑16 + Bits 15-0. 2-D applies decimal point.
58: if F=0 and B–160#0; B-2↑28→B	Correct for overflow. (Really underflow).
59: if F=1 and B–160#0; B-2↑28→B	Correct for overflow. (Really underflow).
60: ret	
61: "prterr":ifF=0; prt "X-AXIS ERROR"	
62: if F=1; prt "Y-AXIS ERROR"	
63: dsp "go to gage";stp	Irrecoverable error, so stop and go to gage.
64: gto 0	
65: end	

It should be noted when a reference error occurs both measure and error signals will also go true. In this example X and Y will both show a measure error although no measure error has occurred.

If using a 5510A Automatic Compensator, a 0V(96) command must be sent to guarantee update of data. (This should be done at beginning of program.)

Table 4-14. Binary Interface Typical Program Variables

VARIABLE	CONTENTS
rl	X Tolerance in Microns
r2	Y Tolerance in Microns
X	X Destination in MM or Fringes
Y	Y Destination in MM or Fringes
C	Compensation Number for VOL and Material Temperature
r3	Current X Location in Fringes
r4	Current Y Location in Fringes

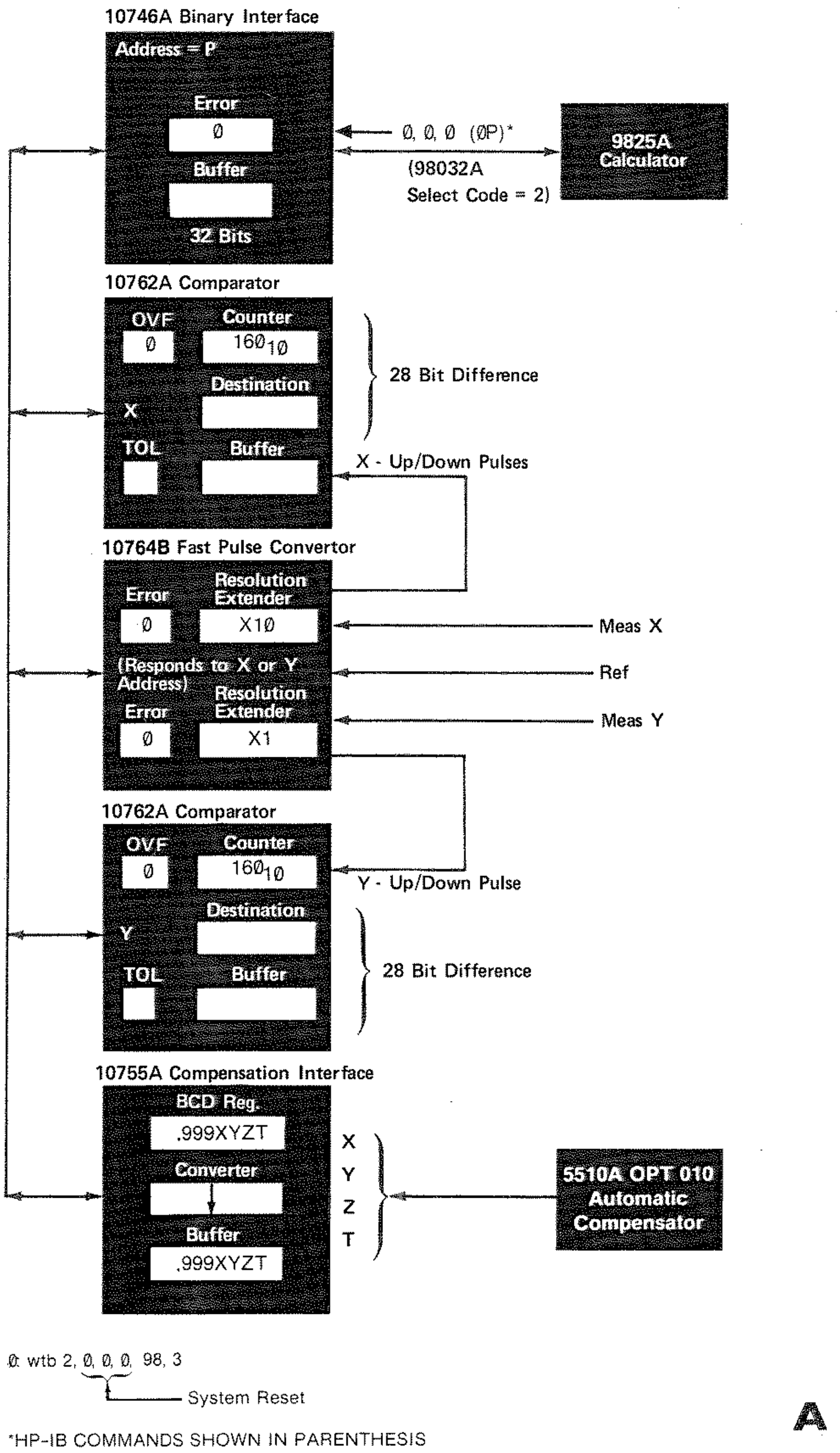


Figure 4-2. Comparator-Based System Data Flow

Table 4-13. 10746A Binary Interface Typical Program (Cont'd)

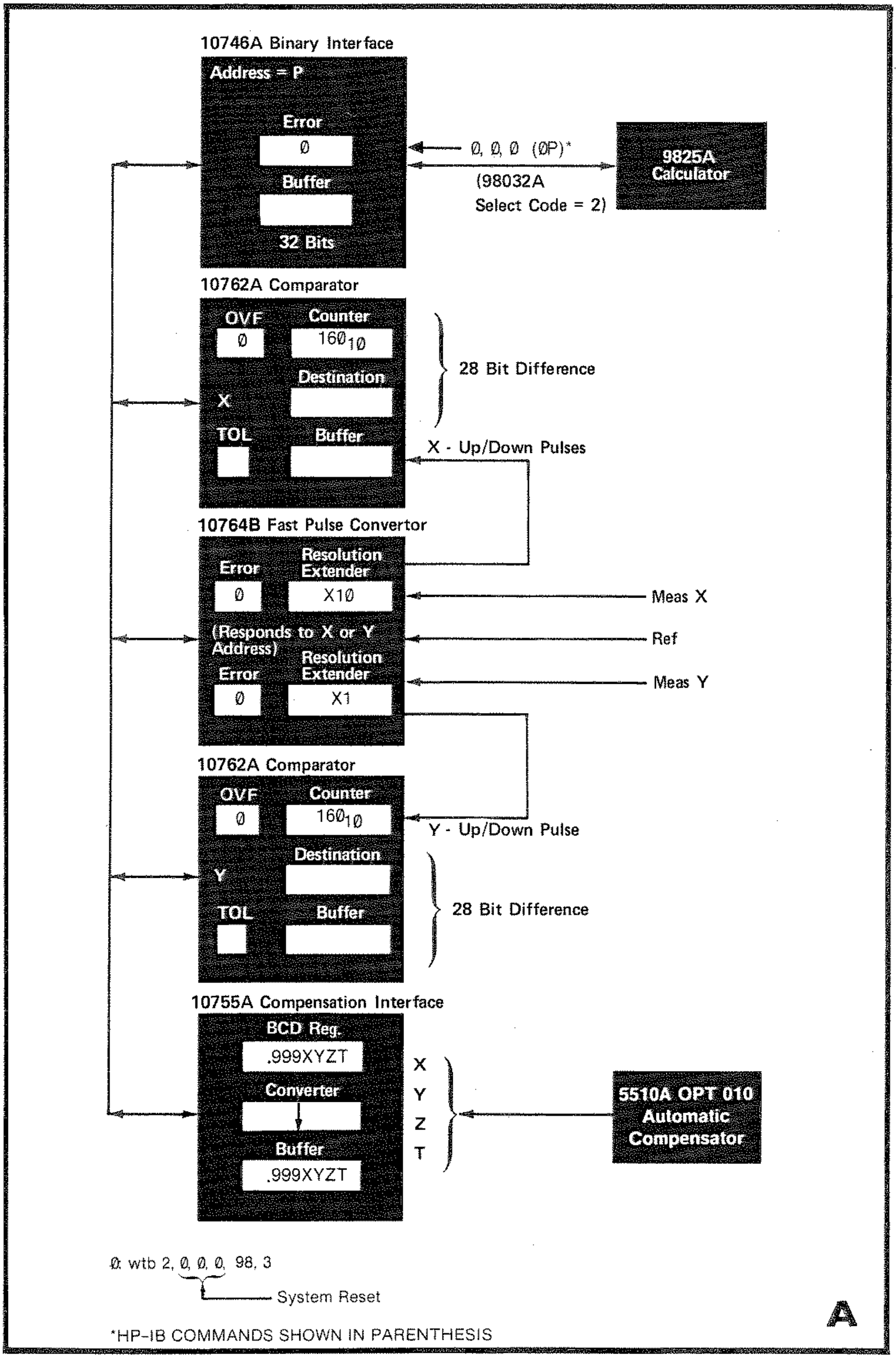
PROGRAM	COMMENT
47: if B>=4;B-4→B;1→D	If Bit 26, D=1 as possible recoverable error. Clear Bit 26.
48: if B>=2;prt "ref error";* 0→D	If Bit 25, D=0 as irrecoverable error. Clear bit 25.*
49: if B=1;prt "meas error"; 0→D	If Bit 24, D = 0 as irrecoverable error. Print "meas error".
50: if D=0;gto"prterr"	go to "prterr" if irrecoverable error. Refer to step 61.
51: rdb(2)→B	Overflow only. Read in bits 15-0 to complete previous 3P command.
52: wtb2,240,3	240 = 0O = clears error bits on 10746A so 28 bits of data can be transferred with 3P command. 3 = 3P = prepare to transfer.
53: rdb(2)→B; if B<0; 65536+B→B	Read in bits 31-16. Complements if negative.
54: rdb(2)→G;ifG<0; 65536+G→G	Reads in bits 15-0. Complements if negative.
55: int(B/4096)→D	D contains bits 31-28 decimal point information.
56: B-4096*D→B	B = Bits 27-16.
57: (65536*B+G)*tn↑(2-D)→B	B*2↑16 + Bits 15-0. 2-D applies decimal point.
58: if F=0 and B-160#0; B-2↑28→B	Correct for overflow. (Really underflow).
59: if F=1 and B-160#0; B-2↑28→B	Correct for overflow. (Really underflow).
60: ret	
61: "prterr":ifF=0; prt "X-AXIS ERROR"	
62: if F=1; prt "Y-AXIS ERROR"	
63: dsp "go to gage";stp	Irrecoverable error, so stop and go to gage.
64: gto 0	
65: end	

It should be noted when a reference error occurs both measure and error signals will also go true. In this example X and Y will both show a measure error although no measure error has occurred.

If using a 5510A Automatic Compensator, a 0V(96) command must be sent to guarantee update of data. (This should be done at beginning of program.)

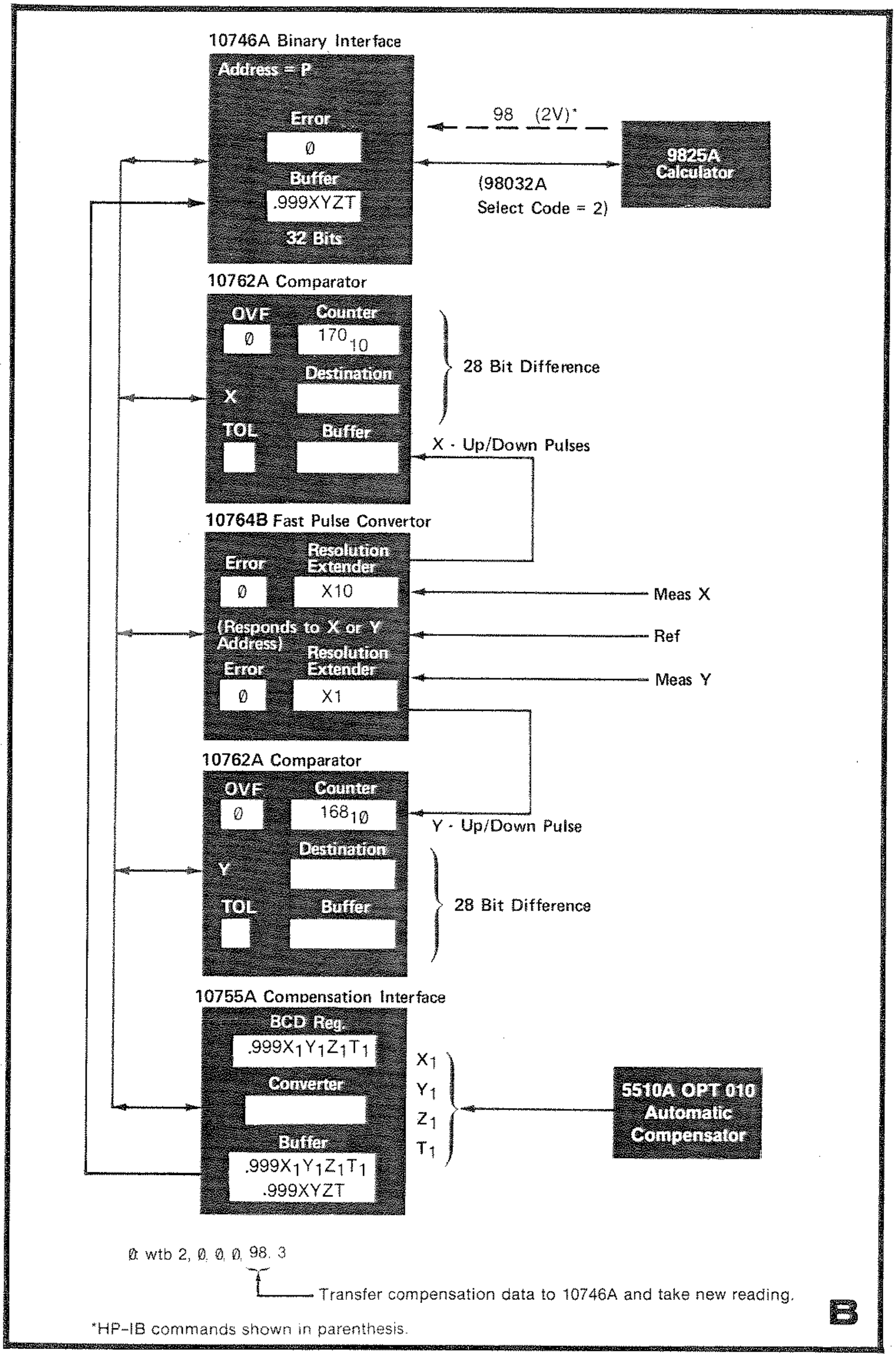
Table 4-14. Binary Interface Typical Program Variables

VARIABLE	CONTENTS
rl	X Tolerance in Microns
r2	Y Tolerance in Microns
X	X Destination in MM or Fringes
Y	Y Destination in MM or Fringes
C	Compensation Number for VOL and Material Temperature
r3	Current X Location in Fringes
r4	Current Y Location in Fringes



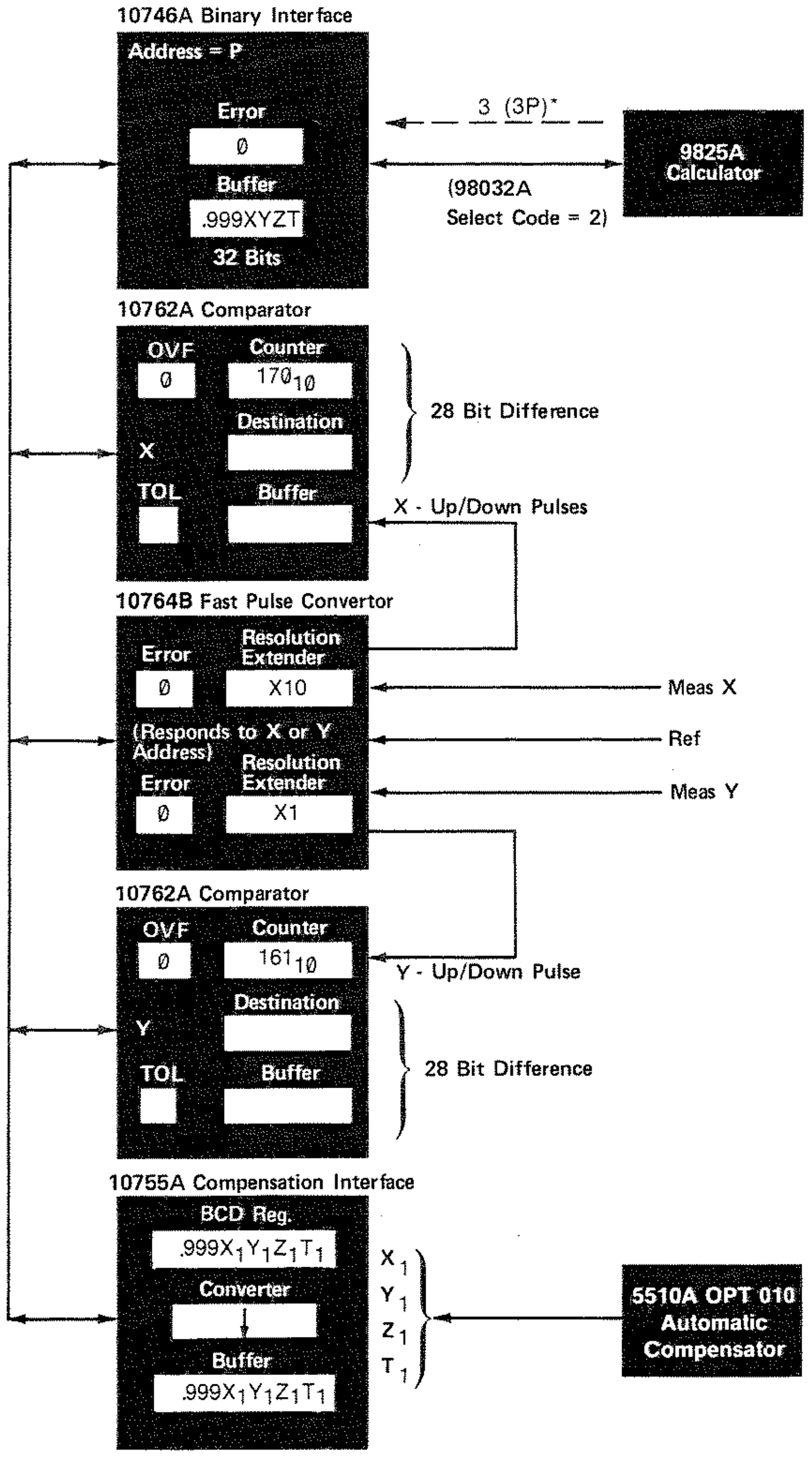
*HP-IB COMMANDS SHOWN IN PARENTHESIS

Figure 4-2. Comparator-Based System Data Flow



*HP-IB commands shown in parenthesis.

Figure 4-2. Comparator-Based System Data Flow (Cont'd)

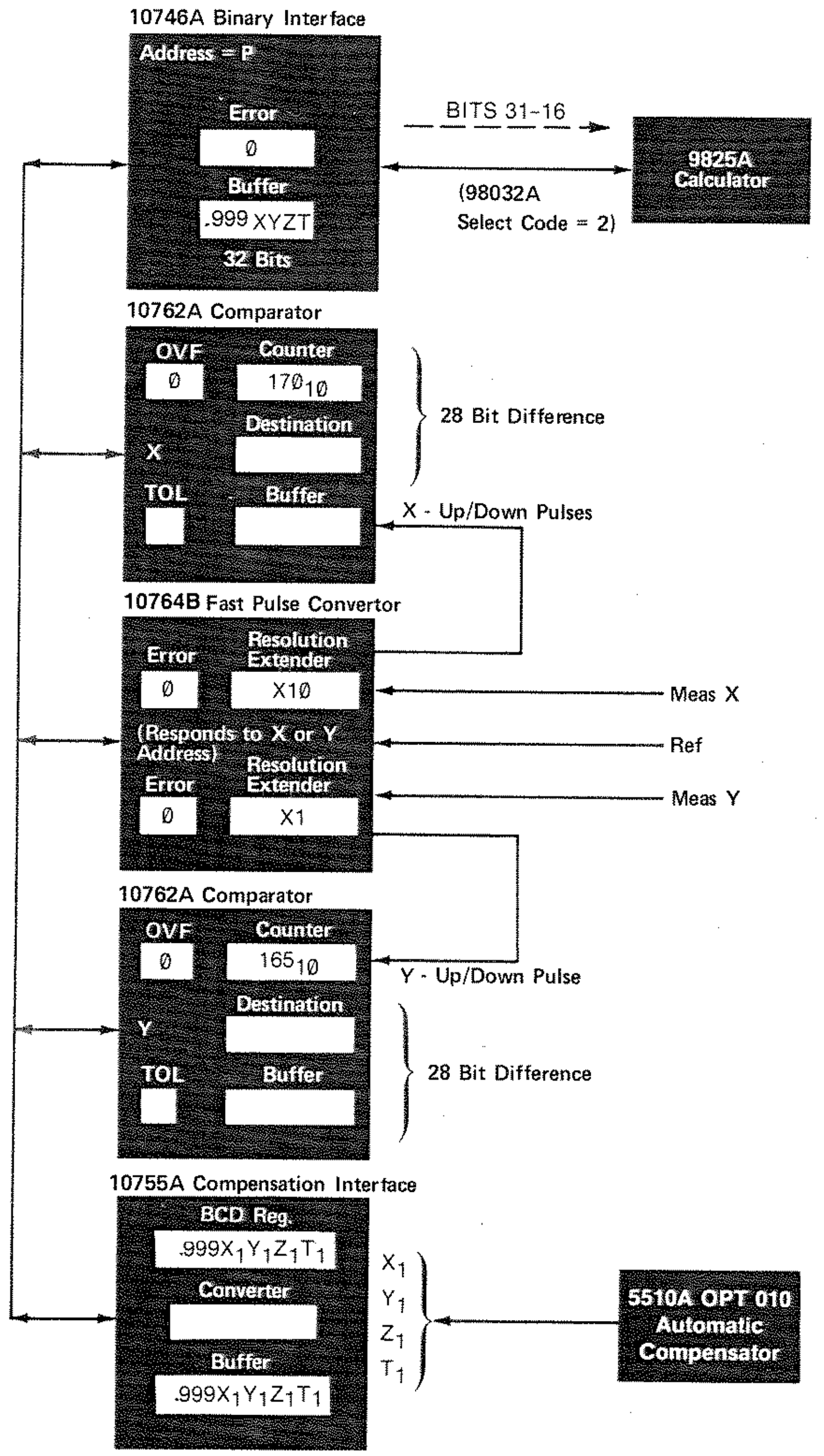


```
0: wtb 2, 0, 0, 0, 98, 3
```

Set 10746A card to data transfer out mode.

*HP-IB commands shown in parenthesis.

Figure 4-2. Comparator-Based System Data Flow (Cont'd)

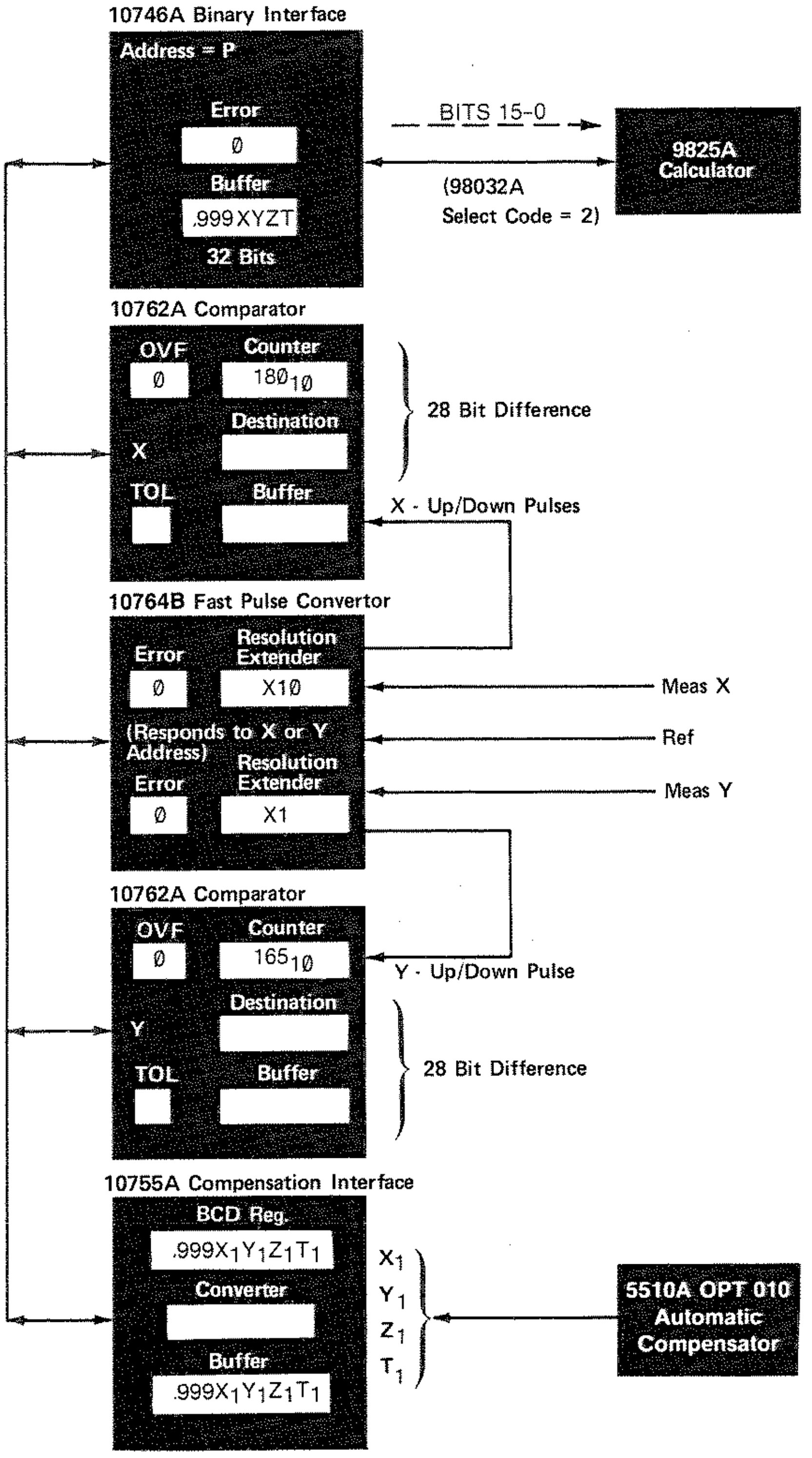


32: "in": rdb (2)→B; if B < 0, 65536 + B→B } ← Read bits 31-16 (1 word), the compensation number into variable B. If negative, complement the number.

*HP-IB commands shown in parenthesis.

D

Figure 4-2. Comparator-Based System Data Flow (Cont'd)

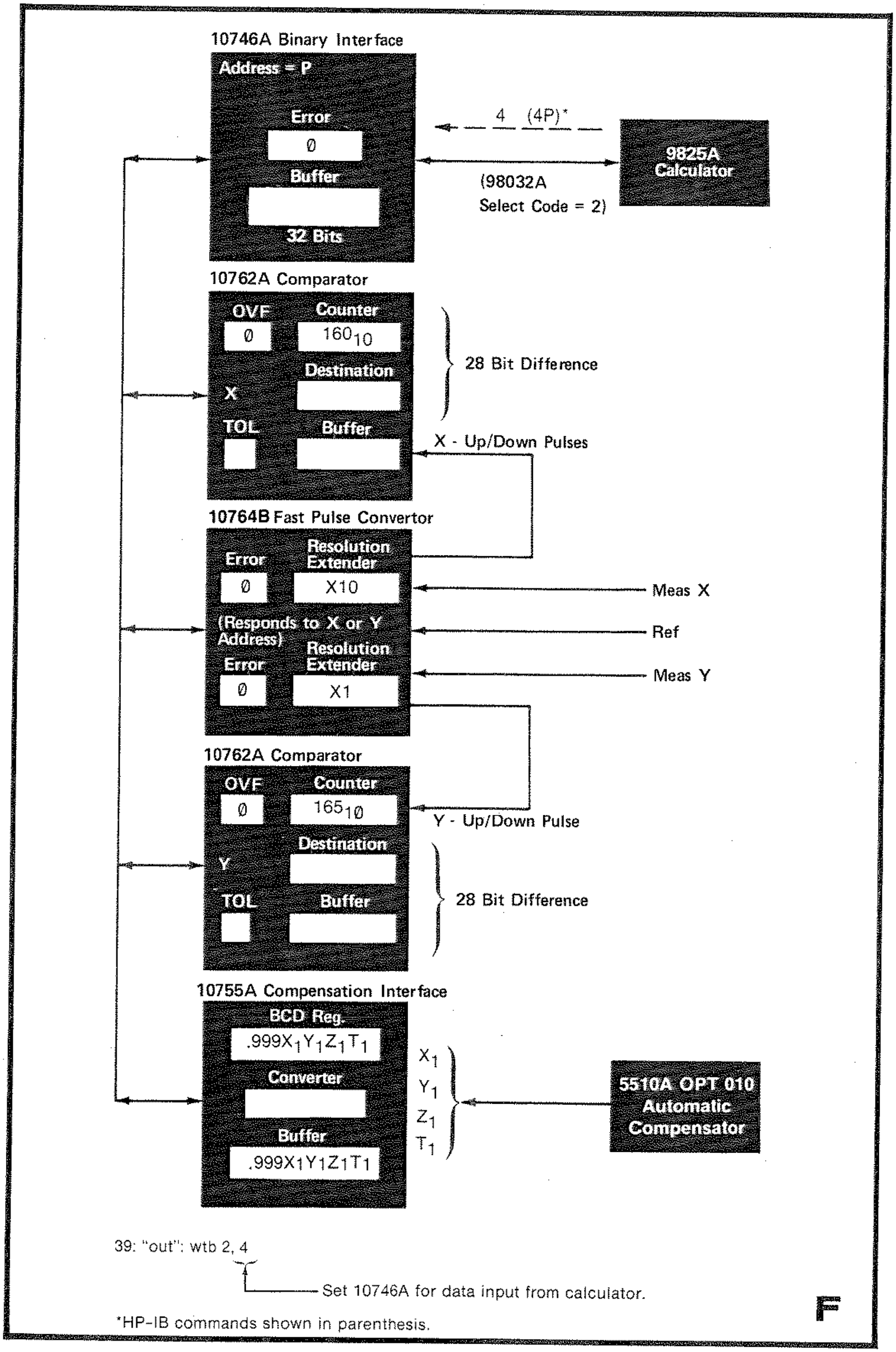


34: rdb (2)→G; if G < 0, 65536 + G→G } ← Read bits 15-0 (1 word). If negative, complement the number.

E

*HP-IB commands shown in parenthesis.

Figure 4-2. Comparator-Based System Data Flow (Cont'd)

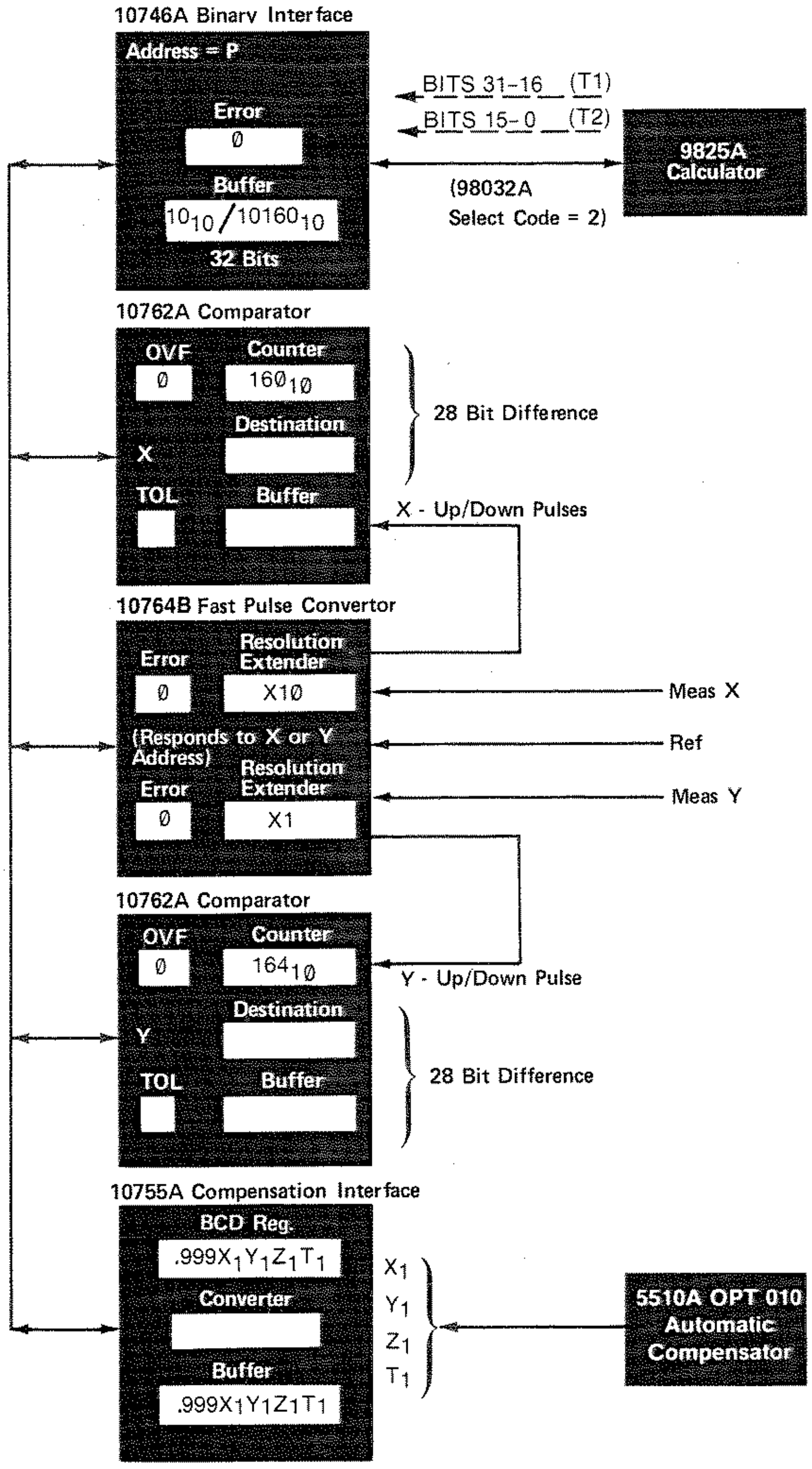


39: "out": wtb 2, 4

Set 10746A for data input from calculator.

*HP-IB commands shown in parenthesis.

Figure 4-2. Comparator-Based System Data Flow (Cont'd)

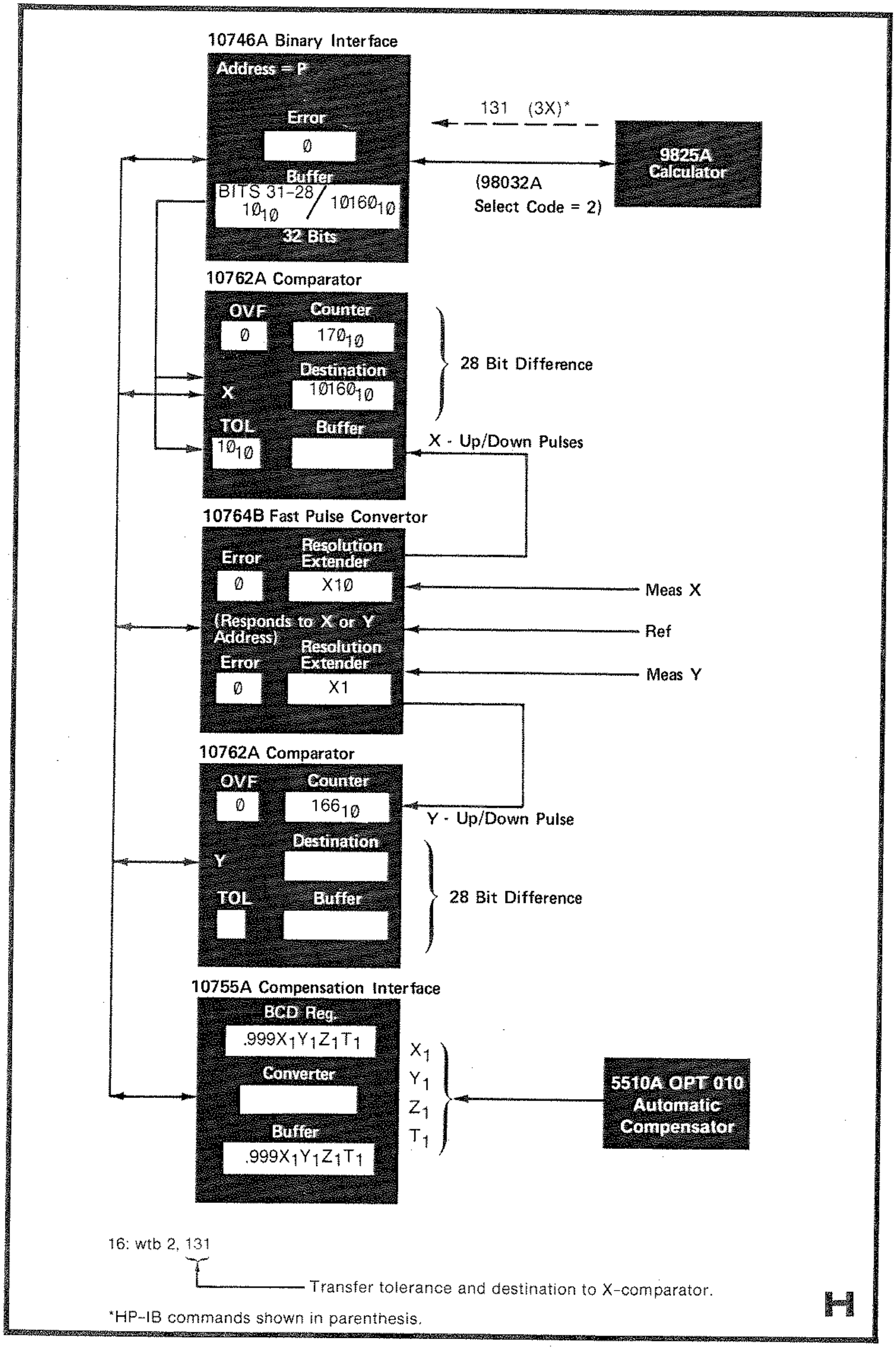


41: wtb 2, B } ← outputs bits 31-16 to 10746A buffer (T1)

43: wtb 2, B } ← output bits 15-0 to 10746A buffer (T2)

*HP-IB commands shown in parenthesis.

Figure 4-2. Comparator-Based System Data Flow (Cont'd)

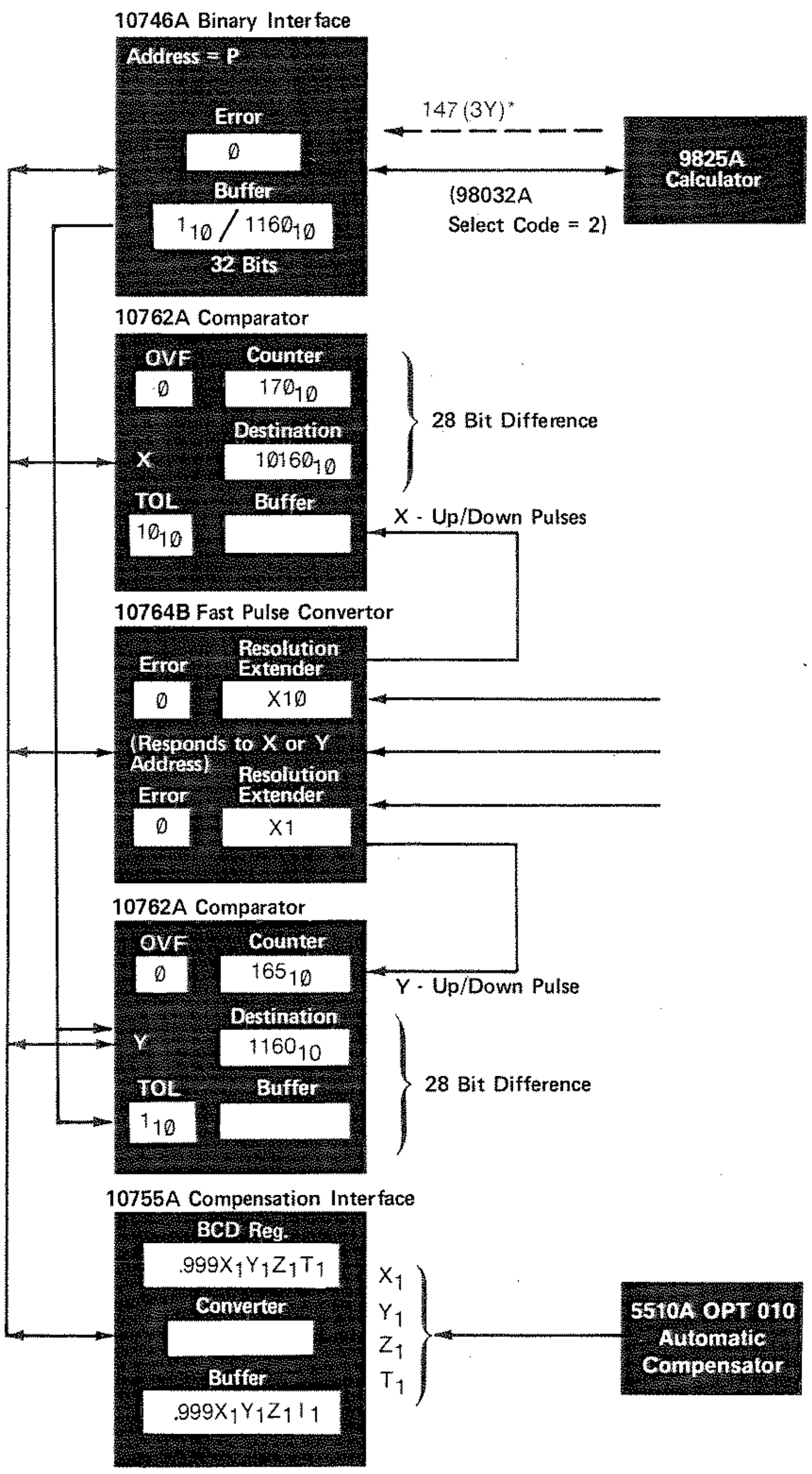


16: wtb 2, 131

Transfer tolerance and destination to X-comparator.

*HP-IB commands shown in parenthesis.

Figure 4-2. Comparator-Based System Data Flow (Cont'd)

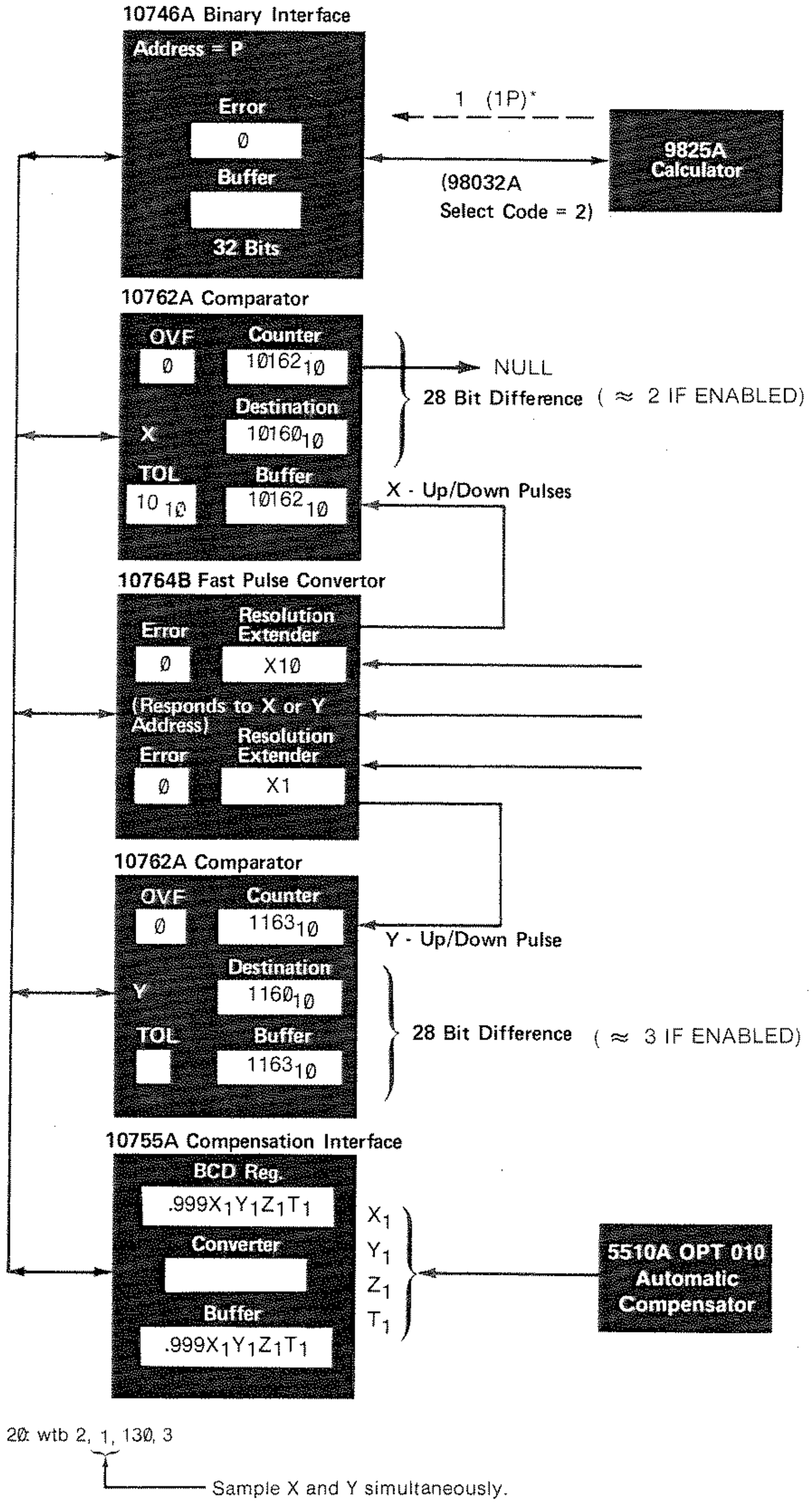


19: wtb 2, 147}←Transfer tolerance and destination to Y-comparator.

*HP-IB commands shown in parenthesis.

I

Figure 4-2. Comparator-Based System Data Flow (Cont'd)



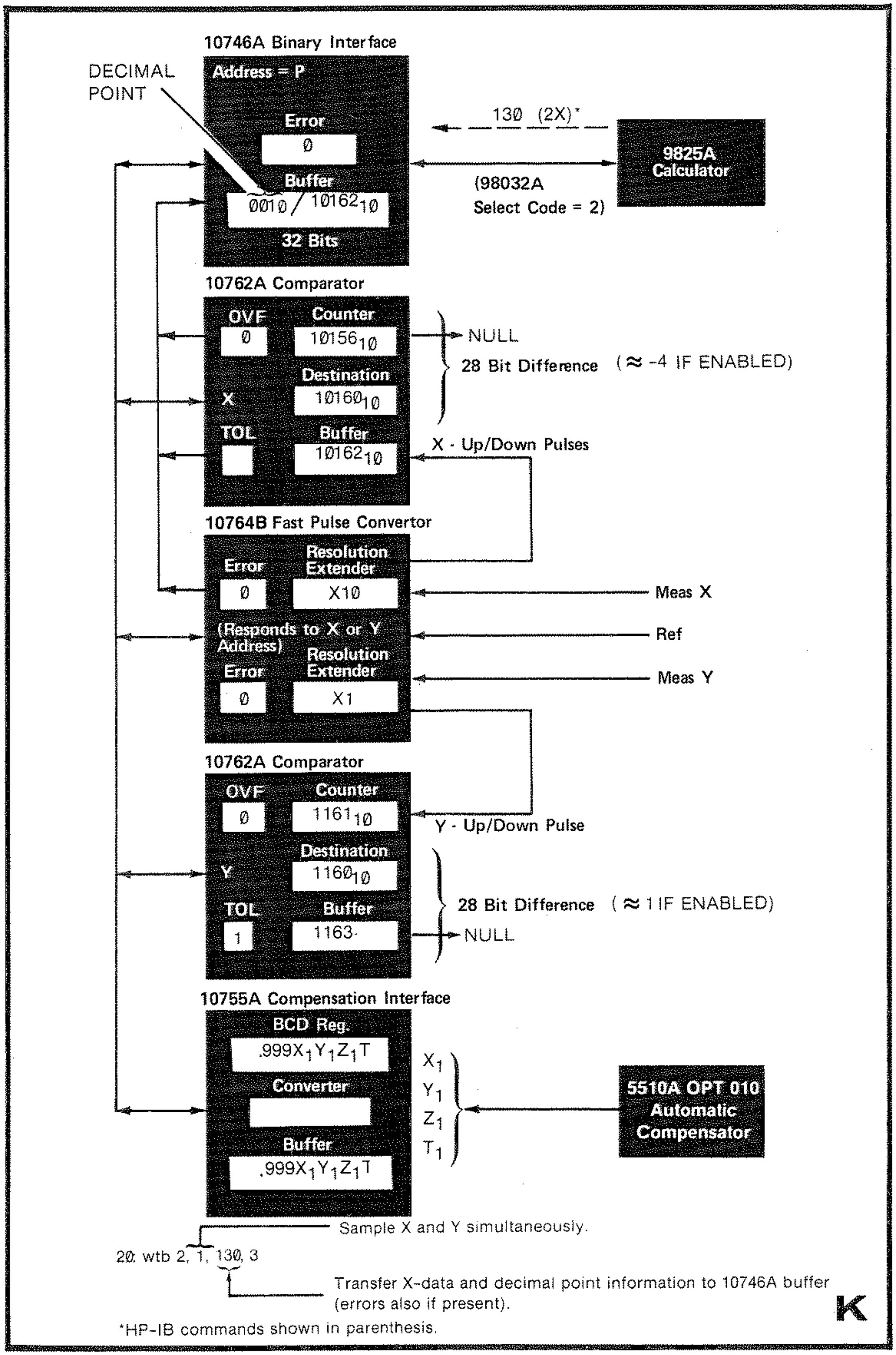
20: wtb 2, 1, 130, 3

Sample X and Y simultaneously.

*HP-IB commands shown in parenthesis.

J

Figure 4-2. Comparator-Based System Data Flow (Cont'd)



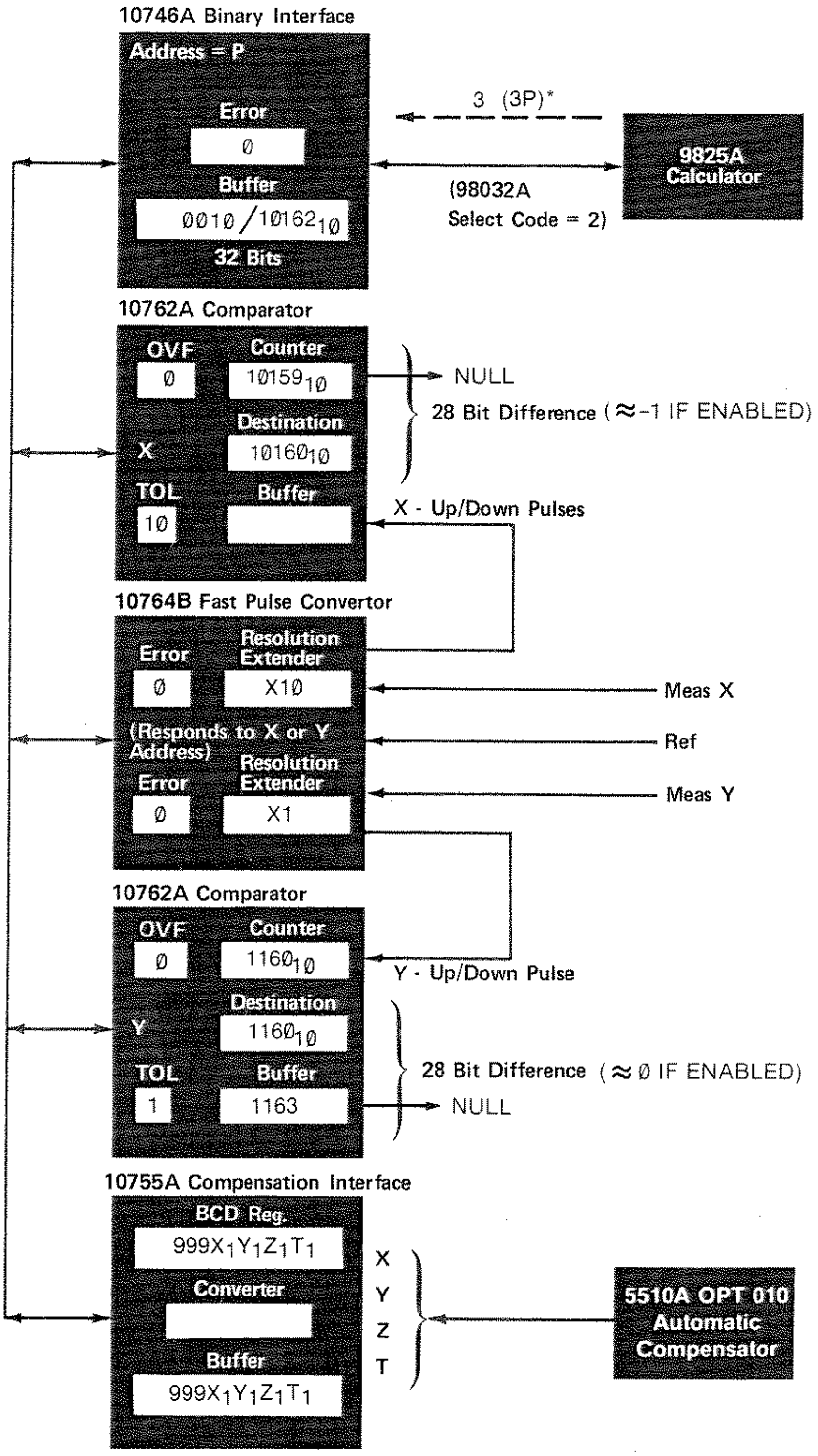
Sample X and Y simultaneously.

20: wtb 2, 1, 130, 3

Transfer X-data and decimal point information to 10746A buffer (errors also if present).

*HP-IB commands shown in parenthesis.

Figure 4-2. Comparator-Based System Data Flow (Cont'd)

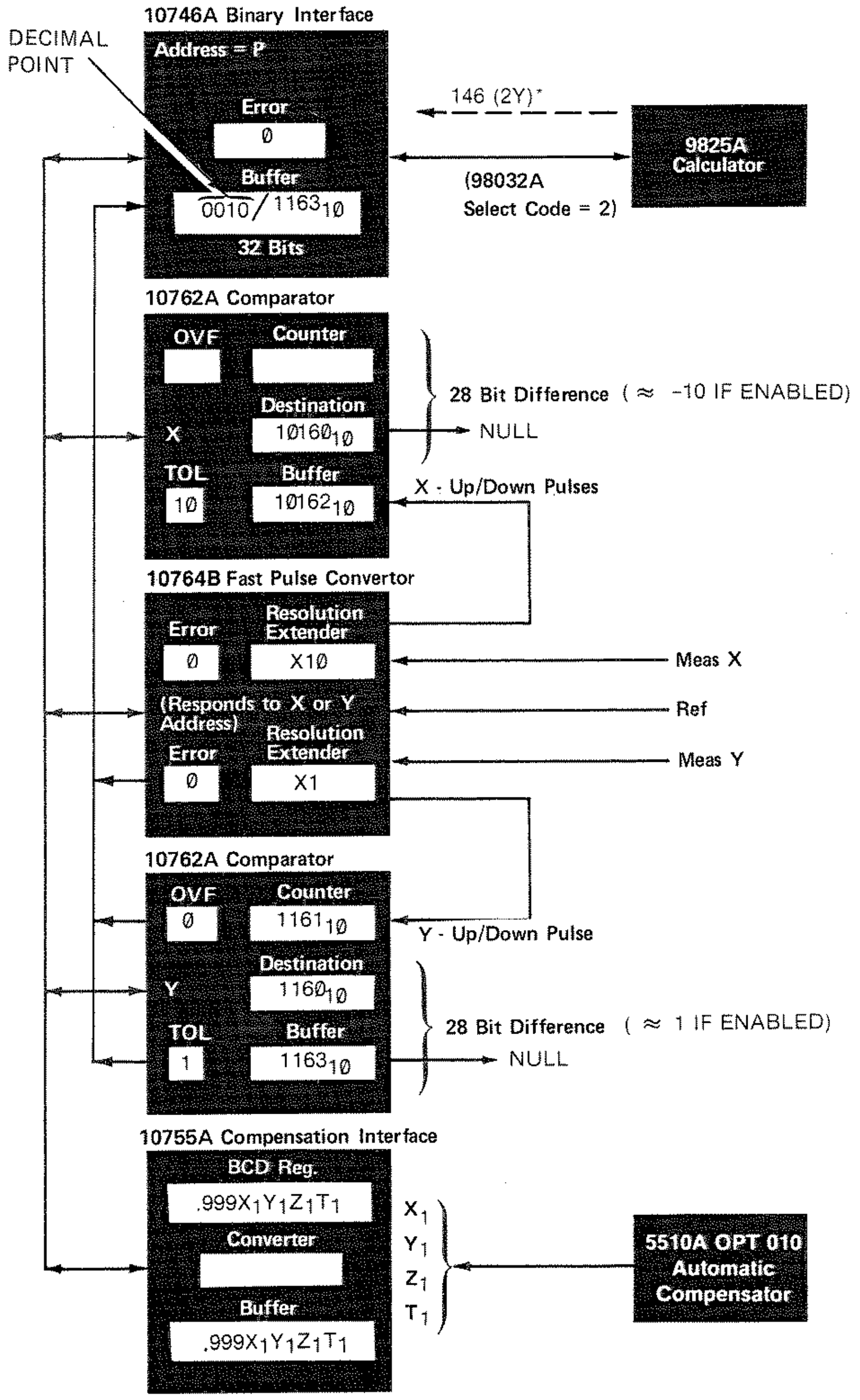


```
20: wtb 2, 1, 130, 3
```

Set up the 10746A card to output to calculator.

*HP-IB commands shown in parenthesis.

Figure 4-2. Comparator-Based System Data Flow (Cont'd)

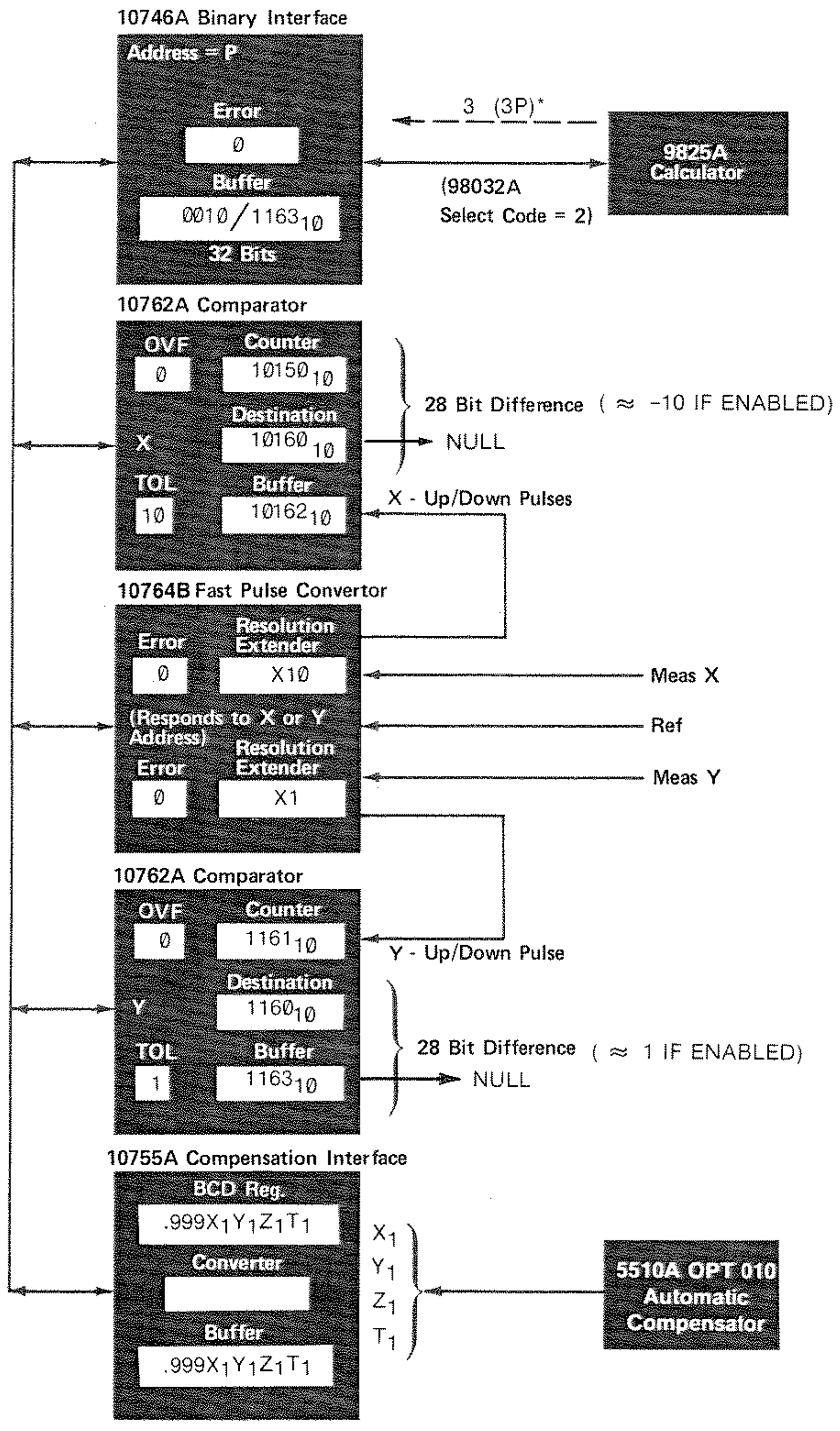


24: wtb 2, 146, 3

Transfer Y-data and decimal point information to 10746A card.

*HP-IB commands shown in parenthesis.

Figure 4-2. Comparator-Based System Data Flow (Cont'd)



24: wtb 2, 146, 3 } ← Set up 10746A card to output to the controller.

N

*HP-IB commands shown in parenthesis.

Figure 4-2. Comparator-Based System Data Flow (Cont'd)

4.11 DATA HANDLING TIPS

When writing application programs for a specific Laser Transducer System, the applicable following paragraphs should be read in addition to reviewing the typical programs in *Tables 4–12* and *4–13*.

a. Subtraction of preset numbers
b. Conversion to inches or metres
c. Conversion when deadpath is included
d. Handshaking routine between a controller and the 10746A Binary Interface
e. Conversion of destination and displacement information when using the 10762A Comparator
f. 10762A Comparator/10764B Fast Pulse Converter I/O format

4.12 Subtraction of Preset Numbers

When using the 10745A HP-IB interface subtract the following counts:

a. 160 counts if in normal mode,
b. 16 counts if in extended resolution.

When using the 10746A Binary Interface, the program is such that you must subtract 160 counts from the raw number that is transferred. The decimal point information is contained in D (bits 31–28). After subtracting the 160 counts, multiply the result by $10^{(2-D)}$ to obtain a calibrated result.

4.13 Conversion to Inches or Millimetres

In the case of displacement data (X,Y,Z, etc.), it is normally necessary to convert the raw data to compensated millimetres or compensated inches. First the number must have the correct preset number subtracted (and in the case of a binary number, the decimal information applied) as explained in the previous paragraphs. The resulting number must then be multipled by the compensation factor and the proper conversion factor. The conversion factors are as follows:

a. Multiply by 6.23023×10^{-6} to convert to inches.
b. Multiply by 1.58248×10^{-4} to convert to millimetres.

The compensation number corrects for the velocity-of-light (VOL) factor and possibly material temperature (if the 5510A Opt 010 is used to monitor this factor). The material temperature compensation converts the information back to a length at 20°C (68°F). These multiplication numbers assume there is no deadpath.

4.14 Conversion when Deadpath is Included

Deadpath is defined as the distance between the interferometer and the cube-corner at the 0 (gage) position (see *Figure 4–3*). It is assumed in the following discussion that you have read and understand the discussions in Section II that explain deadpath and VOL errors.

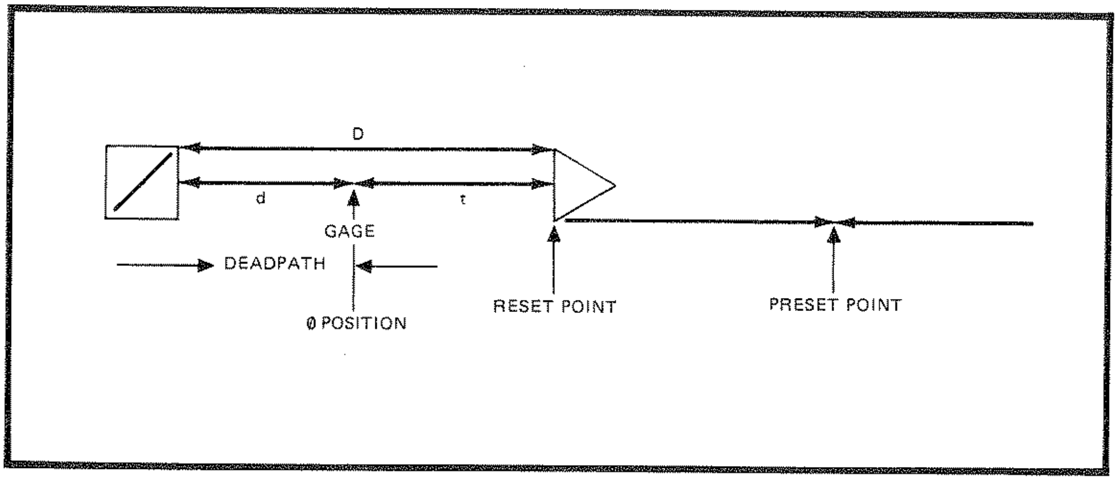


Figure 4–3. Conversion when Deadpth is Included

As was discussed in the Deadpath error compensation section, the gage or 0 position should be a defined machine position. At this 0 position, the distance between the interferometer and the retroreflector must be known. The distance "D" which is the total distance consists of 2 parts "d" and "t".

It is very important that the distance "t" be determined as the absolute distance and all software presets and resets be referenced from the gage or 0 position.

This expression is provided so λd can be computed

$d = (k)\ (C_0)\ (\lambda_d)$ — d must be measured manually. Must be related to 20°C (68°F).

$t = (k)\ (c)\ (\lambda_t)$ — λd and λt are vacuum wavelengths

$D = (k)\ (c)\ (\lambda_d+\lambda_t)$ — λ_d should be approximated by $\frac{d}{k\ (C_0)}$

$t = D-d$

$$t = \underbrace{(k)\ (c)\ (\lambda_d+\lambda_t)}_{\text{Total Compensated Distance}}\ \underbrace{-d}_{\text{Deadpath Distance Related to 20°C (68°F)}}$$

NOTE

1. k is the conversion constant (see 4.13).
2. C_0 is compensation number when gage originally determined.
3. Remember that λ_t+160* is the count from the 10760A Counter or from the 10762A Comparator.
4. The variable "c" in the above expressions is the ratio of air wavelength to vacuum wavelength, i.e., that number provided by 10756 or 5510, e.g., 9997324.

*16 if extended resolution and 10745A HP–IB Card is being used.

Quite often the location is measured on a relative basis; that is, a certain location on a part is a zero or reference. For example, assume that a zero is required at distance "t" from the gage or 0 position of the machine.

$X = t + s$ $\quad$ X = the number currently displayed.
t = compensated distance from the gage.
s = a normalized software offset.

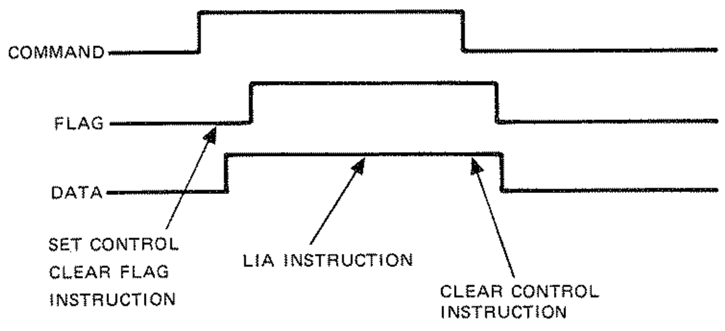
$X = t - t_0$ $\quad$ For reset, $s = t$
and $t_0 = t$ at time of reset

if preset (P) desired, $t_0 = -P + t$ at time of reset, where P is the preset number.

4.15 Handshaking Routine between a Controller and the 10746A Binary Interface

In these examples, the 10746A Binary Interface is inputting from and outputting to an HP 12566B μcircuit interface card. *Figure 4–4* shows how to send data or instructions to the 10746A, and *Figure 4–5* shows how to obtain data from the 10746A.

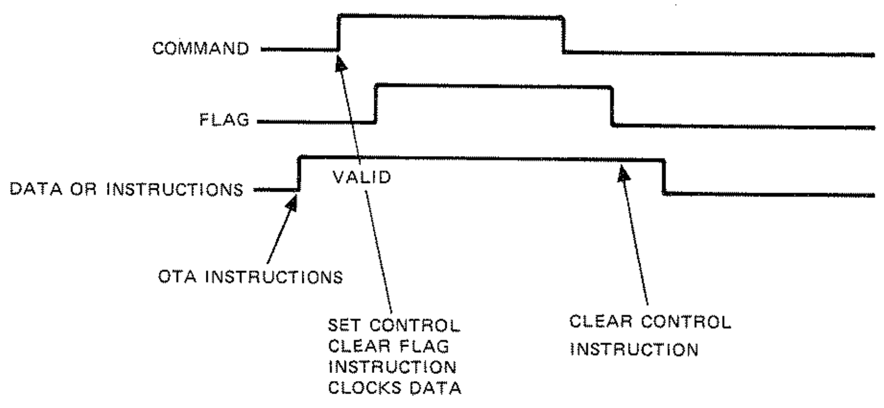
Since the flag and control signals from the 10746A are very fast, care must be taken to interface simply to the 12566B μcircuit interface card. As the 12566B Input latches are not edge triggered, it is necessary to have the input latches follow the data. After a flag is received, the data can be loaded via an LIA instruction and the computer clears the control signal to the computer.



```
INPUT NOP       INPUT DATA INTO A-REG SUBROUTINE
   STC SC, C    SET CONTROL, CLEAR FLAG
   SFS SC       CHECK FLAG
   JMP *-1      10746A
   LIA SC       INPUT DATA TO COMPUTER
   CLC SC       CLEAR
   JMP INPUT, I CONTROL
```

**These should be inverted to be consistent with the polarities of the 12566B (CMD, FLAG)*

*Figure 4-4. Receiving Data from the 10746A**



```
OUTPT NOP           OUTPUT A-REG
      OTA SC        OUTPUT TO BUFFER
      STC SC, C     SET CONTROL, CLEAR FLAG
      SFS SC        CHECK FLAG
      JMP *-1       10746A
      CLC SC        CLEAR CONTROL
      JMP OUTPT, I
```

Figure 4-5. *Sending Data or Instructions to the 10746A*

4.16 Conversion of Destination and Displacement Information When Using the 10762A Comparator

When utilizing the 10762A Comparator, one of the prime functions of the system controller is to transmit to the 10762A Comparator the destination address of the object under control. Since this destination address reflects a displacement in inches or millimetres and the 5501A Laser Transducer System measures in units of some fraction of the wavelength of laser light, a conversion has to be made prior to transmitting the destination address. This wavelength of the laser light is dependent on the environmental conditions under which the measurement is made, therefore, the conversion must take this into account.

The general form for converting to wavelength units is:

$$\text{*Destination in wavelength units} = \frac{\text{Destination in Inches or Millimetres}}{\left(\begin{array}{c}\text{Environmental}\\ \text{Compensation Factor}\end{array}\right) * \left(\begin{array}{c}\text{Conversion Factor for}\\ \text{wavelength units}\end{array}\right)}$$

**As noted earlier the 160 count preset must be included in this destination.*

The environmental compensation factor is a number slightly less than one; i.e., 0.999XYZT, where the digits XYZT are obtained from either the 10756A Manual Compensator or the 5510A Opt 010 Automatic Compensator. The conversion factor for wavelength units depends on the measurement resolution selected in the 10764B Fast Pulse Converter, $\mu/4 = 1.58248 \times 10^{-4}$mm, $\mu/8 = 7.91239 \times 10^{-5}$mm, etc.

This destination in corrected wavelength units is computed by the system controller and outputted to the 10762A Comparator via the 10746A Binary Interface where it is constantly compared to the up/down counter.

Conversely, if the up/down counter contents are transferred to the system controller to determine the position of the object under control, the displacement data in fractional wavelength units can be converted to inches or millimetres as follows:

$$\begin{matrix}\text{Displacement in}\\ \text{Inches or Millimetres}\end{matrix} = \begin{pmatrix}\text{Displacement in}\\ \text{Wavelength Units}\end{pmatrix} \begin{pmatrix}\text{Environmental}\\ \text{Compensation Factor}\end{pmatrix} \begin{pmatrix}\text{Conversion Factor for}\\ \text{Wavelength Units}\end{pmatrix}$$

4.17 10762A Comparator/10764B Fast Pulse Converter Input/Output Format

Table 4-15 shows the input/output format of the 10762A Comparator and the 10764B Fast Pulse Converter.

4.18 PROGRAMMING AND DEBUGGING TIPS

The first and most important thing to remember about programming the HP 9825A Calcuator to act as a system controller is that the documentation for the 9825A Calculator contains extensive examples and techniques of how to properly program and debug the calculator routines.

In addition to that, when specifically programming for the Laser Transducer System keep the following points in mind:

a. When in doubt if it is a hardware or software problem, write some very simple programs to input the raw data (e.g., 2V3P to output the compensation number, or 1O2X3O to output, input, and display in decimal).

b. Use the least number of cards possible to perform a specific function.

c. Make extensive use of STOP, HALT, or PRINT statements that output the results immediatley. These statements make it easy to localize a problem within the software.

d. Check the handshake routine between the system controller and the system interface card, (either the 10745A HP-IB or 10746A Binary Interface). Make sure you are giving a reset at the start of the program. This can be done by pushing the reset button on the calculator, using an external reset line, or sending reset commands. Note that if the system uses the binary interface and 16-bit words, you should send three 0P instructions. If it uses 8-bit words send five 0P instructions.

e. Remember certain instructions (e.g., 3O or 3P) that request an output from the Coupler require that after the next handshake, the controller must read in the data from the Coupler. With the Binary Interface this is normally done using a RBYTE instruction (the controller reads either four 8-bit bytes or two 16-bit bytes).

f. In the case of the 4P command the comparator card expects to receive data from the controller with the next handshake. Note that this applies only to the 10746A Binary Interface. The 10745A HP-IB Interface cannot send data and, therefore, cannot be used with the comparator card.

g. There is one handshake for the instructions (e.g., 3P) and then a handshake for each word or byte of data transfer. For two 16-bit words, two additional handshakes. For four 8-bit bytes, four additional handshakes.

h. With the Laser Transducer System it is easy to check just a few cards at a time. You can check the display by writing a simple program that enters data from the keyboard and then outputs it to the display. The coupler can be checked by simply inputting compensation numbers. Use the calculator display to observe the data to help simplify the troubleshooting.

i. Be sure to determine the correct polarity of your interface card (this does not apply to the 10745A HP-IB Interface). Some cards are positive-true (e.g., the 10746A Binary Interface). Other cards are negative-true. The quickest way to check (if there are no other malfunctions in the system) is to send different commands both ways. Refer to *Table 4–11* for examples of specific commands.

j. Remember that with the binary interface it is possible to have an overflow error and still have valid data. In order to strip off the error bits and get the decimal point bits plus the displacement bits, give any command that starts with 0 (e.g., 0O). This clears the binary interface card error bits. Then give a 3P command.

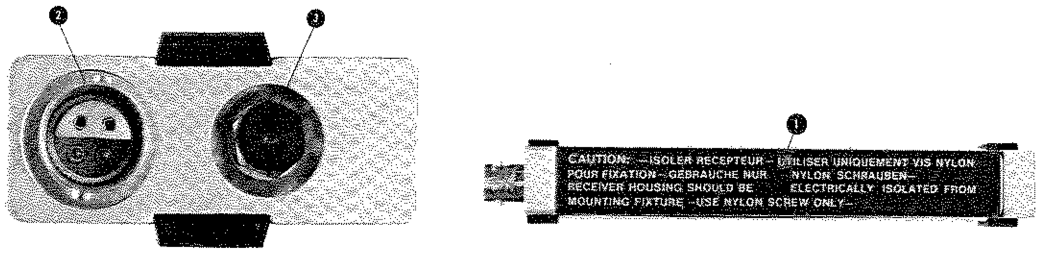
k. At the beginning of each program using the HP-IB, it is very important to give a device clear and a remote enable instruction (refer to *Table 4–12*).

l. Keep in mind that a 2V instruction outputs the previous compensation value. Therefore its accuracy depends on how often the compensation number is updated.

m. The characters 0 (zero) and O (as in Oslo) are different and not equal.

4.19 OPERATION

The operating procedures (other than initial turn on) for the Laser Transducer System are dependent on the programming and design of the system controller. For your convenience, *Figures 4–6* through *4–9* provide locations and descriptions of the controls and indicators on the system units.



① LED Indicator. Lights when laser beam is sufficient to activate receiver.

② Receiver Connector.

③ Test Point. Provides 0.6 to 1.5 Vdc output when receiver is activated.

Figure 4–6. 10780A Receiver

Table 4-15. 10762A Comparator/10764B Fast Pulse Converter Input/Output Format

A. DATA FORMAT OF 10746A BINARY INTERFACE

1. The data output of the 10746A Binary Interface includes 28 bits of data plus 4 bits of status/decimal point which come from both the 10762A Comparator and the 10764B Fast Pulse Converter. Format can be either two 16-bit words or four 8-bit bytes. (Jumper-selectable on the 10746A Binary Interface).

   a. Two 16-bit Word Format
   This format outputs the position data in two 16-bit words in the following format with the most-significant bits first.

Word 1

MSB D_3 D_2 D_1 D_0 C_{27} C_{26} C_{25} C_{24} C_{23} C_{22} C_{21} C_{20} C_{19} C_{18} C_{17} C_{16}

Word 2

LSB C_{15} C_{14} C_{13} C_{12} C_{11} C_{10} C_9 C_8 C_7 C_6 C_5 C_4 C_3 C_2 C_1 C_0

Where D → Decimal Point/Status
C → Counter Data

If $D_3\,D_2\,D_1\,D_0 = 1111$, this indicates either a measurement error or the fact that the counter and comparator are within the ±4-bit tolerance. Bits $C_{27}\,C_{26}\,C_{25}\,C_{24}$ will determine which condition exists. When bits $C_{27}\,C_{26}\,C_{25}\,C_{24} = 1111$ then the Counter and Comparator are within the ±4-bit tolerance. If $C_{27}\,C_{26}\,C_{25}\,C_{24} \neq 1111$, then these bits will be a code indicating the following measurement errors:

If $C_{27} = 0$, a VOL error exists.
If $C_{26} = 0$, an overflow error exists.
If $C_{25} = 0$, a reference error exists.
If $C_{24} = 0$, a measurement error exists.

If $D_3\,D_2\,D_1\,D_0 \neq 1111$ then these bits will indicate a decimal point location (Resolution Extension) and bits $C_{27}\,C_{26}\,C_{25}\,C_{24}$ will then be data.

   b. Four 8-bit Byte Format

   In this case the data will be inputted in a format of four 8-bit bytes with the first word being the decimal point/status and the 4 most-significant data bits.

Word 1

MSB D_3 D_2 D_1 D_0 C_{27} C_{26} C_{25} C_{24}

Word 2

C_{23} C_{22} C_{21} C_{20} C_{19} C_{18} C_{17} C_{16}

Word 3

C_{15} C_{14} C_{13} C_{12} C_{11} C_{10} C_9 C_8

Word 4

LSB C_7 C_6 C_5 C_4 C_3 C_2 C_1 C_0

The same rules for the decimal point status bits apply here as for the two 16-bit word format.

2. Data Input to Comparator Card

   When it is desired to input the Destination and Tolerance data to the 10762A Comparator Card, the data can be inputted in either the two 16-bit word or four 8-bit byte format.

Table 4-15. 10762A Comparator/10764B Fast Pulse Converter Input/Output Format (Cont'd)

The data format would be identical to that discussed for the output mode except that the 4 most-significant bits would now be the tolerance. For example, the two 16-bit words would be as follows:

Word 1

MSB T_3 T_2 T_1 T_0 C_{27} C_{27} C_{25} C_{24} C_{23} C_{22} C_{21} C_{20} C_{19} C_{18} C_{17} C_{16}

Word 2

LSB C_{15} C_{14} C_{13} C_{12} C_{11} C_{10} C_9 C_8 C_7 C_6 C_5 C_4 C_3 C_2 C_1 C_0

Where T → Tolerance Data
C → Command Data

B. INPUT/OUTPUT SEQUENCE

1. Output Sequence

When it is required to sample the counter on the 10762A Comparator Card, the following sequence would be implemented in the form of commands to the 10746A Binary Interface from the System Controller.

a. Sample Command (either both axes simultaneously or individually, 1P, 1X, etc.).

This samples the Counter and stores the sample in an output buffer on the 10762A Comparator Card (1 microsecond).

b. Counter Output Command (2X, 2Y, etc.)

This command transfers the contents of the counter and the 4 status bits to the 10746A Binary Interface and formats this into either two 16-bit words or four 8-bit bytes (2 mircosecond).

c. Binary Interface Output Command (3P)

Sets up card to accept a control bit. After the control bit is received, data is placed on the output lines.

When the first word is accepted by the System Controller it will send a control bit back to the 10746A Binary Interface requesting the second word which will then output the second word, etc., (3 operations for 16-bit words, 5 operations for 8-bit words, 1 microsecond per operation).

2. Input Sequence

When it is desired to load the Destination and Tolerance onto the 10762A Comparator, the following sequence is implemented:

a. Load Data Command (4P)

This command to the 10746A Binary Interface from the System Controller prepares the Binary Interface to accept the four 8-bit bytes, or two 16-bit word Destination and Tolerance (1 microsecond).

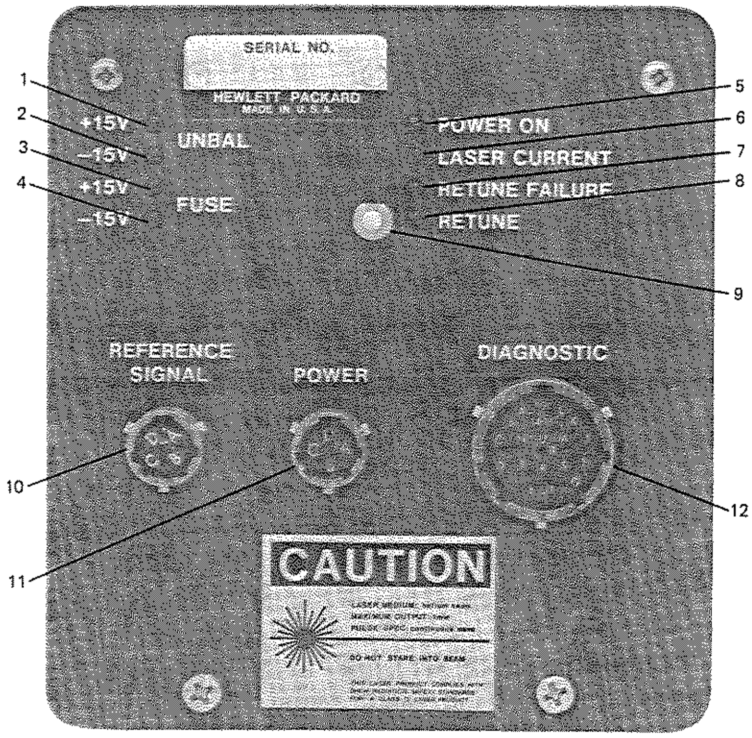
b. The System Controller then outputs the first data word to the 10746A Binary Interface, sends a control bit acknowledging the action and outputs the next data word, etc., until the destination address is loaded. When the last word is loaded, the 10746A Binary Interface formats the address for transfer to the 10762A Comparator (2 operations for 16-bit words and 4 operations for 8-bit bytes. 1-microsecond per operation.)

c. Transfer Command (to specific axis, 3X, 3Y, etc.)

Transfers destination address from 10746A Binary Interface to the specific 10762A Comparator Card (1 microsecond).

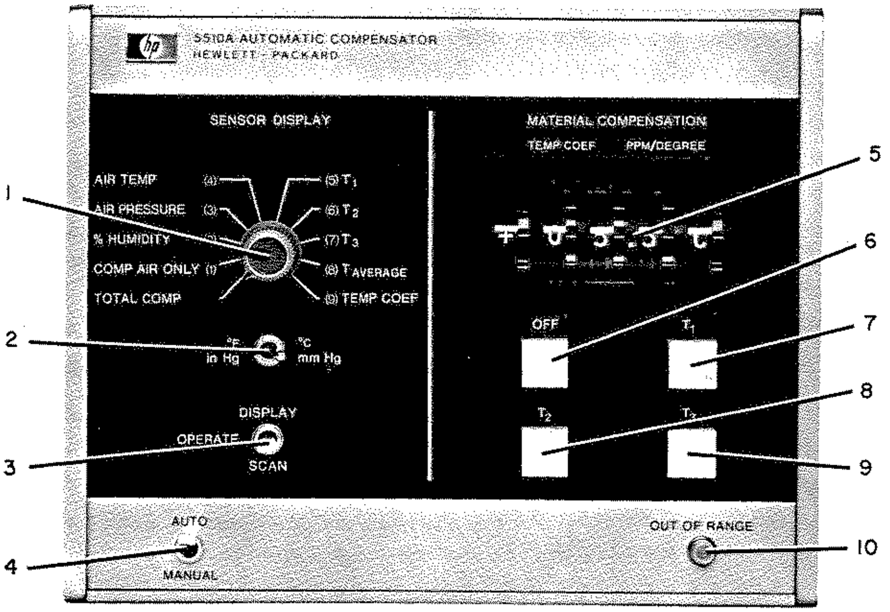
3. Sample Instruction (external or from System Controller, 1P, 1X, 1Y, etc.)

Since the act of loading the Destination and Tolerance will force a Null or Zero difference on the Digital Difference Output, Sample Instruction is required to release the forced null (1 microsecond).



1.	+15V UNBAL (LED Lamp)	Lights when +15V dc power is high by approximately one-volt or more; or when the −15V dc power input is low (i.e., less negative) by one-volt or more.
2.	−15V UNBAL (LED Lamp)	Lights when −15V dc power is high (i.e., more negative) by approximately one-volt or more; or when the +15V dc power input is low (i.e., less positive) by one-volt or more.
3.	+15V FUSE (LED Lamp)	Lights when +15V dc fuse blows.
4.	−15V FUSE (LED Lamp)	Lights when −15V dc fuse blows.
5.	POWER ON (LED Lamp)	Lights when external power has been applied to Laser Head.
6.	LASER CURRENT (LED Lamp)	Lights to indicate Laser Tube current is not within appropriate operating limits.
7.	RETUNE FAILURE (LED Lamp)	Lights to indicate the Laser Tube is not properly tuned or that retune cycle did not retune the laser.
8.	RETUNE (LED Lamp)	Lights to indicate that retuning is required or that retune cycle is in progress. Light should go out approximately 9 seconds after the RETUNE pushbutton is depressed. If light remains on, a tuning fault is indicated.
9.	RETUNE (Pushbutton)	Manually activates Retune sequence.
10.	REFERENCE SIGNAL (Connector, J1)	Allows the reference signals (REF and $\overline{\text{REF}}$) and +15V power to be interconnected to other system components.
11.	POWER (Connector, J2)	Provides connection point for external power supply input.
12.	DIAGNOSTIC (Connector, J3)	Allows monitoring of diagnostic signals and application of RETUNE command by external equipment.

Figure 4–7. 5501A Laser Transducer Rear Panel Controls and Indicators



NOTE

The SENSOR DISPLAY section is not used with most Laser Transducer Systems. If you have a Calculator Interface System a programming routine is included that will display the selected function on the calculator display.

1. SENSOR DISPLAY selector. When the DISPLAY-OPERATE-SCAN (3) switch is set to DISPLAY, the SENSOR DISPLAY switch selects a measurement or factor to be displayed on the calculator display. These measurements or factors are as follows:

    a. TOTAL COMP. Compensation number in parts per million (includes compensation for workpiece temperature).

    b. (1) COMP AIR ONLY. Compensation number in parts per million due to air measurements only.

    c. (2) % HUMIDITY. Percentage of relative humidity.

    d. (3) AIR PRESSURE. Barometric pressure in either inches or mm of mercury as determined by the in Hg — mm Hg switch.

    e. (4) AIR TEMP. Air temperature in degrees Fahrenheit or Centigrade as determined by the °F — °C switch.

NOTE

The calculator will display a reference temperature of 20.0°C (68°F) when a material sensor is not connected to the calculator. However, the pushbutton will only light for those sensors which are connected. If the air probe is not connected, the calculator will display a reference temperature of 28.0°C (82.4°F) and a humidity of 10%.

Figure 4-8. 5510A Opt 010 Automatic Compensator Front Panel Controls and Indicators

f. (5) T_1. Material temperature measurement of sensor No. 1 in Fahrenheit or Centigrade as determined by the °F — °C switch.

g. (6) T_2. Same as T_1 but for sensor No. 2.

h. (7) T_3. Same as T_2 but for sensor No. 3.

i. (8) T AVERAGE. Average temperature of the sensors selected with the while push-button switches (T_1, T_2, T_3).

j. (9) TEMP COEFF. PPM/degree setting on Material Compensation thumbwheel switch.

2. "°F—°C" and "in Hg—mm Hg" switch. Selects either English or Metric units for the display. Only operative in positions (3) through (8) of the SENSOR DISPLAY switch. Setting of this switch does not affect the compensation number.

3. DISPLAY—OPERATE—SCAN switch. In DISPLAY position, the calculator will display the setting of the SENSOR DISPLAY switch. When set to OPERATE, the Laser Interferometer system is operative; the source of the compensation number will be determined by the setting of the AUTO—MANUAL switch. SCAN position, not used with Laser Transducer System.

4. AUTO—MANUAL switch. Always set to AUTO when used with Laser Transducer System to supply compensation numbers to the 10755A Compensation Interface.

5. MATERIAL COMPENSATION thumbwheel switch. Used to enter material temperature coefficients in ppm/degree of Fahrenheit or Centrigrade.

6. OFF indicator switch. When lit, indicates that all material temperature sensors are OFF. When pushed, disconnects all material temperature sensors.

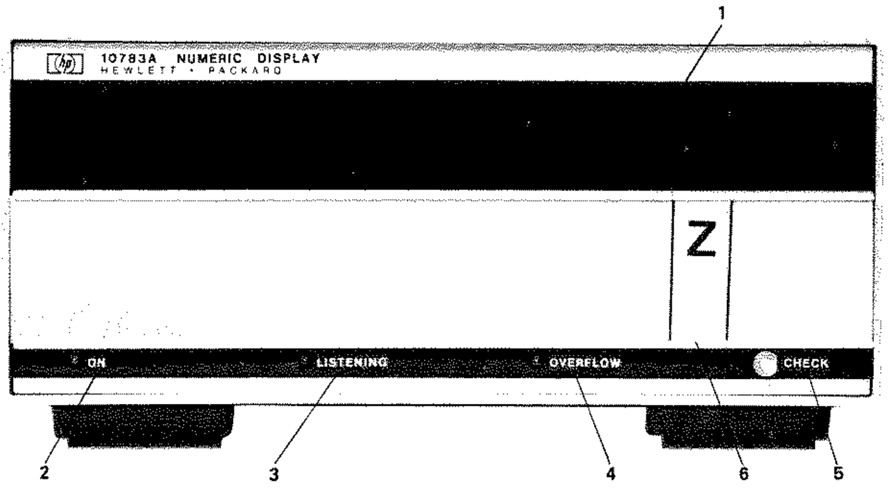
7. T_1 Indicator and Switch. When lit, indicates that temperature sensor 1 is operative, when pushed, selects sensor 1.

8. T_2 Indicator and Switch. Same as above for T_2 sensor.

9. T_3 Indicator and Switch. Same as 7 above for T_3 sensor.

10. OUT OF RANGE indicator. Indicates that measurement conditions are out of the range of the compensator.

Figure 4-8. 5510A Opt 010 Automatic Compensator Front Panel Controls and Indicators (Cont'd)



1. Display: Seven-segment light emitting diode, 10.9 mm (0.43 inches) high; 14 characters, each with decimal point.
2. ON Indicator: When illuminated, indicates instrument has primary power (+5V dc) applied. The +5V dc power on-of switch is on the rear panel.
3. LISTENING Inidicator: When illuminated, indicates that characters will be accepted for display.
4. OVERFLOW Indicator: When illuminated, indicates that the 14-digit capacity of display has been exceeded. The most-significant information (digits) has been lost.
5. CHECK Switch. When pressed, illuminates all 14 digits as character "8" along with all decimal points. This tests all segments and decimal points in the display. The CHECK function also tests the LISTENING and OVERFLOW indicators.
5. Interchangeable panel label to denote measurement data. In this case, the data could represent Z-Axis measurements.

Figure 4-9. 10783A Numeric Display Front Panel Indicators

4.20 Initial Power Application

WARNING

BEFORE PERFORMING THE FOLLOWING STEPS, BE SURE THAT ALL SYSTEM ITEMS THAT ARE CONNECTED TO AN AC POWER SOURCE HAVE A COMMON EARTH GROUND CONNECTION. IT IS POSSIBLE TO HAVE A DIFFERENCE IN ELECTRICAL POTENTIAL BETWEEN THE VARIOUS SYSTEM COMPONENTS IF A COMMON GROUND IS NOT ENSURED. THIS CONDITION CAN CAUSE INJURY TO OPERATING PERSONNEL AND/OR CAUSE DAMAGE TO THE SYSTEM COMPONENTS. ALSO, BE CERTAIN THAT ANY SURROUNDING EQUIPMENT, SUCH AS A MACHINE TOOL, HAS THE SAME COMMON GROUND FOR ITS POWER SOURCE AS THE LASER SYSTEM GROUND.

If the system does not have a separate master power on/off switch, power is applied to all units when the individual power supplies are connected to line power (refer to Section V). For convenience, it is recommended that all power cords be routed through a master power ON/OFF switch.

section V

Installation and Checkout

5.1 INTRODUCTION

This section provides the information necessary to install and checkout your system. It is organized as follows:

a. System grounding considerations. A brief discussion on proper grounding techniques. It is very important that the Laser Transducer System be properly grounded to avoid shock hazards and to eliminate ground loop problems.

b. The preliminary procedures. Checks the power supplies, transducer head, receivers, and system controller prior to installing any equipment. These procedures must be performed for all systems.

c. The physical installation and alignment of the transducer head, receivers, and optics. Refer to Section II for the background information necessary to ensure that the choice of physical location of the components and the overall measurement path is optimum for your application.

d. The installation of the electronic interface components. These procedures are divided into major system configurations. Select the procedure that matches your system.

e. The system checkout procedure. These procedures are divided into major system configurations. Select the procedure that matches your system.

f. Preventive Maintenance. The system electronics require no preventive maintenance. However, the system optics do require periodic cleaning. The frequency of the cleaning is dependent on the cleanliness of the ambient environment.

The procedures are organized in this manner to make installation and checkout as simple as possible. In addition, they can be used as a basis for detailed troubleshooting either during initial installation or at a later time when a system problem cannot be easily located. *Table 5-1* is a list of recommended test equipment needed to install, check out, and troubleshoot the Laser Transducer System. Other equipment can be used if it meets the minimum specifications listed.

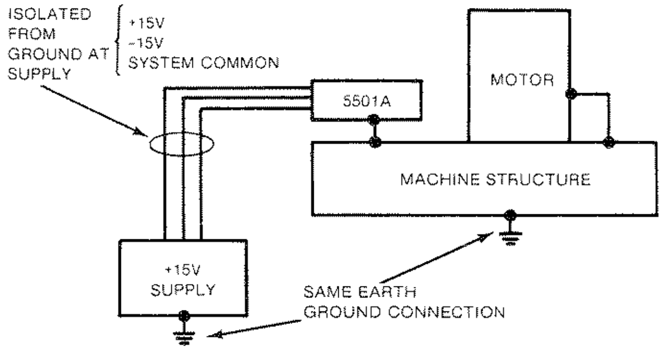
Table 5-1. Recommended Test Equipment

Description	Required Characteristics	Recommended Model
DC Voltmeter	±15V ±0.025V and +5V ±0.01V	HP 3435A
Logic Probe	Ability to Indicate TTL and ECL Logic Levels	HP 10525T/10525E
Oscilloscope	Ability to Display Signals between DC and 20 MHz	HP 180A/1801A/1820A

5.2 SYSTEM GROUND CONSIDERATIONS

If proper system grounding techniques are not observed, two adverse situations can occur:

a. A system can be interconnected so that an electrical shock hazard exists. External parts of various system components can be at different electrical potentials due to incomplete system grounding. (See *Figure 5-1*).

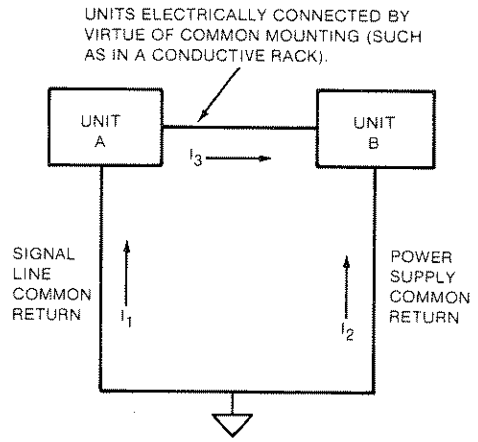


NOTES:

1. Laser head is grounded by being physically mounted on the work table. Power supply is grounded for safety, but its outputs are isolated from ground.
2. Motor currents cannot travel through power supply system common because this line is isolated from earth ground at the power supply. It is at ground potential, however, because the 5501A is grounded.
3. When this grounding system is used, do not connect "system common" to earth ground at the power supply. Be sure, however, that the laser head is grounded to the machine work surface.

Figure 5-1. AC Power Grounding

b. The system electronics can become very sensitive to external noise (such as power line switching transients) due to undesirable currents flowing through ground wiring. These currents cause a voltage potential other than zero volts to exist at points in the grounding system. (See *Figure 5-2*).



Notes:
If the power supply requirements to Unit B fluctuate due to lead switching, for example, a changing current will be present not only in the path of I_2, but also in the path of I_1 and I_3. If the signal line associated with path I_1 is sensitive to the resulting voltage fluctuations, system troubles can result. The remedy is to break the loop, probably at the path of I_3.

Figure 5-2. Grounding to Avoid Ground Loops

In general, try to avoid unnecessary ground or common return connections while wiring the system. Ensure, however, that all units are grounded. The best approach is to have one common earth ground connection in the system with all system components connected at the single ground. Also, avoid connecting both ends of a signal cable shield to a ground point. This would allow currents to flow through the shield and possibly cause interference with the signal lines within the cable. The shields from the 10780A receiver, for example, should be grounded at one end only, and the receivers should be mounted in such a fashion that they form no electrical connection with the mounting surface. A typical distribution of the +15V power and the reference and measurement signals is shown in *Figure 5-3*. The correct wiring of the individual units to the terminal strip on the rear of the 10740A coupler is shown in *Figure 5-4*.

For further information on the subject of system grounding, refer to "Grounding and Shielding Techniques in Instrumentation" by Ralph Morrison. Published by John Wiley and Sons, Inc.

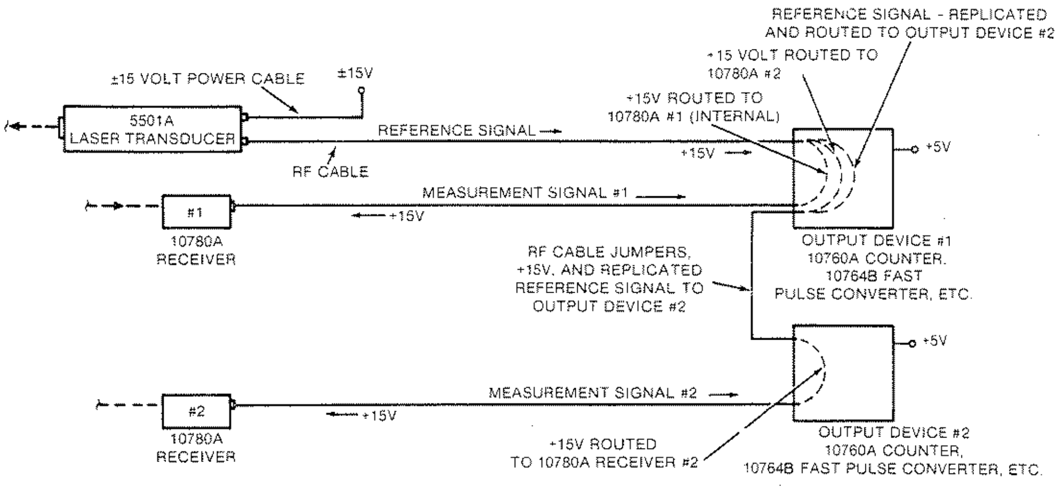


Figure 5-3. Typical Laser Transducer System Measurement Signal and Power Routing

5.3 REQUIRED CABLES AND PRELIMINARY PROCEDURES

NOTE

During system installation and checkout, power must be frequently applied to and removed from the system. Therefore, it is recommended that all of the unit line cords (e.g., power supplies, calculators, etc.) be connected to a common source with a main ON/OFF switch. This will make it more convenient to apply and remove system power.

The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. Before plugging in, make sure the source voltage matches the input rating of the power supplies.

Prior to mounting any equipment, perform the following steps:

a. Unpack and inspect all of the equipment (each of the unit manuals contain unpacking and inspection procedures).

b. Check to determine if you have all of the cables necessary for your system (see *Table 5-2*). If required, fabricate the necessary system cables (refer to Appendix E, BACKDATING for fabrication instructions).

c. Set up the 5501A Laser Transducer Head, the 10780A Receiver, and the Power Supplies in a clear area.

NOTE

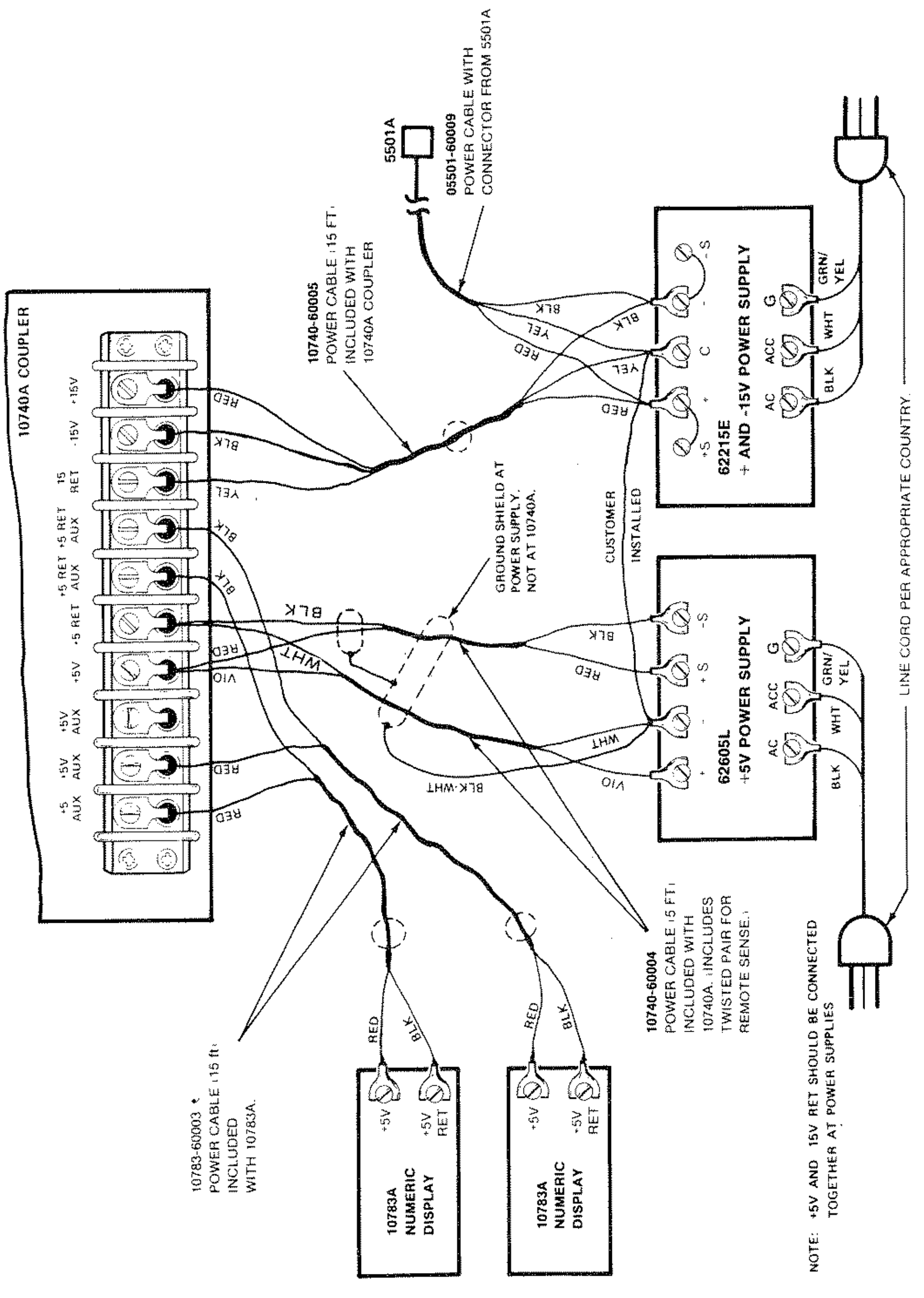
Prior to using the power supplies read the applicable manuals and set them up as follows:

1. The ±15V Power Supply is set for local sensing, and current limiting. (See *Figure 5-4*).
2. The +5V Power Supply is set for single output, remote sensing, and current limiting. (See *Figure 5-4*).

Table 5-2. Required Cables

HP Part Number	Supplied With	Interconnects		Length	Use
		From	To		
05501-60009	5501A	5501A	±15V 62215E Power Supply	4.57 m (15 ft.)	Power
05501-60008	5501A	5501A	10760A or 10764B or 10781A or 10714A	19.81 m (65 ft.)	Reference
10780-60003	10780A	10780A	10760A or 10764B or 10781A or 10714A	19.81 m (65 ft.)	Power & Measurement
10708-60001	10708A/B	10708A	115V/230V	2.29 m (7.5 ft.)	Primary Power
10712-60001	10712A	5510A	2100 Computer	4.57 m (15 ft.)	Signal & Power
10727-60001	10727A	9825A	10746A	4.57 m (15 ft.)	Calculator Interface
10740-60004	10740A	10740A	+5V 62605L Power Supply	1.52 m (5 ft.)	Power
10740-60005	10740A	10740A	±15V 62215E Power Supply	4.57 m (15 ft.)	Power
59310-60002	10745A	10745A	9825A via 98034A Interface Cable	3.66 m (12 ft.)	Interface
10760-60002	10760A	10760A	5501A or 10760A/10780A	2 ea. @ 0.46 m (1.5 ft.) 1 ea. @ 0.3 m (1 ft.)	Reference & Doppler
10763-60002	10763A	10763A	External Controller	1 ea. @ 0.9 m (3 ft.) 2 ea. @ 4.57 m (15 ft.)	Controller Interface
10764-60005	10764B	10764B	5501A or 10764B/10780A	4 ea. @ 1.53 m (5 ft.)	Reference & Doppler
10781-60003	10781A	10781A	10780A/5501A	3 ea. @ 0.46 m (1.5 ft.)	Reference & Doppler
10781-60004	10781A	10781A	+5V Power Supply	4.57 m (15 ft.)	Power
10783-60003	10783A	10783A	+5V via 10740A	4.57 m (15 ft.)	Power
59995-61082	5510A Opt. 010	5510A	10755A	0.3 m (1 ft.) 4.57 m (15 ft.)	V.O.L.
10631A,B,C	10783A	10783A	HP-IB Controller	0.9 m (3 ft.) 1.83 m (6 ft.) 3.66 m (12 ft.)	Interface
10714-60003	10715A	5501A	10714A Interface		Power Cable

See Appendix C, CABLING, for photos and connector pinouts.



*If noise problems occur, try moving this wire to the rear terminal strip of the 10740A coupler.

Figure 5-4. 10740A Coupler Back Panel Wiring and Strapping on Power Supplies

CAUTION

Do not continue with the procedure until the power supplies voltages are within the limits specified in step d. Excessive voltage can cause damage to system components.

d. Connect the ±15V and +5V power supplies to a suitable source of ac power. Verify that the outputs of the ±15V power supply are +15V ±0.25V dc and -15V ±0.25V dc. Verify that the output of the +5-volt power supply is +5 +0.1, -0.05V dc. If out of specification and the HP power supplies are used, refer to the applicable manual. Remove system power.

NOTE

During cable installation, the machine system geometry may require that the ends of the reference and measurement cables fit through spaces too small for the cable connectors. If so, check the laser head and receiver by connecting ±15V from the ±15V power supply. On the laser head, connect the +15V to pin A, the -15V to pin B, and the return to pin D of the POWER connector (*Figure 4-7*). On the receiver(s) connect the +15V to pin 4 and return to pin 3 (see *Figure 4-6*).

WARNING

BEFORE PERFORMING THE FOLLOWING STEPS, BE SURE THAT ALL SYSTEM ITEMS THAT ARE CONNECTED TO AN AC POWER SOURCE HAVE A COMMON EARTH GROUND CONNECTION. IT IS POSSIBLE TO HAVE A DIFFERENCE IN ELECTRICAL POTENTIAL BETWEEN THE VARIOUS SYSTEM COMPONENTS IF A COMMON GROUND IS NOT ENSURED. THIS CONDITION CAN CAUSE INJURY TO OPERATING PERSONNEL AND/OR CAUSE DAMAGE TO THE SYSTEM COMPONENTS. ALSO, BE CERTAIN THAT ANY SURROUNDING EQUIPMENT, SUCH AS A MACHINE TOOL, HAS THE SAME COMMON GROUND FOR ITS POWER SOURCE AS THE LASER SYSTEM GROUND.

e. Connect the ±15V power cable between the ±15V power supply and the laser head POWER connector. If you have fabricated your own cables and have any doubt which cable is indicated, refer to Appendix C, CABLING.

NOTE

In step f (except for the 10781A Pulse Converter System) it is not necessary to connect the electronic interface connectors to their respective units (counter, fast pulse converter, etc). The +15V lines of these connectors are replicated within the interface connectors. For the 10781A Pulse Converter, the connector must be connected since the +15V lines are replicated within the pulse converter.

f. Connect the measurement/reference cable assembly to the laser head and receivers. Connect the reference leg to the REFERENCE SIGNAL connector on the laser head and the measurement leg(s) to each receiver connector.

g. Apply system power and verify that the laser head emits red light. DO NOT VIEW THE LIGHT DIRECTLY. Instead, place a white paper or card in the beam path and view the beam reflection on the white surface.

h. Take each receiver, in turn, and position it in front of the laser so that the laser beam is centered on the receiver photodetector. Be sure to rotate the receiver around the laser beam axis to a point where one of its flat sides rests in the same plane as the base of the laser head. False indications can otherwise result. Verify that the LED on each receiver lights and the voltage at the receiver test point is between 0.6 and 1.5V dc.

i. Block the laser beam and verify the LED indicator goes out.

j. Verify that the system controller is working properly. Refer to the applicable manuals for checkout and diagnostic procedures.

k. Remove system power and disconnect all equipment.

5.4 INSTALLATION AND ALIGNMENT OF LASER HEAD, RECEIVER, AND OPTICS

The proper installation and alignment of the laser head, receiver, and optics is one of the most critical procedures in the installation of the Laser Transducer System. For this reason an entire section (Section II) is devoted to considerations of proper measurement path layout, sources of error, mounting, beam protection, and alignment techniques. Only after you have carefully read Section II and have laid out a measurement path should you attempt to install the equipment.

a. Install the laser head, receiver, and optics in their preplanned positions using the mounting instructions contained in Section II.

b. Run the measurement/reference cabling as planned. Be very sure that there is no possibility of the cable binding during machine operation. Connect the reference leg to the REFERENCE SIGNAL connector on the laser head and the measurement leg(s) to each receiver connector.

c. Install the ±15V and +5V power supplies. Refer to the applicable manuals for dimensions and mounting instructions.

d. Connect the ±15V power cable between the ±15V power supply and the laser head POWER connector. Again, be very sure there is no possibility of the cable binding during machine operation.

e. Connect the ±15V power supply to a suitable source of ac power and apply system power.

f. Verify that the laser head emits red light. DO NOT VIEW THE LIGHT DIRECTLY. Instead, place a white paper or card in the beam path and view the beam reflection on the white surface.

NOTE

> The sequence of the following steps will depend upon the previous decisions you have made regarding the measurement path. If you need laser beam protection such as conduit and junction boxes, you will need to decide whether it will be easier to install the beam protection first and then align the system or vice-versa.

g. Install beam protection equipment if required. Refer to Section II.

h. Align the system. Refer to Section II.

i. Verify that the LED on each receiver lights and the voltage at the receiver test point is between 0.6 and 1.5V dc. Block the laser beam between the interferometer and retro-reflector in each axis and verify the applicable receiver LED goes out.

j. If the optional 5510A Opt. 010 Automatic Compensator is used, install the unit (refer to the 5510A Automatic Compensator Operating and Service Manual) and place the sensors as determined by the measurement path layout (refer to Section II). For an explanation of the individual controls on the 5510A Opt. 010, see *Figure 4-8.*

k. Remove system power.

5.5 INSTALLATION OF ELECTRONIC INTERFACE COMPONENTS

The procedures for the installation of the electronic interface are subdivided into the following categories:

a. Calculator Interface Electronics installation.

b. Computer Interface Electronics installation.
    1. Counter-based system installation.
    2. Comparator-based system installation.

c. English/Metric Pulse Output Electronics installation.

d. 10781A Pulse Converter Electronics installation.

Each of these procedures is complete. Therefore, select the procedure that matches your system and perform the indicated steps.

5.6 HP-IB INTERFACE ELECTRONICS INSTALLATION

The HP-IB Interface Electronics is a wired interface between the 5501A Laser Transducer and any digital controller compatible with the Hewlett-Packard Interface Bus (HP-IB). The basic interface system works with a 9825A Programmable Calculator and interface electronics for two axes of measurement. All interconnecting cables between the Calculator Interface Electronics and the 5501A Laser Transducer are supplied.

Perform the installation as follows:

a. If the 10740A Coupler is to be rack mounted or installed in a cabinet, refer to the 10740A Coupler Operating and Service manual for dimensions and installation instructions.

b. Connect the +5V power supply cable between the power supply and the 10740A Coupler rear panel terminal strip.

c. If the optional 5510A Opt. 010 Automatic Compensator is used, connect the ±15V power supply cable between the power supply and the 10740A Coupler rear-panel terminal strip. Connect the interface cable between the 5510A Opt. 010 and the 10755A Compensation Interface.

d. If the 10783A Numeric Displays are used, connect the +5V power cables between the numeric display rear panels and the +5V power source on the back of the 10740A Coupler.

e. Connect the ±15V power supply (if used) and +5V power supply to suitable sources of ac power. Apply system power. Verify the voltage at the coupler rear panel is +15V dc ±0.25, –15V dc ±0.25, and +5V dc +0.10, –0.05V dc. Remove system power.

NOTE

To connect any hooded connector to a circuit card in the 10740A Coupler, pass the connector through the slot in the rear panel of the coupler and install it on the front edge connector of the applicable card (see *Figure 5–5*).

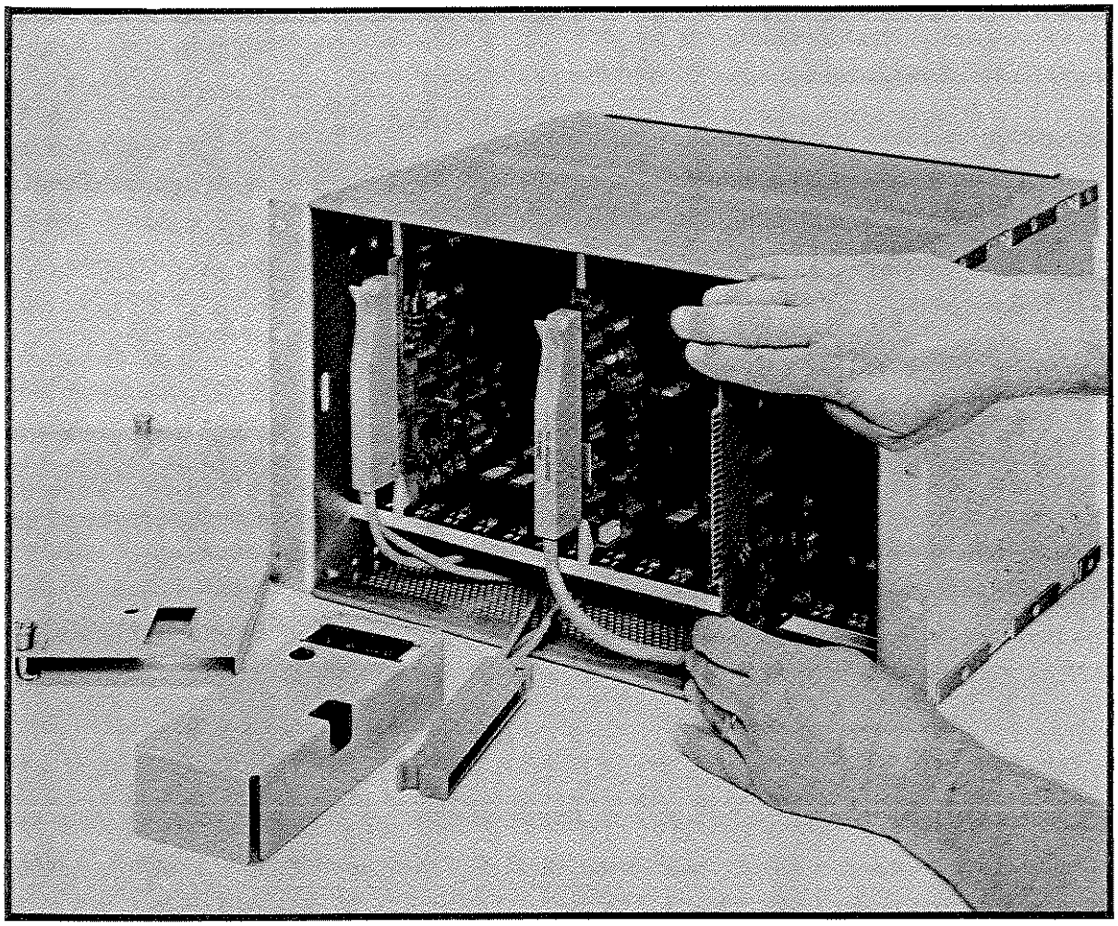


Figure 5–5. Installation of Hooded Connectors and Circuit Cards

f. Remove the front panel of the coupler.

NOTE

> All 10760A Counter cards are supplied with the NORMAL/REVERSE jumper in the NORMAL position. The correct position for the NORMAL/REVERSE jumper is determined during system checkout.

g. Connect the reference/measurement cables from the laser head and first receiver to the first 10760A Counter card (see *Figure 5-6* for a typical system interconnect).

h. Connect the hooded connectors in sequence to each of the additional 10760A Counters in the system and daisy-chain the REF connectors as shown in *Figure 5-6.*

i. Apply system power and verify that the reference and measurement LED indicators located near the bottom front edge of each counter light (the reference LED indicator is the one closest to the front edge). Remove system power.

j. Connect the system controller to the 10745A HP-IB Interface card using the interconnect cable (P/N 59310-60002). Refer to the System Controller Operating Manual.

k. If the 10783A Numeric Displays are used, connect them to the HP-IB Bus using the 10631A, B, or C cables.

l. Apply system power. At the rear panel of the 10740A Coupler verify that the voltage is +15V ±0.25V dc, -15V ±0.25V dc, and +5V +0.10, -0.05V dc.

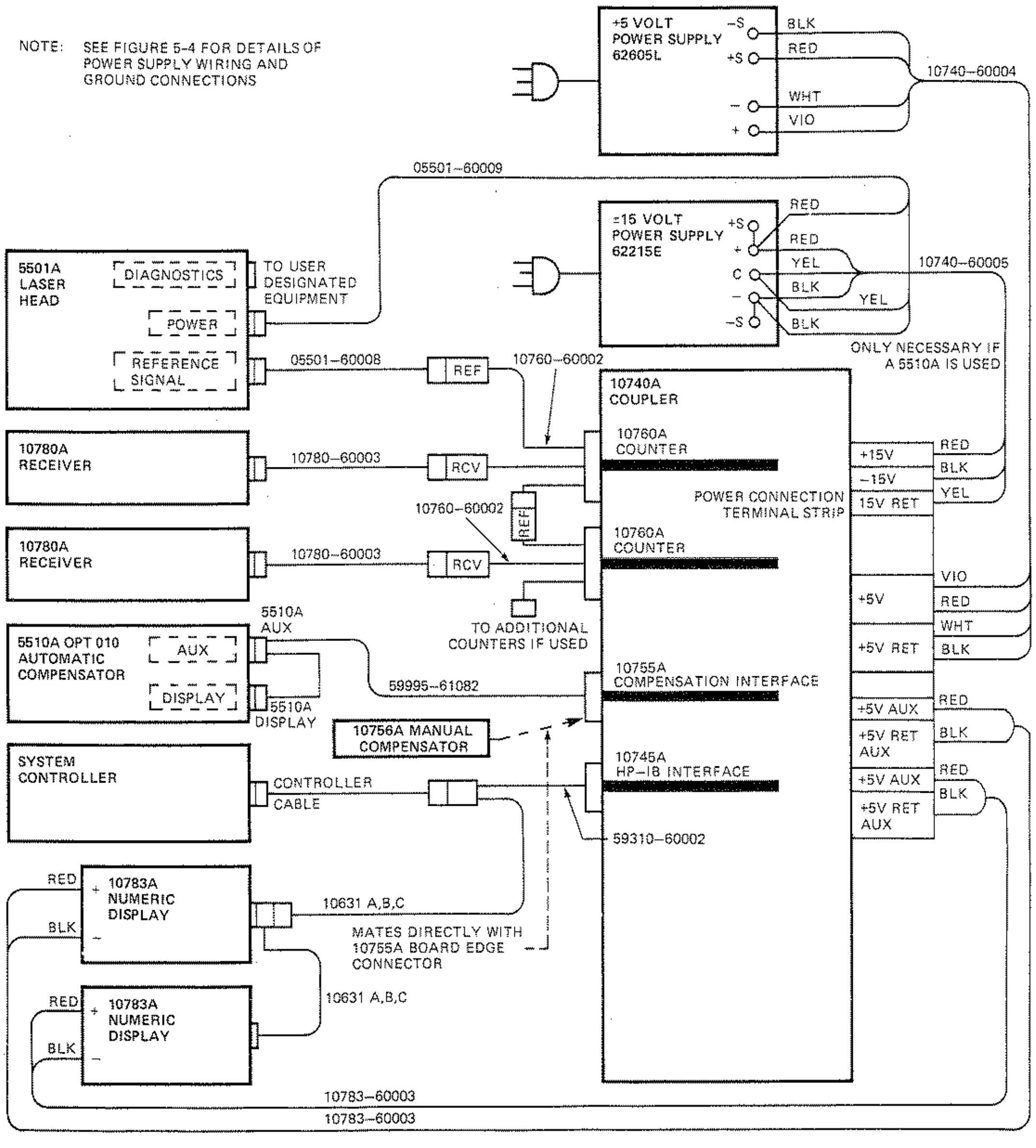

NOTE: SEE FIGURE 5-4 FOR DETAILS OF POWER SUPPLY WIRING AND GROUND CONNECTIONS

Figure 5-6. Typical HP-IB Controller Interface Electronics Interconnecting Diagram

5.7 COMPUTER INTERFACE ELECTRONICS INSTALLATION

The computer interface electronics are designed to interface the 5501A Laser Transducer System to a wide variety of digital processors (including a calculator if desired). Oriented toward the Original Equipment Manufacturers (OEM), the individual components are selected and assembled by the user for a specific application.

The computer interface electronics are subdivided into the following two types of systems:

a. Counter-based system (10760A Counters).
b. Comparator-based systems (10762A Comparator).

Refer to Section I configuration information to determine what equipment is included in your system and use the applicable installation procedure to ensure proper installation.

The computer interface electronics include any system selected from the equipment specified in *Table 1-4* of Section I (i.e., wired, configured, and tested by the end user). The reason this distinction is made is that it is very important that you perform the installation very carefully to avoid system damage or malfunctions. If, for example, a power cable is miswired, it can very easily cause equipment damage. Or, if the address jumpers on the cards are not correct, the system will not function properly.

5.8 Counter-Based System Installation

Perform the installation of a counter-based system as follows:

a. If the 10740A Coupler is to be rack mounted or installed in a cabinet, refer to the 10740A Coupler Operating and Service manual for dimensions and installation instructions.

b. Connect the +5V power supply cable between the power supply and the 10740A Coupler rear panel terminal strip.

c. If the optional 5510A Opt. 010 Automatic Compensator is used, connect the ±15V power supply cable between the power supply and the 10740A Coupler rear-panel terminal strip. Connect the interface cable between the 5510A Opt. 010 and the 10755A Compensation Interface.

d. If the 10783A Numeric Displays are used, connect the +5V power cables between the numeric display rear panels and the +5V power source on the back of the 10740A Coupler.

e. Connect the ±15V power supply (if used) and +5V to suitable sources of ac power. Apply system power. Verify the voltage at the Coupler rear panel is +15V dc ±0.25, -15V dc ±0.25, and +5, +0.10, -0.05V dc. Remove system power.

NOTE

To connect any hooded connector to a circuit card in the 10740A Coupler, pass the connector through the slot in the rear panel of the coupler and install it on the front edge connector of the applicable card (see *Figure 5-5*).

f. Remove the front panel of the coupler.

NOTE

All 10760A Counter cards are supplied with the NORMAL/REVERSE jumper in the NORMAL position. The correct position for the NORMAL/REVERSE jumper is determined during system checkout.

g. Check the addresses and jumpers on all system cards and units. It is advisable to make a list of each of the system addresses for future reference. Refer to the individual unit manuals if it is necessary to change addresses or jumpers.

h. Install all cards in the 10740A Coupler (see *Figure 5–5*). Be certain that the 10760A Counter cards are in the proper order.

i. Connect the reference/measurement cable from the laser head and first receiver to the first 10760A Counter card (see *Figure 5–7* for a typical system setup).

j. Connect the hooded connectors in sequence to each of the additional 10760A Counters in the system and daisy-chain the REF connectors as shown in *Figure 5-7.*

k. If the standard 10756A Manual Compensator is used, mount it on the edge connector of the 10755A Compensation Interface.

l. Apply system power and verify that the reference and measurement LED indicators located near the bottom front edge of each counter light (the reference LED indicator is the one closest to the front edge). Remove system power.

m. Connect the system controller to the 10746A Binary Interface using the cable fabricated during the preliminary procedure.

n. If 10783A Numeric Displays are used, connect them to the system controller using the 10631A, B, or C cables. Refer to the 10783A Numeric Display Operating and Service manual.

o. Apply system power. At the rear panel of the 10740A Coupler, verify that the voltage is +15 ±0.25V dc, –15 ±0.25V dc, and +5 +0.10, –0.05V dc (see *Figure 5–4*).

5.9 Comparator-Based System Installation

Perform the installation of the comparator-based system as follows:

a. If the 10740A Coupler is to be rack mounted or installed in a cabinet, refer to the 10740A Coupler Operating and Service manual for dimensions and installation instructions.

b. Connect the +5V power supply cable between the power supply and the 10740A Coupler rear panel terminal strip.

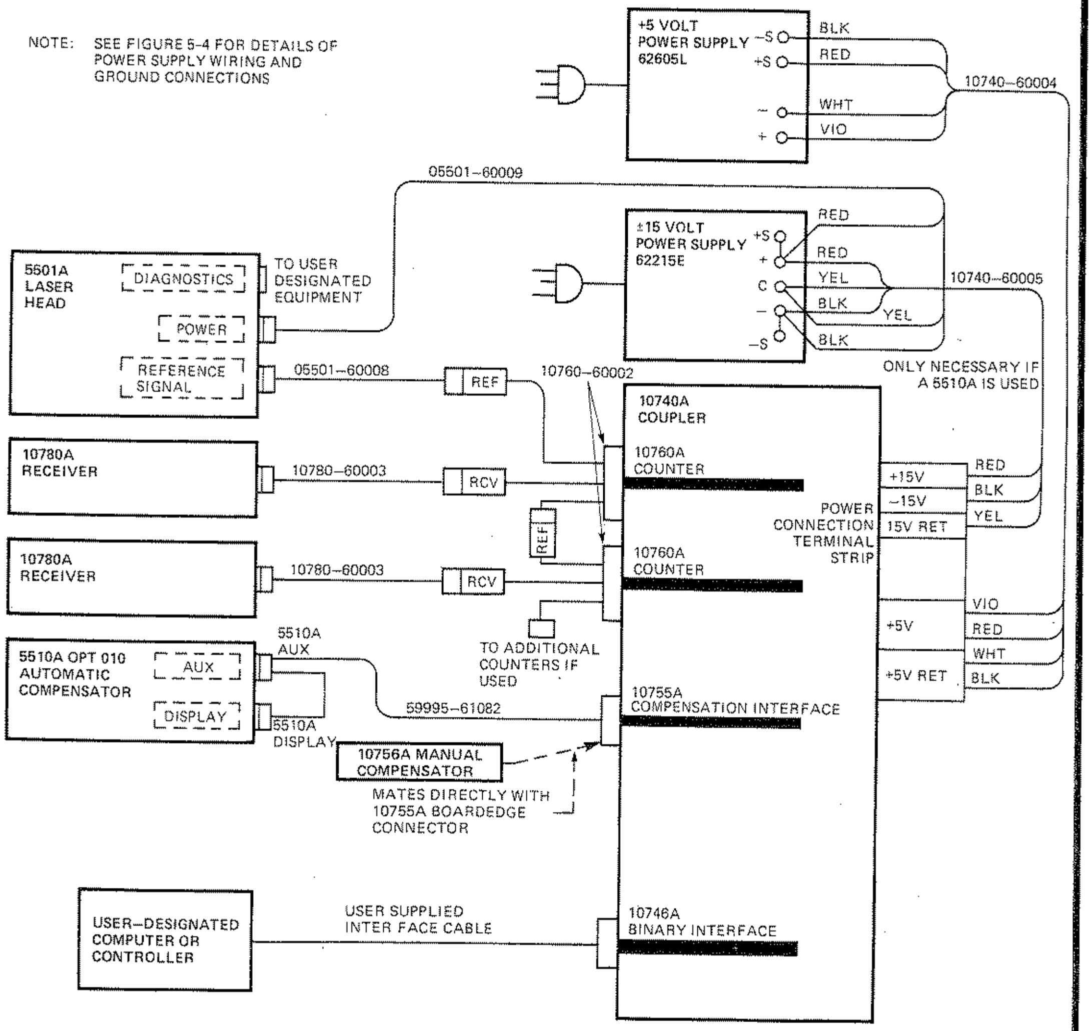
c. Connect the ±15V power supply cable between the power supply and the 10740A Coupler rear-panel terminal strip. Note that if the optional 5510A Opt. 010 Automatic Compensator is used, connect the interface cable between the 5510A Opt. 010 and the 10755A Compensation Interface.

d. If the 10783A Numeric Displays are used, connect the +5V power cables between the numeric display rear panels and the +5V power source on the back of the 10740A Coupler.

e. Connect the ±15V power supply and +5V to suitable sources of ac power. Apply system power. Verify the voltage at the coupler rear panel is +15V dc ±0.25, –15V dc ±0.25, and +5V dc +0.10, –0.05. For 4-axis 10746A systems, the voltage on the front of the left-most card (output card of the recommended configuration) should be set to 4.8 to 4.9 volts. Remove system power.

NOTE

To connect any hooded connector to a circuit card in the 10740A Coupler, pass the connector through the slot in the rear panel of the coupler and install it on the front edge connector of the applicable card (see *Figure 5–5*).



NOTE: SEE FIGURE 5-4 FOR DETAILS OF POWER SUPPLY WIRING AND GROUND CONNECTIONS

Figure 5–7. Counter-Based System Interconnecting Diagram

f. Remove the front panel of the coupler.

g. Check the addresses and jumpers on all system cards and units. It is advisable to make a list of each of the system addresses for future reference. Refer to the individual unit manuals if it is necessary to change addresses or jumpers. Refer to *Tables 5-2a* thru *5-2e* for 10764B resolution extension switch settings.

h. Install all cards in the 10740A Coupler (see *Figure 5-5*). Be certain that if more than one 10764B Fast Pulse Converter card is used, they are installed in the proper order.

NOTE

> If more than one 10764B Fast Pulse Converter card is used the physical configuration of the reference/measurement cable restricts the installation of the hooded connectors to a unique order. Therefore, it is very important that you connect the corresponding measurement legs of the cable to the appropriate receivers. If the optimum optical measurement path layout makes this impossible, it will be necessary to exchange cards in their slot or re-address the 10764B Fast Pulse Converters to conform to the actual system configuration (refer to the 10764B Fast Pulse Converter Operating and Service Manual).

i. Connect the reference/measurement cable from the laser head and first two receivers to the first 10764B Fast Pulse Converter card (see *Figure 5-8* for a typical system setup).

j. If the system includes more than two measurement axes, connect the hooded connectors in sequence to each of the additional 10764B Fast Pulse Converter cards in the system and the associated pairs of RF cables to the 10762A Comparator cards.

k. If the standard 10756A Manual Compensator is used, mount it on the edge connector of the 10755A Compensation Interface.

l. Apply system power and verify that the reference and measurement LED indicators located near the bottom front edge of each counter card lights (the reference LED indicator is the one closest to the front edge). Remove system power.

m. Connect the system controller to the 10746A Binary Interface. Use the cable fabricated during the preliminary procedure. Connect the interface cables between each 10762A Comparator in the coupler to the drive system of the machine.

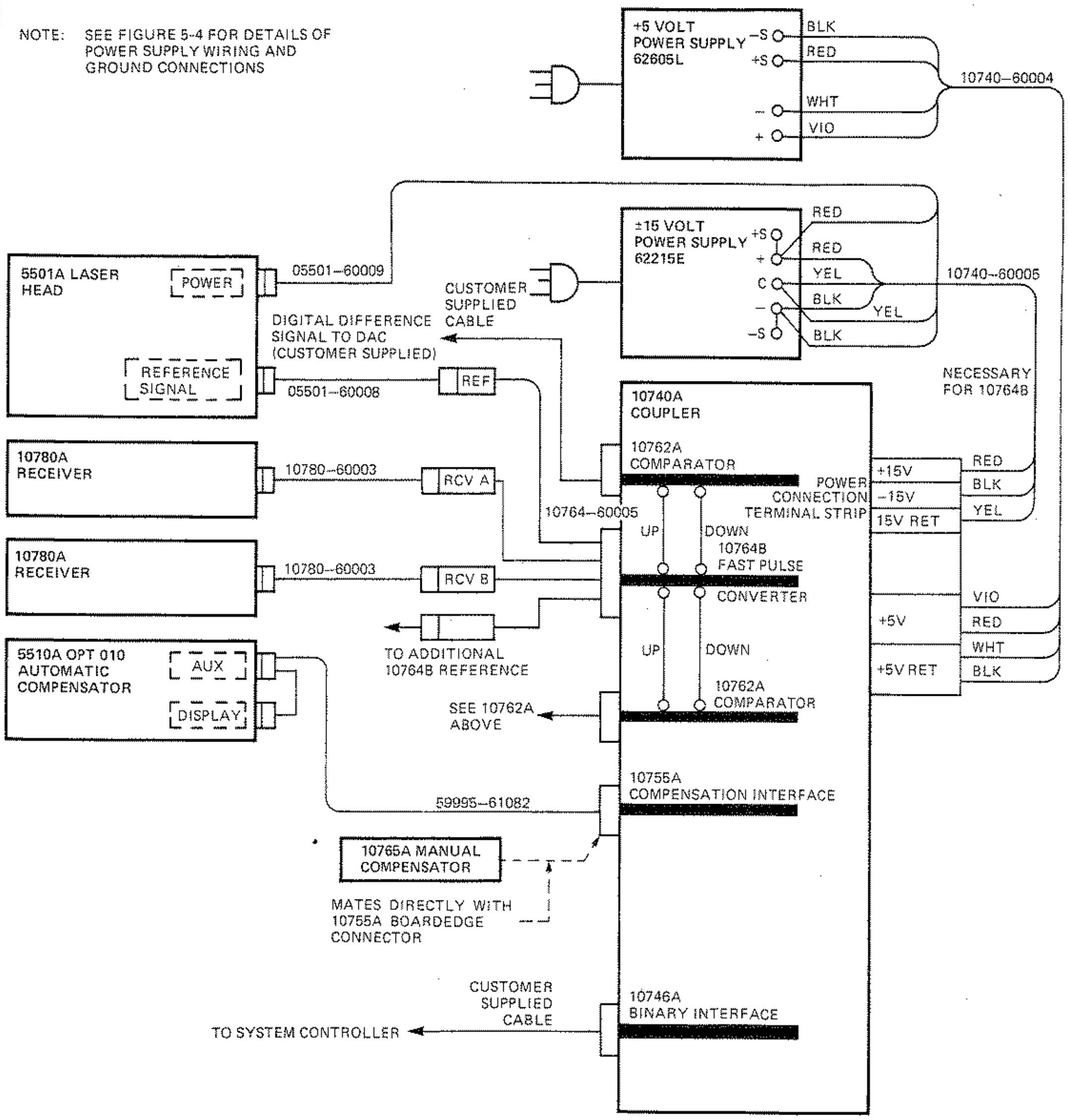
n. If 10783A Numeric Displays are used, connect them to the system controller using the 10631A, B, or C cables. Refer to the 10783A Numeric Display Operating and Service manual.

o. Apply system power. At the rear panel of the 10740A Coupler, verify that the voltage is +15 ±0.25V dc, -15 ±0.25V dc, and +5 +0.10, -0.05V dc (see *Figure 5-4*).

5.9.1 10764B RESOLUTION EXTENSION. Provision is made to select one of 32 resolution factors by means of three switches located on the 10764B. A 4-pole switch labelled P is common to both axes. Two 4-pole switches labelled Q are for the separate measurement axes. The Q switches must have only one switch set up (away from the dot) at any one time. Any combination that results in a number between 8 and 15 may be used on the P switch. The available combinations for the various modes are listed in *Tables 5-2a* through *5-2e*.

NOTE

> System resolution = $Q/P \times \lambda/4$ for linear interferometer and $Q/P \times \lambda 8$ for plane mirror.



NOTE: SEE FIGURE 5-4 FOR DETAILS OF POWER SUPPLY WIRING AND GROUND CONNECTIONS

Figure 5–8. Comparator-Based System Interconnecting Diagram

Table 5-2a. Resolution Extension Factors

RESOLUTION EXTENSION = P/Q								
Q P	8	9	10	11	12	13	14	15
8	1	1.125	1.25	1.375	1.5	1.625	1.75	1.875
4	2	2.25	2.5	2.75	3.0	3.25	3.5	3.75
2	4	4.5	5.0	5.5	6.0	6.5	7.0	7.5
1	8	9	10	11	12	13	14	15

Table 5-2b. Resolution of a Single Beam or Linear Interferometer with the 10764B

Q P	8	9	10	11	12	13	14	15
8	λ/4	λ/4.5	λ/5	λ/5.5	λ/6	λ/6.5	λ/7	λ/7.5
4	λ/8	λ/9	λ/10	λ/11	λ/12	λ/13	λ/14	λ/15
2	λ/16	λ/18	λ/20	λ/22	λ/24	λ/26	λ/28	λ/30
1	λ/32	λ/36	λ/40	λ/44	λ/48	λ/52	λ/56	λ/60

Table 5-2c. Resolution of a Plane Mirror Interferometer with the 10764B

Q P	8	9	10	11	12	13	14	15
8	λ/8	λ/9	λ/10	λ/11	λ/12	λ/13	λ/14	λ/15
4	λ/16	λ/18	λ/20	λ/22	λ/24	λ/26	λ/28	λ/30
2	λ/32	λ/36	λ/40	λ/44	λ/48	λ/52	λ/56	λ/60
1	λ/64	λ/72	λ/80	λ/88	λ/96	λ/104	λ/112	λ/120

Table 5-2d. Maximum Velocity for Non-Differential Mode Single Beam and Linear Interferometer (inches/second)

Q P	8	9	10	11	12	13	14	15
8	13	13.5	13.5	14	13	10	8	6
4	13	13.5	13.5	14	13	10	8	6
2	11.2	9.4	9	7.5	7.4	6.5	6	5.5
1	5.5	4.7	4.4	3.8	3.5	3.2	3	2.8

Plane mirror interferometer specifications are one-half of these values.

Table 5-2e. Maximum Velocity for Differential Mode Single Beam and Linear Interferometer (inches/second)

P Q	8	9	10	11	12	13	14	15
8	13 —	13.5 —	13.5 —	14 —	13 —	10 —	8 —	6 —
4	13 21	13.5 18.5	13.5 17	14 15	13 14	10 13	8 12	6 11.5
2	13.2 11.2	13.6 9.4	13.8 9	14 7.7	13 7.4	10.3 6.5	8 6	6 5.7
1	13.2 5.5	13.0 4.7	13.8 4.4	14 3.8	13 3.5	10.3 3.2	8 3	6 2.8

10764B

Max velocity for DIFFERENTIAL MODE SINGLE BEAM & LINEAR INTERFEROMETER. Upper numbers are limits for individual retroreflectors and lower numbers, if listed, place additional specs on relative velocity of retroreflectors.

The resolution extension factor will only be changed at the time the system reset is enabled on the back plane, or the manual "RESET" switch is raised and lowered, or when a 0X command is received. After changing the resolution, or when powering up, 2 or more reset pulses should be sent to the system to allow for resulting transients to die out.

In addition, check the following switches and jumpers on the 10745A, 10760A, and 10783A (see the individual Operating and Service manuals).

5.10 ENGLISH/METRIC PULSE OUTPUT ELECTRONICS INSTALLATION

The 5501A English/Metric Pulse Output Electronics provides micrometre or microinch value pulses. The output signal cable lengths are standard at 4.57 m (15 ft.) and are terminated in bare wires. All interconnecting cables between the English/Metric Pulse Output Electronics and the 5501A Laser Transducer are supplied.

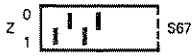
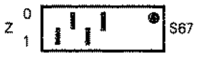
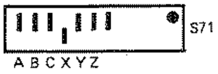
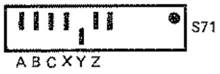
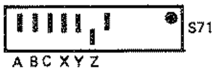
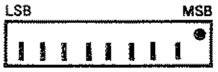
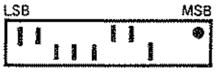
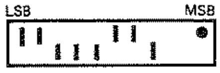
NOTE

> The jumpers and switches on the 10763A English/Metric Pulse Output cards must be properly set prior to operation (refer to *Table 5-3* for a summary of jumper and switch positions). Refer to the 10763A English/Metric Pulse Output Unit manual for detailed information.

a. If the 10740A Coupler is to be rack mounted or installed in a cabinet, refer to the 10740A Coupler Operating and Service manual for dimensions and installation instructions.

b. Connect the +5V power supply cable between the power supply and the 10740A Coupler rear panel terminal strip.

Table 5-3. Typical Configuration Guide for System Jumpers or Switches

	(Master) X-Axis (Labeled on Card)	Y-Axis (Labeled on Card)	Z-Axis (Labeled on Card)
Set Up Address	Already set at factory but may have moved in shipment.* 	Already set at factory but may have moved in shipment.* 	Already set at factory but may have moved in shipment.* 
Set Up Next Address	Already set at factory but may have moved in shipment. 	Already set at factory buy may have moved in shipment. 	Already set at factory but may have moved in shipment. 
Deadpath	Set up by user. See paragraph 5.10.2 or 10763A English/Metric manual for details.	Set up by user. See paragraph 5.10.2 or 10763A English/Metric manual for details.	Set up by user. See paragraph 5.10.2 or 10763A English/Metric manual for details.
Inch	This jumper is installed as the resolution is English. Remove for Metric units.	This jumper is installed as the resolution is English. Remove for Metric units.	This jumper is installed as the resolution is English. Remove for Metric units.
NOR	This jumper is installed as the resolution is normal. Remove for X10.	This jumper is installed as the resolution is normal. Remove for X10.	This jumper is installed as the resolution is normal. Remove for X10.
First	This jumper is removed as this is the master card in the system.	This jumper is inserted since X-axis is the master card.	This jumper is inserted since X-axis is the master card.
One Axis	This jumper installed if only one axis system. This jumper is removed.	This jumper is removed.	This jumper is removed.
ERR Stop/Go	Installed in the GO position.	Installed in the GO position.	Installed in the GO position.
A/UP	Set by user. Set to UP arbitrarily.	Set by user. Set to UP arbitrarily.	Set by user. Set to UP arbitrarily.
B/DWN	Set by user. Set to DWN arbitrarily.	Set by user. Set to DWN arbitrarily.	Set by user. Set to DWN arbitrarily.
TEST/ RUN	Run.	Run.	Run.
800 KHz/ 1.6 MHz	Set up by user. Set to 1.6 MHz arbitrarily.	Set up by user. Set to 1.6 MHz arbitrarily.	Set up by user. Set to 1.6 MHz arbitrarily.
Axis Select	Same as this axis. 	Same as this axis. 	Same as this axis. 
Weight	Set up by user. Determines resolution of pulses out. Basic resolution is .1 μm	Set up by user. Determines resolution of pulses out. Basic resolution is .1 μm	Set up by user. Determines resolution of pulse out. Basic resolution is .1 μm
Examples	Resolution — Switch Settings	Resolution — Switch Settings	Resolution — Switch Settings
X1=(0+1)	.1 μm (10 μin) 	.1 μm (10 μin) 	.1 μm (10 μin) 
X10=(9+1)	1 μm (100 μin) 	1 μm (100 μin) 	1 μm (100 μin) 
X100=(99+1)	10 μm 1000 μin) 	10 μm (1000 μin) 	10 μm (1000 μin) 

*A 10760A Counter card must be addressed to correspond to each 10763A card (e.g., X, Y, and Z for this example).

c. If the optional 5510A Opt. 010 Automatic Compensator is used, connect the ±15V power supply cable between the power supply and the 10740A Coupler rear-panel terminal strip. Connect the interface cable between the 5510A Opt. 010 and the 10755A Compensation Interface.

d. Connect the ±15V power supply (if used) and +5V power supply to suitable sources of ac power. Apply system power. Verify the voltage at the coupler rear panel is +15V dc ±0.25, -15V dc ±0.25, and +5 +0.10, -0.05V dc. Remove system power.

NOTE

> To connect any hooded connector to a circuit card in the 10740A Coupler, pass the connector through the slot in the rear panel of the coupler and install it on the front edge connector of the applicable card (see *Figure 5-5*).

e. Remove the front panel of the coupler.

NOTE

> All 10760A Counter cards are supplied with the NORMAL/REVERSE jumper in the NORMAL position. The correct position for the NORMAL/REVERSE jumper is determined during system checkout.

f. Connect the reference/measurement cable from the laser head and first receiver to the first 10760A Counter card (see *Figure 5-9* for a typical system setup).

g. Connect the hooded connectors in sequence to each of the additional 10760A Counters in the system.

h. Apply system power and verify that the reference and measurement LED indicators located near the bottom front edge of each 10760A Counter light (the reference LED indicator is the one closest to the front edge). Also verify that the ON LED indicator on the 10763A card lights. Remove system power.

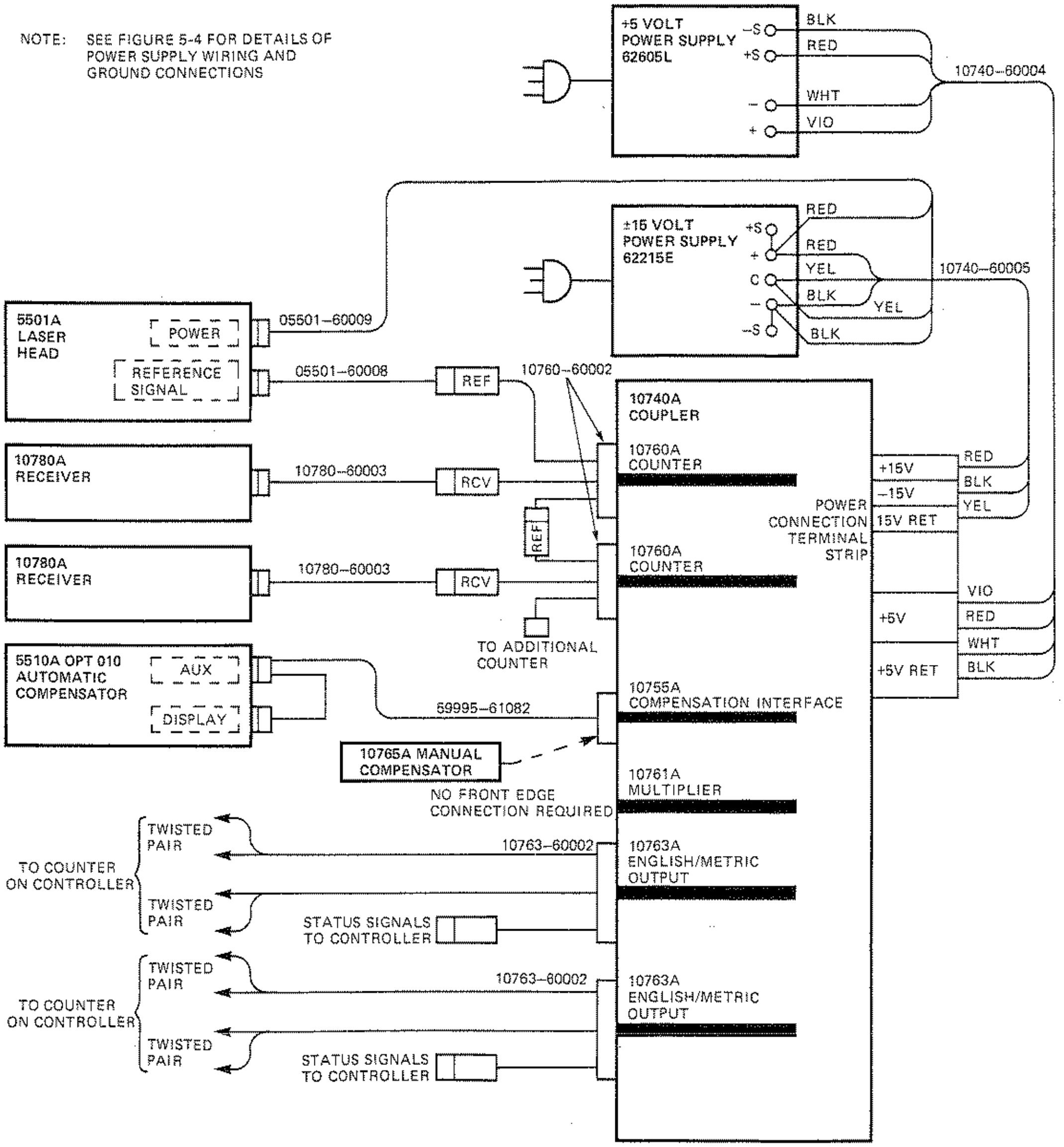
CAUTION

> **Do not connect the twisted pair output cables (part of the 10763-60002 cable) to the system controller or monitoring system until after the correct position for the NORMAL/REVERSE jumper on the 10760A Counter cards is determined. This is done during system checkout.**

i. Connect the control connector (part of the 10763-60002 cable) to the system controller (see *Table 5-4* for signal definitions and *Figure 5-10* for signal timing relations).

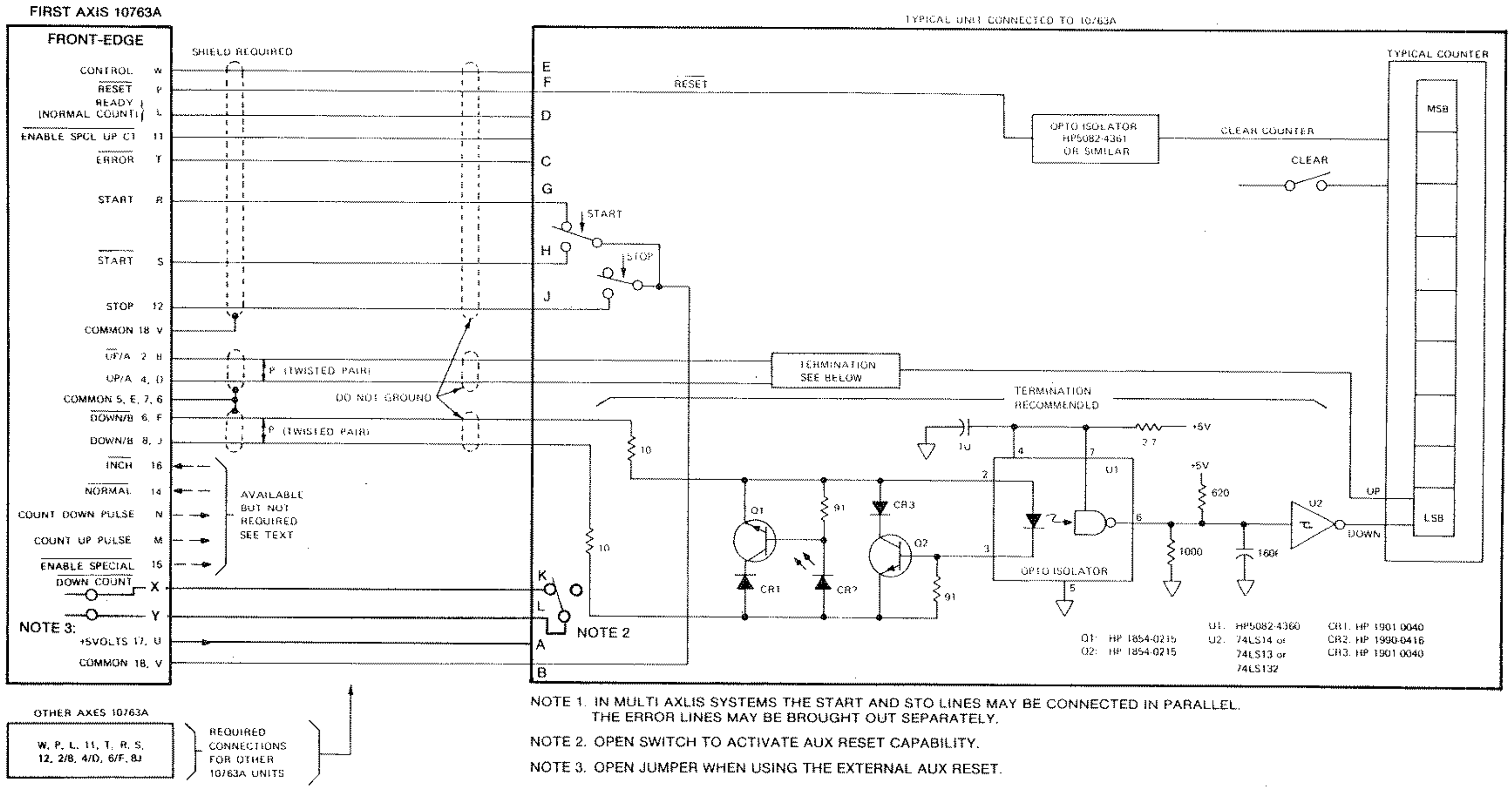
j. Apply system power. At the rear panel of the 10740A Coupler, verify the voltage is +15 ±0.25V dc, -15 ±0.25V dc, and +5 +0.10, -0.05V dc.

5.10.1 10763A INTERFACING TO CONTROLLER. *Figure 5-10a* shows the recommended interface between the 10763A and a controller. Special attention should be paid to the required START and STOP switches as shown.



NOTE: SEE FIGURE 5-4 FOR DETAILS OF POWER SUPPLY WIRING AND GROUND CONNECTIONS

Figure 5-9. Typical English/Metric Pulse Output Electronics Interconnecting Diagram



NOTE 1. IN MULTI AXLIS SYSTEMS THE START AND STO LINES MAY BE CONNECTED IN PARALLEL. THE ERROR LINES MAY BE BROUGHT OUT SEPARATELY.

NOTE 2. OPEN SWITCH TO ACTIVATE AUX RESET CAPABILITY.

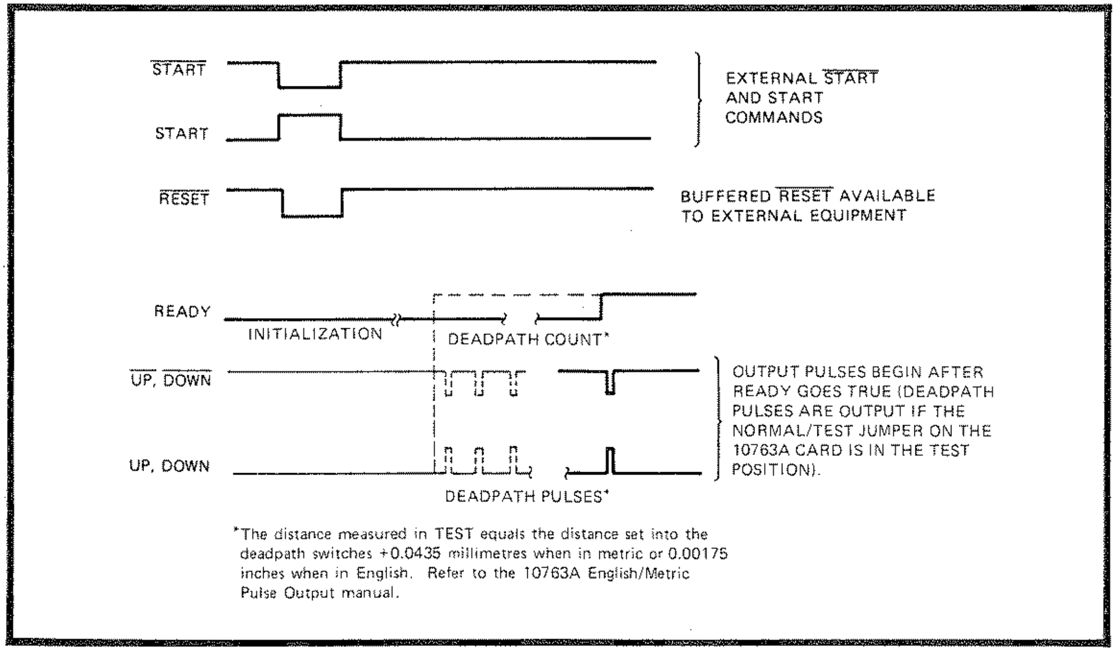
NOTE 3. OPEN JUMPER WHEN USING THE EXTERNAL AUX RESET.

Figure 5-10a. Recommended Interface with 10763A

Table 5-4. 10763A Control Connector Functions

Pin*	Name	Input/Output	Description
F	$\overline{\text{RESET}}$	OUT	Buffered, negative pulse, card and system reset. For initializing external counter or controller at same time as laser transducer system. Monitor only, do not apply signals. Reproduced coupler bus RESET.
J	STOP	IN	Stops entire 10763A-controlled system when this line is set low.
H G	$\overline{\text{START}}$ START	IN IN	Starts entire 10763A-controlled system if pin S goes high and then S returns high and R returns low. Either this signal or power switched on will start the system. See Figure 5-10.
C	$\overline{\text{ERROR}}$	OUT	Indicates an error has been received for axis of particular 10763A. All axes ERROR lines may be wired (OR) together. Monitor only, do not apply signal.
E	CONTROL	OUT	When HIGH indicates "this" card is in control of 10740A coupler bus at moment. Normally used only for troubleshooting. Monitor only.
D	READY	OUT	Indicates initialization is complete. 10763A is ready to begin measurement.
A B	+5 Volts COMMON	OUT	System power supply lines. May be used for external purposes within original supply limits. The maximum allowable current from one 10763A card is one ampere.
K L	AUX RESET	IN	May be wired to a switch on external controller to allow external setting of deadpath switch when necessary.

*Pinouts on Control Connector



*The distance measured in TEST equals the distance set into the deadpath switches +0.0435 millimetres when in metric or 0.00175 inches when in English. Refer to the 10763A English/Metric Pulse Output manual.

Figure 5-10. Control Connector Signal Timing Diagram

5.10.2 PROCEDURE FOR DEADPATH CONVERSION. For the 10763A installation, deadpath should be carefully measured and set in the 14 DEADPATH switches.

NOTE
Maximum Allowable Deadpath*

	Resolution Selected	
	Normal X1	**Extended X10**
Metres	21.2	2.12
Inches	836	83.6

*Deadpath exceeding these amounts can not be compensated for.

The deadpath in metres or inches must be adjusted and converted to binary numbers before it can be set in the 10763A binary DEADPATH switches. Use the following procedure to adjust and convert the measured deadpath to the switch settings.

Calculate N from this formula: $N = \frac{(X)(K)(R)}{\text{CLOCK RATIO}}$

where:

N = number to be converted to binary

X = deadpath

$K = 1.605\ 08 \times 10^5$ for X in inches $= \frac{10\ \mu\text{in}}{6.23023\ \mu\text{in}}$
or
$K = 6.319\ 202 \times 10^6$ for X in metres

CLOCK RATIO = 16 for 800 kHz clock selected
or
CLOCK RATIO = 8 for 1.6 MHz clock selected

or R = 10 for times 10 resolution selected

or R = 1 for normal resolution

In the following steps directions will be given to set the 14 deadpath switches to either one (up) or zero (down) after a subtraction has been made. At each step note the correct switch setting in the box for reference.

Step			Set in Switch
1.	(a) If $N \geq 8\,388\,608$ set switch S53-13 to 1 and subtract 8 388 608 from N to carry to step 2 as N_2.	☐	53-13
	or		
	(b) If $N < 8\,388\,608$ set S13 to 0 and carry N to step 2 as N_2.		
2.	(a) If $N_2 \geq 4\,194\,304$ set S53-12 to 1 and subtract 4 194 304 from N_2 to carry to step 3 as N_3.	☐	12
	or		
	(b) If $N_2 < 4\,194\,304$ set S53-12 to 0 and carry N_2 to step 3 as N_3.		
3.	(a) If $N_3 \geq 2\,097\,152$ set S53-11 to 1 and subtract 2 097 152 from N_3 to carry to step 4 as N_4.	☐	11
	or		
	(b) If $N_3 < 2\,097\,152$ set S53-11 to 0 and carry N_3 to step 4 as N_4.		
4.	(a) If $N_4 \geq 1\,048\,576$ set S53-10 to 1 and subtract 1 048 576 from N_4 to carry to step 5 as N_5.	☐	10
	or		
	(b) If $N_4 < 1\,048\,576$ set S53-10 to 0 and carry N4 to step 5 as N5.		
5.	(a) If $N_5 \geq 524\,288$ set S53-9 to 1 and subtract 524 288 from N_5 to carry to step 6 as N_6.	☐	9
	or		
	(b) If $N_5 < 524\,288$ set S53-9 to 0 and carry N_5 to step 6 as N_6.		
6.	(a) If $N_6 \geq 262\,144$ set S53-8 to 1 and subtract 262 144 from N_6 to carry to step 7 as N_7.	☐	8
	or		
	(b) If $N_6 < 262\,144$ set S53-8 to 0 and carry N_6 to step 7 as N_7.		
7.	(a) If $N_7 \geq 131\,072$ set S53-7 to 1 and subtract 131 072 from N_7 to carry to step 8 as N_8.	☐	7
	or		
	(b) If $N_7 < 131\,072$ set S53-7 to 0 and carry N_7 to step 8 as N_8.		
8.	(a) If $N_8 \geq 65\,536$ set S54-6 to 1 and subtract 65 536 from N_8 to carry to step 9 as N_9.	☐	6
	or		
	(b) If $N_8 < 65\,536$ set S54-6 to 0 and carry N_8 to step 9 as N_9.		
9.	(a) If $N_9 \geq 32\,768$ set S54-5 to 1 and subtract 32 768 from N_9 to carry to step 10 as N_{10}.	☐	5
	or		
	(b) If $N_9 < 32\,768$ set S54-5 to 0 and carry N_9 to step 10 as N_{10}.		

Step			Set in Switch
10.	(a) If $N_{10} \geq$ 16 384 set S54-4 to 1 and subtract 16 384 from N_{10} to carry to step 11 as N_{11}. or (b) If $N_{10} <$ 16 384 set S54-4 yo 0 and carry N_{10} to step 11 as N_{11}.	☐	4
11.	(a) If $N_{11} \geq$ 8 192 set S54-3 to 1 and subtract 8 192 from N_{11} to carry to step 12 as N_{12}. or (b) If $N_{11} <$ 8 192 set S54-3 to 0 and carry N_{11} to step 12 as N_{12}.	☐	3
12.	(a) If $N_{12} \geq$ 4 096 set S54-2 to 1 and subtracts 4 096 from N_{12} to carry to step 13 as N_{13}. or (b) If $N_{12} <$ 4 096 set S54-2 to 0 and carry N_{12} to step 13 as N_{13}.	☐	2
13.	(a) If $N_{13} \leq$ 2 048 set S54-1 to 1 and subtract 2 048 from N_{13} to carry to step 14 as N_{14}. or (b) If $N_{13} <$ 2 048 set S54-1 to 0 and carry N_{13} to step 14 as N_{14}.	☐	1
14.	(a) If $N_{14} \geq$ 1 024 set S54-0 to 1 and subtract 1 024 from N_{14}. If N_{14} – 1 024 > 512 add binary 1 to least significant bit and carry the result up.	☐	0

An example of converting the deadpath to binary is given below:

EXAMPLE: Deadpath = 6.124 metres (extremely large)
Resolution: Normal, 1.6 MHz pulse rate

$$\frac{(6.124)\ (6.319\ 202)\ (10^6)}{8} = 4\ 837\ 349$$

			Switch Number
1.	4 837 349 < 8 388 608	$\boxed{0}$	13
2.	4 837 349 > 4 194 304	$\boxed{1}$	12

$$\text{Result}\quad \begin{array}{r} 4\ 837\ 349 \\ \underline{4\ 194\ 304} \\ 643\ 045 \end{array}$$

3.	643 045 < 2 097 152	$\boxed{0}$	11
4.	643 045 < 1 048 576	$\boxed{0}$	100
5.	643 045 > 524 288	$\boxed{1}$	9

$$\begin{array}{r} 643\ 045 \\ \underline{524\ 288} \\ 118\ 757 \end{array}$$

6.	118 757 < 262 144	$\boxed{0}$	8
7.	118 757 < 131 072	$\boxed{0}$	7
8.	118 757 > 65 536	$\boxed{1}$	6
	118 757 - 65 536 = 53 221		
9.	53 221 > 32 768	$\boxed{1}$	5
	53 221 - 32 768 = 20 453		
10.	20 453 > 16 384	$\boxed{1}$	4
	20 453 - 16 384 = 4 069		
11.	4 069 < 8 192	$\boxed{0}$	3
12.	4 069 < 4 096	$\boxed{0}$	2
13.	4 069 > 2 048	$\boxed{1}$	1
	4 069 - 2 048 = 2 021		
14.	2 021 > 1 024	$\boxed{1}$	0

NOTE: In step 12, 4 069 ≈ 4 096. A better approximation can be obtained by rounding upwards to 4 096 and setting switches, thus:

	Switches
$\boxed{1}$	2
$\boxed{0}$	1
$\boxed{0}$	0

5.11 10781A Pulse Converter Electronics Installation

NOTE

Do not confuse the 10781A Pulse Converter installation requirements with those of the 10764B Fast Pulse Converter. The 10764B is a selectable part of the Computer Interface Electronics.

The 10781A Pulse Converter provides the simplest means of outputting position information to existing system controllers. The output consists of Up/Down or phase quadrature pulses of one-quarter wavelength value. One pulse converter is required for each measurement axis. Perform the installation procedures as follows:

a. Verify that the jumpers in the 10781A Pulse Converter match your system configuration. Refer to the 10781A Pulse Converter Operating and Service manual.

b. If the 10781A Pulse Converters are to be rack mounted or installed in a cabinet, refer to the 10781A Pulse Converter Operating and Service manual for dimensions and installation instructions.

c. Connect the reference and measurement cable from the laser head and first receiver to the applicable 10781A Pulse Converter (see *Figure 5–11* for a typical system interconnect).

d. Connect the additional legs of the cable to the remaining pulse converters.

e. Connect 10781A to +5V power source.

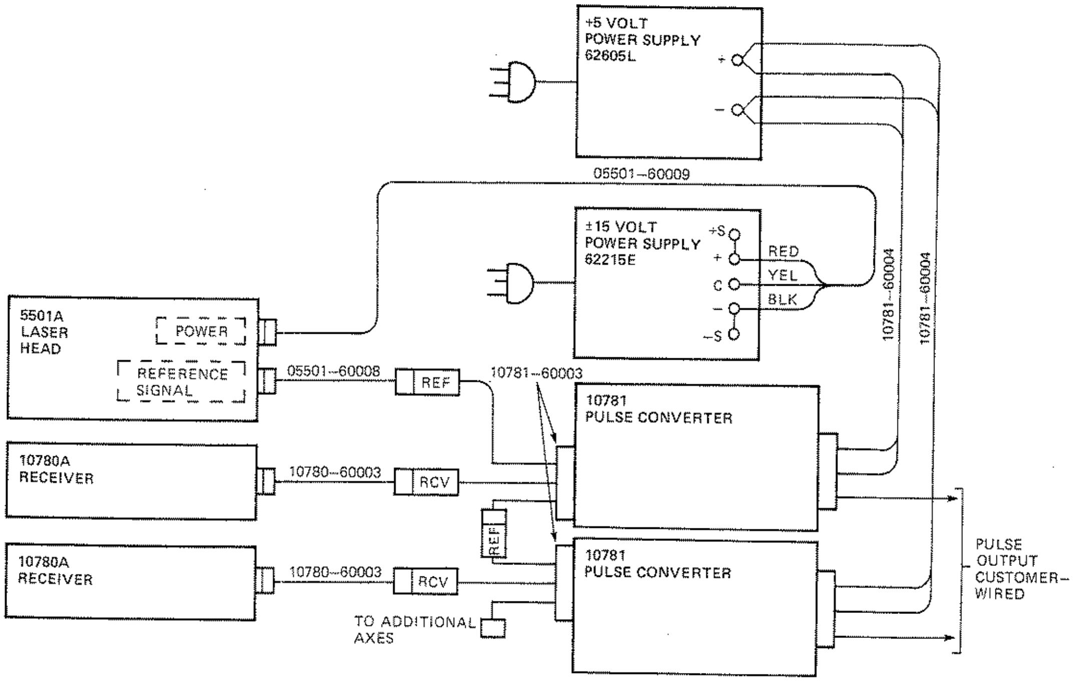


Figure 5-11. 10781A Pulse Converter Electronics Interconnecting

5.12 INTERFACE ELECTRONICS CHECKOUT

Since the computer interface electronics are designed to interface a user selected system to a wide variety of digital processors, it is impossible to give a specific checkout procedure. However, a recommended approach is presented for both the counter-based systems and the comparator-based system.

5.13 HP-IB and/or Binary Controlled Counter-Based System Checkout

When checking out a counter-based system it is necessary to program the system controller to verify specific functions. An example of a typical program is shown in Section IV, *Table 4-12*. The example shows how to program the system using the 9825A and the HP-IB. Examples of programming using the binary interface card are also shown. Once a system program is written and loaded into the system controller, verify system operation by performing the following steps:

a. Verify that the two LED indicators on the lower front edge of each 10760A Counter card are lit. These LED's indicate that the reference and measurement signals from the laser head and receivers are present.

b. If the 10745A HP-IB Interface Card is used, verify that the Talk and Listen lights on the middle front edge of the card are alternately lit when the card is addressed to talk and listen by the system controller.

c. If the 10746A Binary Interface Card is used, verify that the Data light on the upper front edge of the card lights when an instruction is sent from the system controller to transfer data. Note that this light is not lit when instructions (i.e., not data) are transferred from the system controller to the coupler backplane via the 10746A card.

NOTE

If the displayed data counts down from 160 to 0 and then indicates a large number with only a slight movement of the measurement optics, change the position of the NORMAL/REVERSE jumper on the 10760A Counter card (the jumper is in the NORMAL position when shipped). Refer to the 10760A unit manual for additional information if required.

d. Displace the measurement optics in each axis a specific distance and verify that the output devices accumulate the appropriate number of counts for the distance moved.

e. Interrupt the laser beam in each axis and verify the system comes up with an error indication. Reset the system after each error indication.

f. Replace the front panel of the 10740A Coupler.

5.14 Comparator-Based Systems

When checking a comparator-based system refer to *Table 4-13*. This is a typical comparator program and will verify overall system operation. Once a system program is written and loaded into the system controller, verify system operation by performing the following steps:

CAUTION

Prior to performing checkout of the comparator-based systems disconnect the DAC inputs to the drive motors until the correct position of the NORMAL/REVERSE jumpers are established in each axis. In addition, limit switches or stops should be installed in each axis to prevent the stage from overdriving its preset limits.

a. Verify that the data light on the upper front edge of the 10746A Binary Interface card lights when an instruction is sent from the system controller to transfer data. Note that this light is not lit when instructions (i.e., not data) are transferred from the system controller to the coupler backplane via the 10746A card.

NOTE

If the polarity of the DAC outputs in the following step is not correct, change the position of the NORMAL/REVERSE jumper on the 10762A Comparator card or change destination via software. Refer to the 10762A unit manual for additional information if required.

b. Command the system to move the measurement optics a specific distance and verify that the DAC response is appropriate.

c. Interrupt the laser beam in each axis and verify the system comes up with an error indication. Reset the system after each error indication.

d. Connect the DAC to the drive motors.

e. Command the system to move the measurement optics a specific distance and verify the movement is correct.

f. Replace the front panel of the 10740A Coupler.

5.15 ENGLISH/METRIC PULSE OUTPUT SYSTEMS CHECKOUT

The English/Metric Pulse Output System is primarily controlled by firmware programming on the 10763A English/Metric Pulse Output card. Once the system is connected to a system controller and power is applied, the primary control consists of starting and stopping the system and checking the output for errors (see *Figure 5-12*). To check out the system after it is installed perform the following checks:

NOTE

Disregard any of the following steps if the system controller does not have the required capability.

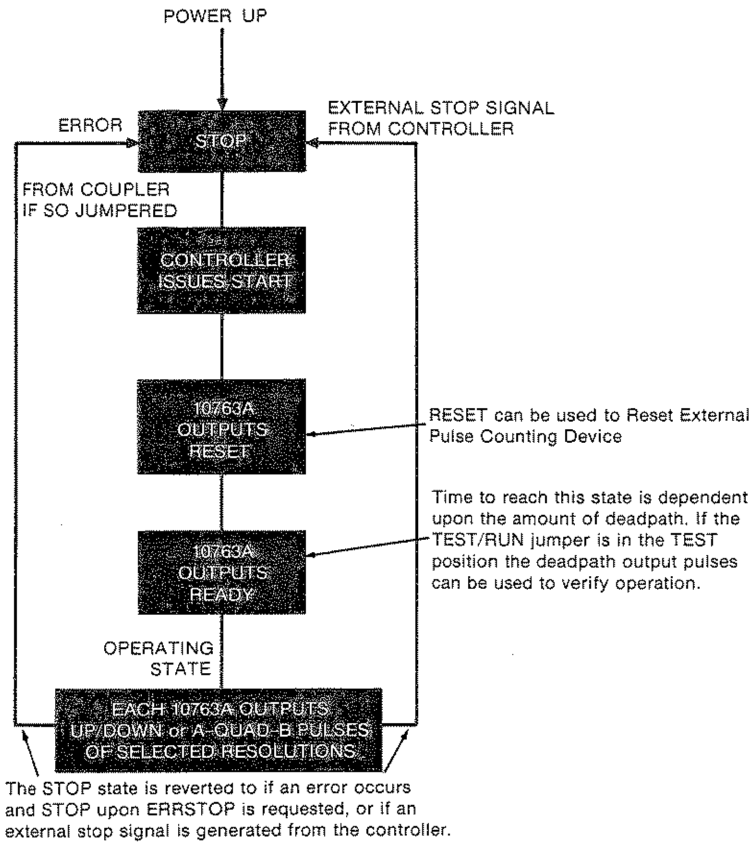


Figure 5-12. English/Metric Pulse Output System State Diagram

a. Give a start command from the system controller and verify that a ready response is returned from the English/Metric Output Pulse System (see *Figures 5-10* and *5-12*).

b. Verify that the two LED indicators on the lower front edge of each 10760A Counter card are lit. These LED's indicate that the reference and measurement signals from the laser head and receivers are present.

c. Verify that the ON light at the upper edge of each 10763A English/Metric Output Pulse card is lit. This indicates +5V power is applied to the cards.

CAUTION

Verify that the twisted pair output cables (part of 10763-60002 cable) are not connected.

d. Verify that the CONTROL indicator at the lower, front edge of each 10763A card is lit. These indicators light to show which 10763A card in a multiaxis system is in control of the system at any given time. When the system is operating the indicators appear to be lit at a reduced level as control is passed from board-to-board.

NOTE

If an error indication is generated when the measurement optics are moved, change the position of the NORMAL/REVERSE jumper on the 10760A Counter card (the jumper is in the NORMAL position when shipped). See *Figure 5–14*. Refer to the 10760A unit manual for additional information if required.

e. Manually displace the measurement optics in each axis in a positive direction and check if the system comes up with an error indication.

f. Set the preset deadpath for each axis in the individual 10763A cards (refer to 10763A unit manual).

g. If the deadpath switch on the 10763A English/Metric Pulse output card has a preset deadpath number set into it and the TEST/RUN jumper is put into the TEST position, the card will output these counts. (See *Figure 5–10.*) This output can be used to verify the card operation. Refer to the 10763A unit manual for additional information.

h. Interrupt the laser beam in each axis and verify the system comes up with an error indication. Reset between each beam interruption.

i. Connect the twisted pair output cables (10763-60002) to the system controller or monitoring system. Refer to the 10763A English/Metric Pulse Output unit manual for additional information.

j. Displace the measurement optics in each axis a specific distance and verify that the output counting devices accumulate the appropriate number of counts for the distance moved.

k. Replace the front panel of the 10740A Coupler.

5.16 10781A Pulse Converter Electronics Checkout

The 10781A Pulse Converter Electronics provide a simple means of interfacing the system optics to a customer supplied counting system. The checkout depends on how the pulse converter is used. Therefore determine your system requirements and reference the 10781A Pulse Converter until manual to determine how to checkout system operation.

Operation of this system results in Up/Down or A–Quad–B signals (which represent movement of the optical devices) being generated from the 10781A Pulse Converter. Checkout consists of verifying the presence of these signals and verifying that an error indication occurs (front-panel indicator lights) when the laser beam is blocked.

5.17 PREVENTIVE MAINTENANCE

The Laser Transducer System electronics require no preventive maintenance. However, the system optics, the laser head lens, and the receiver lens do require periodic cleaning. The frequency of this cleaning is dependent on the cleanliness of the ambient environment.

5.18 Cleaning of Optical Components

Use a soft camel-hair lens brush to remove dust from the optic windows. (A good camera lens brush with a rubber bulb blower is recommended.) Dampen a few optical lens cleaning tissues with optical grade ethyl alcohol, shake off excess alcohol, and wipe across window once. Use fresh tissue dampened with alcohol for each wipe. Allow alcohol to dry naturally.

NOTE

DO use only camera or better grade lens tissue.

DO NOT use any of the various impregnated eyeglass tissues.

DO NOT use harsh solvents such as acetone or MEK for cleaning.

DO NOT use excessive amounts of alcohol.

DO NOT wipe window if there is any abrasive dust or grit on it.

section VI

Troubleshooting

6.1 INTRODUCTION

This section provides system troubleshooting procedures that will locate a problem to the unit or circuit card level. The procedures determine as quickly as possible whether the trouble lies in the system unit hardware or the system controller. System controller troubleshooting, including all software and standard peripherals is contained in separate manuals (refer to *Figure 1-2*, Manuals Supplied with Laser Transducer System).

The troubleshooting information is divided into the following categories:

a. General troubleshooting information. You should use this information when troubleshooting a system that fails after it has been installed and operating. If for any reason you cannot quickly locate the problem, the detailed troubleshooting procedures will prove helpful.

b. Detailed troubleshooting procedures. You should use these procedures when you are installing your system and cannot obtain the results called out in the installation and checkout procedures. The detailed troubleshooting procedures can also be used if you are having difficulty in locating a problem in a system that has failed. In the latter case, it is not necessary to totally disassemble your system. However, be certain as you read through the installation and checkout procedure that your system meets each of the required responses (e.g., LED on the 10780A Receiver is lit when so specified).

Whatever method of troubleshooting you are using, be sure you read and understand the information contained in the following troubleshooting assumptions paragraph.

6.2 Troubleshooting Assumptions

The troubleshooting procedures make the following assumptions:

a. That the detailed troubleshooting procedures use the installation and checkout procedures in Section V as a basis for the directed troubleshooting. This means that the further into the installation and checkout procedure you are, the more equipment that you can assume is operating properly. For example, if you are using a 9825A Calculator as the system controller and it has passed its own diagnostic test, the subsequent troubleshooting will assume that it is operating properly. Therefore, if it will not function with the 10745A HP-IB interface when they are connected together, the initial replacement will be the 10745A.

b. That all system controls have been double checked to verify that they are in the proper positions.

c. That all cabling is correctly and firmly connected and that all system cards are correctly addressed and have the proper jumpers installed.

d. That interconnect wiring will be checked and cabling replaced or repaired as required if the detailed troubleshooting does not correct the malfunction.

e. That for any repair beyond the circuit board level, the individual unit manuals will be used.

f. That power is removed prior to replacing any units or circuit boards.

g. That the system optics are clean. Refer to the paragraph on preventive maintenance in Section V.

h. That all power supplies have been checked for correct output voltages.

i. The final and perhaps most important point to remember about troubleshooting procedures is that they cannot cover all possible malfunctions or combination of malfunctions. However, at the very minimum, they will get you to the general area of the problem. At that point, if you have read and understand the information in the manuals, you should be able to determine the cause of the malfunction.

CAUTION

Use of controls, adjustments, or procedures other than those specified herein may result in hazardous radiation exposure.

6.3 GENERAL TROUBLESHOOTING INFORMATION

If a system has previously been operating, the possible troubles can usually be divided into the following general areas:

a. Malfunction of the laser head.
b. Malfunction of one of the receivers.
c. Malfunction, misalignment, or improper application of the optical devices.
d. Malfunction of the system controller.
e. Malfunction of the coupler and interface electronics.
f. Malfunction of a power supply.

If the problem can be isolated to one or more of these problems, perform the appropriate troubleshooting to isolate a trouble to an assembly or device. The information is arranged to correspond to the general trouble areas listed above. If you cannot isolate the problem, refer to the detailed troubleshooting procedures for additional information.

6.4 Laser Head Troubleshooting

The laser head has diagnostic indicators and corresponding signal levels available on the rear panel. Most common malfunctions of the laser head are evidenced by one of the rear-panel diagnostic indicators being lit, by absence of the REFERENCE SIGNAL, or by absence of the laser beam itself. If the RETUNE FAILURE indicator is lit, press the RETUNE pushbutton. After approximately 9 seconds, the RETUNE FAILURE and RETUNE indicators should go out. If either indicator remains on or if any of the previously described symptoms of failure exist, refer to the separate laser head operating and service manual for specific trouble isolation procedures.

6.5 Receiver Troubleshooting

The system receivers supply the measurement signals (MEAS) for each measurement axis in the system. When a sufficient laser beam signal is received, an LED indicator on the receiver will light and the dc voltage at the external receiver test point will be between approximately 0.6 and 1.5V dc. Additionally, presence of a measurement signal can be verified by observing a lit LED indicator on the 10760A Counter card associated with the suspected receiver. The 10760A contains two LED indicators. The indicator farthest from the front edge of the card, when lit, signifies the presence of a measurement signal. The indicator closest to the front edge of the card signifies presence or absence of the reference signal from the laser head.

Improperly aligned optical devices can also cause a receiver to appear bad. Check for this by either placing the receiver directly in the laser beam path from the laser head, or by reflecting the laser beam onto the receiver's photodetector using only a retroreflector. This isolates all other optical devices from the system. Most systems contain more than one axis and, consequently, more than one receiver. If trouble is suspected with one receiver, exchange it with another receiver to verify the suspected malfunction.

If the receiver or the optical devices are rotated around the laser beam axis, the receiver LED indicator may remain on even if the beam between the interferometer and retroreflector is blocked. This can also occur occasionally with correct optical alignment if the measurement path is very short and few optical devices are used in the measurement path. If this situation occurs, refer to the operating and service manual supplied with the receiver for information regarding the "overload" adjustment.

6.6 Optical Devices Troubleshooting

Problems with the optical devices usually consist of misalignment of the devices. Refer to the alignment procedures in Section II for further information. Air turbulence caused by ventilation equipment or temperature gradients near the laser beam path can also cause measurement problems. If this is suspected, shield the area around the laser beam and optical devices with cardboard tubing, plastic sheet, or other suitable material. Some problems with sporadic counting and drift can be traced to air turbulence around the measurement path. This should be considered as a possibility before troubleshooting other parts of the system. Section II contains extensive information on optical problems and can be used as a basis for additional optics troubleshooting.

6.7 System Controller Troubleshooting

A wide variety of system controllers can be used with a laser measurement system. Diagnostic programs are available for all of the Hewlett-Packard controllers that can be used with the system.

If a controller malfunction is suspected, run the diagnostic programs to determine if the controller operates properly.

6.8 Coupler and Interface Electronics Troubleshooting

The following paragraphs describe some of the methods for isolating a problem to a given plug-in module. For coupler bus signal line information, refer to *Table 4-1* and the 10740A unit manual.

6.9 10745A HP-IB INTERFACE TROUBLESHOOTING. The 10745A interface transfers instructions from a calculator/controller to the 10740A Coupler backplane bus. The instructions are examined by each of the modules plugged into the coupler for applicability to a specific module. These modules function according to the specific instruction and in some cases transfer data back to the controller via the coupler bus and the 10745A interface module. If the system does not respond to any instructions and the controller diagnostics verify proper controller operation, either the 10745A module is the source of the trouble or another module is preventing the backplane handshake lines from operating.

The 10745A has two LED indicators near the front edge of the circuit board. One signifies that the 10745A has been addressed to talk by the HP-IB controller; the other indicator signifies that the 10745A has been addressed to listen. Check these indicators to verify correct addressing by the controller and to verify that the 10745A address switches are properly set.

6.10 10746A BINARY INTERFACE. The 10746A interface transfers instructions and data between the 10740A Coupler backplane bus and a system controller (usually a computer). If communication between these devices does not take place and the controller diagnostics verify proper operation of the controller, either the 10746A is the source of the problem or another module is preventing the backplane handshake lines from operating.

The 10746A contains one LED indicator to signify that the board is in the data mode of operation. Be sure to observe that power is available.

If the problem appears to be within the 10746A module, check that the controller applies a "command" signal to the 10746A prior to replacing the module.

6.11 10755A COMPENSATION INTERFACE. The 10755A, in response to coupler backplane bus instructions, transfers velocity-of-light compensation data to the coupler backplane bus data lines. The 10755A converts the BCD compensation data from a 10756A Manual Compensator or 5510A OPT 010 Automatic Compensator to binary data for placement on the coupler backplane bus. If the compensation number is erroneous, check the compensator for proper operation according to the information given in the separate compensator operating and service manual. If compensation data is not placed on the coupler backplane bus upon command, the 10755A module is probably the source of the trouble.

6.12 10760A COUNTER TROUBLESHOOTING. The 10760A accepts a reference signal from the laser head and a measurement signal from the receiver in a given measurement axis. LED indicators on the 10760A circuit card light when the reference and measurement signals are present. Note, however, that these indicators will light even if the 10760A card is not plugged into the 10740A Coupler. They obtain operating power from the connector on the front edge of the circuit card.

After verifying that the proper reference and measurement signals (approximately 2 MHz, differential) are available at the circuit inputs, you can assume a malfunction of the 10760A if it fails to perform any of its normal operating functions.

Most systems contain more than one measurement axis and, consequently, more than one 10760A Counter. If trouble is suspected with a counter card, exchange it with another card in the system to verify the suspected malfunction. (Remember to change the address jumper and any other jumpers that may be set differently.)

6.13 10761A BINARY MULTIPLIER TROUBLESHOOTING. The 10761A accepts data, via the 10740A Coupler backplane bus, from several sources: 10760A Counter cards, 10755A Compensation Interface, and in some applications, from an external controller via the 10746A Binary Interface. The purpose of this module is to perform the multiplication of measurement data, velocity-of-light compensation factor, and possibly externally entered factors as the application requires. If these arithmetic operations are not properly performed, the binary multiplier card is probably the source of trouble. If all axis exhibit a problem, this card is the likely source of trouble.

6.14 10762A COMPARATOR TROUBLESHOOTING. The 10762A card accepts a measured position signal and a destination signal (both in binary) and supplies a correction signal in binary to a system controller. The correction data is the digital difference between the two inputs. One 10762A card is used for each axis of machine movement. Consequently, after checking the three LED indicators for an indication of trouble, cards can be swapped to verify a problem. (Remember to change the address jumper and any other jumpers that may be set differently.)

The three LED indicators show the presence of +5-volt power, that a null situation exists (destination data and system location data are equal), and zero speed (system not moving). For additional information, refer to the separate unit manual.

6.15 10763A ENGLISH/METRIC PULSE OUTPUT TROUBLESHOOTING. The 10763A controls the other cards in the 10740A Coupler. It does this by issuing backplane instructions in a sequence that is controlled by a ROM on the 10763A card. These instructions cause 10760A Counter cards and the 10755A Compensation Interface to output data to a 10761A Binary Multiplier card. Subsequent instructions cause the multiplier card to output modified measurement data to the 10763A card. This data is outputted by the 10763A card as up/down or A-quad-B signals to external equipment.

Troubles can be isolated by first checking the LED indicators on the card for a malfunction indication and then exchanging the suspect card with another system card. The 10763A card has LED indicators to show the presence of +5-volt power; to indicate which 10763A card is in control of the system at a given time (during normal multiaxis system operation the control LED's on all 10763A cards appear dimly lit); and to indicate any of four possible system errors. Refer to the separate unit manual for additional information.

6.16 10764B FAST PULSE CONVERTER. The fast pulse converter is designed to accept a reference signal from the 5501A Laser Head and a measurement signal from one or two 10780A Receivers. The fast pulse converter then outputs up and down pulses that represent the difference in frequency between the reference signal and the measurement signal(s). Resolution extension factors of 1 through 15 are switch selectable for the 10764B. The number of output pulses for a given physical displacement of the optical devices will be increased by the extension factor selected. The up and down pulses from the card are applied to counting circuits (usually the 10762A Comparator).

After verifying that the proper reference and measurement signals (approximately 2MHz, differential) are available at the circuit inputs, you can assume a malfunction of the 10764B if it fails to perform any of its normal operating functions.

6.17 10781A Pulse Converter Troubleshooting

The 10781A Pulse Converter accepts the reference and measurement signals from the 5501A Laser Head and 10780A Receiver, respectively. The 10781A compares the frequency of these two signals and supplies difference outputs to user-designed equipment in one of two forms — up/down pulses or phase-related square waves. If the unit does not output these signals when reference and measurement signals are available at the inputs, the trouble lies within the 10781A circuits. Remember that output signals exist only when the optical devices are in motion and a difference between reference and measurement signal frequency exists.

The front-panel ERROR indicator illuminates when the allowable rate of movement of the optical devices is exceeded or when either the reference or measurement signal is not present at the circuit inputs. Depending upon internal jumper selection, an error condition can disable output pulses. Errors can be cleared and operation can be resumed by correcting the fault and pressing the front-panel RESTART pushbutton. For additional information refer to the 10781A unit manual.

6.18 Power Supply Troubleshooting

Two power supplies are used with most 5501A Laser Transducer Systems — a ±15-volt supply and a +5-volt supply. Both supplies are current limiting and, consequently, the output voltage drops to near zero volts if the outputs are shorted. If this condition exists, disconnect the suspect supply and measure the open-circuit output voltage. Use of this method determines if the supply itself is malfunctioning or if a short in the cabling or elsewhere is causing the supply to current limit. If the power supply is found to be defective, refer to the separate operating and service documentation supplied with the power supply. These manuals also contain procedures for adjustment of the output voltages.

6.19 DETAILED TROUBLESHOOTING PROCEDURES

Each of these troubleshooting procedures parallels the corresponding installation and checkout procedure in Section V and is subdivided in the same manner. Since the indications during preliminary procedures and installation and alignment of the laser head, receiver, and optics are minimal, they are repeated for ech troubleshooting procedure.

If a malfunction is detected during the installation and checkout of the system (or if you are unable to locate a malfunction in a previously operating system using the general troubleshooting information) use one of the following procedures:

a. HP-IB interface electronics troubleshooting (*Table 6-1*).

b. Computer interface electronics troubleshooting:

    1. Counter-based systems troubleshooting (*Table 6-2*).
    2. Comparator-based systems troubleshooting (*Table 6-3*).

c. English/Metric pulse output electronics troubleshooting (*Table 6-4*).

d. 10781A Pulse Converter troubleshooting (*Table 6-5*).

The most effective method of using these procedures is to note in which procedure (preliminary installation, interface electronics installation, etc.) a problem occurred. Locate the appropriate troubleshooting table (*Tables 6-1* through *6-5*) for your system. Locate the section of the table that pertains to the procedure being performed at the time the trouble was observed. Troubleshoot according to the procedure given.

Table 6-1. HP-IB Interface Electronics System Troubleshooting

PRELIMINARY PROCEDURE

1. If the laser head does not emit red light, check that the rear-panel POWER ON light is lit. If it is not, check for a power line short. This can cause the power supply to current limit and reduce the voltage output level to near zero volts. Also, check for an open circuit in the power supply wiring. If the POWER ON light is lit, check the status of the four rear-panel indicators associated with the ±15-volt supplies (two UNBAL indicators and two FUSE indicators). If power is available to the laser head but the head does not emit red light, refer to the separate manual for the laser head for further troubleshooting.
2. If the LED indicator on one of the system receivers does not light, verify that the +15 volts is present at the system cable connector for the receiver. If it is not, troubleshoot the power supply and the system wiring. If voltage is present at the receiver connector and the LED is not lit, refer to the separate manual for the receiver for further troubleshooting information.

INSTALLATION AND ALIGNMENT OF LASER HEAD, RECEIVER, AND OPTICS PROCEDURE

1. If the laser head does not emit red light, check that the rear-panel POWER ON light is lit. If it is not, check for a power line short. This can cause the power supply to current limit and reduce the voltage output level to near zero volts. Also check for an open circuit in the power supply wiring. If the POWER ON light is lit, check the status of the four rear-panel indicators associated with the ±15-volt supplies (two UNBAL indicators and two FUSE indicators). If power is available to the laser head but the head does not emit red light, refer to the separate manual for the laser head for further troubleshooting information.
2. If the LED indicator on one of the system receivers does not light, verify that the +15 volts is present at the system cable connector for the receiver. If it is not, troubleshoot the power supply and the system wiring. If voltage is present at the receiver connector and the LED is not lit, check optics and alignment (refer to Section II).

ELECTRONIC INSTALLATION PROCEDURE

1. If +5 volts is not present at the 10740A Coupler rear panel, check power wiring for a short or open circuit. Also check the output of the power supply with the cables disconnected.
2. If the reference or measurement LED indicators on the 10760A Counter cards do not all light when power is applied, verify presence of reference signal from laser head and measurement signal from each receiver. If either signal is not present, troubleshoot the laser head or associated receiver. If the signals are present, troubleshoot the associated 10760A Counter card. Counter cards can be interchanged at this point to verify trouble source.
3. If +5-volt power is not available after connecting 10783A Numeric Displays, check power wiring and display itself for short or open circuits.

Table 6-1. HP-IB Interface Electronics System Troubleshooting (Cont'd)

CHECKOUT PROCEDURE

Required Test Equipment

INSTRUMENT TYPE	REQUIRED CHARACTERISTICS
Digital Voltmeter	Range: −15V to +15V ± .01V dc
Logic Probe	TTL Level
Oscilloscope	Ability to display signals between dc and 20MHz.
Individual Circuit Card Operating & Service Manuals	

Load the example program for the typical HP-IB Interface from Section IV (Programming) into the system controller. If the problem disappears, check user's software. If problem remains, continue.

MULTI-AXIS

1. If same problem exists on all axes, check the following possible error sources:

   a) Check temperature in coupler environment:

COUPLER TEMPERATURE	SYMPTOMS	ACTION
0° to 55°C	None-electronics should operate as described.	None
Out of range	Counters may jump count erratically.	Ventilate enclosure

   b) Check voltage on each circuit card in the coupler:

LOCATION	VOLTAGE
+5V Front-edge Test point	At least +5V ± .01V on each card

Table 6-1. HP-IB Interface Electronics System Troubleshooting (Cont'd)

c) 10745 HP-IB Interface

SYMPTOM	POSSIBLE PROBLEM	ACTION
Neither the talk nor listen LED lights on the interface card when card is addressed to talk or listen.	1. 10745 HP-IB address incorrect.	Set the switches on 10745 to correct address.
	2. Controller malfunction	Run controller diagnostic (if possible)
	3. User software	Check for proper command sequence (example program, Section IV).
	4. 10745 Malfunction	Replace or troubleshoot 10745.
	5. Interface Cable Malfunction	Replace or Troubleshoot cable

d) 10783A Numeric Disp.

SYMPTOM	POSSIBLE PROBLEM	ACTION
Displacement information not being displayed	1. 10783A HP-IB address incorrect.	Set switches on back of 10783A to correct address.
	2. 10783A not receiving power.	Connect 10783A to +5V on back of coupler. Turn on 10783A.
	3. 10783A malfunction.	Troubleshoot 10783A.

Table 6-1. *HP-IB Interface Electronics System Troubleshooting (Cont'd)*

e) Check I/O cabling from controller to coupler.

f) If the reference or measurement LED indicators on the 10760A counter cards do not all light when power is applied:

ACTION	LOCATION	RESULT	SUBSEQUENT ACTION
Verify presence of reference and measurement signals with oscilloscope These signals are square waves.	10760A front-edge Measurement: signal (pins 18, 20)	Signal present	If LED is extinguished, troubleshoot 10760A.
		Signal absent	Troubleshoot receiver or cabling.
	Reference: Signal (pins 22, 24)	Signal present	If LED is extinguished, troubleshoot 10760A.
		Signal absent	Troubleshoot laser head or cabling.

If multi-axis system, 10760A counter cards can be interchanged to isolate problem. (Remember to change card address.)

PROBLEM EXISTS BUT NOT ON ALL AXES

2. If the system is multi-axis but the problem is not present on all axes, substitute known good components to isolate the problem system component. The following may also apply:

   a) Check voltage on each coupler card:

LOCATION	VOLTAGE
+5V Front-edge test point.	At least +5V ± .01V on each card.

Table 6-1. *HP-IB Interface Electronics System Troubleshooting (Cont'd)*

b) Intermittent measurement signal on one or more measurement axes may indicate:

CAUSE	CHECK	ACTION
1. Misalignment of optical components.	Reduce beam size by rotating to small aperature on laser head. Place alignment target on receiver lens. Move optics along entire measurement path and verify both return beams overlap on the target along the entire length of movement.	If optics are misaligned and beams do not overlap, refer to Section II for alignment procedure.
2. Misadjustment of 10780A receiver gain	Monitor 10780A test point on back of receiver, voltage should lie in range 0.5–1.0 Vdc. If voltage >1.1V, receiver could be saturated. If voltage <0.2V, gain may be too low.	Refer to 10780A manual for adjustment procedure.
3. Low power in frequency used for measurement	Use power meter, if available, and polarizer and check relative power of horizontal and vertical polarization.*	Rotate interferometer 90 degrees and look for increase in test point voltage.
4. 10780A Malfunction, cable intermittent, or 10760A malfunction.	Look at output signal from 10780 and input of 10760	Troubleshoot appropriate component

**Use laser power meter filtered for 6328 Angstroms (e.g. United Detector Technology #40X meter (w/filter)).*

Table 6-1. *HP-IB Interface Electronics System Troubleshooting (Cont'd)*

DATA ERRORS

Incorrect display or printout results when the measurement optics are displaced a known distance:

SYMPTOM	CAUSE	ACTION
No movement indicated on all measurement axes.	Coupler interface card not placing instructions on coupler backplane.	1. 10745: check HP-IB address 2. Replace or troubleshoot 10745, or I/O from coupler to controller.
System malfunctions in extended resolution (e.g., laser readings are 6 or 10 times greater or less than known measured distance)	1. 10760A counter fails to receive extended resolution command or resolution circuitry is malfunctioning. 2. 10760A resolution jumpers are incorrectly set	1. Using logic probe, verify 10760A receives extended resolution command. (U47 (9) on 10760 should be a TTL high if in extended resolution) 2. If command not received, check proper command decoder output on 10760 with logic probe. 3. Replace interface card. 4. If command received, verify 10760A is correctly jumpered for desired resolution. 5. Replace 10760A card.
No movement indicated on one but not all axes.	10760A Malfunction	If possible, substitute 10760A from other axis.

Table 6-1. HP-IB Interface Electronics System Troubleshooting (Cont'd)

DATA ERRORS (Cont'd)

SYMPTOM	CAUSE	ACTION
Error in displayed reading is less than one part in 100,000 and is evident on all measurement axes.	1. Compensation circuitry malfunction	1. Check output of compensation circuitry.
Laser system reads a shorter distance than the known movement of the optics.	Misalignment of the optics resulting in cosine error.	2. If Comp. number correct, check for cosine error in optical alignment (Refer to Section II, Laser and Optics). 3. If Comp. number incorrect, replace 10755. If using 5510, check BCD inputs to 10755 using logic probe and verify correct Comp. number is being input.
Error in displayed reading that is less than one part in 100,000 and is evident on a single measurement axis.	1. 10760A Malfunction.	1. Troubleshoot or replace 10760A
	2. Cosine error in optical alignment	2. Align optics (Section II)
	3. 10780A Saturation	3. Adjust 10780A (Refer to 10780A Manual)

ERROR DETECTION

4. If an error indication does not occur when the laser beam is interrupted in a measurement axis:
   a) Check LED indicator on associated 10780A receiver. If it extinguishes when beam is interrupted, proceed to step b. If it remains on when beam is interrupted,
      1. Monitor 10780A test point on back of receiver. If voltage is greater than 1.1V dc, refer to 10780A manual to reduce receiver gain.
      2. If voltage is in limits, check for incorrect rotation of optics or receiver (refer to Section II).
      3. If problem continues, troubleshoot or replace 10780A receiver.
   b) If error does not register on any measurement axis, check, replace or troubleshoot system interface card (10745).
   c) If error does not register on one measurement axis only, replace or troubleshoot the associated 10760A card.

Table 6-2. Binary Controlled Counter Interface Electronics Systems Troubleshooting

PRELIMINARY PROCEDURE

1. If the laser head does not emit red light, check that the rear-panel POWER ON light is lit. If it is not, check for a power line short. This can cause the power supply to current limit and reduce the voltage output level to near zero volts. Also check for an open circuit in the power supply wiring. If the POWER ON light is lit, check the status of the four rear-panel indicators associated with the ±15-volt supplies (two UNBAL indicators and two FUSE indicators). If power is available to the laser head but the head does not emit red light, refer to the separate manual for the laser head for further troubleshooting information.
2. If the LED indicator on one of the system receivers does not light, verify that the +15 volts is present at the system cable connector for the receiver. If it is not, troubleshoot the power supply and the system wiring. If voltage is present at the receiver connector and the LED is not lit, refer to the separate manual for the receiver for further troubleshooting information.

INSTALLATION AND ALIGNMENT OF LASER HEAD, RECEIVER, AND OPTICS PROCEDURE

1. If the laser head does not emit red light, check that the rear-panel POWER ON light is lit. If it is not, check for a power line short. This can cause the power supply to current limit and reduce the voltage output level to near zero volts. Also check for an open circuit in the power supply wiring. If the POWER ON light is lit, check the status of the four rear-panel indicators associated with the ±15-volt supplies (two UNBAL indicators and two FUSE indicators). If power is available to the laser head but the head does not emit red light, refer to the separate manual for the laser head for further troubleshooting information.
2. If the LED indicator on one of the system receivers does not light, verify that the +15 volts is present at the system cable connector for the receiver. If it is not, troubleshoot the power supply and the system wiring. If voltage is present at the receiver connector and the LED is not lit, check optics and alignment (refer to Section II).

ELECTRONIC INSTALLATION PROCEDURE

1. If +15 volts is not present at the 10740A Coupler rear panel, check power wiring for a short or open circuit. Also check the output of the power supply with the cables disconnected.
2. If the reference or measurement LED indicators on the 10760A Counter cards do not all light when power is applied, verify presence of reference signal from laser head and measurement signal from each receiver. If either signal is not present, troubleshoot the laser head or associated receiver. If the signals are present, troubleshoot the associated 10760A Counter card. Counter cards can be interchanged at this point to verify trouble source.
3. If +5-volt power is not available after connecting 10783A Numeric Displays, check power wiring and display itself for short or open circuits.

Table 6-2. Binary Controlled Counter Interface Electronics Systems Troubleshooting (Cont'd)

CHECKOUT PROCEDURE

REQUIRED TEST EQUIPMENT	
INSTRUMENT TYPE	REQUIRED CHARACTERISTICS
Digital Voltmeter	Range: −15V to +15V ± .01V dc
Logic Probe	TTL Level
Oscilloscope	Ability to display signals between dc and 20 MHz.
Individual circuit card operating and service manuals	

MULTI-AXIS PROBLEM

1. If the same problem exists on all axes, check the following possible error sources:
   a) Check user software (refer to Section IV Programming, for example program).
   b) Check instruction sequence timing (refer to 10746 manual).
   c) Check temperature in coupler environment.

COUPLER TEMPERATURE	SYMPTOMS	ACTION
0° to 55°C	None—electronics should operate as described.	None
Out of range	Counters may jump or count erratically	Ventilate enclosure

   d) Check voltage on each coupler card.

LOCATION	VOLTAGE
+5V Front-edge test point	At least +5V ± .01V on each card.

Table 6-2. Binary Controlled Counter Interface Electronics Systems Troubleshooting (Cont'd)

e) 10746 Binary Interface card.

SYMPTOM	POSSIBLE PROBLEM	ACTION
Data LED does not light when controller sends command to transfer data	1. User software	Refer to Section IV for instruction sequence.
	2. I/O cabling	Verify proper connections and no shorting.
	3. Controller malfunction	Run controller diagnostic
	4. 10746 malfunction	Replace or troubleshoot 10746.

f) Check I/O cabling from controller to coupler.

g) If all the reference or measurement LED indicators on 10760A counter cards do not light when power is applied:

ACTION	LOCATION	RESULT	SUBSEQUENT ACTION
Verify presence of reference and measurement signals with oscilloscope. Signals are square waves	10760A front-edge	Signal present	If LED is extinguished, troubleshoot 10760A
	Measurement Signal: Pins 18, 20	Signal absent	Troubleshoot receiver or cabling.
	Reference: pins 22, 24	Signal present	If LED extinguished, troubleshoot 10760A
		Signal absent	Troubleshoot laser head or cabling.

PROBLEM EXISTS BUT NOT ON ALL AXES

2. If the system is multi-axis but the problem is not present on all axes, substitute known good components to isolate the problem system component. The following may also apply:

a) Check user software (refer to Section IV for example program).

b) Check voltage on each coupler card.

LOCATION	VOLTAGE
+5V Front-edge test point	At least +5V ± .01V on each card.

Table 6-2. Binary Controlled Counter Interface Electronics Systems Troubleshooting (Cont'd)

c) Intermittent measurement signal on one or more measurement axes may indicate:

CAUSE	CHECK	ACTION
1. Misalignment of optical components	Reduce beam size by rotating to small aperature on laser head. Place alignment target on receiver lens. Move optics along entire measurement path and verify both return beams overlap on the target along the entire length of movement.	If optics are misaligned and beams do not overlap, refer to Section II for alignment procedure.
2. Misadjustment of 10780A Receiver gain	Monitor 10780A test point on back of receiver, voltage should lie in range 0.5–1.0V dc. If voltage >1.1V, receiver could be saturated. If voltage <.02V, gain may be too low.	Refer to 10780A manual for adjustment procedure.
3. Low power in frequency used for measurement	Use power meter, if available, and polarizer and check relative power of horizontal and vertical polarization.*	Rotate interferometer 90 degrees and look for increase in test point voltage.
4. 10780A malfunction, cable intermittent, or 10760A malfunction	Look at output signal from 10780 and input to 10760.	Troubleshoot appropriate component.

**Use laser power meter filtered for 6328 Angstroms*
(e.g. United Detector Technology #40X meter (w/filter))

Table 6-2. Binary Controlled Counter Interface Electronics Systems Troubleshooting (Cont'd)

DATA ERRORS

3. Incorrect display or printout results when the measurement optics are displaced a known distance:

SYMPTOM	CAUSE	ACTION
No movement indicated on all measurement axes	Coupler interface card not placing instructions on coupler backplane	1. Replace or troubleshoot 10746, or I/O from coupler to controller.
System malfunctions in extended resolution. (e.g., laser readings are 6 or 10 times greater or less than known measured distance)	10760A counter fails to receive extended resolution command or resolution circuitry is malfunctioning. Can also be software error.	1. Using logic probe, verify 10760A is receiving extended resolution command (U47 (9) on 10760 should be a TTL high if in extended resolution). 2. If command not received, check proper command decoder output on 10760 with logic probe. 3. Replace interface card. 4. If command received verify 10760A is correctly jumpered for desired resolution. 5. Replace 10760A card.
Correct position data is output but in the wrong format. (i.e. least significant data sent in the first data word transmitted.	1. Incorrect grounding.	See Section V for grounding considerations.
	2. Incorrect I/O cabling.	Check I/O cabling.
No movement indicated on one but not all axes.	10760A malfunction	If possible, substitute 10760A from other axis.

Table 6-2. Binary Controlled Counter Interface Electronics Systems Troubleshooting (Cont'd)

DATA ERRORS (Cont'd)

SYMPTOM	CAUSE	ACTION
Error in displayed reading, error is less than one part in 100,000, and is evident on all measurement axes.	1. Compensation circuitry malfunction 2. Software error	1. Check output of compensation circuit by using program that continually outputs the number. (Refer to Section IV.) 2. If compensation number correct, check for cosine error in optical alignment. (Refer to Section II.) 3. If compensation number is incorrect, replace 10755. If using 5510, check BCD inputs to 10755 using logic probe and verify that correct compensation number is being input. 4. Check software conversion routine.
Laser system reads a shorter distance than the known displacement of the optics.	Misalignment of the optics resulting in cosine error.	
An error results in the displayed reading that is less than one part in 100,000 and is evident on a single measurement axis.	1. 10760A Malfunction	1. Troubleshoot or replace 10760A.
	2. Software error	2. Check software.
	3. Cosine error in optical alignment.	3. Align optics (Section II)
	4. 10780A saturation.	4. Adjust 10780A (Refer to 10780A manual)

ERROR DETECTION

4. If an error indication does not occur when the laser beam is interrupted in a measurement axis:
   a) Check LED indicator on associated 10780A receiver. If it extinguishes when beam is interrupted, proceed to step b. If it remains on when beam is interrupted,
      1. Monitor 10780A test point on back of receiver. If voltage is greater than 1.1V dc, refer to 10780A manual to reduce receiver gain.
      2. If voltage is in limits, check for incorrect rotation of optics or receiver (refer to Section II).
      3. If problem continues, troubleshoot or replace 10780A receiver.
   b) If error does not register on any measurement axis, check, replace, or troubleshoot system interface card (10746).
   c) If error does not register on one measurement axis only, replace or troubleshoot the associated 10760A card.

Table 6-3. Binary Controlled Comparator-Based Systems Troubleshooting

PRELIMINARY PROCEDURE

1. If the laser head does not emit red light, check that the rear-panel POWER ON light is lit. If it is not, check for a power line short. This can cause the power supply to current limit and reduce the voltage output level to near zero volts. Also, check for an open circuit in the power supply wiring. If the POWER ON light is lit, check the status of the four rear-panel indicators associated with the ±15-volt supplies (two UNBAL indicators and two FUSE indicators). If power is available to the laser head but the head does not emit red light, refer to the separate manual for the laser head for further troubleshooting information.
2. If the LED indicator on one of the system receivers does not light, verify that the +15 volts is present at the system cable connector for the receiver. If it is not, troubleshoot the power supply and the system wiring. If voltage is present at the receiver connector and the LED is not lit, refer to the separate manual for the receiver for further troubleshooting information.

INSTALLATION AND ALIGNMENT OF LASER HEAD, RECEIVER, AND OPTICS PROCEDURE

1. If the laser head does not emit red light, check that the rear-panel POWER ON light is lit. If it is not, check for a power line short. This can cause the power supply to current limit and reduce the voltage output level to near zero volts. Also check for an open circuit in the power supply wiring. If the POWER ON light is lit, check the status of the four rear-panel indicators associated with the ±15-volt supplies (two UNBAL indicators and two FUSE indicators). If power is available to the laser head but the head does not emit red light, refer to the separate manual for the laser head for further troubleshooting information.
2. If the LED indicator on one of the system receivers does not light, verify that the +15 volts is present at the system cable connector for the receiver. If it is not, troubleshoot the power supply and the system wiring. If voltage is present at the receiver connector and the LED is not lit, check optics and alignment (refer to Section II).

ELECTRONIC INSTALLATION PROCEDURE

1. If +15 volts is not present at the 10740A Coupler rear panel, check power wiring for a short or open circuit. Also check the output of the power supply with the cables disconnected.
2. If reference LED does not light on the 10764B Fast Pulse Converter card, check for presence of reference signal from laser head and, if the signal is present, replace or troubleshoot the 10764B card. If measurement LED does not light, check for the measurement signal from the associated receiver. If the signal is present, replace or troubleshoot the 10764B card. If either signal is not present, troubleshoot the associated unit.

Table 6-2. Binary Controlled Counter Interface Electronics Systems Troubleshooting (Cont'd)

CHECKOUT PROCEDURE

REQUIRED TEST EQUIPMENT	
INSTRUMENT TYPE	REQUIRED CHARACTERISTICS
Digital Voltmeter	Range: −15V to +15V ± .01V dc
Logic Probe	TTL Level
Oscilloscope	Ability to display signals between dc and 20 MHz
Individual Circuit Card Operating and Service Manuals	

MULTI-AXIS PROBLEM

1. If same problem exists on all axes, check the following possible error sources:

a) Check temperature in the coupler environment.

COUPLER TEMPERATURE	SYMPTOMS	ACTION
0° to 40°C	None — Electronics should operate as described	None
Out of range	Counters may jump or count erratically	Ventilate enclosure

b) Check voltage on each coupler card.

LOCATION	VOLTAGE
+5V Front-edge test point	At least +5V ± .01V on each card.

c) Check user software (Refer to Section IV for example Comparator Program.)

d) Check instruction sequence timing (Refer to 10746 manual.)

e) 10746A Binary Interface Card

SYMPTOM	POSSIBLE PROBLEM	ACTION
Data LED does not light when controller sends command to transfer data	1. User software	Refer to Section IV for instruction sequence.
	2. I/O Cabling	Verify proper connections and no shorting.
In normal operation, Data LED is dimly lit (If sampling continuously.)	3. Controller malfunction	Run controller diagnostic.
	4. 10746A Malfunction.	Replace or Troubleshoot 10746A.

Table 6-3. *Binary Controlled Comparator-Based System Troubleshooting (Cont'd)*

f) If reference or measurement LED indicators on the 10764B Fast Pulse Converter do not all light when power is applied.

ACTION	LOCATION	ACTION
Verify presence of measurement and reference signals with oscilloscope (These signals are square waves.)	10764B front edge.	Measurement or reference present: troubleshoot 10764B
	Measurement 1: pins 18, 20 Measurement 2: pins 14, 16	Measurement absent: Troubleshoot respective receiver and cabling
	Reference: pins 22, 24	Reference absent: troubleshoot laser head and cabling.

g) If system does not move to correct destination:

CHECK	LOCATION
1. Compatibility of DAC with output signal from 10762A.	DAC
2. Software for proper conversion of data word containing tolerance and destination.	Software
3. Destination address is being loaded on 10762A card.	Check output of destination register on 10762A card. Data is in binary form and is negative-true. It can be checked with a TTL level logic probe. (See following example.)

Table 6-3. *Binary Controlled Comparator-Based System Troubleshooting (Cont'd)*

Example: In a system using metric units:
Destination = 2mm
Tolerance = 3 micrometers (.000003 meter)

DESTINATION AND TOLERANCE NUMBER SENT TO COMPARATOR (Binary form) FROM CALCULATOR
00 10 00 00 00 00 00 00 00 11 00 10 00 00 10 11

NUMBER PRESENT AT DESTINATION AND TOLERANCE REGISTER OUTPUT ON 10762A							
U68 11 01	U61 11 11	U62 11 11	U63 11 11	U64 11 00	U65 11 01	U66 11 11	U67 01 00

Tolerance Register Output

Destination Register Output
(See schematic for pin numbers)

Bit: 32 → 0

PROBLEM EXISTS BUT NOT ON ALL AXES

2. If the system is multi-axis but the problem is not present on all axes, substitute known good components to isolate the problem system component. The following may also apply:

   a) Check user software. (Refer to Section IV for example program.)

   b) Check voltage on each coupler card.

LOCATION	VOLTAGE
+5V Front-edge test point	At least +5V ± .01V on each card.

Table 6-3. Binary Controlled Comparator-Based System Troubleshooting (Cont'd)

c) Check indicator LEDs on the 10762A Comparator card.

d) Intermittent measurement signal on one or more measurement axes may indicate:

CAUSE	CHECK	ACTION
1. Misalignment of optical components	Reduce beam size by rotating to small aperature on laser head. Place alignment target on receiver lens. Move optics along entire measurement path and verify both return beams overlap on the target along the entire length of movement.	If optics are misaligned and beams do not overlap, refer to Section II for alignment procedure.
2. Misadjustment of 10780A Receiver Gain	Monitor 10780A test point on back of receiver, voltage should lie in range 0.5 – 1.0V dc. If voltage >1.1V, receiver could be saturated. If voltage <.02V, gain may be too low.	Refer to 10780A manual for adjustment procedure.
3. Low power in frequency used for measurement	Use power meter, if available, and measure relative power of horizontal and vertical polarization.*	Rotate interferometer 90 degrees and look for increase in test point voltage.
4. 10780A malfunction, cable intermittent, or 10764B malfunction	Look at output signal from 10780 and input of fast pulse converter 10764B.	Troubleshoot appropriate component

*Use laser power meter filtered for 6328 Angstroms (e.g., United Detector Technology #40X Meter (w/filter)).

Table 6-3. *Binary Controlled Comparator-Based System Troubleshooting (Cont'd)*

DATA ERRORS

3. If the problem appears to be data related, check the following for the source of error:

SYMPTOM	CAUSE	ACTION
No movement indicated on all measurement axes.	10746A malfunction: coupler interface not placing instructions on backplane.	Replace or troubleshoot 10746A, or I/O cable.
System will not move to desired location.	1. 10746A Malfunction	Troubleshoot 10746A
	2. Destination not being correctly converted in program or command sequence incorrect.	Check user software.
	3. 10762A Malfunction	Troubleshoot 10762A
System malfunctions in extended resolution	10764B Malfunction (Jumpers and switches may be set incorrectly.)	10764B: verify proper switch settings on card. Repair if problem remains.
Correct position data is output but in wrong format (i.e. least significant data being sent in first word transmitted)	1. Improper system grounding	1. See Section V for grounding considerations
	2. Incorrect I/O cabling	2. Check I/O cabling.
DAC output is incorrect by a small amount on all axes of movement	1. Compensation Circuitry 2. Optical misalignment	1. Write program to continually output compensation (Comp) data. 2. If Comp number correct, check for cosine error in optical alignment (refer to Section II). 3. If Comp number incorrect, replace 10755. If using 5510, check BCD inputs to 10755 using logic probe and verify correct Comp number is being output.

Table 6-3. Binary Controlled Comparator-Based System Troubleshooting (Cont'd)

DATA ERRORS (Cont'd)

SYMPTOM	CAUSE	ACTION
Small measurement errors occurring on one positioning axis	1. 10762A Malfunction	1. Substitute 10762A from another axis.
	2. Optical misalignment	2. Check for cosine error (Refer to Section II).
	3. Receiver Saturation	3. See 10780A Manual for adjustment
Error in displayed reading, error is less than one part in 100,000, and is evident on all axes	1. Compensation circuitry 2. Software error 3. Optical misalignment	1. Refer to "action" for DAC errors. 2. Check software.
Incorrect laser position feedback when system is at null. (Position data is incorrect by a large amount.)	Controller reading status bits as data	1. Write routine in software for null detection. 2. If position must be read at null, clear error bits through software and then sample.
Laser System reads a shorter distance than the known displacement of the optics.	Optical misalignment resulting in cosine error	Refer to Section II for alignment procedure.

4. If an error does not occur when the laser beam is interrupted in a measurement axis:
   a) Check LED indicator on associated 10780A Receiver. If it extinguishes when beam is interrupted, proceed to step b. If it remains on when beam is interrupted,
      1. Monitor 10780A test point on back of receiver. If voltage is greater than 1.1V dc, refer to 10780A manual to reduce receiver gain.
      2. If voltage is in limits, check for incorrect rotation of optics or receiver (refer to Section II).
      3. If problem continues, troubleshoot or replace 10780A receiver.
   b) If error does not register on any measurement axis, check, replace, or troubleshoot system interface card (10746A).
   c) If error does not register on one measurement axis only, replace or troubleshoot the associated 10746B fast pulse converter and/or 10762A comparator.
   d) Check user software for correct error checking routine (refer to Section IV).

Table 6-4. English/Metric Pulse Output Electronics System Troubleshooting

PRELIMINARY PROCEDURE

1. If the laser head does not emit red light, check that the rear-panel POWER ON light is lit. If it is not, check for a power line short. This can cause the power supply to current limit and reduce the voltage output level to near zero volts. Also check for an open circuit in the power supply wiring. If the POWER ON light is lit, check the status of the four rear-panel indicators associated with the ±15-volt supplies (two UNBAL indicators and two FUSE indicators). If power is available to the laser head but the head does not emit red light, refer to the separate manual for the laser head for further troubleshooting information.
2. If the LED indicator on one of the system receivers does not light, verify that the +15 volts is present at the system cable connector for the receiver. If it is not, troubleshoot the power supply and the system wiring. If voltage is present at the receiver connector and the LED is not lit, refer to the separate manual for the receiver for further troubleshooting information.

INSTALLATION AND ALIGNMENT OF LASER HEAD, RECEIVER, AND OPTICS PROCEDURE

1. If the laser head does not emit red light, check that the rear-panel POWER ON light is lit. If it is not, check for a power line short. This can cause the power supply to current limit and reduce the voltage output level to near zero volts. Also check for an open circuit in the power supply wiring. If the POWER ON light is lit, check the status of the four rear-panel indicators associated with the ±15-volt supplies (two UNBAL indicators and two FUSE indicators). If power is available to the laser head but the head does not emit red light, refer to the separate manual for the laser head for further troubleshooting information.
2. If the LED indicator on one of the system receivers does not light, verify that the +15 volts is present at the system cable connector for the receiver. If it is not, troubleshoot the power supply and the system wiring. If voltage is present at the receiver connector and the LED is not lit, check optics and alignment (refer to Section II).

ELECTRONIC INSTALLATION PROCEDURE

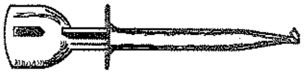
1. If +5 volts is not present at the 10740A Coupler rear panel, check power wiring for a short or open circuit. Also check the output of the power supply with the cables disconnected.
2. If the reference or measurement LED indicators on the 10760A Counter cards do not all light when power is applied, verify presence of reference signal from laser head and measurement signal from each receiver. If either signal is not present, troubleshoot the laser head, associated receiver, or optics (refer to Section II). If the signals are present, troubleshoot the associated 10760A Counter card. Counter cards can be interchanged at this point to verify trouble source.
3. If the + or -15V dc power source supplies a small voltage (near zero volts) check for a short circuit in the 10740A Coupler or on the 10755A Compensation Interface card.

Table 6-4. English/Metric Pulse Output Electronics System Troubleshooting (Cont'd)

CHECKOUT PROCEDURE

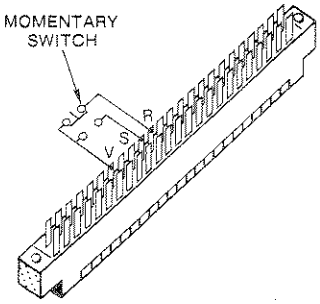
REQUIRED TEST EQUIPMENT	
INSTRUMENT TYPE	REQUIRED CHARACTERISTICS
Digital Voltmeter	Range: −15V to +15V ± .01V dc
Logic Probe	TTL Level
Oscilloscope	Ability to display signals between dc and 20 MHz
Frequency Counter	Totalizing Capability (e.g. HP 5301, 5328)
"E-Z mini hook"*	Used for test purposes to activate output circuitry
Test Fixture (Front-edge)**	Capable of sending "Start" pulses
Individual circuit card operating and service manuals.	

**E-Z mini test hook*



***Test Fixture — To fit on front-edge of 10763A English/Metric card for testing purposes. (To be constructed by user).*

Parts: 48-pin connector (e.g. HP P/N 1251-0335)
Momentary switch, SPDT (e.g. HP P/N 3101-1261)



The switch sends a "Start" pulse to activate the electronics and initialize the system.

The switch should be wired so that pins S&V are shorted when the switch is pushed. Pins R&V should be shorted when switch is at rest.

Laser Coupler Cards: The minimum number of circuit cards in the coupler are as follows:

(1) 10763A English/Metric
(1) 10760A General Purpose Counter
(1) 10761A Binary Multiplier
(1) 10755A Compensation Interface
(1) 10756A Manual Compensator

Table 6-4. English/Metric Pulse Output Electronics System Troubleshooting (Cont'd)

MULTI-AXIS PROBLEM

1. If same problem exists on all axes, check the following possible error sources:
   a) System does not work (control LED's on the 10763A's should be dimly lit when system is cycling).

SYMPTOM	CAUSE	ACTION
Upon sending "start" pulse system does not start.	1. "Start" circuitry malfunction	1. Check wiring of switch to send "start" pulse.
Must send a start pulse!	2. Control not passed between 10763A cards (apparent by control LED lit on only "master" card.) 3. Large deadpath will result in long initialization cycle (>20 seconds). Each 10763A must initialize its own axis before it passes control to another 10763A.	2. Check switch and jumper settings on 10763A card. (Should correspond to table 5-2, Section V.) 3. Check OPC line on backplane (see Table 4-1, Section IV), using TTL Logic Probe. This line should be cycling high and low. 4. If OPC is cycling properly, problem is probably a defective 10763A. 5. If OPC is not cycling properly, problem can be a defective 10760A.
Overflow error is flagged after moving the optics a short distance in the positive direction.	10760A counters trying to count in wrong direction (negatively)	Switch normal/reverse jumper on 10760A card.
Laser not providing feedback information to the controller. (Indicated by the controller not appearing to receive data from the laser electronics.)	1. System not starting (see previous page). 2. Controller not recognizing output pulses from electronics.	1. Disconnect controller and hook up freq. counter. (See Table 6-4a, 6-4b) 2. Jumper 10763 for testing (See table 6-4c). 3. Look at output pulse count. (See test a).

Table 6-4. *English/Metric Pulse Output Electronics System Troubleshooting (Cont'd)*

b) Check system grounding (see Section V).

c) Check temperature in the coupler environment.

COUPLER TEMPERATURE	SYMPTOMS	ACTION
0° to 55°C	None—Electronics should work as described.	None
Out of range	Counters may jump or count erratically	Ventilate enclosure

d) Check voltage on each circuit card in the coupler.

LOCATION	VOLTAGE
+5V Front-edge test point	At least +5V ± .01V on each card.

e) If all reference or measurement LED indicators on the 10760A counter cards do not light when power is applied:

ACTION	LOCATION	RESULT	SUBSEQUENT ACTION
Verify presence of reference and measurement signals with oscilloscope These signals are square waves.	10760A Front-edge Measurement: signal pins 18, 20	Signal present	If LED is extinguished, troubleshoot 10760A.
		Signal absent	Troubleshoot receiver or cabling.
	Reference: signal pins 22, 24	Signal present	If LED is extinguished, troubleshoot 10760A.
		Signal absent	Troubleshoot laser head or cabling.

If multi-axis system, 10760A counter cards can be interchanged to isolate problem. (Remember to change card address.)

PROBLEM EXISTS BUT NOT ON ALL AXES

2. If the system is multi-axis but the problem is not present on all axes, substitute known good components to isolate the problem system component. The following may also apply:

a) Check 10763A switches and jumpers (refer to Section V, Table 5-2).

b) Check voltage on each coupler card

LOCATION	VOLTAGE
+5V front-edge test point	At least +5V ± .01V on each card.

Table 6-4. English/Metric Pulse Output Electronics System Troubleshooting (Cont'd)

c) Intermittent measurement signal on one or more measurement axes may indicate:

CAUSE	CHECK	ACTION
1. Misalignment of optical components	Reduce beam size by rotating to small aperature on laser head. Place alignment target on receiver lens. Move optics along entire measurement path and verify both return beams overlap on the target along the entire length of movement.	If optics are misaligned and beams do not overlap, refer to Section II for alignment procedure.
2. Misadjustment of 10780A receiver gain	Monitor 10780A test point on back of receiver, voltage should lie in range 0.5 – 1.0V dc. If voltage >1.1V, receiver could be saturated. If voltage <0.2V, gain may be too low.	Refer to 10780A manual for adjustment procedure.
3. Low power in frequency used for measurement	Use power meter, if available, and polarizer and check relative power of horizontal and vertical polarization.*	Rotate interferometer 90 degrees and look for increase in test point voltage.
4. 10780A malfunction, cable intermittent, or 10760A malfunction.	Look at output signal from 10780 and input of 10760.	Troubleshoot appropriate component

Use laser power meter filtered for 6328 Angstroms (e.g. United Detector Technology #40X meter (w/filter)).

Table 6-4. English/Metric Pulse Output Electronics System Troubleshooting (Cont'd)

DATA ERRORS

3. Incorrect display or printout results when the measurement optics are displaced a known distance :

SYMPTOM	CAUSE	ACTION
No movement indicated on all axes	1. "Start" pulse not being sent.	See "Multi-Axis problem."
	2. 10763A jumpered incorrectly	Check Table 5-2
	3. Controller not recognizing output pulses from laser electronics.	1. Use totalizing frequency counter (Table 6-4a, 6-4b). 2. Jumper 10763A's as per Tables 6-4c, 6-4d. 3. Send "start" pulse to each 10763A and verify correct number of output pulses (Test a). 4. If counts are incorrect, see Test b, c, d.
System malfunctions in extended resolution	1. 10760A Counter fails to receive extended resolution command or resolution circuitry is malfunctioning.	1. Using logic probe verify 10760A received extended resolution command. (U47 (9) on 10760 should be a TTL high if in extended resolution).
(e.g. Laser readings are 6 or 10 times greater or less than a known measured distance)	2. Resolution jumpers on 10760A not correctly set.	2. If command not received, check proper command decoder output on 10760 with logic probe. 3. If command is received, verify 10760A is correctly jumpered for desired resolution. 4. Replace 10760A.
No movement indicated on one but not all axes.	1. 10760A Malfunction.	1. Substitute 10760A from other axis.
	2. 10763A Malfunction.	2. See Test a.

Table 6-4. English/Metric Pulse Output Electronics System Troubleshooting (Cont'd)

DATA ERRORS (Cont'd)

SYMPTOM	CAUSE	ACTION
Error in displayed reading, error is less than one part in 100,000 and is evident on all measurement axes.	Compensation circuitry malfunction	1. Check output of compensation circuitry by performing Test b. 2. If compensation number correct, check for cosine error in optical alignment (refer to Section II).
Laser System reads a shorter distance than a known displacement of the optics.	Misalignment of the optics resulting in cosine error.	
		3. If Comp. number incorrect, replace 10755. If using 5510, check BCD inputs to 10755 using logic probe and verify correct Comp. number is being input. 4. See Section II for optical alignment procedure.
Small error one measurement axis (Error is less than one part in 100,000.)	1. 10763A malfunction.	See Test a
	2. 10760A malfunction.	Troubleshoot or replace 10760A.
	3. Cosine error in optical alignment (If laser reads shorter than known displacement.)	Align optics (See Section II)
	4. 10780A Saturation	Adjust 10780A (Refer to 10780A Manual.)

ERROR DETECTION

4. If an error indication does not occur when the laser beam is interrupted in a measurement axis:
   a) Check LED indicator on associated 10780A receiver. If it extinguishes when beam is interrupted, proceed to step b. If it remains on when beam is interrupted,
      1. Monitor 10780A test point on back of receiver. If voltage is greater than 1.1V dc, refer to 10780A manual to reduce receiver gain.
      2. If voltage is in limits, check for incorrect rotation of optics or receiver (refer to Section II).

Table 6-4. English/Metric Pulse Output Electronics System Troubleshooting (Cont'd)

3. If problem continues, troubleshoot or replace 10780A receiver.

b) If the error does not register on one measurement axis only, replace or troubleshoot the associated 10760A card.

c) If the controller does not recognize an error occurring on any axis, verify the error output lines from the coupler are being monitored by the controller. The error line is an output from the 10763A.

FREQUENCY COUNTER

Table 6-4a: 5300/5301 Control Settings for Coupler Operation Verification

SET FRONT PANEL CONTROLS AS FOLLOWS:	
GATE	OPEN
WAVEFORM	⎍
COUNTER INPUT LINE	CONNECT TO PIN 4 ON FRONT-EDGE TEST FIXTURE
GROUND FROM INPUT BNC	CONNECT TO PIN 18 ON FRONT-EDGE TEST FIXTURE
SAMPLE RATE	HOLD

Table 6-4b: 5328 Universal Counter Settings

SET FRONT PANEL CONTROLS AS FOLLOWS:	
FUNCTION	START A
FREQ. RESOLUTION/N	1 MHz, 1
SAMPLE RATE	HOLD
(Use channel A input)	
COUNTER INPUT LINE	CONNECT TO PIN 4 ON FRONT-EDGE TEST FIXTURE
GROUND FROM INPUT BNC	CONNECT TO PIN 18 ON FRONT-EDGE TEST FIXTURE
SLOPE	+
AC/DC	DC
ATTEN	1
LEVEL A	ADJUST TOWARD + SO THAT THE COUNTER DISPLAY STABILIZES (NO COUNTING SHOULD TAKE PLACE IF LEVEL IS INCREASED.)
SEP/COM A	SEP

Table 6-4. *English/Metric Pulse Output Electronics System Troubleshooting (Cont'd)*

Table 6-4c: 10763 Initial Jumper and Switch Settings (Single-axis)

SET CARD AS FOLLOWS:	
AXIS SELECT	X
DEADPATH	0 (All switches down)
WEIGHT	1 (All switches down)
AXES	FIRST SWITCH DOWN, ALL OTHERS UP
PULSES	UP/DOWN
RUN/TEST	TEST
OUTPUT PULSE RATE	1.6MHZ
ERR/STOP/GO	GO

INCH	JUMPER IN

NOR	JUMPER IN
FIRST	JUMPER REMOVED
--- ----	
ONE AXIS	JUMPER REMOVED

Table 6-4d: 10763 Initial Jumper and Switch Settings (Multi-Axis)

CARDS SHOULD BE SET AS ABOVE WITH THE FOLLOWING EXCEPTIONS		
	X-AXIS	Y-AXIS
AXIS SELECT	X	Y
AXES: THIS AXIS	X	Y
NEXT AXIS	ALL SWITCHES UP	ALL SWITCHES UP

Switch settings are similar for more than two axes.

MULTIPLE-AXIS TEST INSTRUCTIONS

With 10763 cards jumpered correctly, the system can be initialized for testing by sending a "start" pulse to the front edge of each 10763 card by physically moving the test fixture to each card and applying the pulse. Each successive "start" pulse should result in the preset number of counts being sent from the card and detected by the frequency counter.

TEST A: 10763 OUTPUT COUNT CHECK

In this test, the deadpath switches should be changed one at a time and the output counts compared with those given in the table. A "start" pulse must be sent each time a deadpath switch is set and the counter must be reset before the pulse is sent.

Check for the following:

- 10763 jumpered as per table 6-4c
- 000.0 dialed in 10756 thumbwheels
- deadpath switches numbered as shown:

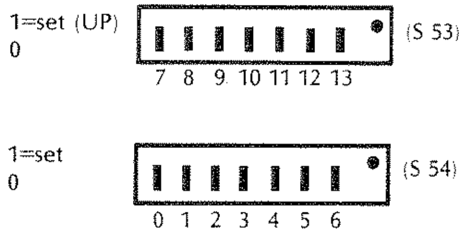


Table 6-4e: 10763A Pulse Output Check

DEADPATH SWITCH SET (UP) (Only Switch Set)	ENGLISH UNITS		METRIC UNITS (inch jumper removed)	
	1.6MHz output	800kHz output	1.6MHz output	800kHz output
–*	175 ± 10	260 ± 10	440 ± 10	655 ± 15
0	5280 ± 15	10460 ± 10	13395 ± 20	26536 ± 40
1	10372 ± 15	20655 ± 15	26350 ± 10	52465 ± 40
2	20577 ± 15	41045 ± 40	52267 ± 20	104280 ± 50
3	40980 ± 15	81860 ± 50	104090 ± 50	207850 ± 70
4	81790 ± 20	163455 ± 50	207740 ± 50	415180 ± 100
5	163340 ± 150	326725 ± 50	414953 ± 70	829300 ± 500
6	326360 ± 300	653185 ± 100	829620 ± 120	

*(all switches down)

A-QUAD-B OUTPUT COUNT CHECK

Jumper 10763 for A-Quad-B output pulses. The number of counts detected by the frequency counter can then be multiplied by four to obtain the total number of representative A-Quad-B output counts.

Table 6-4. English/Metric Pulse Output Electronics System Troubleshooting (Cont'd)

Example:

With no deadpath switches set (all switches down), the frequency counter should detect the following counts:

English Units (Compare with chart above)

1.6 MHz output	800 kHz output
44 [176]	65 [260]

(Number in brackets represents total equivalent A-Quad-B counts output from 10763.)

TEST B: 10755 COMPENSATION INTERFACE TEST

Equipment needed: logic clip or logic probe
10756 manual compensator

Test procedure: Dial in thumbwheel setting on chart
Press update
Tie U2 (11) and U2 (8) to ground, using E-Z mini test hook or equivalent (to enable tri-state output buffers)
Compare signal levels with those given on chart (Table 6-4f)
If signal levels do not correspond, check BCD input lines (Table 6-4g)

Table 6-4f: Compensation Interface Output

THUMBWHEEL SWITCH SETTING	OUTPUT LINES															
	U8						U12						U16			
	pins						pins						pins			
	7	5	3	9	11	13	5	7	3	9	13	11	3	5	9	7
000.0	0	1	1	0	1	1	1	1	0	1	1	1	0	0	0	0
876.5	1	0	0	1	0	0	0	1	1	0	1	0	1	1	0	1
212.1	0	1	1	1	0	1	1	1	1	0	1	1	1	0	0	1

Table 6-4g: Compensation Interface Input

THUMBWHEEL SWITCH SETTINGS	INPUT LINES															
	U17				U13				U9				U5			
	Pins				Pins				Pins				Pins			
	9	10	1	15	9	10	1	15	9	10	1	15	9	10	1	15
000.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
876.5	1	0	0	0	0	1	1	1	0	1	1	0	0	1	0	1
212.1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	1

Table 6-4. English/Metric Pulse Output Electronics System Troubleshooting (Cont'd)

TEST C: 10760 GENERAL PURPOSE COUNTER TEST

Equipment needed: logic clip or logic probe

Test procedure: Jumper 10763 as per Table 6-4c
Send "start" pulse
Compare 10760 counter output with Table 6-4h

Table 6-4h: 10760 Counter Output Check

10763 CARD JUMPERS		FREQUENCY COUNTER OUTPUT	10760 Counter Output																							
			U51				U42				U52				U43				U53				U54			
			pins				pins				pins				pins				pins				pins			
			7	6	2	3	7	6	2	3	7	6	2	3	7	6	2	3	7	6	2	3	7	6	2	3
inch<	1.6MHz	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	0/1
	800KHz	257	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0/1	0/1	0/1
mm<	1.6MHz	437	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0/1	0/1	0/1
	800KHz	665	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0

0/1 ≡ constantly changing

TEST D: 10761 BINARY MULTIPLIER

Equipment needed: logic clip or logic probe

Test procedure: Jumper 10763 as per Table 6-4c
Send "start" pulse
Compare 10761 output with Table 6-4i. The number in the 10761 buffers is the binary representation of the number that is read on the frequency counter (within a ± 1 tolerance).

Table 6-4i: 10761 Output Buffer Check

10763 Switches and Jumpers		Freq. Counter Output	I.C.:	U64	U63	U64	U63	U64	U63	U64	U63	U64	U63	U64	U63	U65			
			Pin:	2	2	4	4	6	6	10	10	12	12	14	14	6	2	10	4
inch<	1.6MHz	175	(174)	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	0
	800KHz	257	(256)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
metric<	1.6MHz	444	(443)	0	0	0	0	0	0	0	1	1	0	1	1	1	0	1	1
	800KHz	652	(651)	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1	1
inch<	1.6MHz	5276	[1 deadpath switch up] (5275)	0	0	0	1	0	1	0	0	1	0	0	1	1	0	1	1

0/1 ≡ constantly changing

Table 6-5. 10781A Pulse Converter Troubleshooting

PRELIMINARY PROCEDURE

1. If the laser head does not emit red light, check that the rear-panel POWER ON light is lit. If it is not, check for a power line short. This can cause the power supply to current limit and reduce the voltage output level to near zero volts. Also check for an open circuit in the power supply wiring. If the POWER ON light is lit, check the status of the four rear-panel indicators associated with the ±15-volt supplies (two UNBAL indicators and two FUSE indicators). If power is available to the laser head but the head does not emit red light, refer to the separate manual for the laser head for further troubleshooting information.
2. If the LED indicator on one of the system receivers does not light, verify that the +15 volts is present at the system cable connector for the receiver. If it is not, troubleshoot the power supply and the system wiring. If voltage is present at the receiver connector and the LED is not lit, refer to the separate manual for the receiver for further troubleshooting information.

INSTALLATION AND ALIGNMENT OF LASER HEAD, RECEIVER, AND OPTICS PROCEDURE

1. If the laser head does not emit red light, check that the rear-panel POWER ON light is lit. If it is not, check for a power line short. This can cause the power supply to current limit and reduce the voltage output level to near zero volts. Also check for an open circuit in the power supply wiring. If the POWER ON light is lit, check the status of the four rear-panel indicators associated with the ±15-volt supplies (two UNBAL indicators and two FUSE indicators). If power is available to the laser head but the head does not emit red light, refer to the separate manual for the laser head for further troubleshooting information.
2. If the LED indicator on one of the system receivers does not light, verify that the +15 volts is present at the system cable connector for the receiver. If it is not, troubleshoot the power supply and the system wiring. If voltage is present at the receiver connector and the LED is not lit, check optics and alignment (refer to Section II).

CHECKOUT PROCEDURE

1. If the up/down or the A-quad-B pulses are not present at the pulse converter output, first check for the presence of the reference and measurement signal inputs to the pulse converter. If they are not present, troubleshoot the laser head or receiver respectively. If both signals are present, replace or troubleshoot the pulse converter.