HP 10751A

Air Sensor

HP 10941A Prototyping Kit

Power

Power Requirements:
5 V @ 0.25 A (HP supplied interface circuitry only)

Heat Dissipation: 1.25 W typical (HP supplied interface circuitry only)

Maximum Power Available for additional circuitry (dependent on configuration):
+5 V @ 4.0 A
+15 V @ 1.0 A
−15 V @ 1.0 A

Data Transfer Format:

Input: eight 8-bit bytes or four 16-bit words

Output: eight 8-bit bytes or four 16-bit words

Data rates (will vary with data format and system setup):

Input: (write to Proto Board):
HP-IB: 100 to 300 Hz
Binary: 0.1 to 5 kHz

Output: (read from Proto Board):
HP-IB: 100 to 160 Hz
Binary: 0.1 to 5 kHz

System Signals:

Clock: 6 MHz

Reset: hard, soft

Error: Indicates error anywhere in system (same as front panel LED)

Board Area

Usable Board Space:
220 sq cm (34 sq in) total
168 sq cm (26 sq in) power-gridded

Diameter and Spacing of Holes:
0.9 mm (0.037 in) diameter
2.5 mm (0.1 in) nominal spacing

Maximum Allowable Component Height:
19 mm (0.75 in)

HP 10946B Automatic Compensation

Power

Typical Power Requirements (not including sensors):
+5 V @ 1.5 A
+15 V @ 17 mA
−15 V @ 12 mA

Fuse Ratings:
+5 V @ 1 A
15 V @ 0.5 A

Calibration Interval:
12 Months (only if HP 10751A/B Air Sensor or HP 10757A/B/C Material Temperature Sensor are used)

Environmental Monitoring

Number of Sensors Allowed:
Air Sensor: 1
Material Temperature Sensors: 2
Wavelength tracker: 1
Auxiliary Channel: 1

Compensation Number Alert Range:
10 ppm

Compensation Number Update Rate:
Wavelength Tracker only: 100 Hz nominal
With HP 10751 and HP 10757 Sensors: 2.5 Hz

Thermal Expansion Coefficient Value Range:
English: 100 ppm/ F
Metric: 180 ppm/ C

Auxiliary Input Range:
0.999 V into 100 kΩ

HP 10751A/B Air Sensor

Mounting: Magnetic (tapped hole in base permits permanent mounting)

Dimensions: (Excluding cable) 18 × 8 × 10 cm

Weight:
- HP 10751A: 840 grams (30 oz)
- HP 10751B: 1.5 Kilograms (53 oz)

Cable Lengths:
- HP 10751A: 5 m (16 ft)
- HP 10751B: 15 m (49 ft)

Typical Power Requirements:
- +15 V @ 53 mA
- −15 V @ 53 mA

Heat Dissipation: 1.6 W typical

Calibration Interval: 12 Months

Operating range:
- Temperature: 0° to 40°C
- Absolute Pressure: 517.2 - 775.7 mm Hg (10 -15 psia)

Accuracy:

Twelve Month Calibration Interval Sensor Accuracy

Operating Temp Ranges	Max Air Pressure Error	Max Air Temperature Error
20°C	1.80 mm Hg	0.55°C
15-25°C	2.20 mm Hg	0.60°C
0-40°C	4.20 mm Hg	1.15°C
If the HP 10751A/B Air Sensor is incorrectly mounted, add 2° to the listed temperature errors.		

Zero Month Calibration Interval Sensor Accuracy

Operating Temp Ranges	Max Air Pressure Error	Max Air Temperature Error
20°C	0.50 mm Hg	0.45°C
15-25°C	1.40 mm Hg	0.50°C
0-40°C	3.80 mm Hg	1.10°C
If the HP 10751A/B Air Sensor is incorrectly mounted, add 2° to the listed temperature errors.		

Time Constant:
- Temperature: 3 min typical
- Pressure: <1 s typical

HP 10757A/B/C Material Temperature Sensor

Mounting: Magnetic Base

Dimensions:
(Excluding cable) 32 mm diameter 15 mm height.

Weight:
HP 10757A: 255 grams (9 oz)
HP 10757B: 525 grams (19 oz)
HP 10757C: 795 grams (28 oz)

Cable Lengths:
HP 10757A: 5 m (16.4 ft)
HP 10757B: 15 m (49.2 ft)
HP 10757C: 25 m (82.0 ft)

Typical Power Requirements:
+15 V @ 7 mA
−15 V @ 7 mA

Heat Dissipation: 0.2 W typical

Calibration Interval: 12 Months

Operating Range: 0° to 40°C

Accuracy (0° to 40°C):
0.10°C with 12 month calibration interval

Time Constant: 15 s (typical)

HP 10790A/B/C RECEIVER CABLE

LENGTHS:
HP 10790A: 5 m (16.4 ft)
HP 10790B: 10 m (32.8 ft)
HP 10790C: 20 m (65.6 ft)

HP 10793A/B/C LASER HEAD CABLE

LENGTHS:
HP 10793A: 3 m (9.8 ft)
HP 10793B: 7 m (23.0 ft)
HP 10793C: 20 m (65.6 ft)

HP 10794B LASER HEAD CABLE

LENGTH: 7 m (23.0 ft)

HP 10780B Receiver

Dimensions: See Figure below.

Weight: 136 grams (4.8 oz)

Typical Power Requirements:
+15 V at 0.136 A

Heat Dissipation:
2.0 W typical

Alignment Tolerances:
Roll: 3
Pitch: 1
Yaw: 1

Sensitivity: Maximum 1.5 µW. Factory adjusted to 5.0 µW. Can be adjusted to maximum using the procedures in the HP 10780B Operating and Service Manual (supplied).

Output: Measured Signal Differential square wave at Doppler-shifted frequency (100 kHz to 5.0 MHz). TTL levels compatible with all HP laser system output accessories.

Maximum cable length (using HP 10790C Cable) 20 m (65 ft)

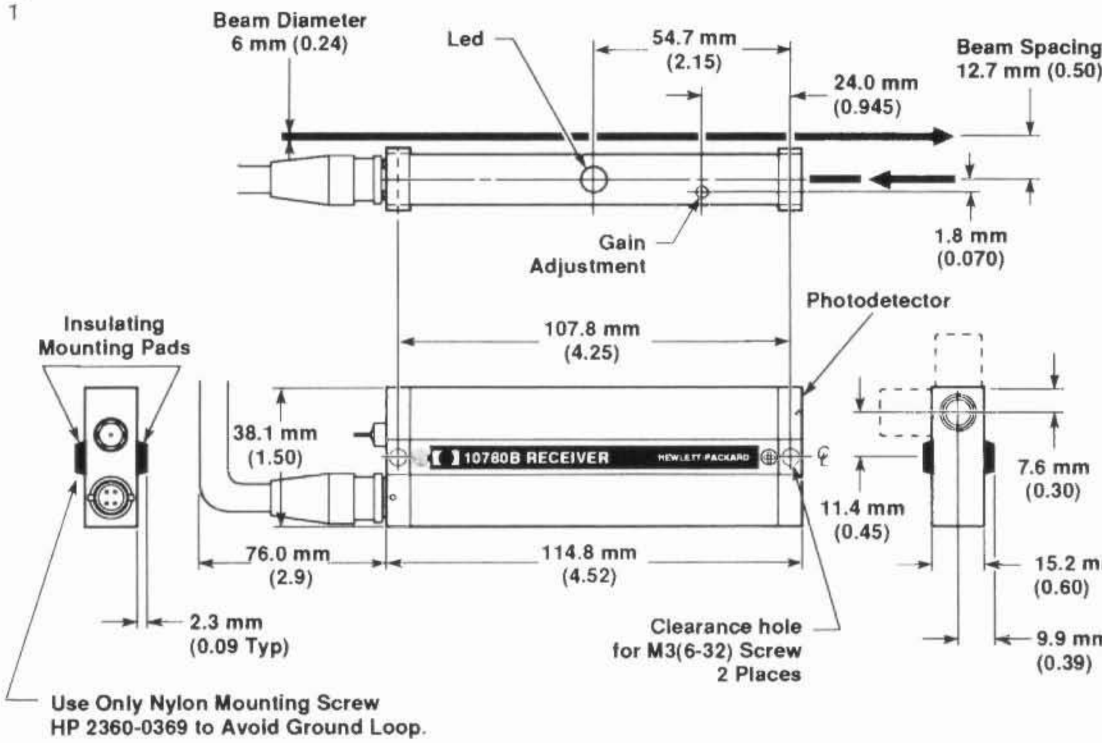


Figure 8-24. HP 10780B Receiver, Dimensions

HP 10780C Receiver

Dimensions: See Figure below.

Weight: 136 grams (4.8 oz)

Typical Power Requirements:
+15 volts at 136 mA

Heat Dissipation:
2.0 W typical

Alignment Tolerances:
Roll: ±3 degrees
Pitch: ±1 degree
Yaw: ±1 degree

Maximum Sensitivity:
1.5 μW (HP 10780C)
Factory adjusted to 5.0 μW; can be adjusted to maximum sensitivity using procedures in the HP 10780C/F Operating and Service manual.

Output Signal:
Differential square wave at Doppler-shifted split frequency (100 kHz to 6.0 MHz).

Electrical Cables:
HP 10790A: 5 m (15.2 ft)
HP 10790B: 10 m (30.5 ft)
HP 10790FC: 20 m (61 ft) (maximum recommended)

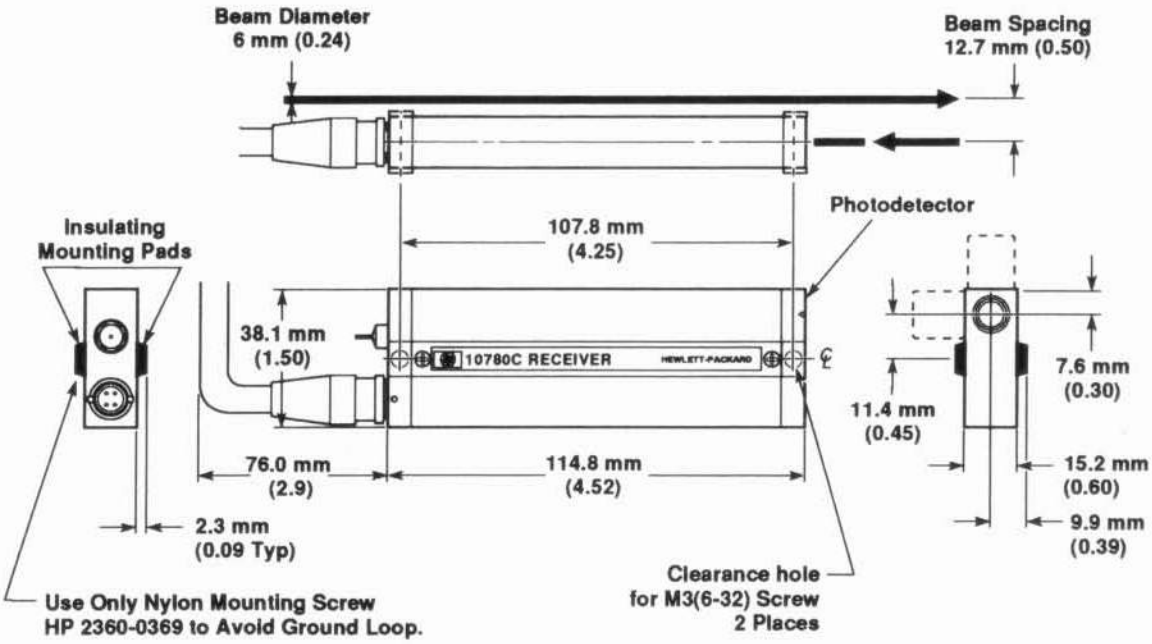


Figure 8-24a. HP 10780C Receiver, Dimensions

HP 10780F Receiver

Dimensions: See Figure below

Weight:
126 grams (4.5 oz) for HP 10780F
26 grams (0.9 oz) for remote sensor with a 2 m cable

Typical Power Requirements:
+15 volts at 136 mA

Heat Dissipation:
0.0 W for remote sensor
2.0 W typical for receiver

Alignment Tolerances:
Roll: ±3 degrees
Pitch: ±1 degree
Yaw: ±1 degree

Maximum Sensitivity:
2.2 µW (with 2m cable) (Becomes 5.0 µW with a 10 m fiber cable.)
Factory adjusted to 5.0 µW; can be adjusted to maximum sensitivity using procedures in the HP 10780C/F Operating and Service manual.

Output Signal:
Differential square wave at Doppler-shifted split frequency (100 kHz to 6.0 MHz).

Fiber-optic Cable Length:
2 m standard
10 m maximum recommended

Electrical Cables:
HP 10790A: 5 m (15.2 ft)
HP 10790B: 10 m (30.5 ft)
HP 10790C: 20 m (61 ft) (maximum recommended)

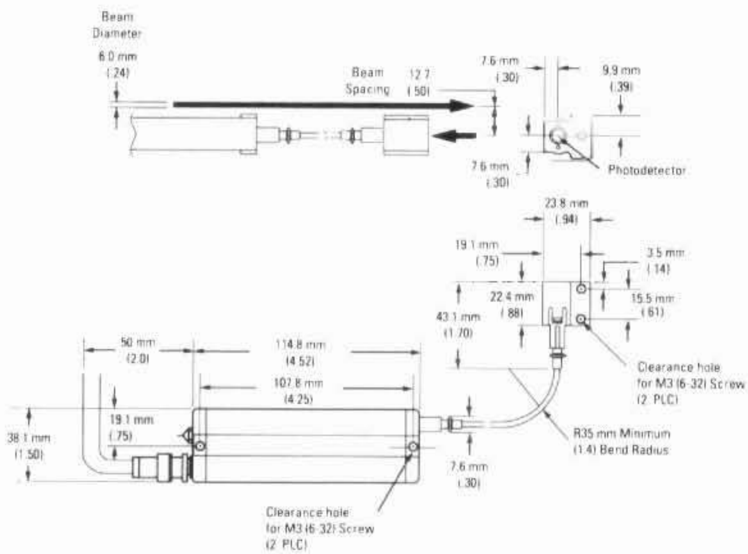


Figure 8-24b. HP 10780F Receiver, Dimensions

HP 10717A Wavelength Tracker

Dimensions: See Figure below.

Weight: 1.7 kg (3.7 lbs)

Etalon Length: 127 mm (5 inches) nominal

Optical Efficiency:
Typical 36%
Worst Case 25%

Angular Adjustment Range (at nominal position):
Pitch: 1
Yaw: 1

Translational Adjustment Range (at nominal position):
Vertical: 3 mm (0.12 inch)
Horizontal: 3 mm (0.12 inch)

Mounting:
Three 10-32 UNF2A tapped holes (hardware supplied)
See Figure below.

Mounting Screw Torque:
0.9 Newton-meter (8 inch-pounds)

Minimum Mounting Clearance Required:
3 mm (0.12 inch) around perimeter

Calibration: none requred

NOTE

If the HP 10946B Automatic Compensation Board is not used, system measurement repeatability may be calculated as follows:

[(R/127+0.028) ppm + (0.06 ppm/ C ΔT)

+(0.002 ppm/mm Hg ΔP)]

where R= electronics resolution in nm (5 nm for HP 10946B or HP 10932A).

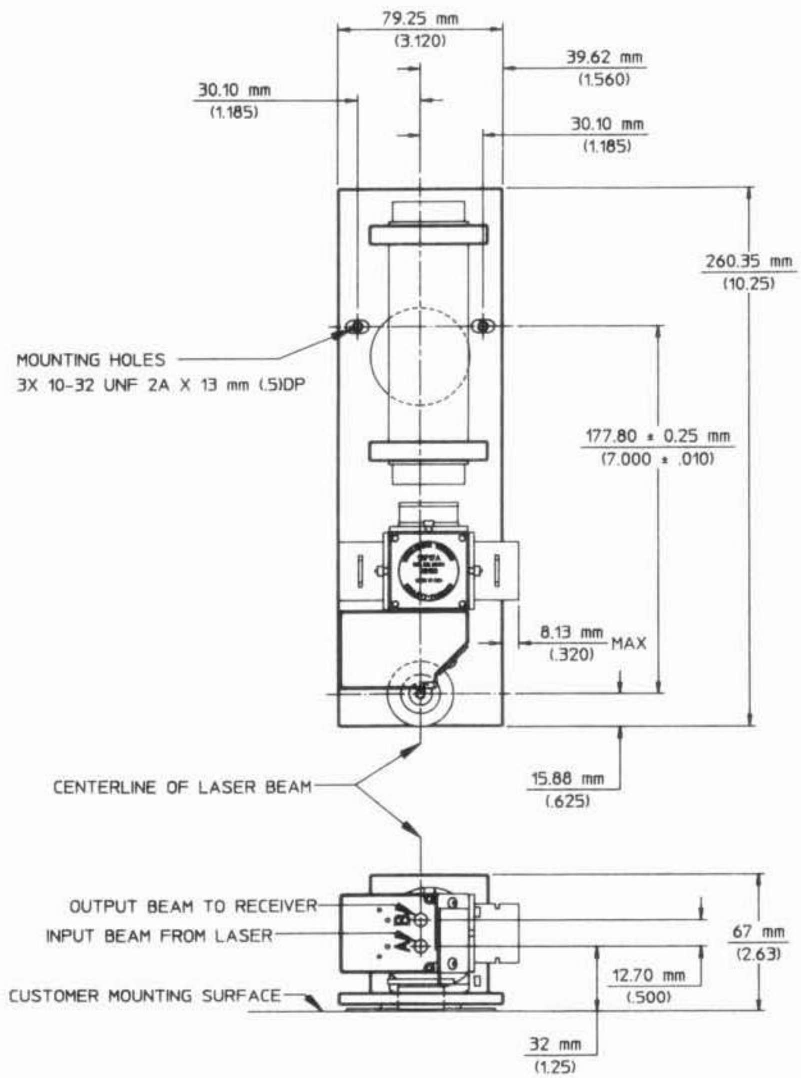


Figure 8-25. HP 10717A Wavelength Tracker, Dimensions

APPENDIX A
HP 5507A/B MNEMONIC SUMMARY

INTRODUCTION

The following table provides a listing of all HP 5507A/B Laser Position Transducer Electronics' programming mnemonics, the HP 5507A/B subassembly that recognizes the mnemonic, the mnemonic type (i.e., Command, Read-only Integer Data, etc.), a brief mnemonic description, and the subsection of Section IV page reference where more detailed information can be found (for example, 4D or 4K). The table is arranged in alphabetical order, listing the HP-IB mnemonics first, followed by the function and compensation board mnemonics.

Table A-1. HP 5507A/B Mnemonic Summary

Mnemonic	Recognized By	Type	Description	See Page
ASGN	A-Quad-B	Read/Write ASCII Data	Reads or Writes the mnemonic associated with the CNUM command number (serial and parallel ports only).	4E-16
BOOT	HP-IB	Command	The HP-IB board performs a "hard" reset (similar to the power-up sequence).	4B-21
	A-Quad-B	Command	The A-Quad-B Axis board pulses the backplane Hard Reset line.	4E-16
CNFG	HP-IB	Read-only ASCII Data	Returns a list of boards installed in the HP 5507A/B backplane.	4B-21
	A-Quad-B	Read-only ASCII Data	Returns a list of boards installed in the HP 5507A/B backplane.	4E-17
CNUM	A-Quad-B	Read/Write Integer Data	Reads or writes the Command Number associated with the ASGN Mnemonic (serial and parallel ports only).	4E-17
DFMT	A-Quad-B	Read/Write Serial Data	Specifies I/O channel data format. Factory setting is 0. The formats are: 0 - ASCII for everything. 1 - BLOCK #A for Floating Point, ASCII for all else. 2 - BLOCK #D for Floating Point, ASCII for all else. 3 - Internal format for Floating Point, ASCII for all else. 4 - ASCII for text requests, Internal format for command number requests. 5 - ASCII for ASCII data items, Internal format for all else.	4E-17
ECHO	A-Quad-B	Read/Write Serial Data	Turns the I/O channel's echo operation ON/OFF. Factory setting is ON (1).	4E-17
ERML	A-Quad-B	Read/Write Byte Data	Reserved	4E-18
ERRM	HP-IB	Read-only ASCII Data	ASCII system error message description.	4B-21
	A-Quad-B	Read-only ASCII Data	Returns a list of all current error descriptions (serial and parallel ports only).	4E-18
ERST	HP-IB	Command	The HP 5507A/B performs an error or "soft" reset.	4B-22
	A-Quad-B	Command	The HP 5507A/B performs an error or "soft" reset.	4E-18

Table A-1. HP 5507A/B Mnemonic Summary (Continued)

Mnemonic	Recognized By	Type	Description	See Page
FMT0	HP-IB	Command	Floating Point Data is output in ASCII format. This is the Power-up Default format.	4B-22
FMT1	HP-IB	Command	Floating Point Data is output in IEEE-728 Block Data Format A.	4B-22
FMT2	HP-IB	Command	Floating Point Data is output in IEEE-728 Block Data Format D.	4B-22
FMT3	HP-IB	Command	Floating Point Data is output in a block data format compatible with the HP Series 200/300 computers.	4B-22
HREV	HP-IB	Read-only Integer Data	HP-IB board places its software revision date code in the output buffer.	4B-22
HSMD	A-Quad-B	Command	Turns the handshake feature ON/OFF for serial or parallel data transfers. Power-up default is handshake OFF (0).	4E-18
HSOF	HP-IB	Command	HP-IB board automatically fills its output buffer when requested to output data (Power-up Default).	4B-23
HSON	HP-IB	Command	HP-IB board waits for "Data Sampled" signal before filling its output buffer (used with axis board's External Sample-input).	4B-23
IMSK	HP-IB	Read/Write Integer Data	The interrupt mask allows bits in the ISTA instrument status byte to generate an SRQ interrupt. Range: 0 - 255 Power-up Default: 0	4B-23
INST	HP-IB	Read-only ASCII Data	All recognized instruction mnemonics are output in 74 byte strings.	4B-23
	A-Quad-B	Read-only ASCII Data	All recognized instruction mnemonics are output in 74 byte strings.	4E-19
IREF	HP-IB	Command	Switches the reference phase-locked loop to an internal 1.5 MHz system clock.	4B-24
ISTA	HP-IB	Read-only Integer Data	The instrument status byte always reflects the current operating status of the HP 5507A/B. Low-to-high transitions in one or more bits will trigger an SRQ interrupt if the corresponding bits of IMSK are set.	4B-24
	A-Quad-B	Read-only Byte Data	Reads the Instrument Status Byte	4E-19
*ACC	Servo	Read/Write Floating Point Data	Reads or writes the Acceleration value used to calculate profiles. Range: Greater than 0 Default: 0.1 g	4F-29
*ACQ	Servo	Command	Causes the Servo-Axis board to turn on the servo with the destination set equal to the current position.	4F-29
*AER	A-Quad-B	Command	Performs a Soft Reset on this axis only	4E-19
*AGO	A-Quad-B	Command	Initializes this axis only	4E-20
*AHV	Comp	Read/Write Floating Point Data	Normal Operation: Air humidity value. Range: 0 to 95% No Sensor Default: 50% Service Mode (*TST = 1): Reads the actual voltage on this A/D channel.	4K-4

Table A-1. HP 5507A/B Mnemonic Summary (Continued)

Mnemonic	Recognized By	Type	Description	See Page
*APV	Comp	Read/Write Floating Point Data	Normal Operation: Air pressure value. Range: 500 to 800 mm Hg No Sensor Default: 760 mm Hg Service Mode (*TST = 1): Reads the actual voltage on this A/D channel.	4K-5
*ATV	Comp	Read/Write Floating Point Data	Normal Operation: Air temperature value. Range: 0 to 40° C No Sensor Default: 20°C Service Mode (*TST = 1): Reads the actual voltage on this A/D channel.	4K-5
*AVS	A-Quad-B	Read/Write Floating Point Data	Reserved	4E-20
*BCN	A-Quad-B	Read/Write Floating Point Data	Reads or Writes the Base Compensation Number Range: 0.99 to 1.01 Factory Setting: 0.999728766	4E-20
*BGO	Servo	Read/Write Integer Data	Start sequence in buffer. Range: 0 to 4	4F-30
*BYA	Proto	Read/Write Integer Data	INA- or OUTA- data strobe line activated. Range: 0 to 255	4I-1
*BYB	Proto	Read/Write Integer Data	INB- or OUTB- data strobe line activated. Range: 0 - 255	4I-1
*BYC	Proto	Read/Write Integer Data	INC- or OUTC- data strobe line activated. Range: 0 - 255	4I-1
*BYD	Proto	Read/Write Integer Data	IND- or OUTD- data strobe line activated. Range: 0 - 255	4I-1
*BYE	Proto	Read/Write Integer Data	INE- or OUTE- data strobe line activated. Range: 0 - 255	4I-1
*BYF	Proto	Read/Write Integer Data	INF- or OUTF- data strobe line activated. Range: 0 - 255.	4I-1
*BYG	Proto	Read/Write Integer Data	ING- or OUTG- data strobe line activated. Range: 0 - 255	4I-1
*BYH	Proto	Read/Write Integer Data	INH- or OUTH- data strobe line activated. Range: 0 - 255	4I-1
*CEB	Comp	Read/Write Integer Data	Used to selectively enable and disable the 8 A/D channels. Range: 0 to 255 Power-up Default: ≤ 128 (depends on sensors connected)	4K-5
*CLK	Servo	Read/Write Integer Data	Selects the servo Sample Clock source. Range: 0 to 4 Default: 0	4F-30
*CLP	Axis	Read/Write Integer Data	Sets the Position Error Output bit clip level. Range: 0, 8 - 20 Power-up Default: 0	4D-8
*CMC	Comp	Read/Write Integer Data	Instructs the compensation board to automatically ignore (*CMC = 0) or implement (*CMC = 1) the Wavelength Tracking function at power-up or system reset. Range: 0 or 1 Factory Setting: 0	4K-6

Table A-1. HP 5507A/B Mnemonic Summary (Continued)

Mnemonic	Recognized By	Type	Description	See Page
*CMD	A-Quad-B	Read/Write Floating Point Data	Reads or Writes the Compensation Mnemonic Data Value. Range: Depends on *CMP	4E-21
*CMP	A-Quad-B	Read/Write Byte Data	Reads or Writes the Compensation Mnemonic Pointer. Range: 0 to 9 Default: 0	4E-21
*CNL	Comp	Read/Write Floating Point Data	Instructs the automatic compensation board to generate an alert (assert SRQ bit) if the *CNV compensation number changes by an amount exceeding the *CNL value (see also IMSK, *WTL, and *WTE). Range: ± 0.0000100 (± 10 ppm) Power-up Default: 0.0000000	4K-6
*CNR	Comp	Read-only Floating Point Data	If the *CNV compensation number deviates from this base line value by more than *CNL, the SRQ bit is asserted (see also IMSK, *WTR, and *WTE).	4K-6
*CNV	Comp	Read-only Floating Point Data	Used to read the current total compensation number (calculated from air pressure, air temperature, air humidity, material temperature, and expansion coefficient values). No Sensor Default: 0.999728766 (20° C, 760 mm Hg, 50% Relative Humidity.	4K-7
*COF	A-Quad-B	Read/Write Floating Point Data	Reads or Writes the Compensation Offset value (in ppm) Range: +/- 100 Factory Setting: 0	4E-22
*CRC	Comp	Command	Instructs the compensation board to store the +10 V REF (*RVA), +0.5 V REF (*RVB), and Wavelength Reference Length (*WRL) data currently stored in the board's mailbox (must be preceded by a *CRE command).	4K-7
*CRE	Comp	Command	Enables the automatic compensator to accept and execute a *CRC command.	4K-7
*CUR	A-Quad-B	Read/Write Integer Data	Reads or Writes the Compensation Update Rate/Mode. Range: -327 to 100 Factory Setting: 0	4E-22
*DAC	Servo	Read/Write Floating Point Data	Reads or writes the Delta acceleration value used to compute a profile. Range: Greater than zero Power-up Default: 1 g/sec	4F-31
*DDV	Comp	Read-only Floating Point Data	Used to read the duration (in seconds) of the most recent (or current) measurement interruption that has generated an error. Resolution: 0.001 seconds	4K-7
*DEQ	Servo	Read/Write Integer Data	Selects the Difference equation (PID, IIR, or downloaded). Range: 0, 1, 2	4F-31

Table A-1. HP 5507A/B Mnemonic Summary (Continued)

Mnemonic	Recognized By	Type	Description	See Page
*DES	Axis	Read/Write Floating Point Data	Writes the axis board's destination register in selected units (*ENG, *MET, *LAM or *RAW). Range: ± 5310 mm (plane mirror optics) Power-up Default: 0	4D-9
	Servo	Read/Write Floating Point Data	Writes the Servo-Axis board's destination register in selected units (*ENG, *MET, *LAM or *RAW). Range: ± 5310 mm (plane mirror optics) Power-up Default: 0	4F-31
*DIR	Servo	Read/Write Integer Data	Sets the Direction sense. Range: 0 to 1	4F-32
	A-Quad-B	Read/Write Byte Data	Sets the Laser Direction Sense Range: 0 or 1 Factory Setting: 0	4E-23
*DPD	Servo	Read/Write Floating Point Data	Reads or writes Deadpath distance. Range: ± 5310 mm (plane mirror optics) Power-up Default: 0	4F-32
	A-Quad-B	Read/Write Floating Point Data	Reads or Writes the Deadpath Distance. Range: 0 to 10500 mm (plane mirror optics) Factory Setting: 0	4E-23
*DR0	Axis	Command	Turns the Drive Enable Out- off and sets the Position Error outputs low. (Power-up Default.)	4D-9
*DR1	Axis	Command	Sets the Drive Enable Out- line to the active state (low) and enables Position Error output lines.	4D-9
*DRE	Servo	Read/Write Integer Data	Turns the servo On or Off. Range: 0 to 1	4F-33
*DTA	Servo	Read/Write Floating Point Data	Used with *PTR for data entry. Range: Varies with *PTR value	4F-33
*DTV	Comp	Read/Write Floating Point Data	Reads or writes the amount of time that a Wavelength Tracking signal measurement interruption exists before the error is indicated by the HP 10946B. Range: 0 to 65 seconds Power-up Default: 0 seconds Resolution: 0.001 seconds	4K-8
*ECV	Comp	Read/Write Floating Point Data	Sets or reads the material expansion coefficient value. Both compensation numbers (*CNV and *WTC) include *ECV's effect. Range: ± 0.000180/° C ± 0.000100/° F Power-up Default: 0.000000	4K-8
*EM0	Axis	Command	Selects Error Mode 0. When in Error Mode 0, measurement errors from only this axis will shut off the Drive Enable Out- line (Power-up default).	4D-10
*EM1	Axis	Command	When in Error Mode 1, any HP 5507A/B error will shut off the Drive Enable Out- line.	4D-10
*EMD	Servo	Read/Write Integer Data	Reads or writes the Servo-Axis board's Error mode. Range: 0 to 3 Factory Setting: 0	4F-33
	A-Quad-B	Read/Write Byte Data	Reads or writes the A-Quad-B board's Error mode. Range: 0 to 3 Default: 0	4E-24

Table A-1. HP 5507A/B Mnemonic Summary (Continued)

Mnemonic	Recognized By	Type	Description	See Page
*ENG	Axis	Command	Sets the Position and Destination I/O units to compensated inches.	4D-10
	Servo	Command	Sets the Position and Destination I/O units to compensated inches.	4F-34
	Comp	Command	Sets the automatic compensator's input and output units to English. *ENG affects *APV, *ATV, *ECV, *MTA, *MT1, and *MT2 mnemonics.	4K-8
*EXT	Axis	Command	Selects the external (hardware) sample triggering source for the position data (*POS).	4D-10
	Servo	Command	Selects the external (hardware) sample triggering source for the position data (*POS).	4F-34
*FFA	Servo	Read/Write Integer Data	Reads or writes the Acceleration feedforward term. Range: 0 to 32767 Default: 0	4F-34
*FFD	Servo	Read/Write Integer Data	Reads or writes the Delta acceleration feedforward term. Range: 0 to 32767 Default: 0	4F-34
*FFV	Servo	Read/Write Integer Data	Reads or writes the Velocity feedforward term. Range: 0 to 32767 Default: 0	4F-34
*FTC	Comp	Read/Write Floating Point Data	Reads or writes the filter time constant for the Wavelength Tracker Compensation number. Range: 0, 0.050 to 5 seconds Power-up Default: 0 seconds (disabled)	4K-8
*INT	Axis	Command	Selects the internal (software) sample triggering source for the position data (*POS).	4D-11
	Servo	Command	Selects the internal (software) sample triggering source for the position data (*POS).	4F-35
*KHZ	A-Quad-B	Read/Write Integer Data	Sets or reads the Output Pulse Rate. Range: 781 to 5154 Factory Setting: 781	4E-24
*LAM	Axis	Command	Sets the Position and Destination I/O units to compensated raw counts (λ/64 or λ/128 depending on the optics used).	4E-24
	Servo	Command	Sets the Position and Destination I/O units to compensated raw counts (λ/64 or λ/128 depending on the optics used).	4E-249
*LBV	A-Quad-B	Read Only Floating Point Data	Reads the value that generated the last Out of Range Error	4E-24
*LHF	A-Quad-B	Read-only Integer Data	Reserved	4E-25
*MCM	Servo	Read/Write Integer Data	Reads or writes the Master Control Mask used for coordinated multiaxis moves. Range: 0 to 255	4F-35
*MEN	A-Quad-B	Read/Write Byte Data	Enables/Disables External Sampling of the Multiplier's Output Range: 0 or 1 Factory Setting: 0	4E-25
*MET	Axis	Command	Sets the Position and Destination I/O units to compensated millimetres (power-up default).	4D-11
	Servo	Command	Sets the Position and Destination I/O units to compensated millimetres (power-up default).	4F-36

Table A-1. HP 5507A/B Mnemonic Summary (Continued)

Mnemonic	Recognized By	Type	Description	See Page
*MET (Cont'd.)	Comp	Command	Sets the automatic compensator's input and output units to metric (power-up default). *MET affects *APV, *ATV, *ECV, *MTA, MT1, and *MT2 mnemonics.	4K-8
*MEX	Axis	Command	Selects the external measurement input channel (HP 10780 Receiver). Power-up Default.	4D-11
	Servo	Command	Selects the external measurement input channel (HP 10780 Receiver). Power-up Default.	4F-36
	A-Quad-B	Command	Selects the external measurement input channel (HP 10780 Receiver).	4E-25
*MIN	Axis	Command	Selects the internal measurement input channel (HP 5518A's internal receiver).	4D-11
	Servo	Command	Selects the internal measurement input channel (HP 5518A's internal receiver).	4F-36
	A-Quad-B	Command	Selects the internal measurement input channel (HP 5518A's internal receiver).	4E-26
*MKR	Servo	Read/Write Floating Point Data	Reads or writes the Marker position used for Threshold and Window Outputs Range: ± 5310 MM (Plane Mirror Optics)	4F-36
*MKW	Servo	Read/Write Integer Data	Reads or writes the width specifier for the Window Output. Range: 0 to 12	4F-37
*MLE	A-Quad-B	Read-only Floating Point Data	Reads the Multiplier's External Sample output value	4E-26
*MPO	A-Quad-B	Read/Write Floating Point Data	Reads or Writes the Maximum Position Offset value Range: 0 to 100 mm Factory Setting: 0.1	4E-26
*MSW	A-Quad-B	Read-only Integer Data	Reads the 16-bit Miscellaneous Status Word	4E-27
*MTA	Comp	Read/Write Floating Point Data	Average material temperature value: Sets or reads the material temperature average used in calculations. Range: 0 to 40°C No Sensor Default: 20°C	4K-9
*MT1	Comp	Read-Only Floating Point Data	Normal Operation: Reads Material Temperature 1 channel. No Sensor Default: 0° C Service Mode (*TST =1): Reads the actual voltage on this channel.	4K-9
*MT2	Comp	Read-only Floating Point Data	Normal Operation: Reads Material Temperature 2 channel No Sensor Default: 0°C Service mode (*TST =1): Reads the actual voltage on this channel.	4K-9
*MUL	A-Quad-B	Read-only Floating Point Data	Reads the Multiplier's Output value (sampling set by MUR)	4E-28
*MUR	A-Quad-B	Read/Write Integer Data	Reads or Writes the Multiplier (*MUL) Update Rate/Mode Range: -327 to 1000 Factory Setting: 0	4E-28

Table A-1. HP 5507A/B Mnemonic Summary (Continued)

Mnemonic	Recognized By	Type	Description	See Page
*NAM	Axis	Read-only ASCII Data	Returns the string "AXIS<CR><LF> and EOI".	4D-12
	Servo	Read-only ASCII Data	Returns the string "SRVO<CR><LF> and EOI".	4F-37
	Comp	Read-only ASCII Data	Returns the string "COMP<CR><LF> and EOI".	4K-9
	Proto	Read-only ASCII Data	Returns the string "PROT<CR><LF> and EOI".	4I-3
	A-Quad-B	Read Only ASCII Data	Returns the string "QUAD<CR><LF> and EOI".	4E-29
*NUL	Axis	Read/Write Integer Data	Defines the Position Error Null range (*see Table 4D-7*). Range: 0 - 12 Power-up Default: 0	4D-12
	Servo	Read/Write Integer Data	Defines the Position Error Null range in current units. Range: 0 to 10620 mm (Plane Mirror Optics) Power-up Default: 0	4F-38
*OP0	Axis	Command	Informs the axis board that linear optics are used with this axis (λ/64 resolution).	4D-12
*OP1	Axis	Command	Informs the axis board that plane mirror optics are used with this axis (λ/128 resolution). (Power-up Default)	4D-12
*OP2	Axis	Command	Informs the Axis board that High resolution optics are used with this axis (λ/256 resolution).	4D-12
*OPT	Servo	Read/Write Integer Data	Specifies the Optics type. Range: 0, 1, 2 Default: 1	4F-38
	A-Quad-B	Read/Write Byte Data	Specifies the Optics Type Range: 0, 1, or 2 Factory Setting: 0	4E-29
*OUT	Servo	Read/Write Integer Data	Selects which Motor Drive Outputs will be active. Range: 0 to 7 Default: 1	4F-38
*PEN	A-Quad-B	Read/Write Byte Data	Enables/Disables External Position Sampling. Range: 0 or 1 Factory Setting: 0	4E-29
*POF	A-Quad-B	Read/Write Floating Point Data	Reads or Writes the Position Offset value. Range: +/- *MPO Default: 0	4E-30
*POS	Axis	Read-only Floating Point Data	Returns the position counter's value in the selected I/O units (*RAW, *LAM, *ENG, *MET).	4D-13
	Servo	Read-only Floating Point Data	Returns the position counter's value in the selected I/O units (*RAW, *LAM, *ENG, *MET).	4F-39
	A-Quad-B	Read-only Floating Point Data	Returns a compensated Position Value (sampling set by *PUR) in the units selected by *PUN (mm or inches).	4E-30
*PRD	A-Quad-B	Read/Write Floating Point Data	Reads or Writes the Preset Distance. Range: +/- 10500 mm (plane mirror optics) Factory Setting: 0	4E-31

Table A-1. HP 5507A/B Mnemonic Summary (Continued)

Mnemonic	Recognized By	Type	Description	See Page
*PRE	Axis	Command	Presets the position counter to the value currently in the axis board's destination register. (The five least significant bits are set to zero.)	4D-13
*PRE (Cont'd.)	Servo	Command	Presets the position counter to the value currently in the Servo-Axis board's Marker register. (The five least significant bits are set to zero.)	4F-39
*PSE	A-Quad-B	Read-only Floating Point Data	Returns a compensated position value (External Sample only).	4E-31
*PTR	Servo	Read/Write Integer Data	Data pointer used with *DTA for data entry. Range: 0 to 231	4F-39
*PUN	A-Quad-B	Read/Write Byte Data	Selects the I/O and Pulse Units. Range: 0 or 1 Factory Setting: 0	4E-32
*PUR	A-Quad-B	Read/Write Integer Data	Reads or Writes the Position (*POS) Update Rate/Mode. Range: -327 to 1000 Factory Setting: 1000	4E-32
*QAD	A-Quad-B	Read/Write Byte Data	Selects the pulse Output Format (up/down pulses or A-Quad-B signals). Range: 0 or 1 Factory Setting: 0	4E-33
*RAW	Axis	Command	Sets the Position and Destination I/O units to uncompensated raw counts.	4D-13
	Servo	Command	Sets the Position and Destination I/O units to uncompensated raw counts.	4F-39
*RCM	A-Quad-B	Read-only ASCII Data	Reads the Compensation Mnemonic associated with the *CMP value	4E-33
*RES	A-Quad-B	Read/Write Floating Point Data	Specifies the output Pulse Resolution and Direction. Range: depends on *PUN and *OPT Factory Setting: 1E-5	4E-33
*REV	Axis	Read-only Integer Data	Returns the Axis board's software revision date.	4D-14
	Servo	Read-only Integer Data	Returns the Servo-Axis board's software revision date.	4F-50
	Comp	Read-only Integer Data	Returns the compensation board's software revision data code.	4K-9
	A-Quad-B	Read-only Integer Data	Returns the A-Quad-B Axis board's software revision data code.	4E-34
*RLP	A-Quad-B	Read-only Floating Point Data	Reads the uncompensated Raw Laser Position.	4E-34
*RST	Comp	Command	Resets the board to its power-up condition.	4K-10
*RSV	A-Quad-B	Read-only Floating Point Data	Reads the value sent to the Multiplier.	4E-34
*RVA	Comp	Read/Write Floating Point Data	+10 V Reference Value: used during calibration (see Section VII). Range: +9.99 to +10.01 Volts	4K-10
*RVB	Comp	Read/Write Floating Point Data	+0.5 Volt Reference Value: used during calibration (see Section VII). Range: +0.49875 to +0.50125 Volts	4K-10

Table A-1. HP 5507A/B Mnemonic Summary (Continued)

Mnemonic	Recognized By	Type	Description	See Page
*SAM	A-Quad-B	Read/Write Byte Data	Specifies Serial Port A's Mode. Range: 0 to 255 Factory Setting: 24	4E-35
*SAR	A-Quad-B	Read/Write Integer Data	Specifies Serial Port A's Baud Rate. Range: 110 to 19,200 Factory Setting: 2400	4E-35
*SAV	A-Quad-B	Command	Saves the Setup Parameters in nonvolatile memory.	4E-36
*SBM	A-Quad-B	Read/Write Byte Data	Specifies Serial Port B's Mode. Range: 0 to 255 Factory Setting: 24	4E-37
*SBR	A-Quad-B	Read/Write Integer Data	Specifies Serial Port B's Baud Rate. Range: 110 to 19,200 Factory Setting: 2400	4E-37
*SGO	A-Quad-B	Command	Initializes all A-Quad-B Axis boards simultaneously.	4E-38
*SMG	Axis	Command	Switches the hardware Position Error lines to signed-magnitude format.	4D-14
*SPD	Servo	Read/Write Integer Data	Specifies the Servo Sample Period in increments of 125 ns. Range: 1000 to 32000 Default: 8000	4F-50
*STA	Axis	Read-only Integer Data	Axis board's status byte. Non-zero values indicate that an error condition exits (see *Table 4D-9*).	4D-14
	Servo	Read-only Integer Data	Reads the status byte of the Servo-Axis board. (See page 4F-51 for status byte values.)	4F-50
	Comp	Read-only Integer Data	Reads the status byte of the automatic compensation board. (See *Table 4K-5* for status byte values.)	4K-10
	Proto	Read-only Integer Data	Prototyping board's status byte. A status byte value of zero indicates that the Prototyping board is operational.	—
	A-Quad-B	Read Only Byte Data	Reads the status byte of the A-Quad-B Axis board. (See the A-Quad-B Axis Board Error Messages for status byte values.)	4E-38
*STP	A-Quad-B	Command	Disables Pulse Outputs on this axis only.	4E-38
*SVC	Servo	Read/Write Integer Data	Selects the Servo-Axis board's profiling method. Range: 0 to 12 Default: 0	4F-52
*TCN	Axis	Read/Write Floating Point Data	*TCN is the wavelength-of-light and material temperature compensation number. Range: 0.99 - 1.01 Power-up Default: 1.00	4D-15
	Servo	Read/Write Floating Point Data	*TCN is the wavelength-of-light and material temperature compensation number. Range: 0.99 - 1.01 Power-up Default: 0.999728766	4F-52
*TCP	Axis	Command	Switches the hardware Position Error lines to two's complement form. (Power-up Default)	4D-15
*TRC	Servo	Read/Write Integer Data	Specifies which parameters will be traced. Range: 0 to 255	4F-53

Table A-1. HP 5507A/B Mnemonic Summary (Continued)

Mnemonic	Recognized By	Type	Description	See Page
*TST	Axis	Read/Write Floating Point Data	A special test mnemonic that switches the axis measurement input between the normal measurement inputs (as selected by *MIN and *MEX) and three fixed test frequencies of 1.0 MHz, 1.5 MHz, and 2.0 MHz. Range: +0.24, 0.76 - 2.24 Power-up Default: 0.00	4D-15
*TST (Cont'd.)	Servo	Read/Write Integer Data	A special test mnemonic that switches the axis measurement input between the normal measurement inputs (as selected by *MIN and *MEX) and seven fixed test frequencies of (6/Value +1) MHz. Range: 0 to 7 Power-up Default: 0.00	4F-53
	Comp	Read/Write Integer Data	Allows the reading of either measured channel data (*TST0) or actual channel voltages (*TST1). (*TST0 also resets board to power-up state.) Range: 0 or 1 Power-up Default: 0	4K-10
	A-Quad-B	Read/Write Byte Data	A special test mnemonic that switches the axis measurement input between the normal measurement inputs (as selected by *MIN and *MEX) and seven fixed test frequencies of (6/Value +1) MHz. The mnemonic also turns off the axis and enables *SAV. Range: 0 to 7, 254, and 255 Power-up Default: 0.00	4E-39
*UCN	Servo	Command	Updates the compensation number (*TCN) using a previously defined mnemonic (see *PTR 106).	4F-53
*VAC	Comp	Read-only Floating Point Data	Reads the actual voltage on the auxiliary channel.	4K-11
*VEL	Servo	Read/Write Floating Point Data	Reads or writes the maximum velocity for profiled moves. Range: ± 25.4 cm/secs (Plane Mirror Optics) Default: 50 mm/sec	4F-54
*VGC	Comp	Read-only Floating Point Data	Reads the actual voltage on the ground channel.	4K-11
*VRC	Comp	Read-only Floating Point Data	Reads the actual voltage on the reference channel.	4K-11
*WCM	A-Quad-B	Read/Write Integer Data	Writes the Compensation Mnemonic associated with the *CMP value. Range: two packed ASCII characters	4E-39
*WDA	Proto	Read/Write Integer Data	INA- then INB- or OUTA- then OUTB- data strobe lines activated. Range: –32768 to +32767	4I-1
*WDC	Proto	Read/Write Integer Data	INC- then IND- or OUTC- then OUTD- data strobe lines activated. Range: –32768 to +32767	4I-1

Table A-1. HP 5507A/B Mnemonic Summary (Continued)

Mnemonic	Recognized By	Type	Description	See Page
*WDE	Proto	Read/Write Integer Data	INE- then INF- or OUTE- then OUTF- data strobe lines activated. Range: –32768 to +32767	4I-1
*WDG	Proto	Read/Write Integer Data	ING- then INH- or OUTG- then OUTH - data strobe lines activated. Range: –32768 to +32767	4I-1
*WRL	Comp	Read/Write Floating Point Data	Reads and writes the Wavelength Reference Length (etalon's length). Sign determines direction sense. Set to actual length stamped on etalon. Range: ± 1.00 metre, ≠ 0 Default Setting: 0.127 metre	4K-11
*WTC	Comp	Read/Write Floating Point Data	Sets or reads the compensation number derived from the Wavelength Tracker data. *WTC includes material expansion compensation if *ECV < >0. Range: 0 to 1 Power-up Default: 0.99728766 (20°C, 760 mm Hg, 50% Relative Humidity) Service mode (*TST - 1): Reads the actual phase measurement in $\lambda/32$ units.	4K-11
*WTE	Comp	Read/Write Integer Data	Enables (*WTE =1) or disables (*WTE =0) Wavelength Tracking function and selects which compensation number (*WTC or *CNV) is used to generate a compensation alert. Range: 0 or 1 Power-up Default: 0 when *CMC=0 and 1 when *CMC=1	4K-12
*WTL	Comp	Read/Write Floating Point Data	Instructs the Automatic Compensation board to generate an alert (asserts SRQ bit) if the Wavelength Tracker Compensation number (*WTC) changes by an amount greater than or equal to the *WTL value. (See also IMSK, *CNL, and *WTE.) Range: –0.0000100 to +0.0000100 (± 10 ppm) Power-up Default: 0.0000000	4K-12
*WTR	Comp	Read-only Floating Point Data	If the Wavelength Tracker Compensation number (*WTC) deviates from *WTR by more than the *WTL value, the SRQ bit is asserted and a system interrupt is generated. (See also IMSK, *CNR, and *WTE.)	4K-12
*ZRO	Axis	Command	Resets the position counter to zero.	4D-15
	Servo	Command	Resets the position counter and destination to zero and defines TCN_0 for deadpath correction.	4F-54

APPENDIX B
HP 5507A/B ERROR MESSAGE SUMMARY

INTRODUCTION

The following table lists all HP 5507A/B Laser Position Transducer Electronics' error message, the subassemblies that generate them, and a Section IV subsection page reference where more detailed information may be found. The table is arranged in ascending error number order.

Table B-1. HP 5507A/B Error Message Summary

Error	Description	Source	See Page
-500	Unidentified System Error	HP-IB Proto A-Quad-B	4B-26 4I-4 4E-43
-201	Numeric Output Conversion Error	HP-IB	4B-26
-102	Card Self-test Failure	Axis Comp Servo A-Quad-B	4D-17 4K-18 4F-56 4E-43
-101	System Error	HP-IB Axis A-Quad-B	4B -26 4D-17 4E-43
-100	No Boards Found During Boot	HP-IB	4B-26
100	No Active Listeners Present	HP-IB	4B-27
200	Input Format Error	HP-IB	4B-27
202	No Data Available for Output	HP-IB	4B-27
203	Input String More Than 80 Characters Long	HP-IB	4B-27
210	Numeric Input Format Error	HP-IB	4B-27
211	Numeric Entry Out of Range	HP-IB	4B-27
212	Block Input Format/Range Error	HP-IB	4B-27
300	Unrecognized Mnemonic	HP-IB	4B-27
301	Data Mnemonic Used as a Command	HP-IB	4B-27
302	Command Mnemonic Used as Data	HP-IB	4B-27
303	Write to Read-only Variable	HP-IB	4B-27
440	Measurement Signal Absent	Axis	4D-17
441	Measurement Loss of Lock	Axis	4D-17
442	Maximum Slew Rate Exceeded	Axis	4D-17
443	Position Counter Overflow	Axis	4D-17
444	Destination Entry Out of Range	Axis	4D-17
445	Clip Limit Entry Out of Range	Axis	4D-18
446	Null Limit Out of Range	Axis	4D-18
447	Compensation Entry Out of Range	Axis	4D-18
448	PLL Test Entry Out of Range	Axis	4D-18
450	Laser Reference Unlocked	HP-IB	4B-27

Table B-1. HP 5507A/B Error Message Summary (Continued)

Error	Description	Source	See Page
520	Input Format Error	A-Quad-B	4E-43
521	Command Number Out of Range	A-Quad-B	4E-43
522	Extended Command Number Error	A-Quad-B	4E-43
525	Numeric Input Format Error	A-Quad-B	4E-43
526	Numeric Entry Out of Range	A-Quad-B	4E-43
527	Block Input Format/Range Error	A-Quad-B	4E-43
528	Missing Item Separator	A-Quad-B	4E-43
530	Unrecognized Mnemonic	A-Quad-B	4E-43
531	Data Mnemonic Used as Command	A-Quad-B	4E-44
532	Command Mnemonic Used with Data	A-Quad-B	4E-44
533	Write to Read-Only Mnemonic	A-Quad-B	4E-44
534	Unknown Data Type	A-Quad-B	4E-44
535	CNUM Entry Out of Range	A-Quad-B	4E-44
536	ASGN Error - Mnemonic Not Found	A-Quad-B	4E-44
537	ERML Entry Out of Range	A-Quad-B	4E-44
538	DFMT Entry Out of Range	A-Quad-B	4E-44
539	HSMD Entry Out of Range	A-Quad-B	4E-44
540	Measurement Signal Absent	A-Quad-B	4E-44
541	Measurement Loss of Lock	A-Quad-B	4E-44
542	Maximum Slew Rate Exceeded	A-Quad-B	4E-44
543	Position Counter Overflow	A-Quad-B	4E-45
544	Pulse Circuits Failure - Re-BOOT	A-Quad-B	4E-45
545	Pulse Counter Underflow	A-Quad-B	4E-45
546	EEPROM Addressing Error	A-Quad-B	4E-45
547	System Mnemonic Write Data Error	A-Quad-B	4E-45
548	Output Data Formatting Error	A-Quad-B	4E-45
550	Pulse Counter Preset Error	A-Quad-B	4E-45
551	Setup Parameters Locked	A-Quad-B	4E-45
552	WCM Mnemonic Does NOT Exist	A-Quad-B	4E-45
553	Read Comp. Number Failure	A-Quad-B	4E-45
554	Write Expansion Coef. Failure	A-Quad-B	4E-45
555	Write Compensation Limit Failure	A-Quad-B	4E-46
556	Write Filter TC Failure	A-Quad-B	4E-46
557	Read Init. Comp. Number Failure	A-Quad-B	4E-46
558	Write Init. Comp. Number Failure	A-Quad-B	4E-46
559	Send *BCN Value Failure	A-Quad-B	4E-46
560	CMP Entry Out of Range	A-Quad-B	4E-46
561	DIR Entry Out of Range	A-Quad-B	4E-46
562	EMD Entry Out of Range	A-Quad-B	4E-46
563	MEN Entry Out of Range	A-Quad-B	4E-46

Table B-1. HP 5507A/B Error Message Summary (Continued)

Error	Description	Source	See Page
564	OPT Entry Out of Range	A-Quad-B	4E-46
565	PEN Entry Out of Range	A-Quad-B	4E-46
567	PUN Entry Out of Range	A-Quad-B	4E-47
568	QAD Entry Out of Range	A-Quad-B	4E-47
571	TST Entry Out of Range	A-Quad-B	4E-47
572	CUR Entry Out of Range	A-Quad-B	4E-47
573	MUR Entry Out of Range	A-Quad-B	4E-47
574	PUR Entry Out of Range	A-Quad-B	4E-47
575	WCM Entry Out of Range	A-Quad-B	4E-47
576	AVS Entry Out of Range	A-Quad-B	4E-47
577	BCN Entry Out of Range	A-Quad-B	4E-47
578	CMD Entry Out of Range	A-Quad-B	4E-47
579	COF Entry Out of Range	A-Quad-B	4E-47
580	DPD Entry Out of Range	A-Quad-B	4E-48
581	MPO Entry Out of Range	A-Quad-B	4E-48
582	POF Entry Out of Range	A-Quad-B	4E-48
583	PRD Entry Out of Range	A-Quad-B	4E-48
584	RES Entry Out of Range	A-Quad-B	4E-48
585	RES Incompatible with PUN & OPT	A-Quad-B	4E-48
586	WCM Mnemonic not Floating Point	A-Quad-B	4E-48
587	Bad Address for WCM Mnemonic	A-Quad-B	4E-48
590	Serial Port A Buffer Overflow	A-Quad-B	4E-48
591	Serial Port A OverRun Error	A-Quad-B	4E-48
592	Serial Port A Parity Error	A-Quad-B	4E-48
593	Serial Port A Framing Error	A-Quad-B	4E-49
594	Serial Port B Buffer Overflow	A-Quad-B	4E-49
595	Serial Port B OverRun Error	A-Quad-B	4E-49
596	Serial Port B Parity Error	A-Quad-B	4E-49
597	Serial Port B Framing Error	A-Quad-B	4E-49
598	Parallel Port Buffer Overflow	A-Quad-B	4E-49
599	Fatal Error SSSS PPPPPPPP TTNN	A-Quad-B	4E-49
740	Measurement Loss of Lock	Servo-Axis	4F-56
741	Measurement Signal Absent	Servo-Axis	4F-56
742	Position Counter Overflow	Servo-Axis	4F-56
750	DEQ Entry with Drive On	Servo-Axis	4F-56
751	DEQ Entry Out of Range	Servo-Axis	4F-57
752	SVC Entry Out of Range	Servo-Axis	4F-57
753	Profile Parameter Error	Servo-Axis	4F-57
754	PTR Entry Out of Range	Servo-Axis	4F-57
755	DRE Entry Out of Range	Servo-Axis	4F-57

Table B-1. HP 5507A/B Error Message Summary (Continued)

Error	Description	Source	See Page
756	Negative Feed Fwd Entry	Servo-Axis	4F-57
757	TST Entry Out of Range	Servo-Axis	4F-57
758	Slaved Board is Not Servo	Servo-Axis	4F-57
759	NUL Entry Out of Range	Servo-Axis	4F-57
760	MKR Entry Out of Range	Servo-Axis	4F-57
761	MKW Entry Out of Range	Servo-Axis	4F-57
762	Data Sent to Non-Data PTR	Servo-Axis	4F-57
763	CLK Entry Out of Range	Servo-Axis	4F-57
764	Bad CLK for Multi-Axis Move	Servo-Axis	4F-57
765	BGO Entry Out of Range	Servo-Axis	4F-57
766	Bad SVC for Buffered Move	Servo-Axis	4F-58
767	OPT Entry Out of Range	Servo-Axis	4F-58
768	SPD Entry Out of Range	Servo-Axis	4F-58
769	DIR Entry Out of Range	Servo-Axis	4F-58
770	EMD Entry of Out Range	Servo-Axis	4F-58
771	TCN Entry Out of Range	Servo-Axis	4F-58
772	DES Entry Out of Range	Servo-Axis	4F-58
773	GPIO Command to Non Servo Board	Servo-Axis	4F-58
774	Unable to Locate UCN Mnemonic	Servo-Axis	4F-58
775	UCN Mnemonic Not Initialized	Servo-Axis	4F-58
776	Excessive Following Error	Servo-Axis	4F-58
777	Limit Sense Entry Out of Range	Servo-Axis	4F-58
778	Unable to Compile Mnemonic	Servo-Axis	4F-58
779	Compiled Mnemonic Non-existent	Servo-Axis	4F-58
780	Attempted Read from Compiled Command	Servo-Axis	4F-58
781	Write to Non-Writable Mnemonic	Servo-Axis	4F-59
782	Too Many Compile Mnemonics	Servo-Axis	4F-59
783	Data Mnemonic Used as Command	Servo-Axis	4F-59
784	User Equation Space Overflow	Servo-Axis	4F-59
799	Fatal Exception: SSSS PPPPPPPP FVVV	Servo-Axis	4F-59
880	Sensor Channel Out of Range	Comp	4K-18
881	AHV Entry Out of Range	Comp	4K-18
882	APV Entry Out of Range	Comp	4K-19
883	ATV Entry Out of Range	Comp	4K-19
884	CNL Entry Out of Range	Comp	4K-19
885	ECV Entry Out of Range	Comp	4K-19
886	MTA Entry Out of Range	Comp	4K-19
887	RVA Entry Out of Range	Comp	4K-19
888	RVB Entry Out of Range	Comp	4K-19
889	TST Entry Out of Range	Comp	4K-19

Table B-1. HP 5507A/B Error Message Summary (Continued)

Error	Description	Source	See Page
890	CRE Command Must Precede CRC	Comp	4K-19
891	Firmware Execution Error	Comp	4K-19
892	Firmware Execution Error	Comp	4K-19
893	Variable Address Byte Error	Comp	4K-19
894	Command Byte Error	Comp	4K-19
895†	Ground Channel Tolerance Error	Comp	4K-20
896†	Reference Channel Tolerance Error	Comp	4K-20
897†	A/D Status Signal Not Working	Comp	4K-20
898†	A/D Digital Output Read Error	Comp	4K-20
899†	Calibration Memory Checksum Error	Comp	4K-20
900†	Counter Control Signal Error	Comp	4K-20
901†	Counter Preset Error	Comp	4K-20
902†	Counter Output Error	Comp	4K-20
903	Measurement Signal Error	Comp	4K-20
904	Reference Signal Error	Comp	4K-20
905	WTE Entry Out of Range	Comp	4K-20
906	FTC Entry Out of Range	Comp	4K-20
907	DTV Entry Out of Range	Comp	4K-20
908	WTL Entry Out of Range	Comp	4K-21
909	CMC Entry Out of Range	Comp	4K-21
910	WRL Entry Out of Range	Comp	4K-21
911	WTC Entry Out of Range	Comp	4K-21

† These messages are enabled only if *TST is set to 1.

APPENDIX C
SYNTAX DIAGRAMS AND NUMERIC REPRESENTATION EXAMPLES

Appendix C augments information already presented in Section IV of this manual. The syntax diagrams provide a graphical description of the preferred alternatives for constructing measurement and program messages. The numeric representation examples (NR1, NR2 NR3, BDFA, and BDFD) will clarify and illustrate how data is interpreted by the HP 5507A.

SYNTAX DIAGRAMS

The following HP-IB syntax diagrams are provided to explain the format in which HP-IB programming commands should be sent to the instrument. All characters enclosed by a rounded envelope must be entered exactly as shown. Words enclosed by a rectangular box name items used in the commands.

Command elements, connected by lines, can be followed in only one direction, as indicated by the arrowhead at the end of the line. Any combination of command elements that can be generated by following the lines in the proper direction is syntactically correct.

There are four possible types of command elements:

- command mnemonics (referred to as "headers")
- data message separators
- program message separators, and
- data separators

A separator is required between each command, as shown in *Figure C-1*. All HP-IB commands require a command header. Command headers consist of a four-character mnemonic. Commands that cause data to be returned to the controller (queries) include a question mark (?) as the last character of the header.

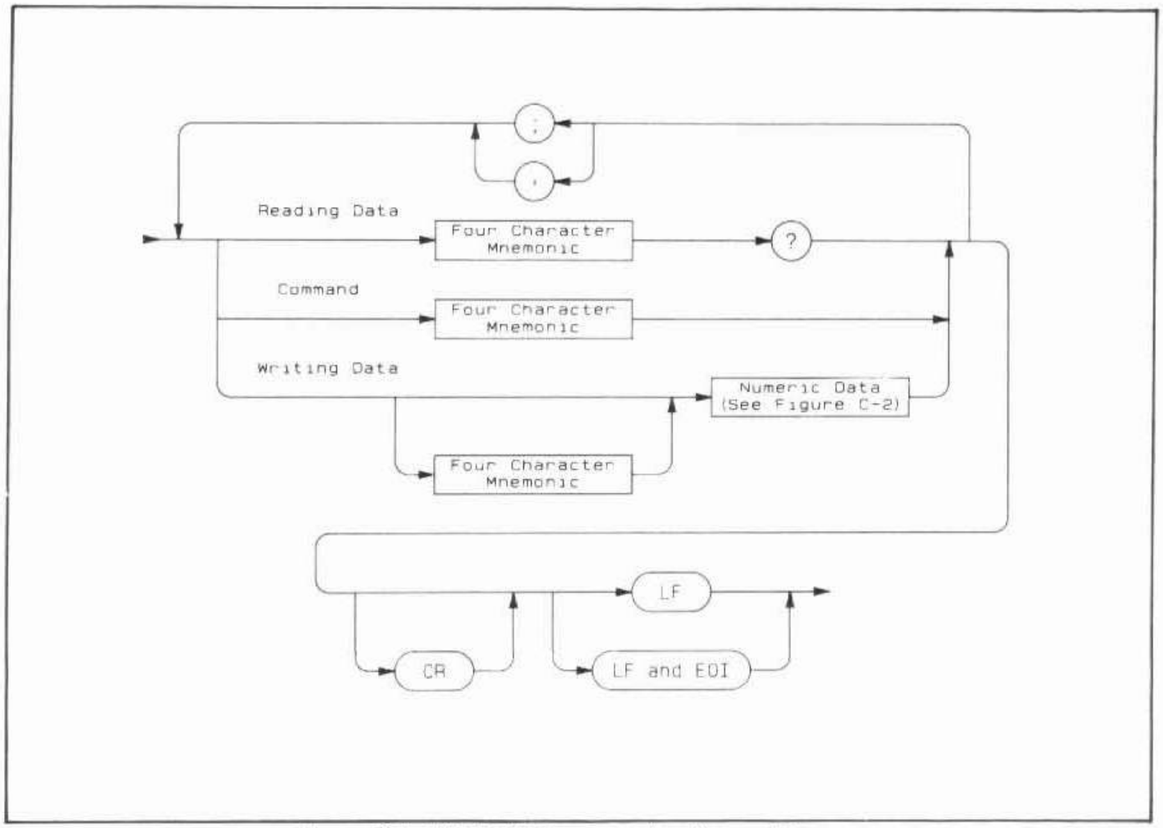


Figure C-1. HP 5507A Programming Syntax Diagram

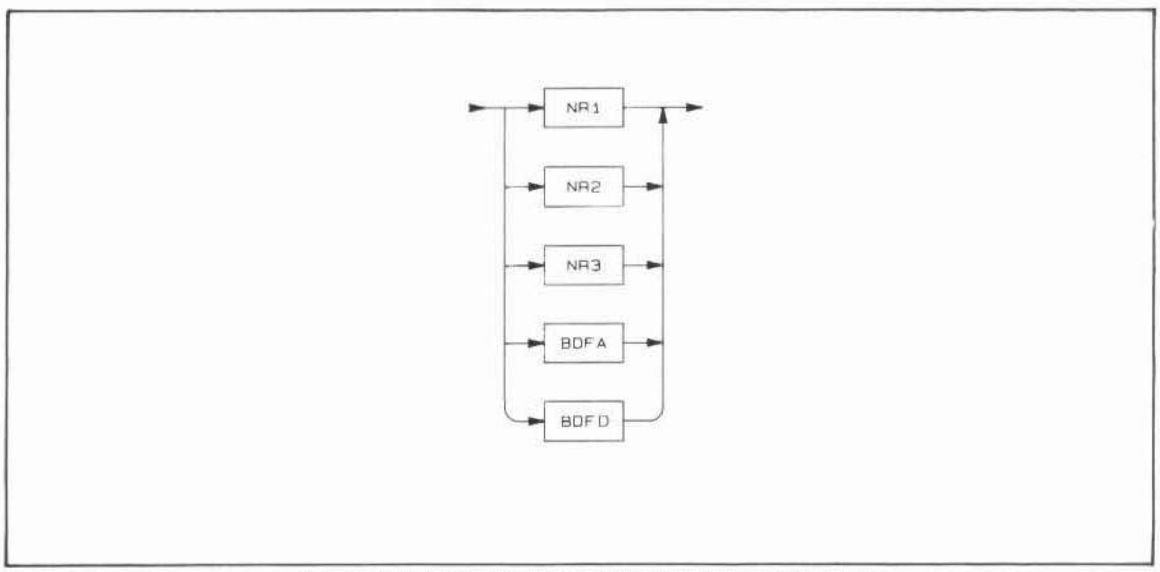


Figure C-2. Numeric Representation Syntax Diagram

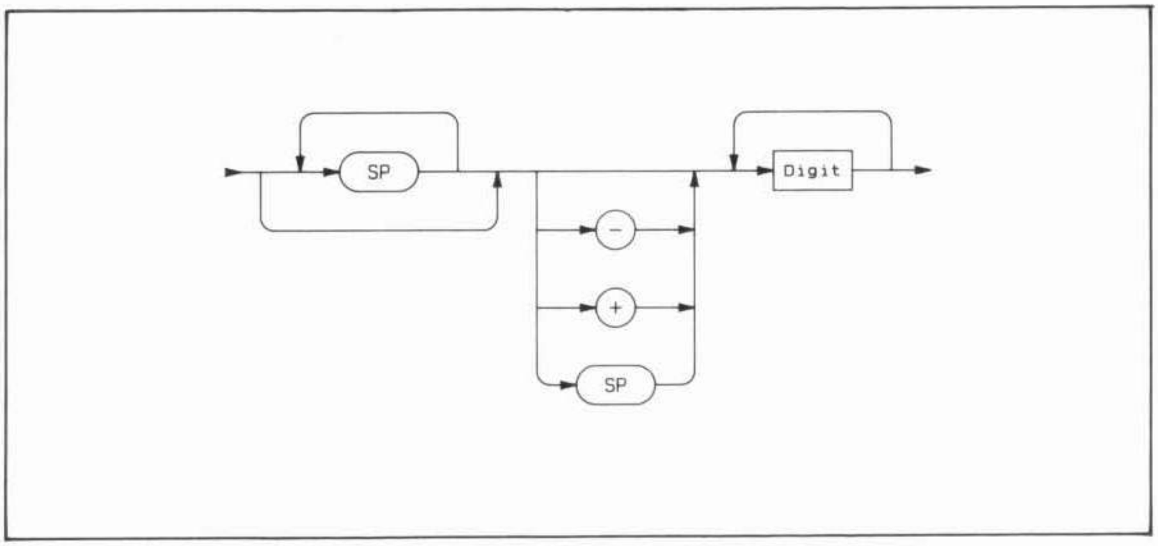


Figure C-3. NR1 Syntax Diagram

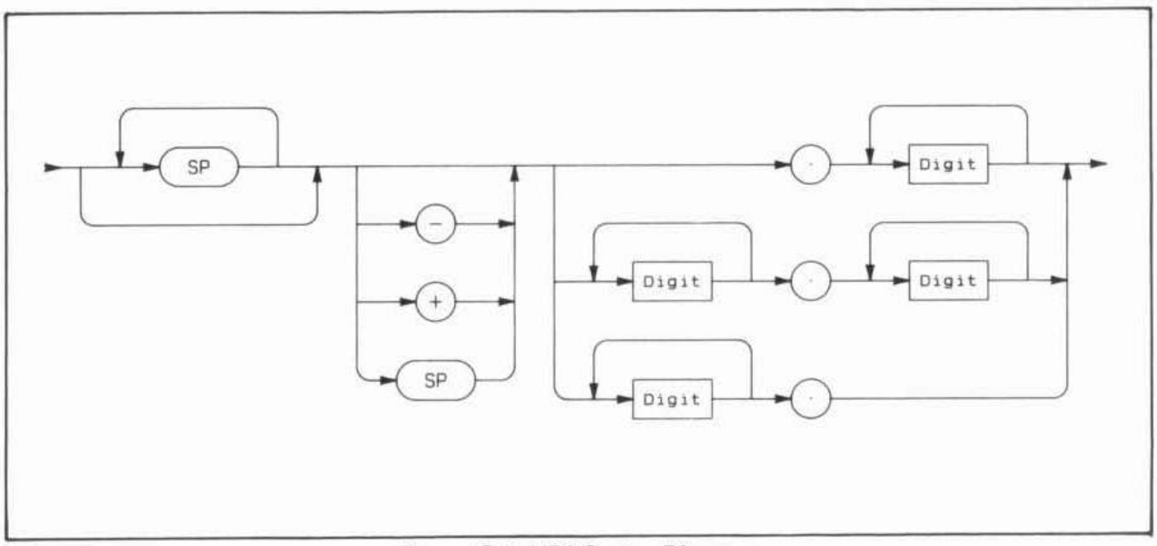


Figure C-4. NR2 Syntax Diagram

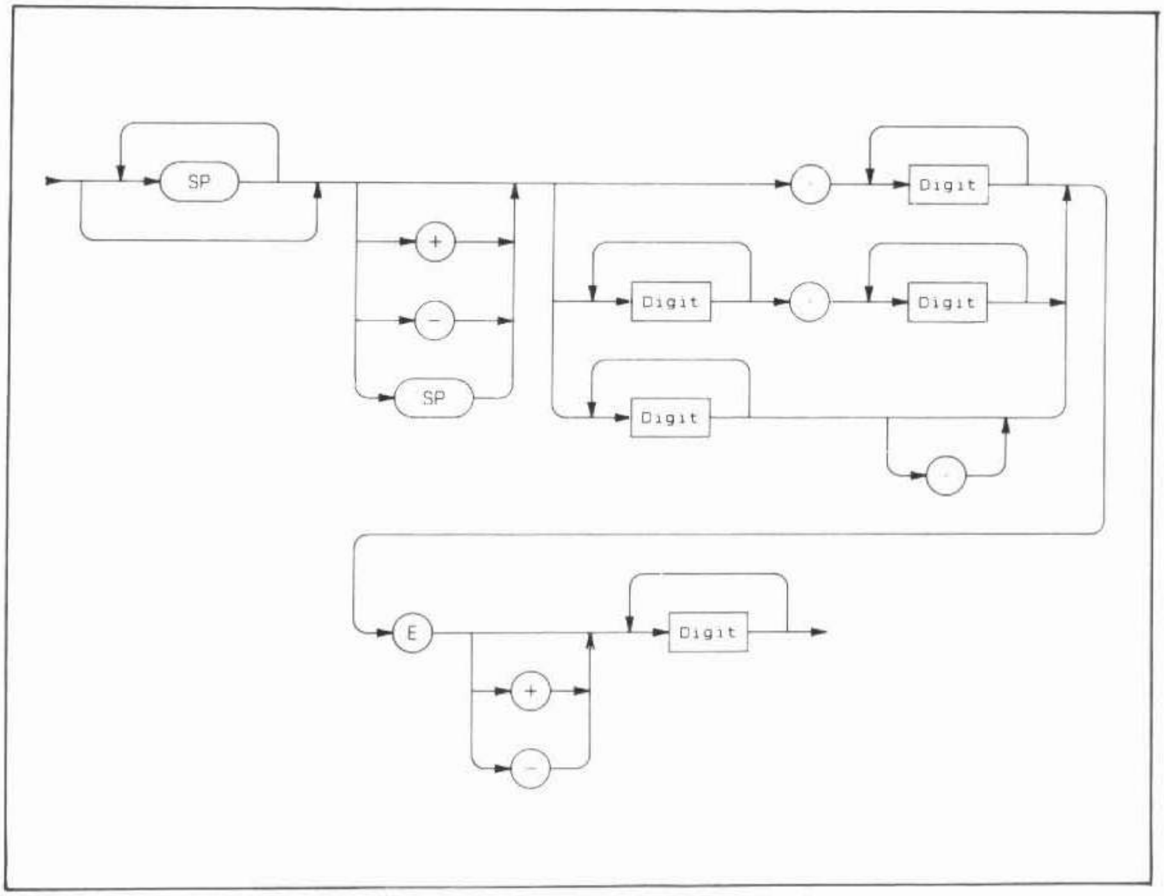


Figure C-5. NR3 Syntax Diagram

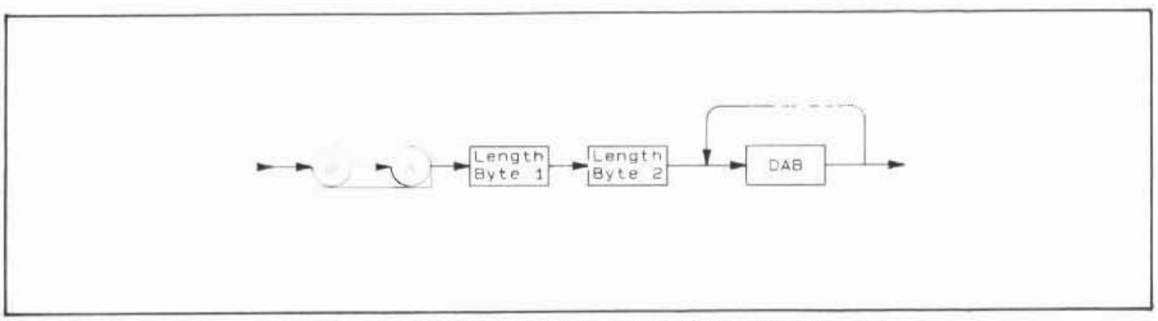


Figure C-6. IEEE-728 BDFA Format Code Syntax Diagram

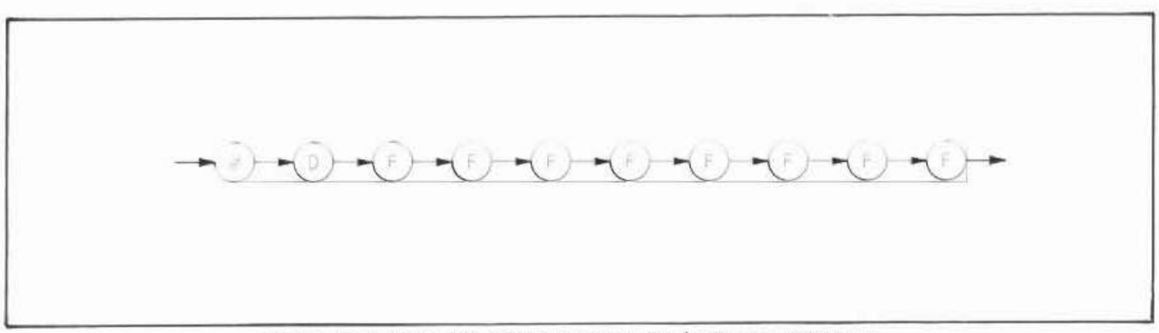


Figure C-7. IEEE-728 BDFD Format Code Syntax Diagram

NUMERIC REPRESENTATION EXAMPLES

The HP 5507A will accept data in the NR1, NR2, or NR3 Input Data Format without being programmed to do so. At power-up, numeric data is output in either the NR1 or NR2 format, depending on the data type. The HP 5507A must be programmed to transmit floating point data messages in the BDFA and BDFD Data Formats, but will accept such data (for integer or floating point variables) without being programmed to do so. The HP 5507A can be programmed to output floating point data in a block format that is compatible with the HP Series 200 Computers. The following paragraphs provide written examples of such numeric representations to clarify and illustrate their application to the HP 5507A.

NR1,NR2, and NR3

Table C-1. Numeric Representation Examples

DECIMAL EQUIVALENT	NR1	NR2	NR3
0	0 +0 -0	0.0 +0.0 -0.0	0.0E+00 0.0
0.00015	No Representation Possible	0.00015	1.5E-4 150E-6
-10	-10	-10.0	-10.0E+00 -1E1
-14.203	No Representation Possible	-14.203	-1.4203E1
1234.5	No Representation Possible	1234.5	1.2345E3
5600	5600	5600.00	5600E0

Block Data Examples

BINARY BLOCK A (BDFA)

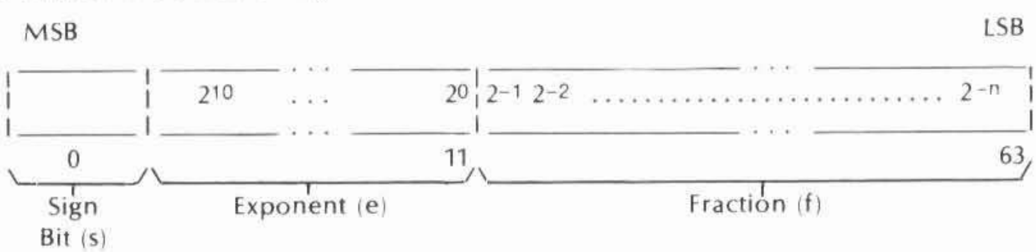
Example #1: Assume that the X-axis position is to change to -2 units. The string sent by the controller reads "XDES # A␀␈"; -2. The data is transmitted in Binary Block A (BDFA) Format.

Sixteen bytes of information are transmitted in this format. The bytes are configured as outlined below.

XDES-2 in BDFA Format

TRANSMITTED BYTE	BINARY EQUIVALENT	DESCRIPTION
X	0101 1000	ASCII Mnemonic Character
D	0100 0100	” ” ”
E	0100 0101	” ” ”
S	0101 0011	” ” ”
#	0010 0011	Block Format Specifier
A	0100 0001	Block Format A
0	0000 0000	Length Specifier Byte 1
8	0000 1000	Length Specifier Byte 2
	1100 0000	
	0000 0000	
	0000 0000	
	0000 0000	Data Bytes in IEEE-P754 (Double Precision Format)
	0000 0000	
	0000 0000	
	0000 0000	
	<EOI> & 0000 0000	

The transmitted data bytes are interpreted as follows. Recall that the double precision floating point number is a 64-bit binary value. The individual bits are formatted as follows:



1=negative
0=positive

where

"s" is the sign bit
"e" is the exponent
"f" is the 52-bit fraction

The value (v) of a double precision floating point number (–2) can be computed using the following formula. The most significant bit (MSB) is always transmitted first.

If $0<e<2047$, then $v=(-1)^s\, 2^{(e-1023)}\, (1.f)$.

In our example, s=1, e=1024, and f=0. Solving the equation

$$\begin{aligned} v &= (-1)^1\, 2^{(1024-1023)}\, (1.0) \\ &= (-1)\,(2)\,(1.0) \\ &= -2 \end{aligned}$$

BLOCK D FORMAT (BDFD)

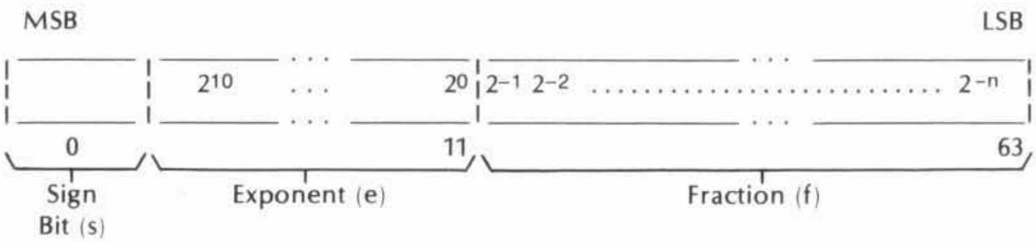
Example #2: Assume that the position of the X-axis is to change to +3 units. The string sent by the controller reads "XDES #D"; 3. The data is transmitted in Block D Format.

Fourteen bytes of information are transmitted in this format. The bytes are configured as outlined below.

XDES 3 in BDFF Format

TRANSMITTED BYTE	BINARY EQUIVALENT	DESCRIPTION
X	0101 1000	ASCII Mnemonic Character
D	0100 0100	" " "
E	0100 0101	" " "
S	0101 0011	" " "
#	0010 0011	Block Format Specifier
D	0100 0100	Block Format D
	0100 0000	
	0000 1000	
	0000 0000	
	0000 0000	Data Bytes in IEEE-P754 (Double Precision Format)
	0000 0000	
	0000 0000	
	0000 0000	
	<EOI> & 0000 0000	

The transmitted data bytes are interpreted as follows. Recall that the double precision floating point number is a 64-bit binary value. The individual bits are formatted as follows:



1=negative
0=positive

where

"s" is the sign bit

"e" is the exponent

"f" is the 52-bit fraction

The value (v) of a double precision floating point number (3) can be computed using the following formula. The most significant bit (MSB) is always transmitted first.

If $0<e<2047$, then $v=(-1)^s\, 2^{(e-1023)}\, (1.f)$.

In our example, s=0, e=1024, and f=0.5. Solving the equation

$$v = (-1)^0\, 2^{(1024-1023)}\, (1.5)$$
$$= (2)\, (1.5)$$
$$= +3$$

APPENDIX D
HP-IB BASICS

Appendix D provides a description of the technical fundamentals of the Hewlett-Packard Interface Bus (HP-IB). Its intent is to provide a thorough overview of HP-IB basics.

GENERAL BUS DESCRIPTION

The Hewlett-Packard Interface Bus (HP-IB) is a carefully defined instrumentation interface which simplifies the integration of instruments, calculators, and computers into systems. It minimizes compatibility problems between devices and has sufficient flexibility to accommodate future products. The HP-IB is Hewlett-Packard's implementation of IEEE Std 488-1978 "Standard Digital Interface for Programmable Instrumentation".

The HP-IB employs a 16-line bus to interconnect up to 15 instruments. This bus is normally the sole communication link between the interconnected units. Each instrument on the bus is connected in parallel to the 16 lines of the bus. Eight of the lines are used to transmit data and the remaining eight are used for communication timing (Handshake), and control.

Data is transmitted on the eight HP-IB data lines as a series of eight-bit characters referred to as "bytes". Normally, a seven-bit ASCII (American Standard Code for Information Interchange) code is used with the eighth bit available for a parity check, if desired. Data is transferred by means of an interlocked "handshake" technique. This sequence permits asynchronous communication over a wide range of data rates.

Communication between devices on the HP-IB employs the three basic functional elements listed below. Every device on the bus must be able to perform at least one of these functions:

a. LISTENER — A device capable of receiving data from other instruments. Examples of this type of device are: printers, display devices, programmable power supplies, programmable signal sources, etc.

b. TALKER — A device capable of transmitting data to other instruments. Examples of this type of device are: tape readers, voltmeters that are outputting data, counters that are outputting data, and so on.

c. CONTROLLER — A device capable of managing communications over the HP-IB, such as, addressing and sending commands. A calculator or computer with an appropriate I/O interface is an example of this type of device.

An HP-IB system allows only one device at a time to be an active talker. Up to 14 devices may simultaneously be listeners. Only one device at a time may be an active controller.

BUS STRUCTURE

The HP-IB interface connections and bus structure are shown in *Figure D-1*.

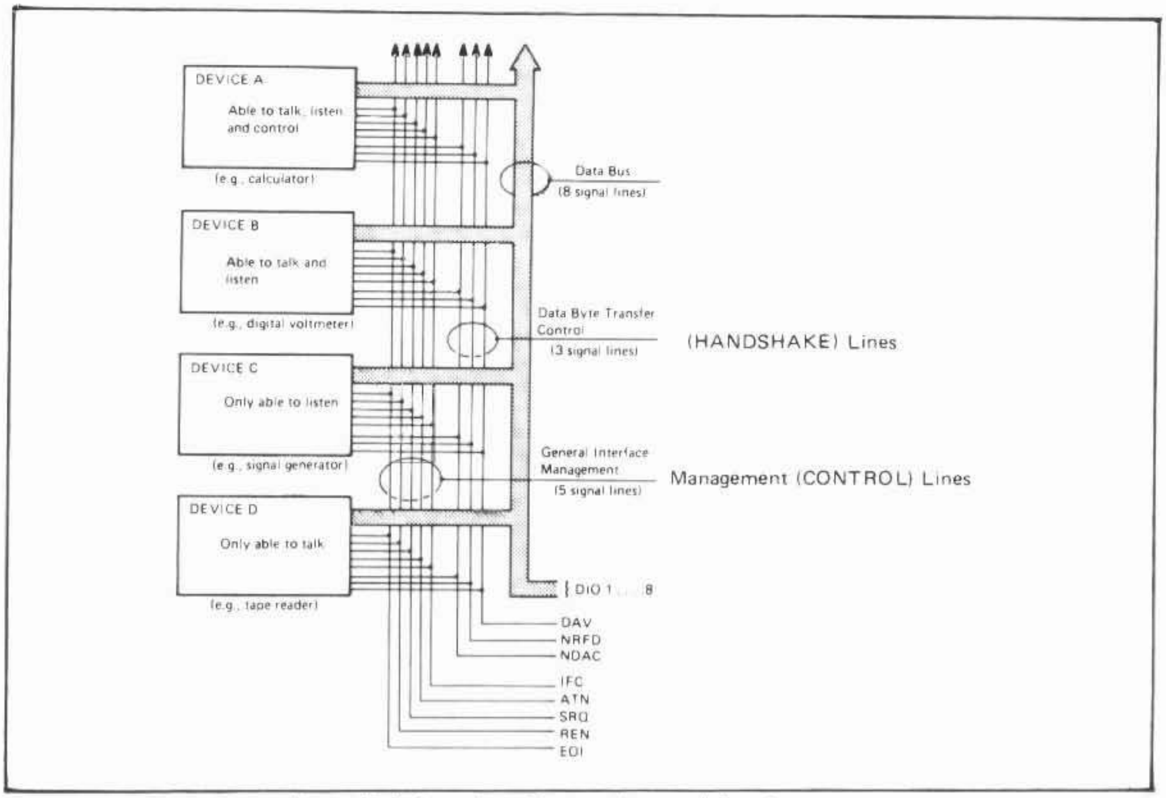


Figure D-1. Interface Connections and Bus Structure

Command Mode — ATN Line

The active controller manages all bus communications. The state of the ATN (attention) line, determined by the controller, defines how data on the eight data (DIO) lines will be interpreted by the other devices on the bus. When ATN is low (true), the HP-IB is in Command Mode. In Command Mode, the controller is active and all other devices are waiting for instructions. Command Mode instructions that can be issued by the Controller in "Command Mode" include:

a. Talker Address — A seven-bit code transmitted on the HP-IB that enables a specific device to talk. Only one bus device at a time may act as the talker. When the controller addresses a unit to talk, the previous talker is automatically unaddressed and ceases to be a talker. Confusion would result if more than one device were allowed to talk at a time.

b. Listener Address — A seven-bit code transmitted on the HP-IB that enables a specific device to listen. Several bus devices at a time (up to 14) may be listeners.

c. Universal Commands — Bus devices capable of responding to these commands from the controller will do so at any time regardless of whether they are addressed. These commands will be covered in more detail later.

d. Addressed Commands — These commands are similar to Universal Commands except that they are recognized only by devices that are addressed as listeners.

e. Unaddress Commands —

   1. "Unlisten" Address Command — This command unaddresses all listeners that have been previously addressed to listen.

   2. "Untalk" Address Command — This command unaddresses any talker that had been previously addressed to talk.

Bus Commands

In "Command Mode", one or more special codes known as "Bus Commands" may be placed on the HP-IB. These commands have the same meaning in all bus systems. Each device is designed to respond to those commands that have a useful meaning to the device and will ignore all others. The operating manual for each device will state which bus commands it will obey.

Bus Commands fall into three categories:

a. Universal Commands affect all responding devices on the bus, whether addressed or not.

b. Addressed Commands affect only responding devices that are addressed to listen. Addressed commands allow the controller to initiate a simultaneous action from a selected group of devices on the bus.

c. Unaddress Commands are obeyed by all addressable devices. These commands unaddress devices that are currently addressed.

Bus Commands are summarized in *Table D-1*.

Service Request and Serial Polling — SRQ Line

Some devices that operate on the interface bus have the ability to request service from the system controller. A device may request service when it has completed a measurement, when it has detected a critical condition, or for any other reason. Service request is initiated when a device sets the HP-IB SRQ line low. The controller has the option of determining when or if a service request will be serviced. The following sequence is used to respond to a service request:

a. The controller checks for the presence of a service request.

b. If a service request is present, the controller sets the Serial Poll Mode. The Serial Poll Mode is initiated by the controller transmitting the Universal Command "SPE" [ASCII character "CAN" (Octal 030)] in the "Command Mode".

c. The controller polls one of the devices that may have requested service. It then polls the next device, and so on. Once the Serial Poll Mode has been enabled, responding devices on the bus are prepared to accept a serial poll. This is accomplished by setting the ATN line, addressing the device as a talker, and then clearing the ATN line. If the device polled has requested service, that device will respond by setting line DIO7 low. Other DIO lines may also be set low, indicating the nature of the service request.

d. For each device that has requested service, the controller takes appropriate action.

e. When all devices have been polled, the controller terminates the Serial Poll Mode by issuing the Universal Command "SPD" [ASCII Character "EM", (Octal 031)].

Table D-1. Summary of Bus Commands

	COMMAND	ASCII CHAR-ACTER	OCTAL CODE	PURPOSE
UNADDRESS COMMANDS	UNL UNLISTEN	?	077	Clears Bus of all listeners.
	UNT UNTALK	-	137	Unaddresses the current talker so that no talker remains on the Bus.†
UNIVERSAL COMMANDS	LLO Local Lockout	DC1	021	Disables front panel local-reset button on responding devices.
	DCL Device Clear	DC4	024	Returns all devices capable of responding to predetermined states, regardless of whether they are addressed or not.
	PPU Parallel Poll Unconfigure	NAK	025	Sets all devices on the HP-IB with Parallel Poll capability to a prefined condition.
	SPE Serial Poll Enable	CAN	030	Enables Serial Poll Mode on the Bus.
	SPD Serial Poll Disable	EM	031	Disables Serial Poll Mode on the Bus.
ADDRESSED COMMANDS	SDC Selective Device Clear	EOT	004	Returns addressed devices, capable of responding, to predetermined states.
	GTL Go to Local	SOH	001	Returns responding devices to local control.
	GET Group Execute Trigger	BS	010	Initiates a simultaneous preprogrammed action by responding devices.
	PPC Parallel Poll Configure	ENQ	005	Permits the DIO lines to be assigned to instruments on the Bus for the purpose of responding to a parallel poll.
	TCT Take Control	HT	011	This command is given when the active controller on the Bus transfers control to another instrument.

†Talkers can also be unaddressed by transmitting an unused talk address over the Bus.

The full sequence of operations is not necessary in all cases. For example, a system may have only one device that requests service and then only for a single purpose. When the controller detects a service request, the source of the request and the appropriate action is known immediately. Thus the use of the service request and the serial poll depends entirely on the make-up of each system and the devices involved.

(SENT AND RECEIVED WITH ATN TRUE)

b_4	b_3	b_2	b_1	COLUMN → / ROW ↓	0 0 0	MSG (1)	0 0 1	MSG	0 1 0	MSG	0 1 1	MSG	1 0 0	MSG	1 0 1	MSG	1 1 0	MSG	1 1 1	MSG
					0		1		2		3		4		5		6		7	
0	0	0	0	0	NUL		DLE		SP	MLA ASSIGNED TO DEVICE	0	MLA ASSIGNED TO DEVICE	@	MTA ASSIGNED TO DEVICE	P	MTA ASSIGNED TO DEVICE		MEANING DEFINED BY PCG CODE	p	MEANING DEFINED BY PCG CODE
0	0	0	1	1	SOH	GTL	DC1	LLO	!		1		A		Q		a		q	
0	0	1	0	2	STX		DC2		"		2		B		R		b		r	
0	0	1	1	3	ETX		DC3		#		3		C		S		c		s	
0	1	0	0	4	EOT	SDC	DC4	DCL	$		4		D		T		d		t	
0	1	0	1	5	ENQ	PPC (3)	NAK	PPU	%		5		E		U		e		u	
0	1	1	0	6	ACK		SYN		&		6		F		V		f		v	
0	1	1	1	7	BEL		ETB		'		7		G		W		g		w	
1	0	0	0	8	BS	GET	CAN	SPE	(		8		H		X		h		x	
1	0	0	1	9	HT	TCT	EM	SPD	)		9		I		Y		i		y	
1	0	1	0	10	LF		SUB		*		:		J		Z		j		z	
1	0	1	1	11	VT		ESC		+		;		K		[		k		{	
1	1	0	0	12	FF		FS		,		<		L		\		l		|	
1	1	0	1	13	CR		GS		–		=		M		]		m		}	
1	1	1	0	14	SO		RS		.		>		N		^		n		~	
1	1	1	1	15	SI		US		/		?	UNL	O		___	UNT	o		DEL	

Bits: b_7, b_6, b_5 (2)

Columns 0–1 MSG: ADDRESSED COMMAND GROUP (ACG); UNIVERSAL COMMAND GROUP (UCG)

Columns 2–5 (4): LISTEN ADDRESS GROUP (LAG) (columns 2–3); TALK ADDRESS GROUP (TAG) (columns 4–5)

PRIMARY COMMAND GROUP (PCG) (columns 0–5)

SECONDARY COMMAND GROUP (SCG) (columns 6–7)

NOTES:
1. MSG = INTERFACE MESSAGE
2. b_1 = DIO1 . . . b_7 = DIO7
3. REQUIRES SECONDARY COMMAND
4. DENSE SUBSET (COLUMN 2 THROUGH 5). ALL CHARACTERS USED IN BOTH COMMAND & DATA MODES.

Table D-2. Code Assignments for "Command Mode" of Operation

Parallel Poll — EOI and ATN Lines

Parallel polling permits the status of up to eight devices on the HP-IB to be checked simultaneously. The operator assigns each device a data line (DIO1 through DIO8) which the device sets low during the parallel poll routine if it requires service. More devices can be handled, if desired, by sharing the use of each DIO line.

The parallel polling function requires the controller to periodically poll the instruments connected to the bus. The controller interrogates (polls) the instruments by sending an EOI with ATN activated. When either EOI or ATN is removed, the controller stops polling.

Code Summary

A code assignment summary is shown in *Table D-2*. These assignments apply only when operating in "Command Mode".

In "Data Mode" there are no specific code assignments. However, the devices communicating in this mode must agree on the meaning of the codes they use.

The set of codes labeled "Primary Command Group" are the codes commonly used to communicate on the HP-IB. The "Secondary Command Group" is used when addressing Extended Listeners and Talkers, or enabling the Parallel Poll Mode.

Other Bus Lines

The three remaining HP-IB lines and their functions are:

REN (Remote Enable)

The system controller sets REN low and then addresses the the devices to Listen before they will operate under remote control.

IFC (Interface Clear)

Only the system controller can activate this line. When IFC is set (true), all talkers, listeners, and active controllers go to their inactive states.

EOI (End or Identify)

This line is used to indicate the end of a multiple byte transfer sequence or, in conjunction with ATN, to execute a parallel polling sequence.

NOTE

During power-up, individual instruments can momentarily set the IFC line to a true state.

Address Codes

Devices with the functional capability of a listener normally recognize a single character address†. The 7-bit codes reserved for Listen addresses are listed in *Table D-3*. Each device has a unique Listen Address which can normally be modified.

Devices with the functional capability of talker normally recognize a single byte address††. A certain group of ASCII seven-bit bytes is reserved for talk address (refer to *Table D-4*). The state of the eighth bit is ignored in the "Command Mode" when addresses are being transmitted. Each device has a unique talk address which can normally be modified. The Talk Address, bits 1 through 5, are individually selected in each device to be either high or low. The selection of these bits allows changing the device Listen and/or Talk Address.

†An "Extended Listener" is capable of recognizing a two-byte listen address.

††An "Extended Talker" is capable of recognizing a two-byte talk address.

NOTE

Bits 6 and 7 determine whether the "address" is a "Listen" or "Talk" Address (see *Tables D-3 & D-4*).

Devices with both Listen and Talk Addresses have these addresses assigned in pairs, e.g., if the fourth address in the column of Listen Addresses "#" is selected, the Talk Address is "C", the fourth address in the talker address column. The Talk Address is automatically changed whenever the Listen Address is changed and vice versa. Addresses are normally alterable by the use of switches or jumpers within the instrument.

Table D-3. Listen Addresses

LISTEN ADDRESSES										
ASCII CHARACTER	DECIMAL VALUE	HP-IB BUS ADDRESS	BITS							
			b_8	b_7	b_6	b_5	b_4	b_3	b_2	b_1
SP	32	0	X	0	1	0	0	0	0	0
!	33	1	X	0	1	0	0	0	0	1
"	34	2	X	0	1	0	0	0	1	0
#	35	3	X	0	1	0	0	0	1	1
$	36	4	X	0	1	0	0	1	0	0
%	37	5	X	0	1	0	0	1	0	1
&	38	6	X	0	1	0	0	1	1	0
'	39	7	X	0	1	0	0	1	1	1
(	40	8	X	0	1	0	1	0	0	0
)	41	9	X	0	1	0	1	0	0	1
*	42	10	X	0	1	0	1	0	1	0
+	43	11	X	0	1	0	1	0	1	1
,	44	12	X	0	1	0	1	1	0	0
-	45	13	X	0	1	0	1	1	0	1
.	46	14	X	0	1	0	1	1	1	0
/	47	15	X	0	1	0	1	1	1	1
0	48	16	X	0	1	1	0	0	0	0
1	49	17	X	0	1	1	0	0	0	1
2	50	18	X	0	1	1	0	0	1	0
3	51	19	X	0	1	1	0	0	1	1
4	52	20	X	0	1	1	0	1	0	0
5	53	21	X	0	1	1	0	1	0	1
6	54	22	X	0	1	1	0	1	1	0
7	55	23	X	0	1	1	0	1	1	1
8	56	24	X	0	1	1	1	0	0	0
9	57	25	X	0	1	1	1	0	0	1
:	58	26	X	0	1	1	1	0	1	0
;	59	27	X	0	1	1	1	0	1	1
<	60	28	X	0	1	1	1	1	0	0
=	61	29	X	0	1	1	1	1	0	1
>	62	30	X	0	1	1	1	1	1	0
?	63	31	X	0	1	1	1	1	1	1
X = Don't Care										

Table D-4. Talk Addresses

ASCII CHARACTER	DECIMAL VALUE	HP-IB BUS ADDRESS	BITS							
			b_8	b_7	b_6	b_5	b_4	b_3	b_2	b_1
@	64	0	X	1	0	0	0	0	0	0
A	65	1	X	1	0	0	0	0	0	1
B	66	2	X	1	0	0	0	0	1	0
C	67	3	X	1	0	0	0	0	1	1
D	68	4	X	1	0	0	0	1	0	0
E	69	5	X	1	0	0	0	1	0	1
F	70	6	X	1	0	0	0	1	1	0
G	71	7	X	1	0	0	0	1	1	1
H	72	8	X	1	0	0	1	0	0	0
I	73	9	X	1	0	0	1	0	0	1
J	74	10	X	1	0	0	1	0	1	0
K	75	11	X	1	0	0	1	0	1	1
L	76	12	X	1	0	0	1	1	0	0
M	77	13	X	1	0	0	1	1	0	1
N	78	14	X	1	0	0	1	1	1	0
O	79	15	X	1	0	0	1	1	1	1
P	80	16	X	1	0	1	0	0	0	0
Q	81	17	X	1	0	1	0	0	0	1
R	82	18	X	1	0	1	0	0	1	0
S	83	19	X	1	0	1	0	0	1	1
T	84	20	X	1	0	1	0	1	0	0
U	85	21	X	1	0	1	0	1	0	1
V	86	22	X	1	0	1	0	1	1	0
W	87	23	X	1	0	1	0	1	1	1
X	88	24	X	1	0	1	1	0	0	0
Y	89	25	X	1	0	1	1	0	0	1
Z	90	26	X	1	0	1	1	0	1	0
[	91	27	X	1	0	1	1	0	1	1
\	92	28	X	1	0	1	1	1	0	0
]	93	29	X	1	0	1	1	1	0	1
^	94	30	X	1	0	1	1	1	1	0
_	95	31	X	1	0	1	1	1	1	1

X = Don't Care

Handshake Lines

Each character byte transferred on the HP-IB data lines employs the three-wire handshake sequence. This sequence has the following characteristics:

a. Data transfer is asynchronous — Data can be transferred at any rate suitable for the devices operating on the bus. (Data rates up to 500 kilobytes per second are typical; with a maximum of 1 megabyte per second).

b. Devices with different input/output speeds can be interconnected. Data transfer rate automatically adjusts to slowest active device.

c. More than one device can accept data at the same time.

The following definitions are used throughout the remaining text.

Source — A device transmitting information on the Bus in either the Command or Data Mode.

Talker — An "addressed" source in the Data Mode only.

Acceptor — A device receiving information on the Bus in either the Command or Data Mode.

Listener — An "addressed" acceptor in the Data Mode only.

The Data Transfer or "Handshake" lines are shown in *Figure D-1*. The mnemonics of each line have the following meanings:

DAV — Data Valid
NRFD — Not Ready for Data
NDAC — Not Data Accepted

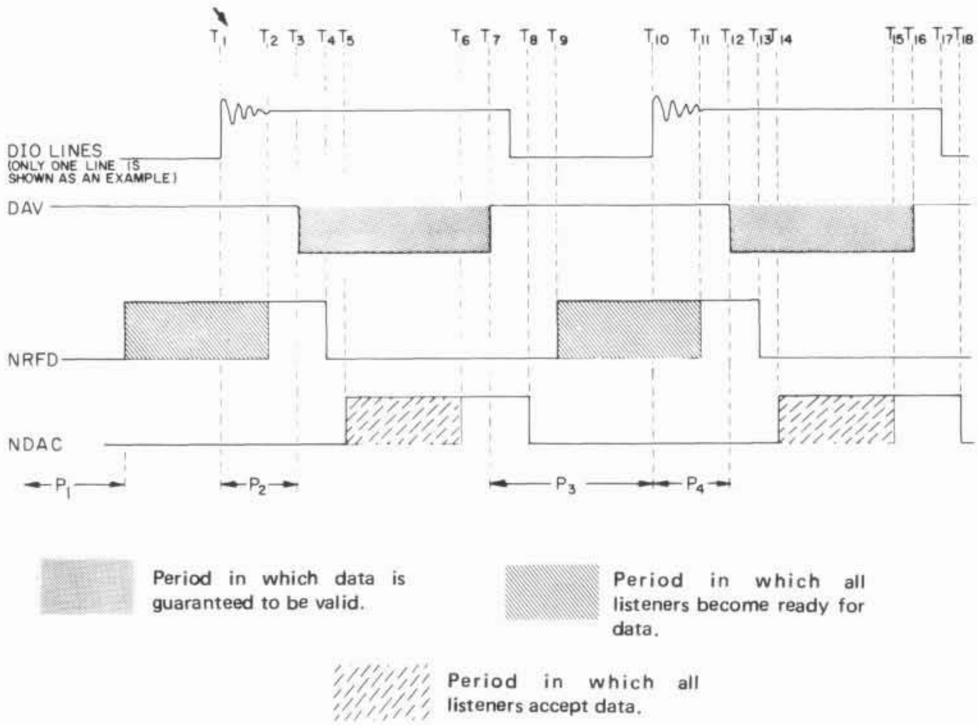
Each data byte transferred by the interface system uses the handshake process when exchanging data between source and acceptor. The handshake timing sequence is illustrated in *Figure D-2*. In Data Mode, the source is a Talker and the acceptor is a Listener.

The timing diagram illustrates the handshake process by indicating the actual waveforms on the DAV, NRFD, and NDAC lines. The NRFD and NDAC signals each represent composite waveforms resulting from two or more Listeners accepting the same data byte at slightly different times. This is usually due to variations in the transmission path length and individual instrument response rates (delays).

The flowchart represents the same sequence of events in a different form.

The subscripted letters on the flowchart and the timing diagram refer to the same event on the list of events.

Handshake line timing diagram for one talker and multiple listeners using the handshake process. Two cycles of the handshake sequence are shown. Also refer to the flow diagram and list of events on this figure.



List of Events for Handshake Process

P_1 — Source initializes DAV to high (False — data not valid).
— Acceptors initialize NRFD to low (True — none are ready for data), and set NDAC to low (True — none have accepted the data).

T_1 Source checks for error condition (both NRFD and NDAC high), then places data byte on DIO lines.

P_2 Source delays to allow data to settle on DIO lines.

T_2 Acceptors have all indicated readiness to accept first data byte; NRFD goes high.

T_3 When the data has settled and is valid, and the source has sensed NRFD high, DAV is set low.

T_4 First acceptor sets NRFD low to indicate that it is no longer ready, then accepts the data. Other acceptors follow at their own rates.

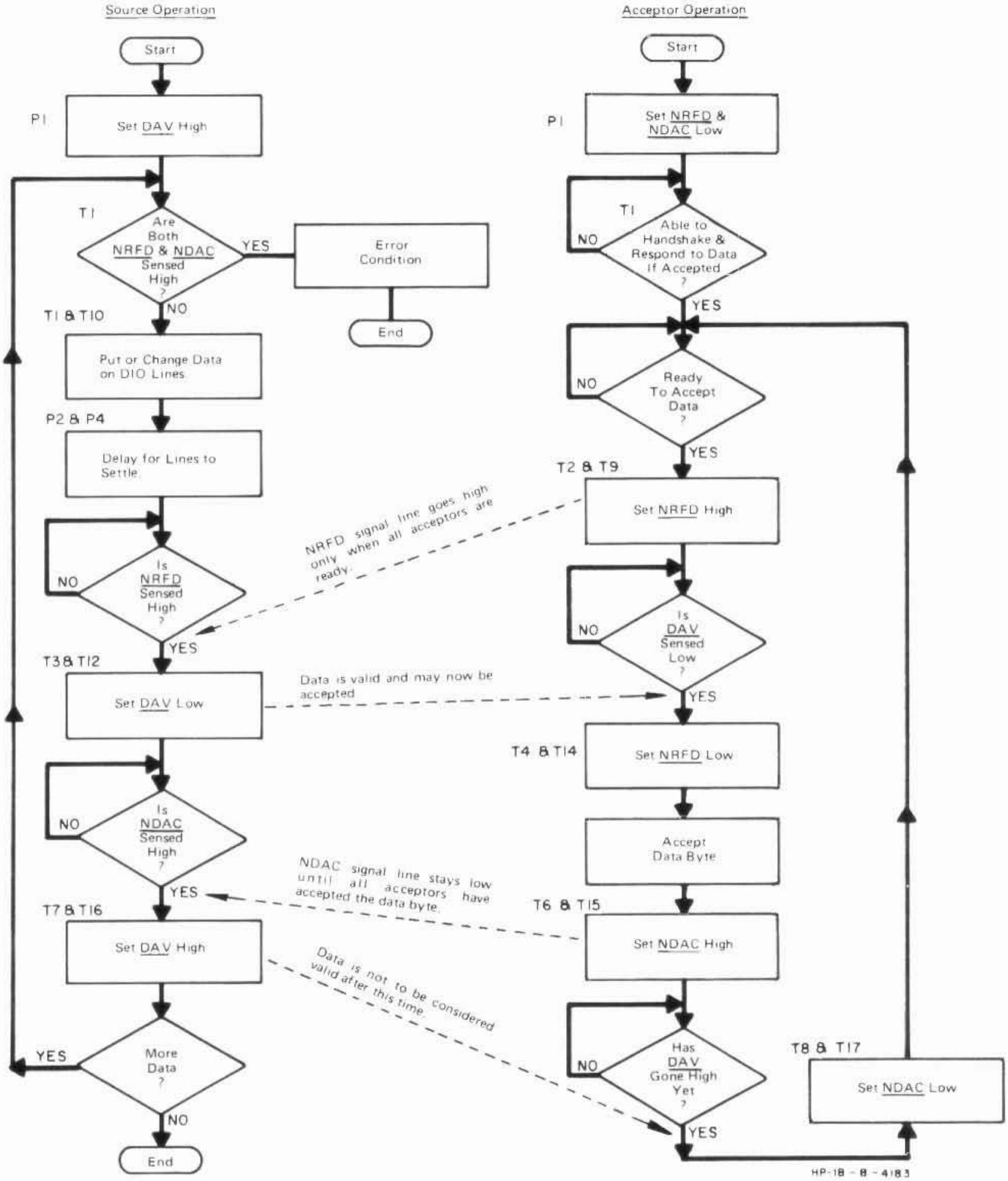
T_5 First acceptor sets NDAC high to indicate that it has accepted the data. (NDAC remains low due to other acceptors driving NDAC low).

Part of Figure D-2. Handshake Timing Sequence

T_6	Last acceptor sets NDAC high to indicate that it has accepted the data; all acceptors have accepted the data and NDAC goes high.
T_7	Source, having sensed that NDAC is high, sets DAV high. This indicates to the acceptors that data on the DIO lines must now be considered not valid. Upon completion of this step, one byte of data has been transferred.
P_3 (T_7-T_{10})	Source changes data on the DIO lines.
T_8†	Acceptors, upon sensing DAV high, set NDAC low in preparation for next cycle. NDAC goes low as the first acceptor sets it low.
T_9	First acceptor indicates that it is ready for the next data byte by setting NRFD high. (NRFD remains low due to other acceptors driving NRFD low).
T_{10}	Source checks for error condition (both NRFD and NDAC are high), then places data byte on DIO lines (as at T_1).
P_4 (T_{10}-T_{12})	Source delays to allow data to settle on DIO lines.
T_{11}	Last acceptor indicates that it is ready for the next data byte by setting NRFD high; NRFD signal lines goes high.
T_{12}	Source, upon sensing NRFD high, sets DAV low to indicate that data on DIO lines has settled and is valid.
T_{13}	First acceptor sets NRFD low to indicate that it is no longer ready, then accepts the data.
T_{14}	First acceptor sets NDAC high to indicate that it has accepted the data.
T_{15}	Last acceptor sets NDAC high to indicate that it has accepted the data (as at T_6).
T_{16}	Source, having sensed that NDAC is high, sets DAV high (as at T_7).
T_{17}	Source removes data byte from DIO signal lines after setting DAV high.
T_{18}†	Acceptors, upon sensing DAV high, set NDAC low in preparation for next cycle.

†Note that all three handshake lines return to their initialized states as at T_1 and T_2.

Part of Figure D-2. Handshake Timing Sequence



Logical flow of events for Source and Acceptor when transferring data using the handshake process. See list of events on next page.

Part of Figure D-2. Handshake Timing Sequence

Data Lines

A set of eight interface lines is available to carry all seven-bit interface messages and device dependent messages. These are Data Input/Output lines, DIO1 through DIO8. Only seven lines are required for transfer of data. The eighth line is usually used for parity check. The data on the DIO lines is transferred in a bit-parallel, byte-serial form, asynchronously and bidirectionally.

DATA MODE

When ATN (attention) goes high (false), the HP-IB is in the "Data Mode". In this mode, data may be transferred between devices that were addressed when the HP-IB was in "Command Mode". Messages that can be transferred in "Data Mode" include:

a. Programming Instructions — Codes are seven- (or eight-) bit bytes placed on the HP-IB data (DIO) lines. The meaning of each byte is device dependent and is selected by the equipment designer. These types of messages are usually between the controller, acting as the talker, and a single device that has been addressed as listener.

b. Data Codes — Data codes are seven- (or eight-) bit bytes placed on the data lines. The meaning of each byte is device dependent. For meaningful communication to occur, both the talker and listener must agree on the meaning of the codes they use.

Data Byte

Individual data bytes transmitted on the HP-IB can be described in an octal code. The binary bits are separated into groups of three starting from the right-hand side (see *Table D-5*). Within the groups, each binary bit is assigned a weight —"1", "2", and "4", respectively. The octal numbers corresponding to each group of bits is the summation of the weights of the binary ones in each group.

NOTE

In *Table D-5*, the hundreds group has two bits rather than three since there are eight data lines. When seven-bit character ASCII code is used the hundreds group contains only one bit which can take on the octal value of "0" or "1".

Table D-5. Octal Code Conversion

BITS	b_8	b_7	b_6	b_5	b_4	b_3	b_2	b_1	OCTAL CODE		
WEIGHTS	"2" (Hundreds)	"1"	"4"	"2" (Tens)	"1"	"4"	"2" (Ones)	"1"			
	1	0	0	1	1	0	1	0	2	3	2
	1	1	1	1	1	0	0	0	3	7	0
	0	1	0	0	1	0	1	1	1	1	3
	0	0	0	1	0	1	1	1	0	2	7

INTERFACE

A list of the available functions is given in *Table D-6*. Every HP-IB compatible device is able to perform at least one function on the HP-IB. Devices ignore all commands relating to functions they do not have.

EXAMPLE: An HP-IB compatible programmable voltage source includes the "listen function" so that it can be programmed to accept data. However, it does not output information so it does not include a "talk function". Therefore, the programmable voltage source would ignore all information on the HP-IB pertaining to the "talk function".

Table D-6. HP-IB Instrument Interface Functions

INTERFACE FUNCTIONS THAT MAY BE INCLUDED IN AN HP-IB DEVICE	COMMENTS
Source Handshake	This functional capability must be included in any device that can be a "talker" on the bus.
Acceptor Handshake	This functional capability must be included in all devices that can be "listeners".
Talker or Extended Talker†	Capability required for a device to be a "talker".
Listener or Extended Listener†	Capability required for a device to be a "listener".
Service Request	This capability permits a device to asynchronously request service from the controller.
Remote/Local	Provides capability to select between two sources of input information. "Local" corresponds to front panel controls and "Remote" to the input information from the bus.
Parallel Poll	Provides capability for a device to uniquely identify itself if it requires service and the controller is requesting a response. This capability differs from "Service Request" in that it requires a commitment of the controller to periodically conduct a Parallel Poll.
Device Clear	This function allows a device to be initialized to a predefined state. A device with this capability will have the effect of this command as described in its operating manual.
Device Trigger	This function permits a device to have its basic (measurement) operation initiated by the talker on the Bus.
Controller	This function permits a device to send addresses, Universal Commands and Addressed Commands to other devices on the HP-IB. It may also include the ability to conduct parallel polling to determine devices requiring service.

†Extended Talker and Extended Listener provide increased address capability. Devices with this functional capability recognize addresses that are two bytes in length rather than just one byte.

Bus Operating Considerations

a. When a device capable of activating the IFC line is powered up during system operation, the active controller on the bus may be forced to relinquish its control, resulting in errors. The controller must transmit IFC to regain active control.

b. Prior to addressing new listeners, it is recommended that all previous listeners be unaddressed using the Unlisten Command (?).

c. Only one talker can be addressed at a time. When a new talker is addressed the former talker is automatically unaddressed.

d. The maximum cumulative length of the HP-IB cable in any system must not exceed more than 2 metres of cable per device or 20 metres, whichever is less.

e. For additional programming information, consult the HP-IB User Guide for the appropriate calculator.

Example Bus Sequences

Most data transfers through the HP-IB involve a talker and only one listener. For instance, when an OUTPUT statement is used (by the Active Controller) to send data to an HP-IB device, the following sequence of commands and data are sent through the bus.

OUTPUT 703;"Data"

a. The controller asserts the Attention Line [ATN goes low (true)].

b. The Unlisten Command (an ASCII "?" or decimal 63) is sent.

c. The talker's address is sent (here, the address of the computer).

d. The listener's address (an ASCII "#" or decimal 35 which corresponds to Listen Address 3) is sent, which is also a command.

e. The controller clears the Attention Line [ATN goes high (false)].

f. The ASCII data bytes "D", "a", "t", "a", CR, and LF are sent; all bytes are sent using the HP-IB's interlocking handshake to ensure that the listener has received each byte.

Similarly, most ENTER statements involve transferring data from a talker to only one listener. For instance, the following ENTER statement invokes the following sequence of commands and data transfer operations.

ENTER 722;"Voltage"

a. The controller asserts the Attention Line [ATN goes low (true)].

b. The Unlisten Command (an ASCII "?" or decimal 63) is sent.

c. The talker's address (an ASCII "V" or decimal 86 which corresponds to Talk Address 22) is sent.

d. The listener's address is sent (here, the computer's address).

e. The controller clears the Attention Line [ATN goes high (false)].

f. The data is sent by device 22 to the computer using the HP-IB interlocking handshake.

The Serial Poll function also transfers data. However, a number of talkers could be involved, and the listener is generally the active bus controller. The following sequence polls two devices at bus addresses 03 and 09.

a. The controller asserts the Attention Line [ATN goes low (true)].

b. The Unlisten Command (an ASCII "?" or decimal 63) is sent.

c. The first device's talk address (an ASCII "C" or decimal 67, corresponding to talk address 03) is sent.

d. The listener address is sent (usually the active bus controller's listen address).

e. The Serial Poll Enable command (SPE or decimal 24) is sent.

f. The controller clears the Attention Line [ATN goes high (false)].

g. The listener (controller) reads one byte of data using the HP-IB interlocking handshake.

h. The controller asserts the Attention Line [ATN goes low (true)].

i. The second device's talk address (an ASCII "I" or decimal 73, corresponding to talk address 09) is sent.

j. The controller clears the Attention Line [ATN goes high (false)].

k. The listener (controller) reads one byte of data using the HP-IB interlocking handshake.

l. The controller asserts the Attention Line [ATN goes low (true)].

m. The Serial Poll Disable command (SPD or decimal 25) is sent.

n. The Untalk Command (an ASCII "–" or decimal 95) is sent.

HP-IB Connector

Figure 3-2 in Section III (of this manual) shows the pin configuration of the HP-IB connector.

System Configurations

HP-IB systems can be categorized into three types:

a. Systems With No Controller

The mode of data transferred is limited to a direct transfer between one device manually set to "talk only", and one or more devices manually set to "listen only", to form a basic fixed network system.

b. Systems With a Single Controller

The modes of data transfer for these systems are:

1. Direct transfer between talkers and listeners (Data Mode).
2. Transfer from a device to a controller (Data Mode).
3. Transfer from a controller to a device (Command Mode).

c. Systems With Multiple Controllers

The modes of data transfer for these systems are the same as those listed in b. In addition, a method of passing control from one controller to another is required. One controller must be designed as the system controller. The system controller is the only device that can control the HP-IB lines designated IFC (Interface Clear) and REN (Remote Enable). When the system controller sets IFC low, all I/O operations cease and all talkers, listeners, and controllers are unaddressed. Control is passed to a different controller by addressing it as a talker and commanding it to "take control" (Octal code 011).

GLOSSARY OF TERMS

ACCEPTOR — A device receiving information on the Bus in either the Command or Data Mode (also see Source).

ADDRESS — A 7-bit code applied to the HP-IB in "Command Mode" that enables instruments capable of responding to listen and/or talk on the Bus.

ADDRESSED COMMANDS — These commands allow the bus controller to initiate simultaneous actions from addressed instruments that are capable of responding.

ATN — Mnemonic (Attention) referring to the "Command Mode" of operation on the HP-IB, or the control line which places the HP-IB in this mode.

BIT — The smallest part of an HP-IB character (Byte) that contains intelligible information.

BUS COMMANDS — A group of special codes which initiate certain types of operation in instruments capable of responding to these codes. Each instrument on the HP-IB is designed to respond to those codes that have special meaning to them. The instrument will ignore all other codes (see *Table D-6*).

BYTE — An HP-IB character sent over the DIO lines, normally consisting of seven bits.

COMMAND MODE — In this mode, devices on the HP-IB can be addressed or unaddressed as talker or listeners. Bus commands are also issued in this mode.

CONTROLLER — Any device on the HP-IB that is capable of setting the ATN line and addressing instruments on the Bus as talkers and listeners. (Also see System Controller.)

DEVICE CLEAR (DCL) — ASCII character "DC4" (Octal 024) which, when sent on the HP-IB, will return all devices capable of responding to predefined states.

DATA MODE — The HP-IB is in this mode when the control line "ATN" is high (false). In this mode, data or instructions are transferred between instruments on the HP-IB.

DAV — Mnemonic referring to the control line "Data Valid" on the HP-IB. This line is used in the HP-IB "Handshake" sequence.

DIO — Mnemonic referring to the eight "Data Input/Output" lines of the HP-IB.

EOI — Mnemonic referring to the control line "End or Identify" on the HP-IB. This line is used to indicate the end of a multiple byte message on the bus. It is also used in parallel polling.

EXTENDED LISTENER — An instrument that requires two HP-IB bytes to address it as a listener. (Also see Listener.)

EXTENDED TALKER — An instrument that requires two HP-IB bytes to address it as a talker. (Also see Talker.)

GO TO LOCAL (GTL) — ASCII character (Octal 001) which, when sent to the HP-IB, will return devices (addressed to listen and capable of responding) back to local control.

GROUP EXECUTE TRIGGER (GET) — ASCII character "BS" (Octal 010) which, when sent on the HP-IB, initiates simultaneous actions by devices addressed to listen and capable of responding to this command.

HANDSHAKE — Refers to the sequence of events on the HP-IB during which each data byte is transferred between addressed devices. The conditions of the HP-IB handshake sequence are as follows:

a. NRFD

When false, indicates that a device is ready to receive data.

b. DAV

When true, indicates that data on the DIO lines is stable and available to be accepted by the receiving device.

c. NDAC

When false, indicates to the transmitting device that data has been accepted by the receiver.

HP-IB — An abbreviation that refers to the "Hewlett-Packard Interface Bus".

IFC — Mnemonic referring to the control line "Interface Clear" on the HP-IB. Only the system controller can activate this line. When IFC is set (true) all talkers and listeners on the HP-IB are unaddressed, and controllers go to the inactive state.

LISTENER — A device which has been addressed to receive data or instructions from other instruments on the HP-IB. (Also see Extended Listener.)

LOCAL LOCKOUT — ASCII character "DC1" (Octal 021) which, when sent on the HP-IB, disables the front panel controls of responding devices.

NDAC — Mnemonic referring to the control line "Data Not Accepted" on the HP-IB. This line is used in the "Handshake" sequence.

NRFD — Mnemonic referring to the control line "Not Ready For Data" on the HP-IB. This line is used in the HP-IB "Handshake" sequence.

PARALLEL POLLING — A method of simultaneously checking status of up to eight instruments on the HP-IB. Each instrument is assigned a DIO line that indicates whether it requested service or not.

PRIMARY COMMANDS — The group of ASCII characters that are typically used on the HP-IB (see *Table D-6*).

REN — Mnemonic referring to the control line "Remote Enable" on the HP-IB. This line is used to enable bus-compatible instruments to respond to commands from the controller or another talker. It can be issued by the system controller only.

SECONDARY COMMANDS — The group of ASCII characters that are used to increase the address length of Extended Talkers and Listeners to two bytes.

SELECTIVE DEVICE CLEAR — ASCII character "EOT" (Octal 004) which, when sent on the HP-IB, returns addressed devices capable of responding to a predetermined state.

SERIAL POLLING — The method of sequentially determining which device connected to the HP-IB has requested service. Only one instrument is checked at a time.

SERIAL POLLING DISABLE (SPD) — ASCII character "EM" (Octal 031) which, when sent on the HP-IB, will cause the Bus to go out of Serial Poll Mode.

SOURCE — A device transmitting information on the Bus in either the Command or Data Mode (also see Acceptor).

SRQ — Mnemonic referring to the control line "Service Request" on the HP-IB. This line is set low (true) by any instrument requesting service.

SYSTEM CONTROLLER — This is an instrument on the HP-IB which has all the features of a standard controller and the added ability to control the IFC and REN lines (Also see Controller.)

TALKER — A device that has been addressed to transmit data on the HP-IB. (Also see Extended Talker.)

UNADDRESS COMMANDS — These commands are obeyed by all addressable devices. This category consists of the Unlisten Command (?) and the Untalk Command (–). When the Unlisten Command (?) is transmitted on the HP-IB, all devices on the bus will be unaddressed as listeners. When the Untalk Command (–) is transmitted, all devices will be unaddressed as talkers.

UNIVERSAL COMMANDS — These commands affect every device capable of responding on the HP-IB, regardless of whether they have been addressed or not [e.g., Serial Poll Enable (SPE) and Serial Poll Disable (SPD)].

UNLISTEN COMMAND — See "UNADDRESS COMMANDS".

UNTALK COMMAND — See "UNADDRESS COMMANDS".

APPENDIX E
WAVELENGTH-OF-LIGHT COMPENSATION

Appendix E provides the tables of WOL compensation values for different environmental conditions, and step-by-step instruction on how to calculate the compensation factor if your system operates in an environment other than those covered by the tables.

"Absolute" Pressure Versus "Barometric" Pressure

The ambient pressure used in determining your compensation factor must be "absolute" pressure, not the "barometric" pressure (which is usually absolute pressure that has been "corrected to sea level").

"Barometric pressure", as defined here, is the absolute pressure that would be measured at a given location, if that location was at sea level and the weather conditions were the same. Suppose, for example, that you were in Denver (Colorado, U.S.A.) at a time when the weather report said the barometric pressure was "762 mm" (30.00 inches) of mercury. Since Denver's altitude is about 1.5 km (5000 feet), the absolute air pressure there and then would be closer to 635 mm (25 inches) of mercury.

To measure pressure, you need an absolute pressure indicator, which is equivalent to a barometer that has not been corrected to sea level. When such a pressure indicator is not readily available, you can make a reasonable approximation to absolute pressure by reducing the barometric pressure obtained from the nearest weather station (at the local airport, for instance) by 2.5 mm (0.1 inch) of mercury for each 30 metres (100 feet) of altitude. That is —

$$P_A = P_B - \frac{\text{Altitude}}{30} \times 2.5 \qquad P_A = P_B - \frac{\text{Altitude}}{100} \times 0.1$$

For Metric Units — For English Units

where P_A is the absolute pressure, and P_B is the barometric pressure.

Note that the altitude of the weather station is not considered here, since the number they report has already been corrected to sea level by the station.

CALCULATION OF EXACT WAVELENGTH-OF-LIGHT (WOL) COMPENSATION FACTOR

If the Laser Position Transducer is being operated in an environment that is not included in the compensation factor tables in this manual, you can calculate the exact compensation factor to an accuracy of 0.1 ppm by using the following formulas.

CAUTION

The accuracy of your Laser Position Transducer is a function of your ability to provide it with the correct compensation factor for your measurement conditions. When determining the compensation factor by calculation rather than by using the compensation factor tables, the result you get depends on the resolution of the equipment on which you make your calculation and on your ability to operate it without error. You will be working with numbers that are very small and numbers that are very large; even the smallest error can have a significant effect on the accuracy of your answer, and any error is extremely difficult to detect or trace. We strongly suggest that you make a "practice" run, using values from any of the compensation factor tables, to get a feeling for what is required.

In the formulas below —

T = Air Temperature

P = Air Pressure

H = Relative Humidity

C =Compensation Factor, to be entered into the controller.

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

where "N" is given in Metric and English systems by —

Metric: T in degrees Celsius, P in millimetres of mercury, H in %

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

English: T in degrees Fahrenheit, P in inches of mercury, H in %

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

EXAMPLE:

Using the "standard" conditions, —

Humidity = 50% = "H"

Pressure (absolute) = 760 mm Hg = "P"

Temperature = 20°C = "T"

We will calculate the compensation factor, using the Metric formula for finding "N", and showing all our work.

$0.0133T = 0.266000000$	(#1)
$0.817 - (\#1) = 0.551000000$	(#2)
$P \times 10^{-6} \times (\#2) = 0.000418760$	(#3)
$1 + (\#3) = 1.000418760$	(#4) (Save)
$0.0036610T = 0.073220000$	(#5)
$1 + (\#5) = 1.073220000$	(#6)
$(\#4)/(\#6) = 0.932165595$	(#7)
$0.3836391 \times P \times (\#7) = 271.7875292$	(#8) (Save)
$e^{0.057267T} = 3.143409969$	(#9)
$H \times (\#9) = 157.1754985$	(#10)
$3.033 \times 10^{-3} \times (\#10) = 0.476737287$	(#11) (Save)
$(\#8) - (\#11) = 271.3108159$	(#12)
$(\#12) + 10^6 = 1000271.311$	(#13)
$C = \frac{10^6}{(\#13)} = 0.9997287626$	(#14)

For comparison, the answer we were looking for in this example just happens to be "0.9997288".

WAVELENGTH-OF-LIGHT (WOL) COMPENSATION TABLES

This appendix contains tables of WOL compensation values for a variety of operating conditions. The tables are divided into two groups; the Metric group *Tables E-1* through *E-25*), and the English group (*Tables E-26* through *E-50*). Each group of tables (i.e., Metric or English) are organized as follows:

- *Tables E-1* and *E-26* are wide-range charts offering coarse compensation numbers for nonprecision measurements.
- *Tables E-2* through *E-25*, and *Tables E-27* through *E-50*, are more detailed charts, progressing from "low" to "high" altitudes, and from "low" to "high" temperature and humidity.

To locate the appropriate table for your application, read the table heading for the percent humidity, pressure, and temperature range. The precise compensation number can be found where the temperature and pressure columns intersect.

The compensation number in the *Tables E-1* through *E-50* represent the last four digits of a seven-digit fraction of the form "0.999abcd". Disregard the decimal point in numbers having the form "abc.d". The wavelength-of-light (WOL) compensation number is entered in the form "0.999abcd", where "abcd" are found in the tables.

Table E-1. Metric — Wide-Range
(Temp = 2 to 50°C, Press = 525 to 800 mm, 50% Humidity)

TEMPERATURE IN DEGREES CELSIUS

BAROMETRIC PRESSURE IN MILLIMETERS OF MERCURY

	2.0	5.0	8.0	11.0	14.0	17.0	20.0	23.0	26.0	29.0	32.0	35.0	38.0	41.0	44.0	47.0	50.0
800	695.4	698.7	702.0	705.2	708.3	711.4	714.5	717.5	720.4	723.4	726.3	729.1	732.0	734.8	737.6	740.4	743.2
795	697.3	700.6	703.8	707.0	710.2	713.2	716.3	719.2	722.2	725.1	728.0	730.8	733.7	736.5	739.3	742.0	744.8
790	699.2	702.5	705.7	708.9	712.0	715.0	718.1	721.0	723.9	726.8	729.7	732.5	735.3	738.1	740.9	743.7	746.4
785	701.1	704.4	707.6	710.7	713.8	716.8	719.8	722.8	725.7	728.6	731.4	734.2	737.0	739.8	742.6	745.3	748.1
780	703.0	706.2	709.4	712.6	715.6	718.7	721.6	724.6	727.4	730.3	733.1	735.9	738.7	741.5	744.2	746.9	749.7
775	704.9	708.1	711.3	714.4	717.5	720.5	723.4	726.3	729.2	732.0	734.8	737.6	740.4	743.1	745.9	748.6	751.3
770	706.8	710.0	713.2	716.2	719.3	722.3	725.2	728.1	731.0	733.8	736.6	739.3	742.1	744.8	747.5	750.2	752.9
765	708.7	711.9	715.0	718.1	721.1	724.1	727.0	729.9	732.7	735.5	738.3	741.0	743.8	746.5	749.2	751.9	754.6
760	710.6	713.8	716.9	719.9	722.9	725.9	728.8	731.6	734.5	737.2	740.0	742.7	745.4	748.1	750.8	753.5	756.2
755	712.5	715.7	718.7	721.8	724.8	727.7	730.6	733.4	736.2	739.0	741.7	744.4	747.1	749.8	752.5	755.1	757.8
750	714.4	717.5	720.6	723.6	726.6	729.5	732.4	735.2	738.0	740.7	743.4	746.1	748.8	751.5	754.1	756.8	759.4
745	716.3	719.4	722.5	725.5	728.4	731.3	734.1	736.9	739.7	742.4	745.1	747.8	750.5	753.1	755.8	758.4	761.0
740	718.2	721.3	724.3	727.3	730.2	733.1	735.9	738.7	741.5	744.2	746.9	749.5	752.2	754.8	757.4	760.0	762.7
735	720.1	723.2	726.2	729.2	732.1	734.9	737.7	740.5	743.2	745.9	748.6	751.2	753.9	756.5	759.1	761.7	764.3
730	722.0	725.1	728.1	731.0	733.9	736.7	739.5	742.3	745.0	747.6	750.3	752.9	755.5	758.1	760.7	763.3	765.9
725	723.9	727.0	729.9	732.8	735.7	738.5	741.3	744.0	746.7	749.4	752.0	754.6	757.2	759.8	762.4	764.9	767.5
720	725.9	728.9	731.8	734.7	737.5	740.3	743.1	745.8	748.5	751.1	753.7	756.3	758.9	761.5	764.0	766.6	769.1
715	727.8	730.7	733.7	736.5	739.4	742.1	744.9	747.6	750.2	752.9	755.5	753.0	760.6	763.1	765.7	768.2	770.8
710	729.7	732.6	735.5	738.4	741.2	743.9	746.7	749.3	752.0	754.6	757.2	759.7	762.3	764.8	767.3	769.9	772.4
705	731.6	734.5	737.4	740.2	743.0	745.7	748.4	751.1	753.7	756.3	758.9	761.4	764.0	766.5	769.0	771.5	774.0
700	733.5	736.4	739.3	742.1	744.8	747.6	750.2	752.9	755.5	758.1	760.6	763.1	765.6	768.1	770.6	773.1	775.6
695	735.4	738.3	741.1	743.9	746.7	749.4	752.0	754.6	757.2	759.8	762.3	764.8	767.3	769.8	772.3	774.8	777.2
690	737.3	740.2	743.0	745.8	748.5	751.2	753.8	756.4	759.0	761.5	764.0	766.5	769.0	771.5	773.9	776.4	778.9
685	739.2	742.0	744.9	747.6	750.3	753.0	755.6	758.2	760.7	763.3	765.8	768.2	770.7	773.1	775.6	778.0	780.5
680	741.1	743.9	746.7	749.4	752.1	754.8	757.4	760.0	762.5	765.0	767.5	769.9	772.4	774.8	777.2	779.7	782.1
675	743.0	745.8	748.6	751.3	754.0	756.6	759.2	761.7	764.2	766.7	769.2	771.6	774.1	776.5	778.9	781.3	783.7
670	744.9	747.7	750.4	753.1	755.8	758.4	761.0	763.5	766.0	768.5	770.9	773.3	775.7	778.2	780.5	782.9	785.4
665	746.8	749.6	752.3	755.0	757.6	760.2	762.7	765.3	767.7	770.2	772.6	775.0	777.4	779.8	782.2	784.6	787.0
660	748.7	751.5	754.2	756.8	759.4	762.0	764.5	767.0	769.5	771.9	774.3	776.7	779.1	781.5	783.9	786.2	788.6
655	750.6	753.4	756.0	758.7	761.3	763.8	766.3	768.8	771.2	773.7	776.1	778.4	780.8	783.2	785.5	787.9	790.2
650	752.5	755.2	757.9	760.5	763.1	765.6	768.1	770.6	773.0	775.4	777.8	780.1	782.5	784.8	787.2	789.5	791.8
645	754.4	757.1	759.8	762.4	764.9	767.4	769.9	772.3	774.7	777.1	779.5	781.8	784.2	786.5	788.8	791.1	793.5
640	756.3	759.0	761.6	764.2	766.7	769.2	771.7	774.1	776.5	778.9	781.2	783.5	785.9	788.2	790.5	792.8	795.1
635	758.2	760.9	763.5	766.1	768.6	771.0	773.5	775.9	778.3	780.6	782.9	785.2	787.5	789.8	792.1	794.4	796.7
630	760.1	762.8	765.4	767.9	770.4	772.8	775.3	777.6	780.0	782.3	784.6	786.9	789.2	791.5	793.8	796.0	798.3
625	762.1	764.7	767.2	769.7	772.2	774.6	777.0	779.4	781.8	784.1	786.4	788.6	790.9	793.2	795.4	797.7	799.9
620	764.0	766.5	769.1	771.6	774.0	776.5	778.8	781.2	783.5	785.8	788.1	790.3	792.6	794.8	797.1	799.3	801.6
615	765.9	768.4	771.0	773.4	775.9	778.3	780.6	783.0	785.3	787.5	789.8	792.0	794.3	796.5	798.7	800.9	803.2
610	767.8	770.3	772.8	775.3	777.7	780.1	782.4	784.7	787.0	789.3	791.5	793.7	796.0	798.2	800.4	802.6	804.8
605	769.7	772.2	774.7	777.1	779.5	781.9	784.2	786.5	788.8	791.0	793.2	795.4	797.6	799.8	802.0	804.2	806.4
600	771.6	774.1	776.5	779.0	781.3	783.7	786.0	788.3	790.5	792.7	794.9	797.1	799.3	801.5	803.7	805.9	808.0
595	773.5	776.0	778.4	780.8	783.2	785.5	787.8	790.0	792.3	794.5	796.7	798.8	801.0	803.2	805.3	807.5	809.7
590	775.4	777.9	780.3	782.7	785.0	787.3	789.6	791.8	794.0	796.2	798.4	800.5	802.7	804.8	807.0	809.1	811.3
585	777.3	779.7	782.1	784.5	786.8	789.1	791.4	793.6	795.8	797.9	800.1	802.2	804.4	806.5	808.6	810.8	812.9
580	779.2	781.6	784.0	786.3	788.6	790.9	793.1	795.3	797.5	799.7	801.8	803.9	806.1	808.2	810.3	812.4	814.5
575	781.1	783.5	785.9	788.2	790.5	792.7	794.9	797.1	799.3	801.4	803.5	805.6	807.7	809.8	811.9	814.0	816.2
570	783.0	785.4	787.7	790.0	792.3	794.5	796.7	798.9	801.0	803.1	805.3	807.3	809.4	811.5	813.6	815.7	817.8
565	784.9	787.3	789.6	791.9	794.1	796.3	798.5	800.7	802.8	804.9	807.0	809.0	811.1	813.2	815.2	817.3	819.4
560	786.8	789.2	791.5	793.7	795.9	798.1	800.3	802.4	804.5	806.6	808.7	810.7	812.8	814.8	816.9	818.9	821.0
555	788.7	791.0	793.3	795.6	797.8	799.9	802.1	804.2	806.3	808.3	810.4	812.4	814.5	816.5	818.5	820.6	822.6
550	790.6	792.9	795.2	797.4	799.6	801.7	803.9	806.0	808.0	810.1	812.1	814.1	816.2	818.2	820.2	822.2	824.3
545	792.5	794.8	797.1	799.3	801.4	803.5	805.7	807.7	809.8	811.8	813.8	815.8	817.8	819.8	821.8	823.9	825.9
540	794.4	796.7	798.9	801.1	803.2	805.4	807.4	809.5	811.5	813.6	815.6	817.5	819.5	821.5	823.5	825.5	827.5
535	796.3	798.6	800.8	802.9	805.1	807.2	809.2	811.3	813.3	815.3	817.3	819.2	821.2	823.2	825.1	827.1	829.1
530	798.3	800.5	802.6	804.8	806.9	809.0	811.0	813.0	815.0	817.0	819.0	820.9	822.9	824.8	826.8	828.8	830.7
525	800.2	802.4	804.5	806.6	808.7	810.8	812.9	814.8	816.8	818.8	820.7	822.6	824.6	826.5	828.5	830.4	832.4

APPENDIX F
LINEAR THERMAL EXPANSION COEFFICIENTS OF METALS AND ALLOYS

For your convenience, *Table F-1* provides the linear thermal expansion coefficients of the most frequently used metals and alloys.

Table F-1. Linear Thermal Expansion Coefficients of Metals and Alloys

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
ALUMINUM AND ALUMINUM ALLOYS		
Aluminum (99.996%)	23.6	13.1
Wrought Alloys		
EC 1060 and 1100	23.6	13.1
2011 and 2014	23.0	12.8
2024	22.8	12.7
2218	22.3	12.4
3003	23.2	12.9
4032	19.4	10.8
5005, 5050, and 5052	23.8	13.3
5056	24.1	13.4
5083	23.4	13.0
5086	23.9	13.3
5154	23.9	13.3
5357	23.7	13.2
5456	23.9	13.3
6061 and 6063	23.4	13.0
6101 and 6151	23.0	12.8
7075	23.2	12.9
7090 and 7178	23.4	13.0
Casting Alloys		
A13	20.4	11.4
43 and 108	22.0	12.3
A108	21.5	12.0
A132	19.0	10.6
D132	20.5	11.4
F132	20.7	11.5
138	21.4	11.9
142	22.5	12.5
195	23.0	12.8
B195	22.0	12.3
214	24.0	13.4
220	25.0	13.9
319	21.5	12.0
355	22.0	12.3
356	21.5	12.0
360	21.0	11.7
750	23.1	12.9
40E	24.7	13.8

Table F-1. Linear Thermal Expansion Coefficients of Metals and Alloys (Continued)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
COPPER AND COPPER ALLOYS		
Wrought Coppers		
Pure Copper	16.5	9.2
Electrolytic Tough Pitch Copper (ETP)	16.8	9.4
Deoxidized Copper, High Residual Phosphorous (DHP)	17.7	9.9
Oxygen-Free Copper	17.7	9.9
Free-Machining Copper 0.5% Te or 1% Pb	17.7	9.9
Wrought Alloys		
Gilding, 95%	18.1	10.1
Commercial Bronze, 90%	18.4	10.3
Jewelry Bronze, 87.5%	18.6	10.4
Red Brass, 85%	18.7	10.4
Low Brass, 80%	19.1	10.6
Cartridge Brass, 70%	19.9	11.1
Yellow Brass	20.3	11.2
Muntz Metal	20.8	11.5
Leaded Commercial Bronze	18.4	10.2
Low-Leaded Brass	20.2	11.3
Medium-Leaded Brass	20.3	11.3
High-Leaded Brass	20.3	11.3
Extra-High-Leaded Brass	20.5	11.4
Free-Cutting Brass	20.5	11.4
Leaded Muntz Metal	20.8	11.6
Forging Brass	20.7	11.5
Architectural Bronze	20.9	11.6
Inhibited Admiralty	20.2	11.3
Naval Brass	21.2	11.8
Leaded Naval Brass	21.2	11.8
Manganese Bronze (A)	21.2	11.8
Phosphorous Bronze, 5% (A)	17.8	9.9
Phosphorous Bronze, 8% (C)	18.2	10.1
Phosphorous Bronze, 10% (D)	18.4	10.3
Phosphorous Bronze, 1.25%	17.8	9.9
Free-Cutting Phosphorous Bronze	17.3	9.6
Cupro-Nickel, 30%	16.2	9.0
Cupro-Nickel, 10%	17.1	9.5
Nickel Silver, 65-18	16.2	9.0
Nickel Silver, 55-18	16.7	9.3
Nickel Silver, 65-12	16.2	9.0
High-Silicon Bronze (A)	18.0	10.0
Low-Silicon Bronze (B)	17.9	10.0
Aluminum Bronze (3)	16.4	9.2
Aluminum-Silicon Bronze	18.0	10.0
Aluminum Bronze	16.8	9.4
Beryllium Copper	17.8	9.9
Casting Alloys		
88 Cu-8 Sn-4 Zn	18.0	10.0
89 Cu-11 Sn	18.4	10.3
88 Cu-6 Sn-1.5 Pb-4.5 Zn	18.5	10.3
87 Cu-8 Sn-1 Pb-4 Zn	18.0	10.0
87 Cu-10 Sn-1 Pb-2 Zn	18.0	10.0
80 Cu-10 Sn-10 Pb	18.5	10.3
78 Cu-7 Sn-15 Pb	18.5	10.3
85 Cu-5 Sn-5 Pb-5 Zn	18.1	10.0
72 Cu-1 Sn-3 Pb-24 Zn	20.7	11.5
67 Cu-1 Sn-3 Pb-29 Zn	20.2	11.3
61 Cu-1 Sn-1 Pb-37 Zn	21.6	12.0
Manganese Bronze (60,000 psi)	20.5	11.4
Manganese Bronze (65,000 psi)	21.6	12.0
Manganese Bronze (110,000 psi)	19.8	11.0
Aluminum Bronze (Alloy 9A)	17.0	9.5
Aluminum Bronze (Alloy 9B)	17.0	9.5
Aluminum Bronze (Alloys 9C & 9D)	16.2	9.0

Table F-1. Linear Thermal Expansion Coefficients of Metals and Alloys (Continued)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
IRON AND IRON ALLOYS		
Pure Iron	11.7	6.5
Fe-C Alloys		
0.06% C	11.7	6.5
0.22% C	11.7	6.5
0.40% C	11.3	6.3
0.56% C	11.0	6.1
1.08% C	10.8	6.0
1.45% C	10.1	5.6
Invar (36 Ni)	0 to 2	to 1.1
13 Mn-1.2 C	18.0	10.0
13 Cr-0.35 C	10.0	5.6
12.0 Cr-0.4 Ni-0.09 C	9.8	5.5
17.7 Cr-9.6 Ni-0.06 C	16.5	9.2
18 W-4 Cr-1 V	11.2	6.2
Gray Cast Iron	10.5	5.7
Malleable Iron (Pearlitic)	12.0	6.7
LEAD AND LEAD ALLOYS		
Corroding Lead (99.73+% Pb)	29.3	16.3
5-95 Solder	28.7	16.0
20-80 Solder	26.5	14.8
50-50 Solder	23.4	13.0
1% Antimonial Lead	28.8	16.1
Hard Lead (96 Pb, 4 Sb)	27.8	15.5
Hard Lead (94 Pb, 6 Sb)	27.2	15.2
8% Antimonial Lead	26.7	14.9
9% Antimonial Lead	26.4	14.7
Lead-Base Babbitt:		
SAE 14	19.6	10.9
Alloy 8	24.0	13.4
MAGNESIUM AND MAGNESIUM ALLOYS		
Magnesium (99.8%)	25.2	14.1
Casting Alloys		
AM100A	25.2	14.1
AZ63A	26.1	14.6
AZ91A, B, C	26.0	14.5
AZ92A	25.2	14.1
HZ32A	26.7	14.9
ZH42	27.0	15.1
ZH62A	27.1	15.1
ZK51A	26.1	14.6
EZ33A	26.1	14.6
EK30A and EK41A	26.1	14.6
Wrought Alloys		
M1A and A3A	26.0	14.5
AZ31B and PE	26.0	14.5
AZ61A and AZ80A	26.0	14.5
ZK60A, B	26.0	14.5
HM31A	26.1	14.6

Table F-1. Linear Thermal Expansion Coefficients of Metals and Alloys (Continued)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
NICKEL AND NICKEL ALLOYS		
Nickel (99.95% Ni+Co)	13.3	7.4
Duranickel	13.0	7.2
Monel	14.0	7.8
Monel (cast)	12.9	7.2
Inconel	11.5	6.4
Ni-o-nel	12.9	7.2
Hastelloy B	10.0	5.6
Hastelloy C	11.3	6.3
Hastelloy D	11.0	6.1
Hastelloy F	14.2	7.9
Hastelloy N	10.4	5.8
Hastelloy W	11.3	6.3
Hastelloy X	13.8	7.7
Illium G	12.19	6.8
Illium R	12.02	6.7
80 Ni-20 Cr	17.3	9.6
60 Ni-24 Fe-16 Cr	17.0	9.5
35 Ni-45 Fe-20 Cr	15.8	8.8
Constantan	18.8	10.5
STAINLESS STEELS		
301	16.9	9.4
302	17.3	9.6
302B	16.2	9.0
303	17.3	9.6
304	17.3	9.6
305	17.3	9.6
308	17.3	9.6
309	14.9	8.3
310	14.4	8.0
314	15.1	8.4
316	16.0	8.9
317	16.0	8.9
321	16.7	9.3
347	16.7	9.3
501	11.15	6.2
502	11.15	6.2
403	9.9	5.5
405	10.8	6.0
410	11.0	6.1
416	9.9	5.5
420	10.25	5.7
430	10.45	5.8
430F	10.45	5.8
431	11.7	6.5
440A	10.1	5.6
440B	10.1	5.6
440C	10.1	5.6
446	10.6	5.9

Table F-1. Linear Thermal Expansion Coefficients of Metals and Alloys (Continued)

Alloys	Coefficient of Expansion	
	ppm/°C	ppm/°F
TITANIUM AND TITANIUM ALLOYS		
99.9% Ti	8.41	4.7
99.0% Ti	8.55	4.76
Ti-5 A1-2.5 Sn	9.36	5.2
Ti-8 Mn	8.64	4.8
ZINC AND ZINC ALLOYS		
Pure Zinc	39.7	22.1
AG40A Alloy	27.4	15.3
AC41A Alloy	27.4	15.3
Commercial Rolled Zinc:		
0.08 Pb	32.5	18.1
03 Pb, 0.3 Cd	33.9*	18.9
Rolled Zinc Alloy (1 Cu, 0.010 Mg)	34.8**	19.4
Zn-Cu-Ti Alloy (0.8 Cu, 0.15 Ti)	24.9***	13.9
PURE METALS		
Beryllium	11.6	6.5
Cadmium	29.8	16.6
Calcium	22.3	12.4
Chromium	6.2	3.5
Cobalt	13.8	7.7
Gold	14.2	7.9
Iridium	6.8	3.8
Lithium	56.0	31.0
Manganese	22.0	12.3
Palladium	11.76	6.6
Platinum	8.9	5.0
Rhenium	6.7	3.7
Rhodium	8.3	4.6
Ruthenium	9.1	5.1
Silicon	5.0	2.8
Silver	19.68	11.0
Tungsten	4.6	2.7
Vanadium	8.3	4.6
Zirconium	5.85	3.3

*With the grain; 23.4 across the grain
**With the grain; 21.1 across the grain
***With the grain; 19.4 across the grain

APPENDIX G
ANGULAR AND STRAIGHTNESS OPTICS

Appendix G provides information on the use of angular and straightness optics, designed for the HP 5528A Laser Measurement System, with the HP 5527A Laser Transducer System. Drawings of other calibrator optics are also provided.

ANGULAR OPTICS

The HP 55281A Angular Optics Kit consists of the HP 10770A Angular Interferometer and the HP 10771A Angular Reflector (*Figure G-1*). With these optics the angular rotation of the HP 10771A Angular Reflector can be measured over a range of ±10 degrees.

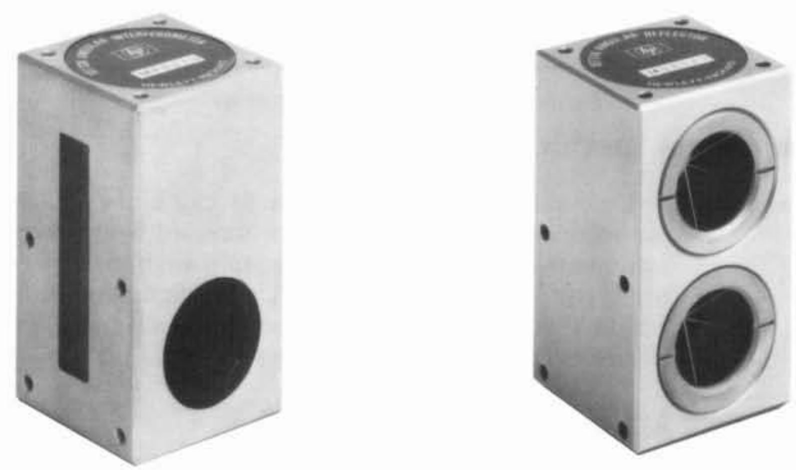


Figure G-1. HP 10770A Angular Interferometer and HP 10771A Angular Reflector

Theory of Operation

Figure G-2 shows the laser beam path through the optics. The angular optics create two parallel beam paths between the angular interferometer and the angular reflector. The spacing between the two paths (32.61 mm) is precisely known since this spacing is set by the optics and the retroreflectors within the angular reflector. Both components are positioned 32.61 mm apart at their centerlines. The optics are initially set parallel to each other and the system is initialized. The two beam paths are initially the same length. If either optic is rotated, the relative path lengths will change. This change will cause a Doppler-shifted frequency change in the beam returned from the interferometer to the receiver. The change will result in an indicated change in path length. From geometry the angle of rotation is related to the change in relative path length by:

$\sin \theta = D/32.61$ mm

so $\theta = \arcsin(D/32.61 \text{ mm})$,

where θ = the angle of rotation, and

D = the indicated change in relative path length in mm, and 32.61 mm is the spacing of the retroreflectors in the angular reflector, and also the spacing between the parallel beam paths from the angular interferometer to the angular reflector.

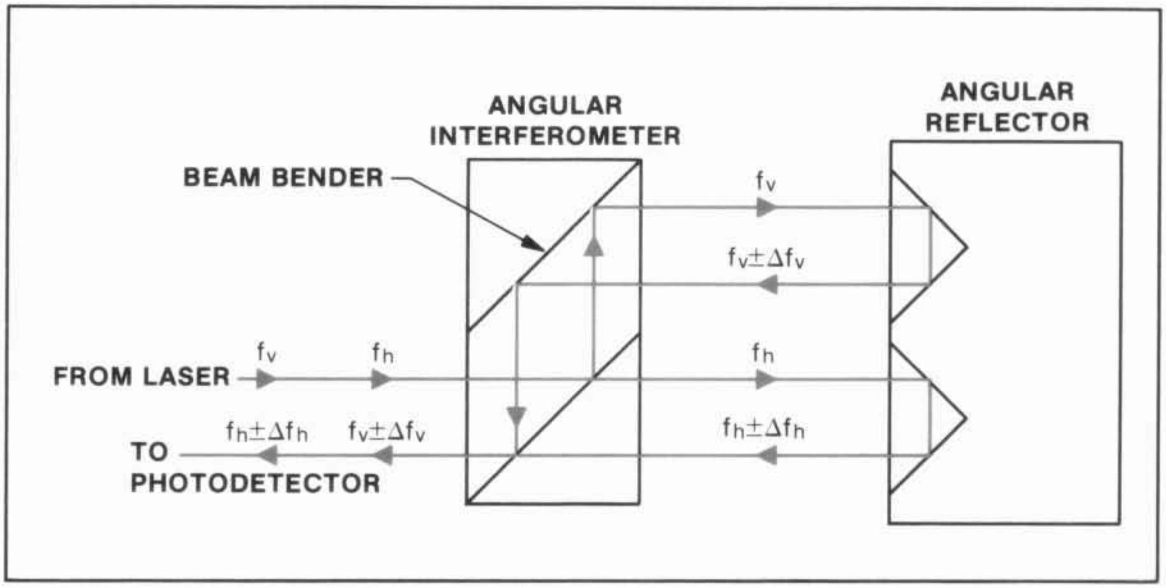


Figure G-2. Angular Measurements

Angular Measurement Specifications

Accuracy: Angle measurements are accurate to ±0.2% of calculated value ±0.05 arc-seconds per metre of distance traveled by the moving optic. This assumes that the HP 10771A Reflector is aligned within 40 arc-minutes using retroreflection techniques, roll alignment by the operator is within 1° relative to the measurement plane, and the temperature of all optics is stabilized in the range 15-25°C.

Resolution: 0.06 arc-seconds

Range: ±36000 arc-seconds (±10°)

Axial Separation: (Typical, with proper alignment, 15-25°C, distance between the laser head and the reflector): 15 metres (50 feet).

Installation and Alignment

GENERAL CONSIDERATIONS

a. Carefully read Section V of this manual ("Important Notes on Installation and Accuracy").

b. Alignment of the angular optics is very similar to alignment of the Linear Interferometer. Read the alignment procedure for the Linear Interferometer given in Section VI of this manual ("Installation and Optical Alignment").

c. The angular interferometer must be located between the laser head and the angular reflector. The beam from the laser head must enter the angular interferometer either through the single opening on one side for an in-line measurement, or through the opening in the bottom for a measurement along an axis perpendicular to the laser beam. The side of the angular interferometer with two openings should always be facing the angular reflector.

d. When initializing the laser, the angular optics must be parallel to within 20 arc-minutes to achieve the specified accuracy (corresponds to 40 arc-minutes misalignment by autoreflection).

e. Supply a rigid mounting surface for both optics. The mounts should be adjustable for alignment.

f. The Angular Interferometer's apertures are 18.0 mm in diameter. With this aperture the beam spacing will be 11.0 mm. This beam spacing (11.0 mm) differs from that used for other interferometers (see *Figure 5-10*).

ALIGNMENT PROCEDURE

There are two techniques to align the angular optics. They are:

- Moving Dot Method, and
- Autoreflection Method.

Moving Dot Method

The principal steps used for the "moving dot" method of alignment are:

a. The laser head and optics are mounted in their desired location.

b. Select the small beam aperture on the laser head.

c. With the reflector as close as possible to the interferometer, adjust any component (laser head, interferometer, or reflector) to center the measurement beams on the receiver aperture.

NOTE

Placing a piece of translucent tape over the receiver lens will help in observing the impinging beams.

d. Move the reflector away from the interferometer. If the laser beam is not parallel to the axis of travel, the measurement beams will begin to move away from their original position. The impinging beams will move until the beam is cut off by the edge of the interferometer's aperture. Stop moving the reflector before the beam is blocked, or when the end of travel is reached. *Figure G-3* illustrates this situation.

e. Adjust the laser beam by angularly moving the beam until the dots again overlap at the receiver. This adjustment of the laser beam is accomplished by moving the laser head, beam bender, or interferometer depending on the optical layout.

NOTE

Some translations of either the laser head or interferometer may also be necessary to achieve alignment.

f. Select the large aperture on the laser head. Verify that the receiver's LED is ON and that the voltage at the receiver test point is between 0.7 and 1.3 Vdc.

Autoreflection Method

The principal alignment procedure for the angular optics is the same as that for the Linear Interferometer and Retroreflector. The following is the step-by-step procedure that corresponds

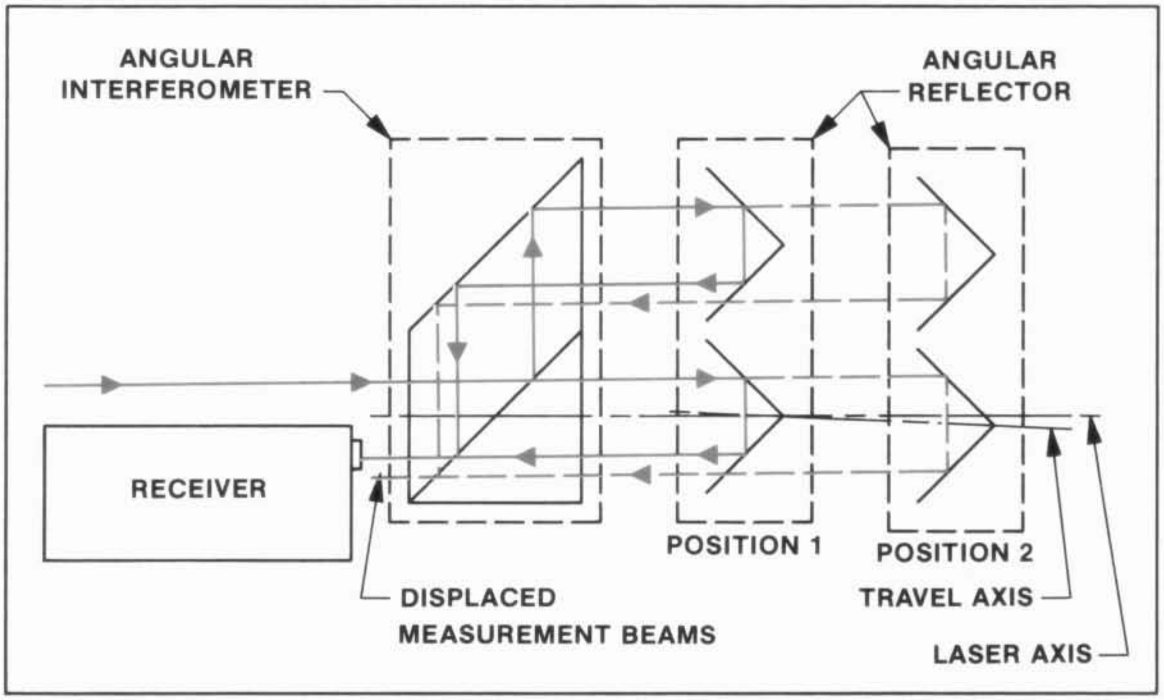


Figure G-3. Measurement Beam Dots Movement

to the example in Section VI. Refer to *Figure 6-30*. In this case the angular optics will be used on the X-axis instead of the Linear Interferometer and Retroreflector.

a. With all optical components in place, visually align the laser beam parallel to the axis of travel. This is accomplished by blocking the laser beam with a piece of paper and moving this paper along the axis of travel.

b. With the laser beam passing through the 50% beam splitter, rough adjust optical components so that the measurement beams strike the center of the receiver aperture. Use the "Moving Dot" method to do this.

c. Place a referenced mirror between the interferometer and the reflector so that the measurement beams from the interferometer strike this mirror. Align the referenced mirror with a precision indicator until the mirror's reflective surface is perpendicular to the direction of travel.

d. Select the small aperture on the laser head by rotating the front turret.

e. Adjust the laser head angularly until the beam reflects back on itself from the referenced mirror and is centered on the small aperture of the laser head.

f. Lock down the laser head and interferometer securely. Make sure that the alignment is not disturbed.

g. Reposition the reflector until the return measurement beams are centered on the receiver. Select the large aperture on the laser head.

NOTE

Placing a piece of translucent tape over the receiver lens will help observing the impinging beams.

h. Verify that the receiver's LED is ON and that the voltage at the receiver test point is between 0.7 and 1.3 Vdc.

More detailed, step-by-step procedures and sketches are available in the HP 5528A Laser Measurement System User's Guide (HP Part Number 05528-90014).

Accuracy Considerations

There are three error sources that are controlled by the operator. First, the accuracy depends on the nodal point spacing. The optics must be temperature-stabilized in the 15-25°C range or thermal expansion will change the nodal point spacing causing excessive error. Second, misalignment in roll effectively reduces the nodal point spacing in the plane of the measurement. The accuracy specification includes allowance for 1 degree of roll misalignment by the operator. Third, the initial angle must be near zero when the system is initialized or the measured change in angle will have an error. The accuracy specification includes allowance for 20 arc-minutes of initial angle. The error in measured path length due to an initial angle error is given by:

$$D_t = D_m\{\sin\theta_t/[\sin(\theta_t - \theta_i) + \sin\theta_i]\},$$

where D_t = the true change in path for the true angle of rotation,

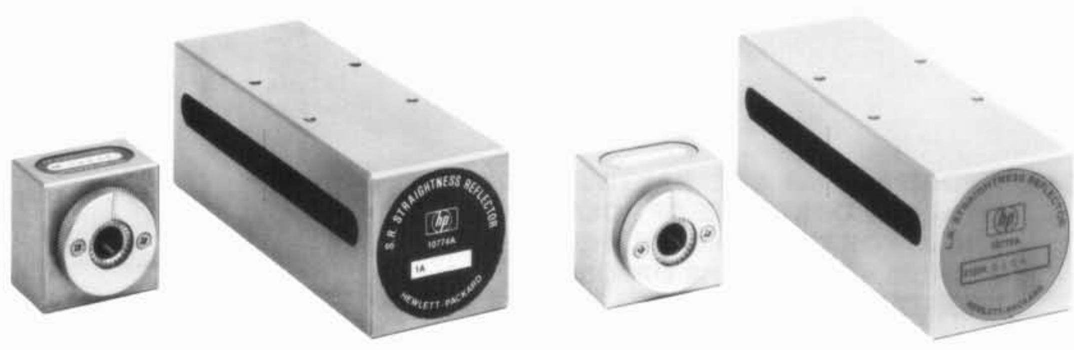
θ_t = the true angle of rotation,

D_m = the measured change in path length caused by an initial angle error, and

θ_i = the initial angle error.

STRAIGHTNESS OPTICS

Straightness measures displacement perpendicular to the axis of intended motion of the optics (*Figure G-4*). There are two sets of straightness optics available. The HP 10774A Short Range Straightness Optics will measure straightness over a range of 0.1 m to 3 m (4 in to 120 in). The HP 10774A is available separately or as part of the HP 55283A Straightness Measurement Kit, which also includes the HP 10776A Straightness Accessory Kit, the HP 10772A Turning Mirror with Mount, and the HP 10787A Case. The HP 10775A Long Range Straightness Optics will measure straightness over a range of 1 m to 30 m (3 feet to 100 feet).



HP 10774A
SHORT RANGE STRAIGHTNESS OPTICS

HP 10775A
LONG RANGE STRAIGHTNESS OPTICS

Figure G-4. Straightness Optics

Theory of Operation

Figure G-5 shows the laser beam path in the straightness optics. Initially, the two paths from the interferometer have the same length. As one of the optics is moved along the axis of travel, both beams will increase or decrease in length at the same rate. If the moving optic, either the straightness interferometer or straightness reflector, moves perpendicular to the intended axis of motion, the relative lengths of the two beams will change. The change in relative path lengths will be

$$X = 2D \sin(\theta/2),$$

where D = the distance of offset (out of straightness),

θ = the angle between the two beams leaving the interferometer, and

X = the indicated change in path length.

Then $D = X/2 \sin(\theta/2)$. The angle of the Short Range Interferometer is 1.5916 degrees, and the angle of the Long Range Interferometer is 0.1592 degrees. Thus, for short range optics, $D = 36X$, and for long range optics, $D = 360X$. In practice, the interferometer angles can vary due to manufacturing tolerances. Therefore, the result must be multiplied by the calibration factor K, which is stamped on each interferometer. The final result is $D = 36KX$ for short range optics and $D = 360KX$ for long range optics.

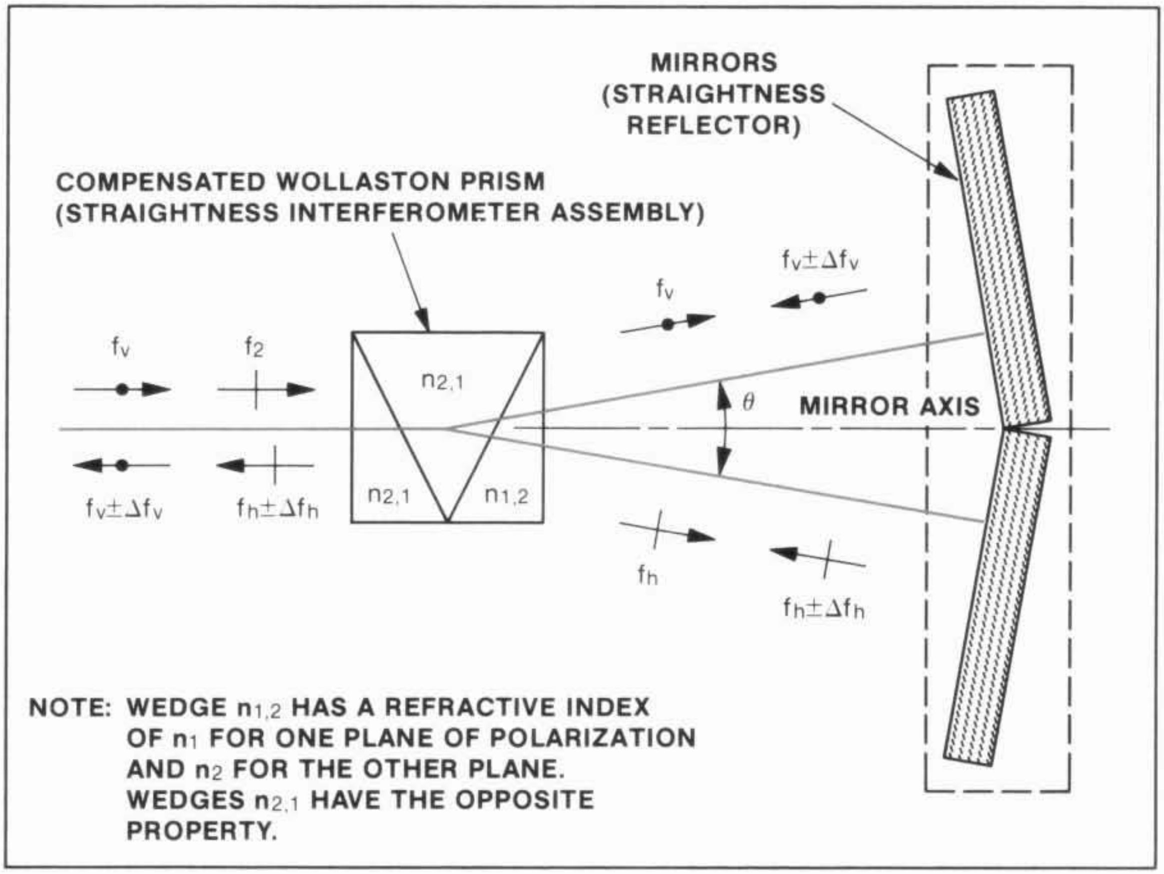


Figure G-5. Straightness Measurements

Small pitch, yaw, or roll motions of the interferometer do not create a path difference and therefore do not affect the measurement accuracy. This is an advantage of using the interferometer as the moving optic. The two return beams from the Straightness Reflector combine in the prism at the same point where the beam from the laser head was split. The combined beam is returned along the same path as the laser head's exit beam.

Straightness Measurement Specifications

Accuracy: Overall accuracy = Optical Reference Accuracy + Measurement Accuracy

(This is analogous to the traditional straight-edge and indicator method of measuring straightness, where Optical Reference Accuracy corresponds to the straight-edge accuracy, and Measurement Accuracy corresponds to the indicator accuracy.)

Optical Reference Accuracy: [This can be eliminated by using straight-edge (mirror) reversal techniques.]

Short Range Optics:
Metric Units Mode: ±0.15 M^2 microns
English Units Mode: ±0.5 F^2 microinches

where M = distance of travel of the moving optic in metres, and
F = distance of travel of the moving optic in feet.

Long Range Optics:
Metric Units Mode: ±0.015 M^2 microns
English Units Mode: ±0.05 F^2 microinches

where M = distance of travel of the moving optic in metres, and
F = distance of travel of the moving optic in feet.

Measurement Accuracy:

Short Range Optics:

Temperature Range	Displayed Value	
	0-10 µm (0-400 µin)	10-1500 µm (400-60000 µin)
15-25°C	±3.5%	±1% ±0.25 µm (10 µin)
0-40°C	±6%	±1% ±0.5 µm (20 µin)

Long Range Optics:

Temperature Range	Displayed Value	
	0-100 µm (0-4000 µin)	100-1500 µm (4000-60000 µin)
15-25°C	±5%	±2.5% ±2.5 µm (100 µin)
0-40°C	±7.5%	±2.5% ±5.0 µm (200 µin)

Straightness Measurement Resolution:

	Basic	Averaged*
Short Range Optics:	0.36 micron (14.0 microinches)	0.01 micron (0.4 microinch)
Long Range Optics:	3.6 microns (140 microinches)	0.1 micron (4.0 microinches)

*Based on averaging 1296 measurements. The resolution of n measurements is $1/\sqrt{n}$ times the basic resolution.

Straightness Measurement Range: ±1.5 mm (0.060 in).

Axial Separation: (Typical, with proper alignment, 15-25°C, distance between the interferometer and reflector)

Short Range Optics: 0.1 - 3 m (4 - 120 in)

Long Range Optics: 1 - 30 m (3 - 100 feet)

Installation and Alignment

GENERAL CONSIDERATIONS

a. Choose the optical configuration carefully for best results. The following diagrams indicate which of the possible configurations are acceptable. The latter two diagrams also indicate system performance based on minimizing power returned to the laser head (which can cause instability of the laser output) and maximizing power returned to the receiver.

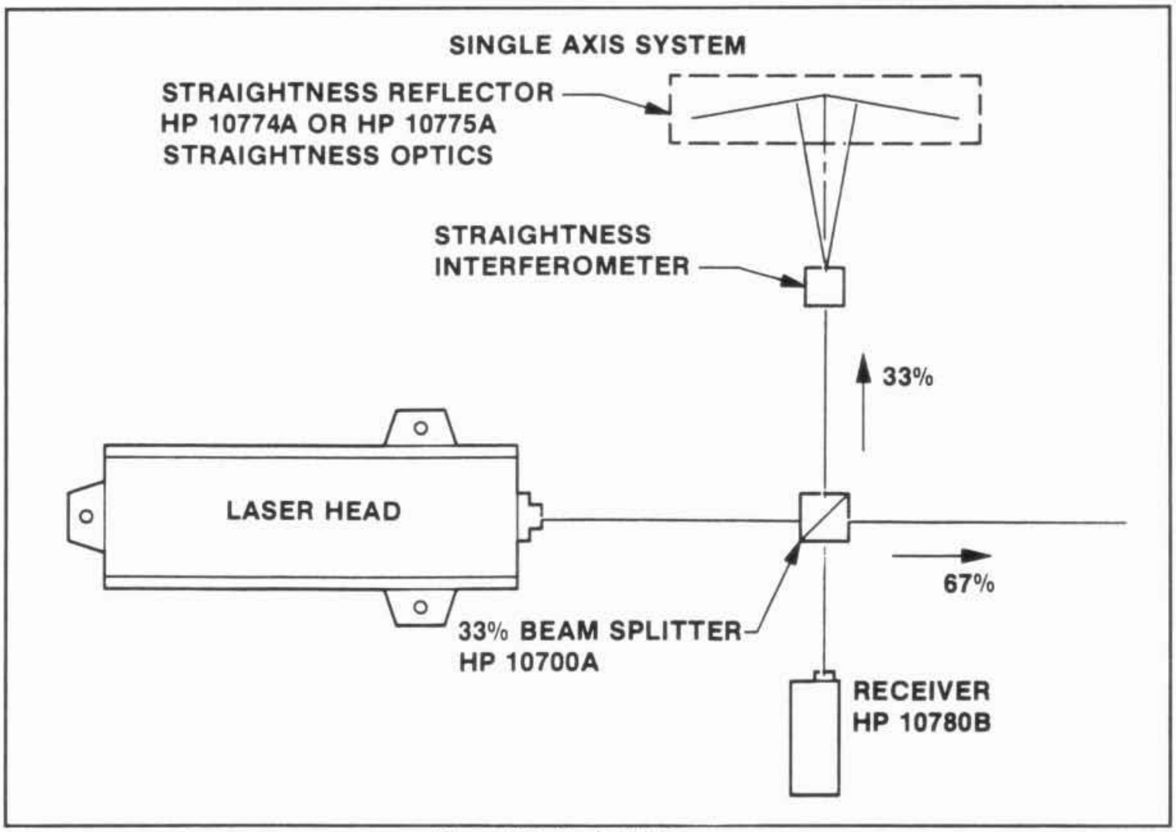
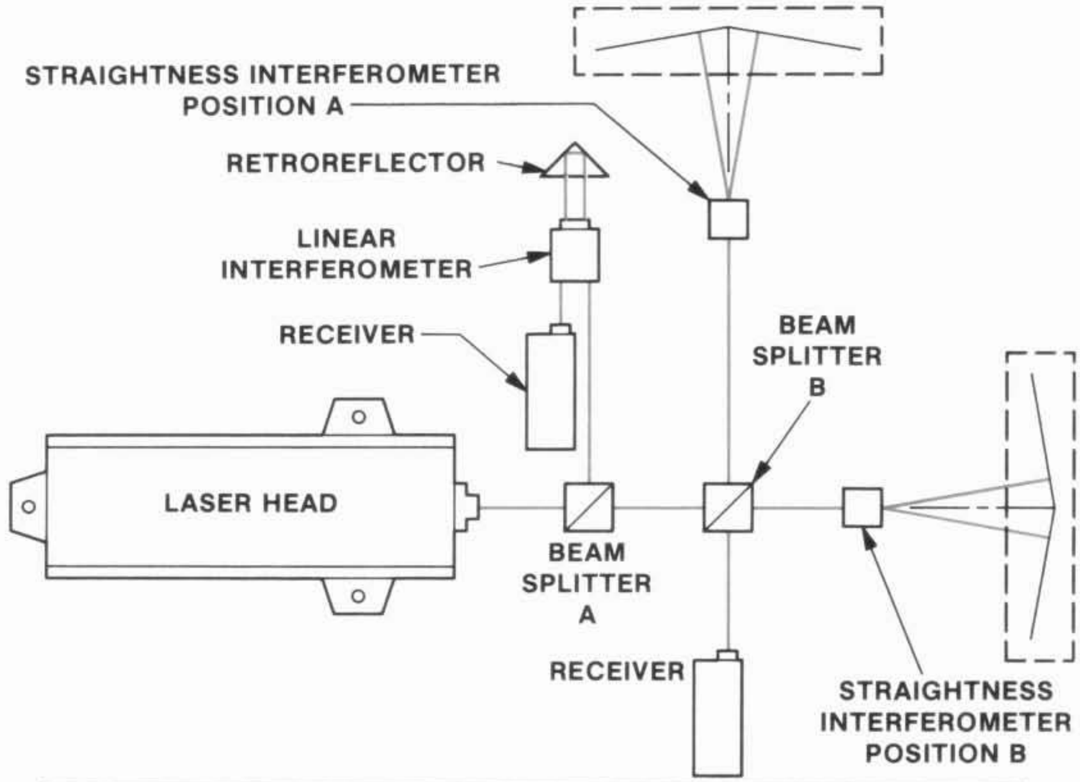
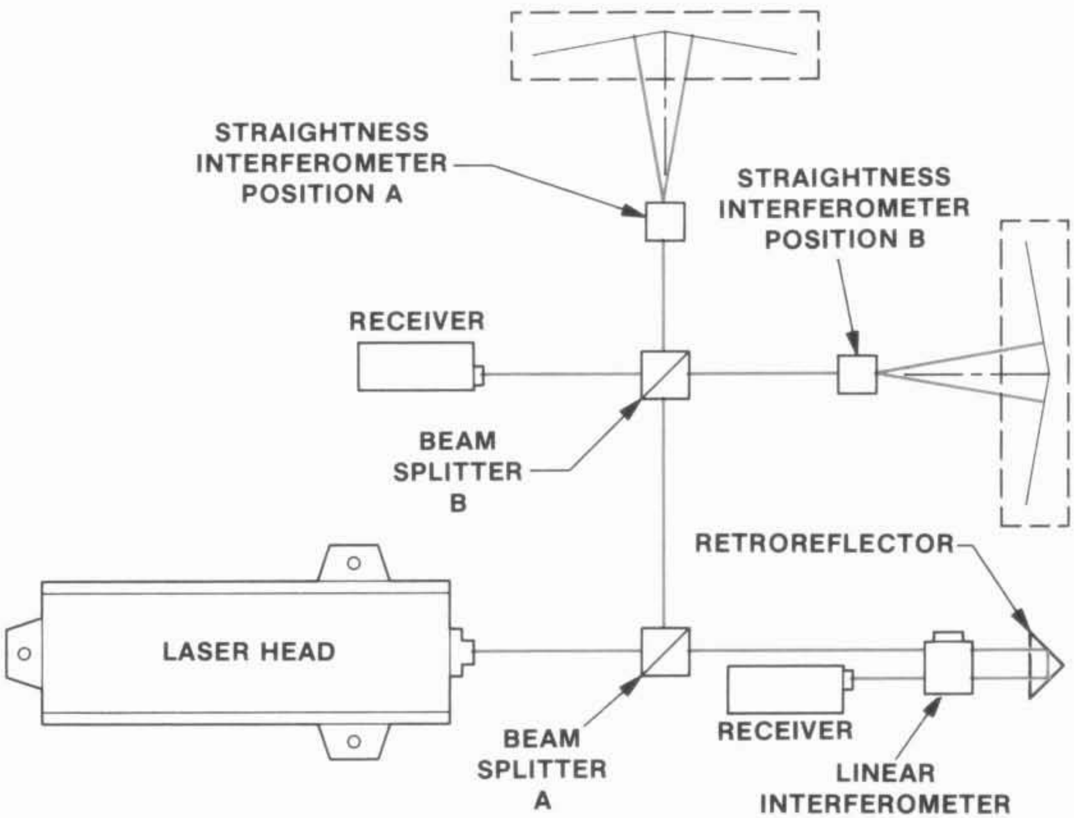


Figure G-6. Single Axis System



BEAM SPLITTER A	BEAM SPLITTER B	STRAIGHTNESS POSITION A	STRAIGHTNESS POSITION B
33%	33%	BEST	BAD
33%	50%	OK	OK
50%	33%	BEST	OK
50%	50%	GOOD	GOOD

Figure G-7. One Linear and One Straightness Axis



BEAM SPLITTER A	BEAM SPLITTER B	STRAIGHTNESS POSITION A	STRAIGHTNESS POSITION B
33%	33%	OK	OK
33%	50%	GOOD	GOOD
50%	33%	OK	BEST
50%	50%	GOOD	GOOD

Figure G-8. One Linear and One Straightness Axis

b. Supply a rigid mounting surface for both optical components. Fine position adjustments of both components will be necessary. The Straightness Reflector Mount gives full angular adjustment capability for the reflector.

c. The Straightness Interferometer must be located between the laser head (or beam directing optic) and the Straightness Reflector.

d. The measurement beams are returned to the receiver See the previous configuration diagrams.

PRINCIPAL ALIGNMENT STEPS

The principal steps used to align the Straightness optics are listed below, followed by a detailed alignment procedure for a specific configuration.

a. The laser head and optics are mounted in the desired locations and the laser beams are visually aligned parallel to the axes of travel.

b. Align the laser beam parallel to the axis of travel by using the "Gunsight" or "Autoreflection" alignment method.

c. Align the Straightness Reflector so that its mirror axis (see *Figure G-5*) is parallel to the laser beam and axis of travel. This mirror axis forms the optical straight-edge (analogous to a traditional straight-edge).

d. Adjust the interferometer to align its optic to the reflector to obtain a measurement signal at the receiver (green LED is on).

e. Fine adjust the interferometer bezel and reflector to obtain maximum measurement signal at the receiver (monitor the voltage at the receiver test point).

f. Remove measurement slope. This slope refers to the angle inscribed by the mirror axis and the axis of travel (see *Figure G-12*).

ALIGNMENT PROCEDURE

The following procedure describes the step-by-step alignment of an axis of straightness optics. *Figure G-6* shows the measurement setup with only the straightness axis shown.

a. With all optical components in place, visually align the laser beam parallel to the axis of travel. This may be done by blocking the laser beam with a piece of paper and moving this paper along the axis of travel while watching the beam relative to the axis.

b. Align the laser beam even closer to the axis of travel. This may be done by using the "Gunsight" or "Autoreflection" alignment methods.

GUNSIGHT METHOD

1. Position the optics for their near-end of travel, that is when the interferometer and reflector are nearest each other. For short range measurements this should be about 100 mm (4 inches). For long range measurements this should be about 1 m (3 feet).

2. Orient the Straightness Reflector horizontally or vertically to match the type of measurement to be made (horizontal or vertical straightness).

3. Select the small aperture on the laser head by rotating the front turret.

4. Attach the round target (supplied with the straightness optics) to the entrance face of the interferometer. Make sure that the target is centered over the interferometer bezel.

5. Adjust the interferometer (or laser beam) so the laser beam goes through the target's hole. The interferometer should be mounted perpendicular to the laser beam. This may be done by autoreflecting off the front face with a gage block.

6. Rotate the interferometer's bezel until the bezel's scribe line is oriented perpendicular to the aperture slot on the Straightness reflector. See *Figure G-9*. Two beams should now exit the interferometer in a plane perpendicular to the aperture slot on the reflector.

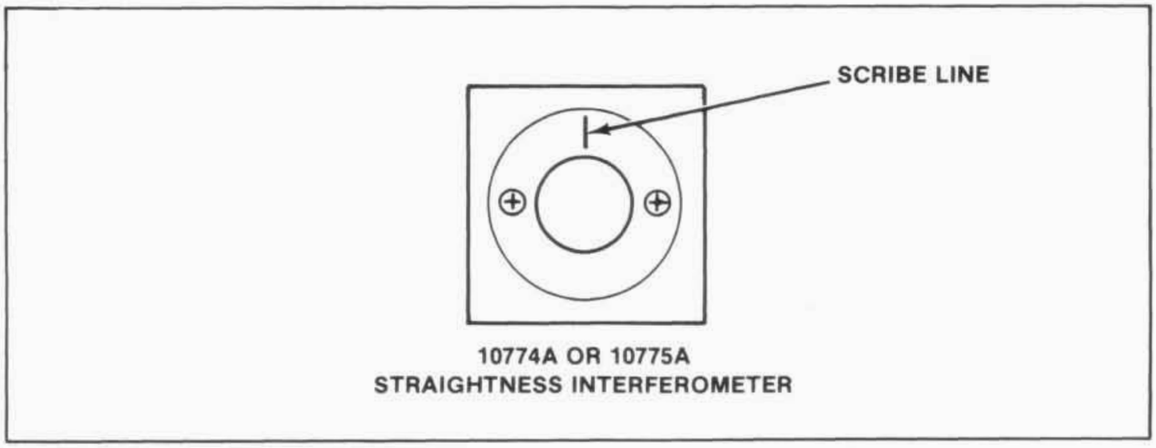


Figure G-9. HP 10774A or HP 10775A Interferometer Scribe Line

7. Position the reflector so that the two dots are located over the scribed center-line of the reflector housing and the face is square relative to the incoming beam. See *Figure G-10.*

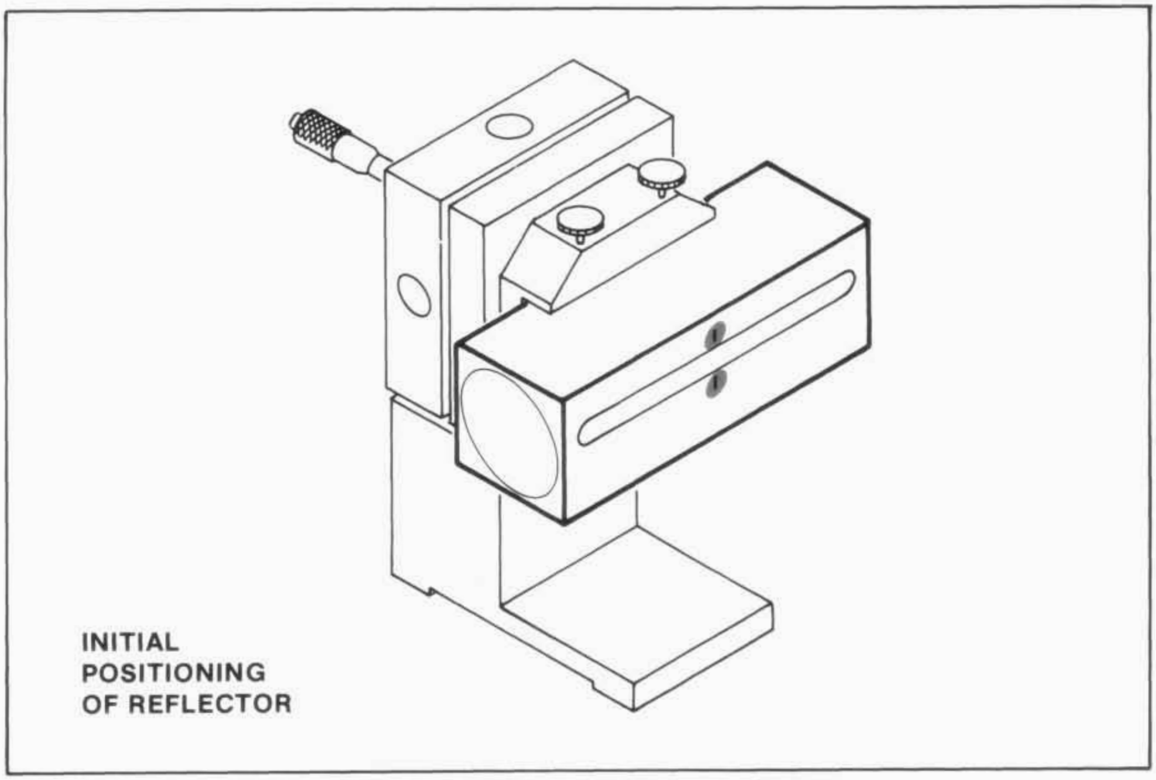


Figure G-10. Initial Positioning of Reflector

8. Move the optics to their far-end of travel.

9. Realign the laser beam, in this case by using the 33% beam splitter, so that the two dots are located over the scribed center-line of the reflector housing. Since the dots will move apart as the optics move, you may have to hold a card on each side of the reflector's slot to follow their movement. The beam splitter may need to be translated to re-center the laser beam in the interferometer target. The laser beam should now be aligned parallel to the axis of travel. Proceed to step c.

AUTOREFLECTION METHOD

Refer to Section VI's basic explanation of this method.

1. Remove the Straightness Interferometer from its mount surface.

2. Place a referenced mirror or gage block between the beam splitter and reflector so that the laser beam strikes its reflective surface.

3. Align the referenced mirror until its reflective surface is perpendicular to the axis of travel.

4. Select the small aperture on the laser head by rotating the front turret.

5. Adjust the laser beam angularly until the beam reflects back on itself from the referenced mirror and is centered on the small aperture of the laser head. Make sure that the laser beam is centered over the intended measurement axis.

6. Lock down the laser head and beam splitter securely. Make sure not to disturb the alignment. Remove the referenced mirror.

7. Orient the Straightness Reflector horizontally or vertically to match the type of measurement to be made (horizontal or vertical straightness).

8. Center the reflector about the laser beam. The laser beam should strike centered between the two mirrors in the reflector. The laser beam should now be aligned parallel to the axis of travel.

c. Remove the interferometer from its mount if not already done. Select the large aperture on the laser head by rotating the front turret. The laser beam should strike the center of the reflector. When properly centered the laser beam will be reflected back as two semicircles. See *Figure G-11*.

d. Adjust the Straightness Reflector angularly (if using the Straightness Reflector Mount, adjust its micrometers) until the reflected semicircular dots are centered about the aperture of the beam splitter. Place a piece of cardboard, with a hole cut in the middle, between the beam splitter and the reflector. This will help locate these dots. The mirror axis of the reflector (the optical straight edge) should now be aligned parallel to the laser beam and the axis of travel.

e. Install the Straightness Interferometer so that it is centered about the laser beam. The interferometer should also be perpendicular to the laser beam. This may be done by autoreflecting off the front face with a gage block.

f. Rotate the Interferometer's bezel to bring the scribed line parallel to the Straightness Reflector's aperture slot. See *Figure G-9*. Turn the bezel until the dots overlap on the reflector side of the interferometer. Use a card to locate the return beam and make the appropriate angular adjustments to the reflector to get the beam back through the interferometer and the beam splitter.

g. Adjust the receiver position to center the laser beam in its aperture.

h. If the receiver LED is not on, carefully rotate the interferometer's bezel until the LED goes on. To maximize the receiver signal, attach a fast responding voltmeter or oscilloscope to the receiver test point and receiver case ground. Only very slight rotation of the bezel is required, typically less than 1 degree.

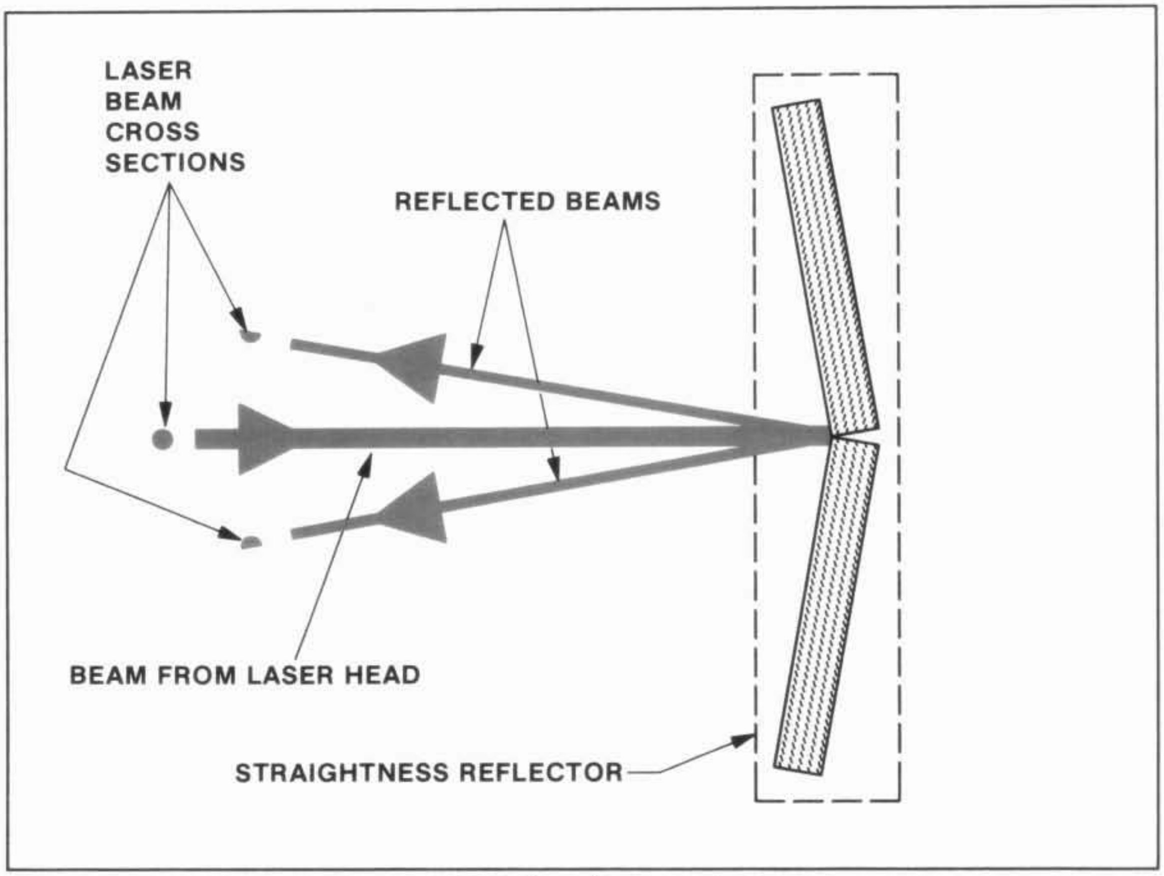


Figure G-11. Reflected Semicircular Beams

i. Fine adjust the Interferometer's bezel and Reflector until the receiver test voltage is maximized. See Section VI for the adjustment procedures of the Receiver.

j. Move the optic over its full travel range, making sure that the receiver signal strength is adequate (0.7 to 1.3 Volts) over the entire travel range.

The straightness optics are now aligned. There may be further fine adjustment to be done, but first make several measurement passes and observe the data. If a steady change in the data occurs, rather than either a random scattering of numbers or a constant number, this indicates misalignment between the axis of travel and the reflector's mirror axis. See *Figure G-12* for an illustration of this error. This error is called "slope", and must be removed to obtain proper straightness information.

SLOPE REMOVAL

The slope should be removed as much as possible by readjusting the Straightness Reflector's mirror axis. Slope removal is typically required only for the short range optics because long range alignment is normally more accurate. Slope removal can be done by the following procedure.

a. Reset the measurement (reset the counter to zero) with the optics at the near-end of travel.

b. Move the optics to the far-end of travel and note the last data point.

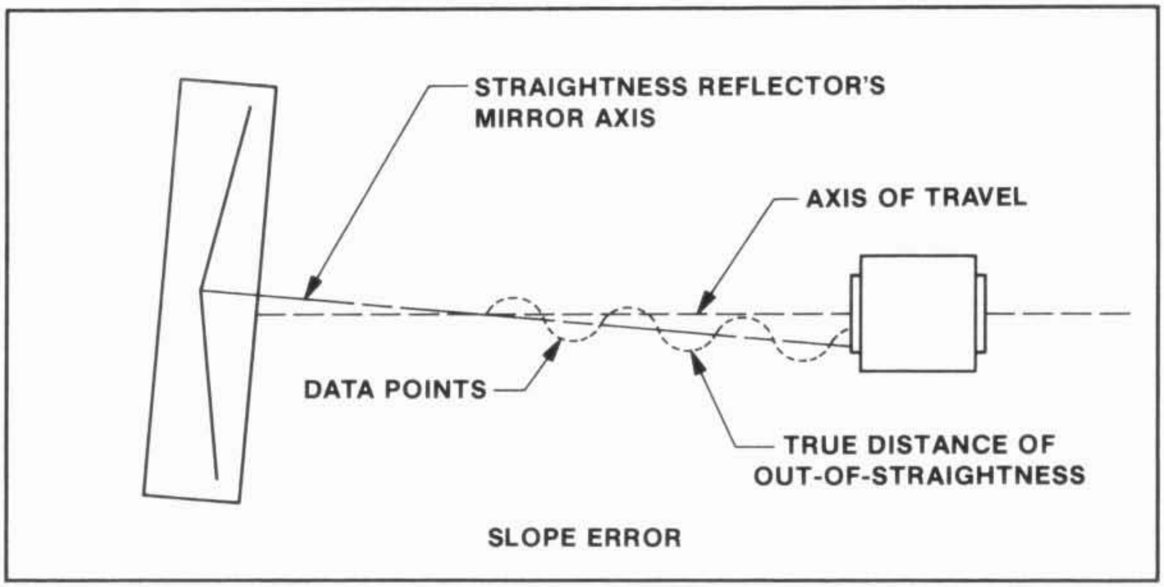


Figure G-12. Slope Error

c. Adjust the reflector (if using the Straightness Mount, adjust the micrometer) in the plane of the reflector's aperture slot to cause the straightness measurement to change to the following calculated value.

$$x = -(r/s)d$$

where x = the new value,

r = distance between optics at near-end of travel,

s = distance of moving optic at far-end of travel, and

d = old value read.

See *Figure G-13* for a representation of this.

d. Reset the measurement again, and return the optics to the near-end of travel.

e. If the signal strength gets too low, adjust the laser beam to achieve peak signal strength.

f. Repeat steps a through e as often as necessary to make the straightness measurement at both ends of travel to be near "zero".

The alignment procedure for the straightness optics is now complete.

When taking straightness data there will still be some residual slope that has not been removed. During data reduction the best-fit straight line should be determined and the straightness errors recalculated based on that line.

Accuracy Considerations

There are several sources of error under the control of the operator. First, the calibration factor on the interferometer must be used to obtain the correct value. Multiply the measured value by the interferometer calibration factor number to get the correct straightness. Second, the optical reference accuracy term can be eliminated by rotating the mirror 180° and making another measurement. Third, the slope must be removed manually or in software. Fourth, environmental

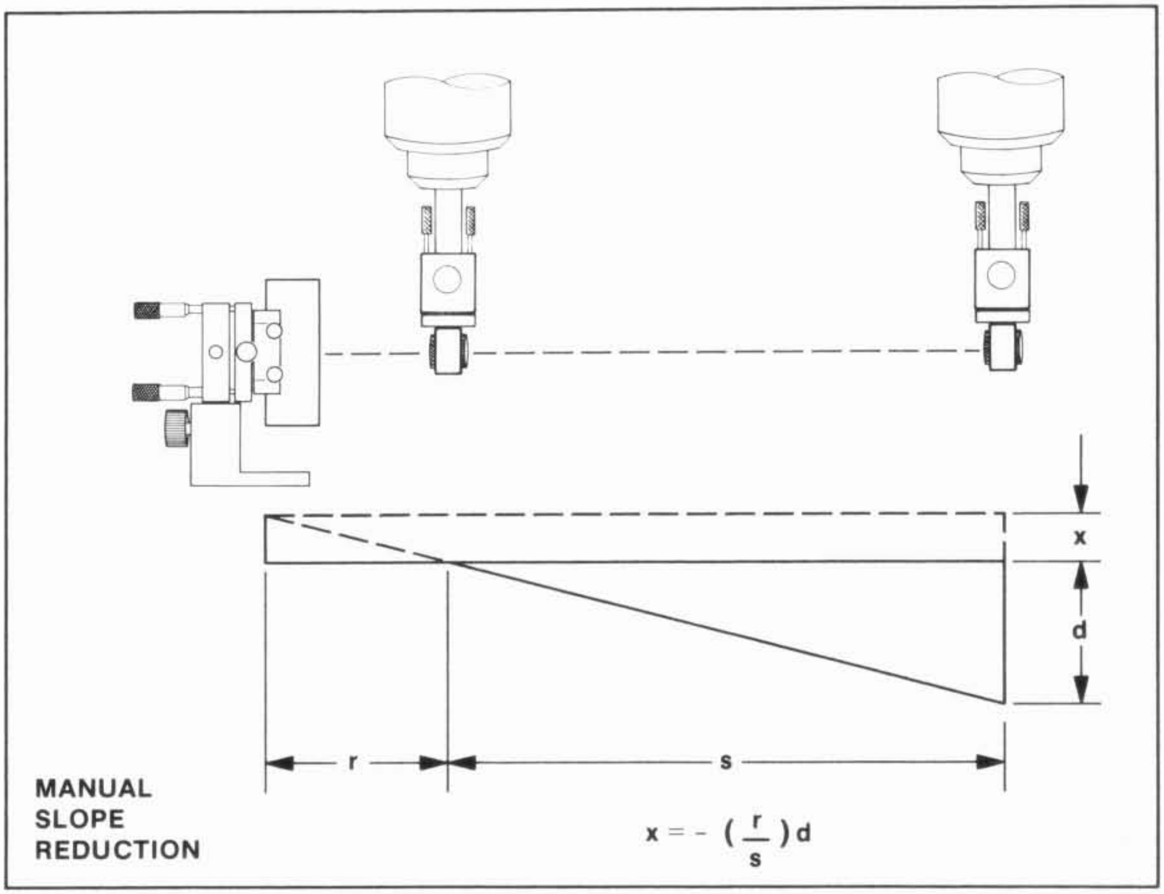


Figure G-13. Manual Slope Reduction

conditions (such as temperature changes of the machine or optics, vibration, and air turbulence) can cause errors. Errors due to thermal expansion can be minimized by allowing the machine and optics to reach thermal equilibrium before making a measurement. The effects of vibration can be reduced by good fixturing, averaging successive runs, reducing the slew rate, and more accurate manual slope removal. Air turbulence effects can be minimized by using baffles, while thermal gradient effects can be minimized by mixing the air with fans.

Squareness and Parallelism

A squareness measurement consists of two perpendicular straightness measurements made from the same straightness reflector. Perpendicularity is achieved using the HP 10777A Optical Square. Squareness is calculated by adding or subtracting the slopes from each straightness measurement based on a right angle. For details, see Section 21 of the HP 5528A Laser Measurement System User's Guide (HP Part Number 05528-90014).

A parallelism measurement is similar to a squareness measurement, except that it does not use an optical square. A parallelism measurement consists of two straightness measurements made along the same axis from the same straightness reflector. Parallelism is calculated by comparing the slopes of the two straightness measurements. For details, see Section 14 of the HP 5528A Laser Measurement System User's Guide (HP Part Number 05528-90014).

OPTICS SPECIFICATIONS (DIMENSIONAL DRAWINGS AND SPECS OF ALL CALIBRATOR OPTICS)

LINEAR OPTICS

Dimensions: See *Figure G-14.*
Weight: HP 10766A, 312 grams (11.0 oz);
HP 10767A, 224 grams (7.9 oz);
Materials Used: Same as HP 10702A
Optical Efficiency: (interferometer combination plus remote HP 10767A)
Typical: 73%
Worst Case: 69%

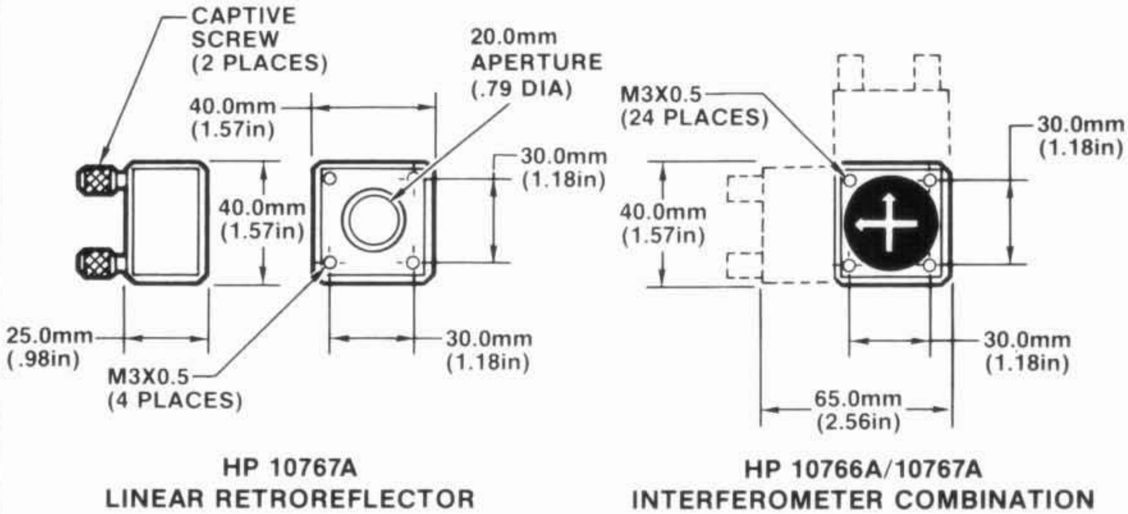


Figure G-14. HP 10766A Linear Interferometer and HP 10767A Linear Retroreflector, Dimensions

LINEAR OPTICS (Continued)

Dimensions: See *Figure G-15.*
Weight: Base: 365 grams (12.9 oz)
Height Adjuster: 215 grams (7.6 oz)
Post: 230 grams (8.1 oz)
Materials Used: Aluminum and Stainless Steel

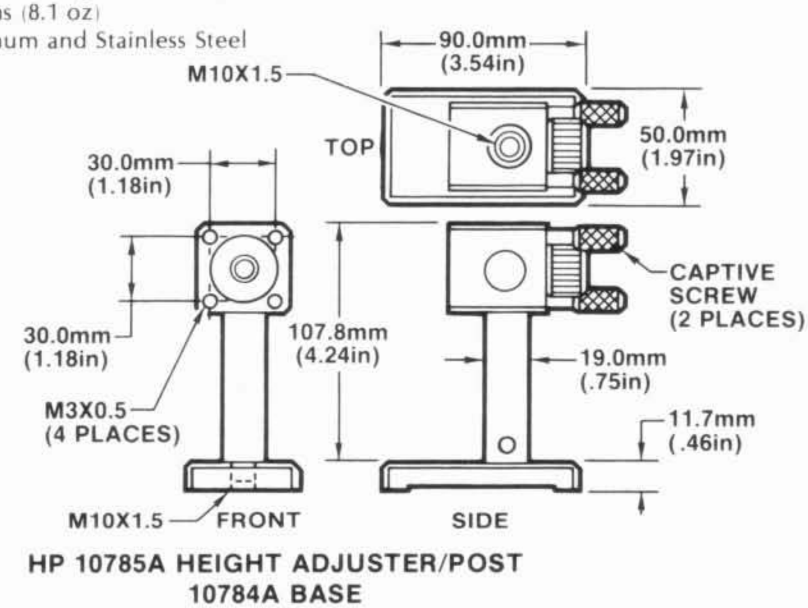


Figure G-15. HP 10784A Base and HP 10785A Height Adjuster Post, Dimensions

ANGULAR OPTICS

Dimensions: See *Figure G-16.*
Weight: 553 grams (19.5 oz)
Materials Used: Same as HP 10702A
Maximum Transmitted Beam Deviation: ±30 arc-seconds
Optical Efficiency:
Typical: 75%
Worst Case: 71%

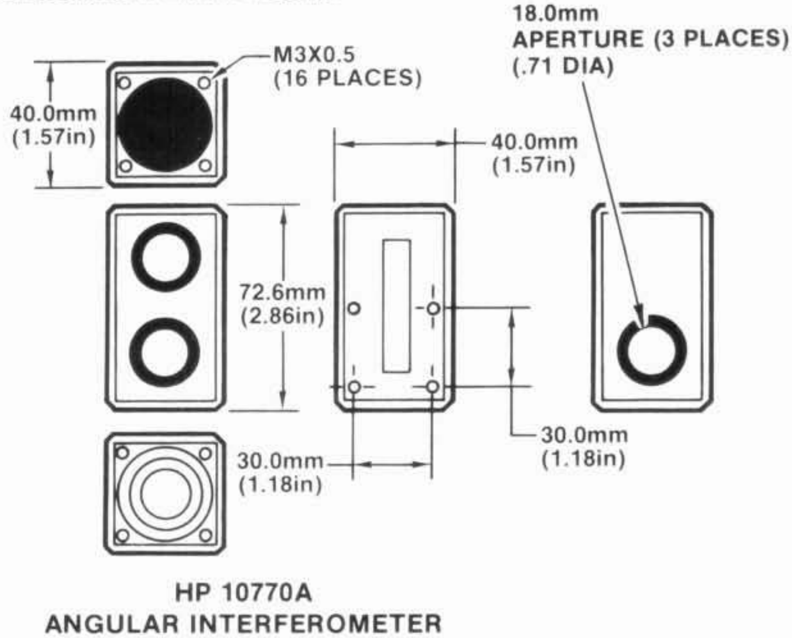


Figure G-16. HP 10770A Angular Interferometer, Dimensions

ANGULAR OPTICS (Continued)

Dimensions: See *Figure G-17.*
Weight: 650 grams (23 oz)
Materials Used: Same as HP 10702A

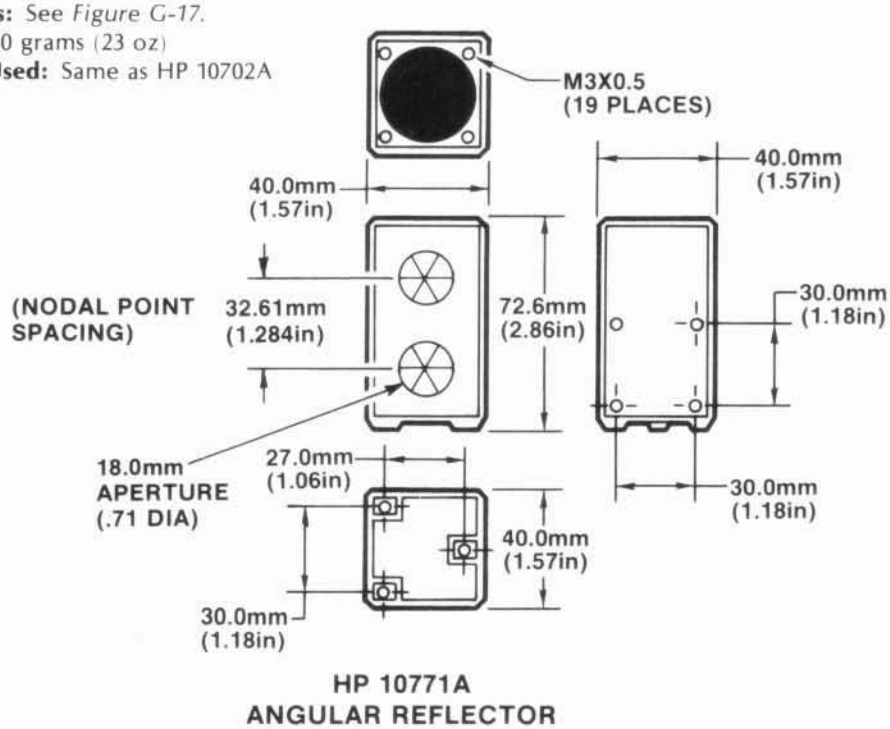


Figure G-17. HP 10771A Angular Reflector, Dimensions

FLATNESS ACCESSORIES

Dimensions: See *Figure G-18.*
Weight: 1.4 kg (3.1 lb)
Materials Used: Stainless Steel

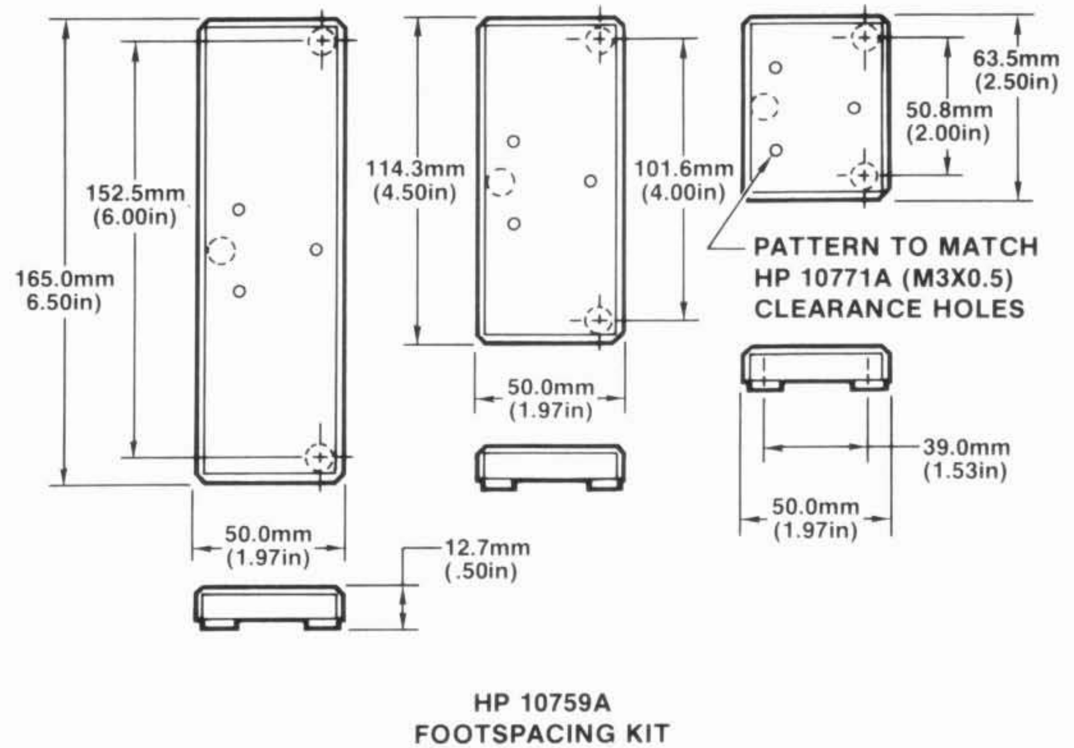


Figure G-18. HP 10759A Foot Spacing Kit, Dimensions

FLATNESS ACCESSORIES (Continued)

Dimensions: See *Figure G-19.*
Weight: 661 grams (23.3 oz)
Materials Used: Same as HP 10700A
Optical Efficiency:
Typical: 99%
Worst Case: 98%

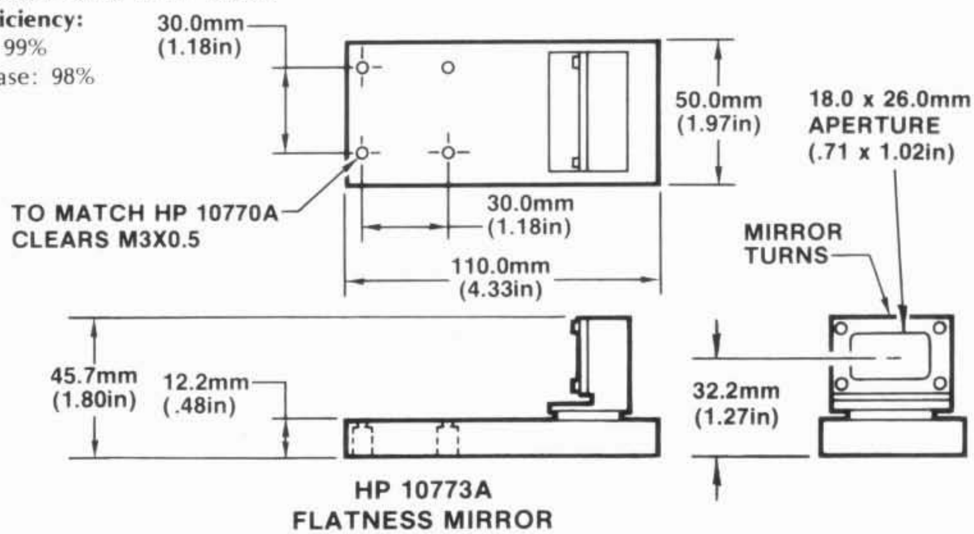
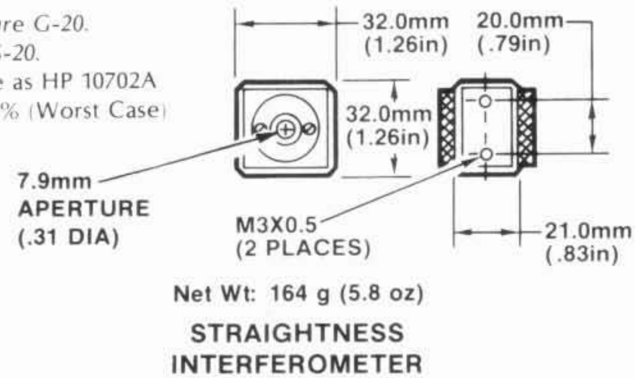


Figure G-19. HP 10773A Flatness Mirror, Dimensions

STRAIGHTNESS/SQUARENESS OPTICS

Dimensions: See *Figure G-20.*
Weight: See *Figure G-20.*
Materials Used: Same as HP 10702A
Optical Efficiency: 90% (Worst Case)



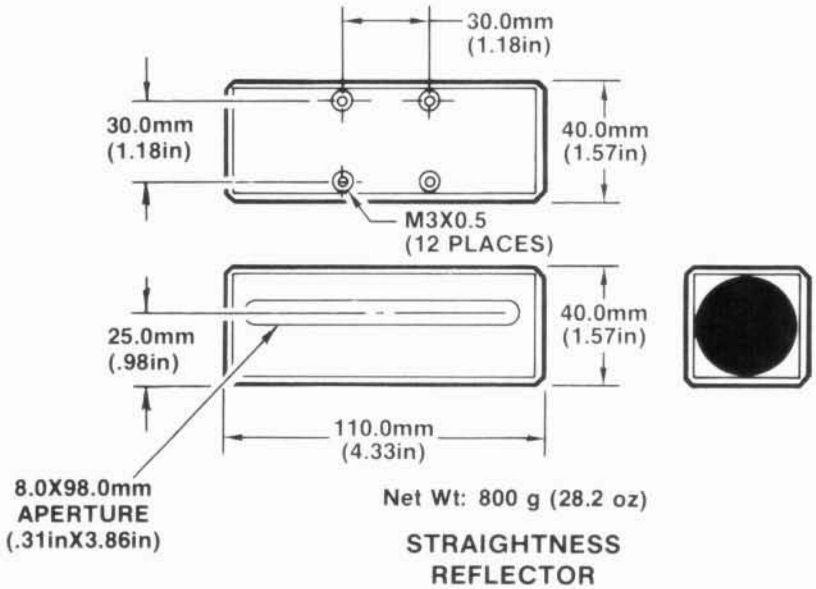


Figure G-20. HP 10774A Short Range Straightness Optics and HP 10775A Long Range Straightness Optics, Dimensions

STRAIGHTNESS/SQUARENESS OPTICS (Continued)

Dimensions: See *Figure G-21.*
Weight: 510 gm (18 oz)
Materials Used: Same as HP 10702A
Optical Efficiency:
Typical: 99%
Worst Case: 98%

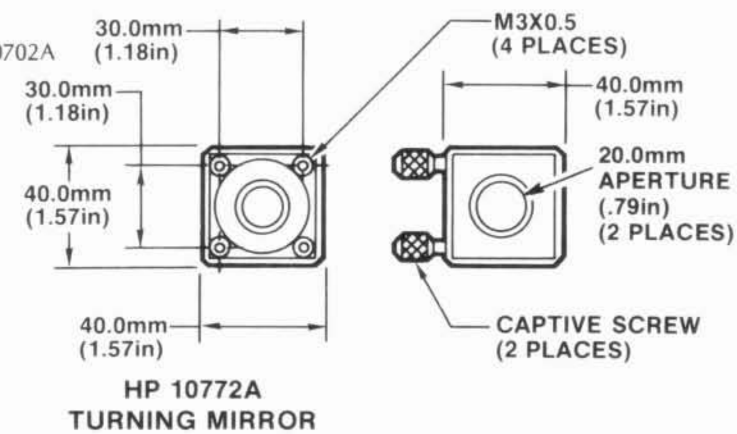


Figure G-21. HP 10772A Turning Mirror, Dimensions

STRAIGHTNESS/SQUARENESS OPTICS (Continued)

Dimensions: See *Figure G-22.*
Weight: 374 grams (13.0 oz)
Materials Used: Housing — Aluminum
Optics — Optical Grade Glass
Optical Efficiency: 80% (Worst Case)

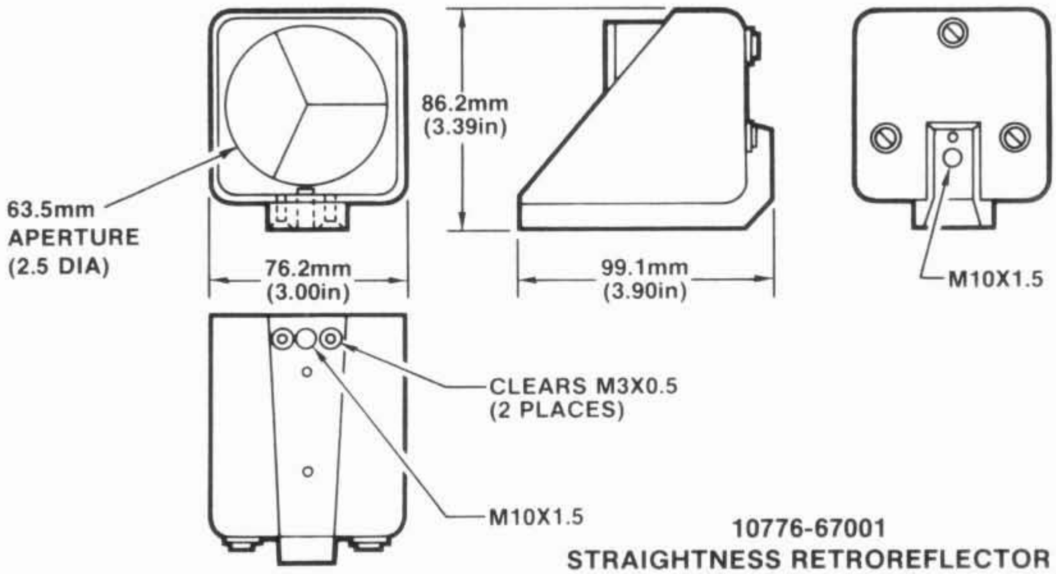


Figure G-22. HP Straightness Retroreflector (HP Part Number 10776-67001), Dimensions

STRAIGHTNESS/SQUARENESS OPTICS (Continued)

Dimensions: See *Figure G-23.*
Weight: 4.0 kg (8.9 lb)
Materials Used: Housing — Aluminum
Optics — Optical Grade Glass
Optical Efficiency: 92% (Worst Case)

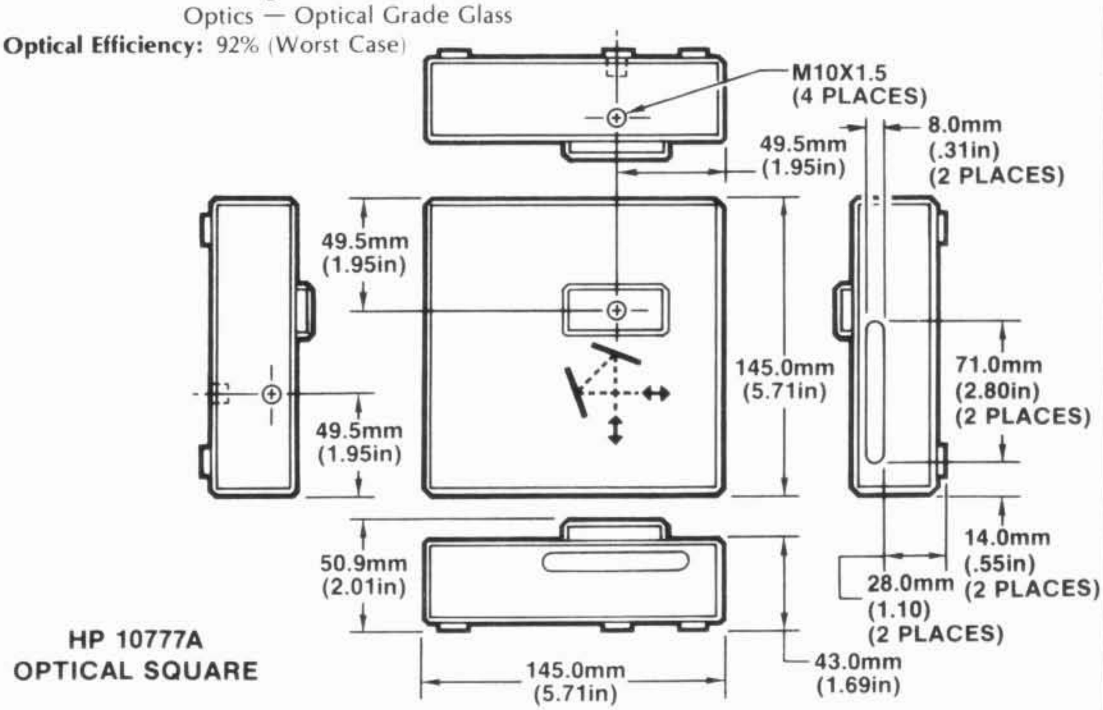


Figure G-23. HP 10777A Optical Square, Dimensions

MANUAL CHANGES

INTRODUCTION

This section contains information necessary to adapt this manual to HP 5527A Laser Position Transducer systems comprised of either obsolete laser products or those laser products that have been mechanically and/or electrically modified. To adapt this manual to your individual HP 5527A system, make all applicable changes that follow.

MANUAL CHANGES

This manual applies directly to the following laser products with the serial number prefixes or board series numbers listed in *Table MC-1*.

Table MC-1. HP 5527A System Component Serial Prefix and Series Numbers

5527A System Component	Serial Number Prefix or Series Number
HP 5507A Laser Position Transducer Electronics	2712
HP 5517A Laser Head	2532
HP 5517B Laser Head	2708
HP 5518A Laser Head	2532
HP 10717A Wavelength Tracker	2648
HP 10751A/B Air Sensor	2452
HP 10757A/B/C Material Temperature Sensor	2416
HP 10780B Receiver	2649
HP 10932A Axis Board	2612
HP 10941A Prototyping Kit	2604
HP 10946B Automatic Compensation Board	2708

Manual changes, which directly effect the performance of the HP 5527A system, for laser products with lower or higher serial number prefixes/board series numbers are described on the following pages. Additional backdating information pertaining to each individual laser product can be found in each product's service manual.

Newer Instruments

As engineering changes are made, the modified laser product may have a serial number prefix or board series number higher than the one listed above. This manual will be provided with "MANUAL UPDATING CHANGES" sheets that document any related system information changes. Replace the affected pages or modify existing manual information as directed in the "MANUAL UPDATING CHANGES" sheets. Contact the nearest Hewlett-Packard Sales and Support Office (listed at the back of this manual) if the applicable change information is missing.

Older Laser Products

To adapt this Designer's Guide to reflect the use of an older laser product within your system, refer to the backdating change applicable to the instruments in your system. The following laser products have been replaced by new and improved "B" versions.

- Table MC-2. HP 5501A Laser Head
- Table MC-3. HP 10780A Receiver
- Table MC-4. HP 10946A Automatic Compensation Board

Table MC-2. HP 5501A Laser Head

Hewlett-Packard discontinued manufacturing the HP 5501A Laser Head in October of 1986. Its direct replacement is the HP 5501B Laser Head. The HP 5501B model has the same footprint, beam polarization, and power requirements as the A model. The B model has a thermally-tuned laser tube, which increases the warm-up time to 10 minutes, and uses the same control electronics found in the HP 5517A/B and HP 5518A Laser Heads.

NOTE

The HP 5501A/B Laser Heads are not recommended for use with the HP 5527A Laser Position Transducer system. Use of these laser heads would degrade the HP 5527A system performance.

The following information provides section by section information that could prove helpful if your system is equipped with the HP 5501A Laser Head.

I. Section I, General Information:

EQUIPMENT DESCRIPTION

HP 5501A Laser Head. The HP 5501A Laser Head is supplied with mating connectors for each connector on its rear panel (Diagnostic — HP Part Numbers 1251-2797 and 1251-3749, Ref Signal — HP Part Number 1251-3450, Power — HP Part Number 1251-3447). The HP 10794B Laser Head Cable is used to connect the HP 5501A Laser Head to the HP 5507A. The cable length is 7 metres (23 feet).

II. Section II, HP Laser Interferometry:

MEASUREMENT COMPONENTS — HP 5501A LASER HEAD

POLARIZATION ORIENTATION. The HP 5501A produces F1 with vertical polarization and F2 with horizontal polarization.

AUTOMATIC TUNING. Piezoelectric tuning with its very short warmup period is used. (Typically 9 seconds).

BEAM SHUTTER. The shutter on this head can be set for open, reduced, or closed aperture.

INDICATORS AND REAR PANEL FEATURES. Eight LED indicators are included to indicate the status of the ±15 Volt power, laser current, and the retune functions. A diagnostic connector permits monitoring of diagnostic signals and application of a RETUNE command by external equipment. The RETUNE cycle may also be initiated by a RETUNE switch on the HP 5501A rear panel.

III. Section VI, Installation and Optical Alignment:

EXTERNAL CABLING

The HP 5501A Laser Head has two connectors on its rear panel needed for operation, a power input connector and a reference signal output connector (the diagnostic input not required). The HP 10794B cable connects the HP 5501A Laser Head to the HP 5507A Laser Position Transducer Electronics. The connectors on the cable, laser head and the HP 5507A are "keyed" so they will go together in only one way and cannot be interchanged. The cable connectors include a locking ring to lock the cable to the respective mating connectors. The locking ring takes about 1/3 turn clockwise to lock the cable to the mating connector.

Table MC-2. HP 5501A Laser Head (Continued)

IV. Section VIII, Specifications:

HP 5501A LASER HEAD

Physical Characteristics

Dimensions: See figure below.
Weight: 3.67 Kilograms (8.1 pounds)
Magnetic Field Emissions (nominal):
At 91.44 cm (3 ft) radius: 60 mGauss
At 243.84 cm (8 ft) radius: 3.8 mGauss
Clearance Required For Cabling: 5.72 cm (2.25 in) beyond back.

Power

Power Input Requirements:
+15V ±0.5V at 0.8A
−15V ±0.5V at 0.7A
Heat Dissipation: 21 Watts
Warmup Time: Instantaneous

Laser Beam Characteristics

Type: Helium-Neon, Continuous Wave, Two-Frequency
Maximum Beam Power Output: 1 milliwatt
Minimum Beam Power Output: 120 microwatts
Beam Diameter: 6 millimetres (0.24 inch) typical
Vacuum Wavelength Accuracy (3 sigma, lifetime): 0.5 ppm
Vacuum Wavelength Stability: Not Available
Nominal Vacuum Wavelength: 632.99137 nanometres

Safety Classification:

Class II Laser Product conforming to U.S. National Center for Devices and Radiological Health Regulations 21 CFR 1040.10 and 1040.11. HP 5501A Laser Head, Dimensions

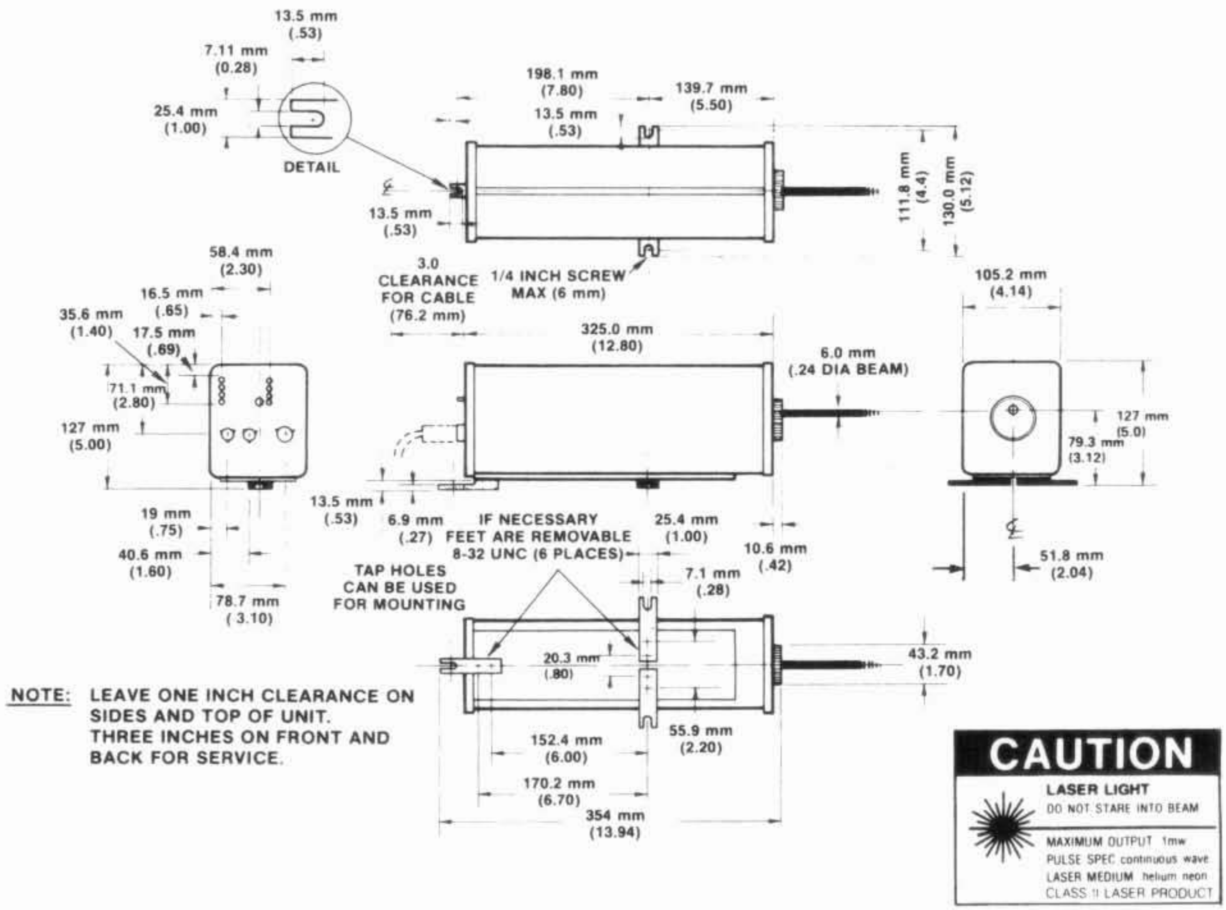


Table MC-3. HP 10780A Receiver

The HP 10780B Receiver was introduced March 1, 1987. With a maximum sensitivity specification of 1.5 μW, the HP 10780B is three times more sensitive than its predecessor, the HP 10780A. The increased sensitivity is important when using the receiver with the HP 10715A Differential Interferometer and the HP 10717A Wavelength Tracker, both complex optics that attenuate the laser beam, in systems with three or more axes. Other advantages of the model B receiver are that (1) more system axes may be added, (2) measured distances may be increased, (3) measured angles may be increased, and (4) gain adjustment can be made by using the externally accessible potentiometer and signal-detection LED indicator. The gain of the HP 10780B is factory set to that of the HP 10780A (5 microwatts) making the B model a "drop-in" backward compatible replacement.

I. Page 8-21, Section VIII, Specifications:

Replace HP 10780B specifications with the following:

HP 10780A Receiver

Physical Characteristics

Dimensions: See HP 10780B Dimensional drawing in Section VIII. Dimensional drawing for the A and B models are identical.
Weight: 134 grams (4.73 ounces)

Power

Power Dissipation: 2.5 Watts (nominal)
Power Requirements: +15 Volts (+1V) at 0.18 Ampere maximum

Alignment Tolerances:

Roll: ±3°
Pitch: ±1°
Yaw: ±1°

Minimum Optical Power Requirement:

5 microwatt (assuming good wavefront).

Table MC-4. HP 10946A Automatic Compensation Board

The HP 10946B Automatic Compensation Board was introduced March 1, 1987. The B model was designed to provide signal processing required to implement Wavelength Tracking Compensation. The HP 10946B and the HP 10717A Wavelength Tracker, the optical sensor that measures any change in the wavelength of the laser light, work together to extend the measurement performance of HP laser transducer systems by optically measuring and correcting for changes in atmospheric conditions (such as gas pressure, temperature, composition, and humidity). As with the HP 10946A, the HP 10946B also accommodates one HP 10751A/B Air Sensor and two HP 10757A/B/C Material Temperature Sensors should they be required.

The HP 10946B Automatic Compensation Board is completely compatible with the HP 10946A, and is designed as a direct replacement for it. The HP 10946A CANNOT support Wavelength Tracking Compensation.

The HP 5507A laser Position Transducer Electronics package serial number prefix was changed from 2612 to 2712 to reflect the implementation of the Wavelength Tracking function to the Automatic Compensation Board assembly of the HP 5507A Option 046.

I. Page 2-19, Section II, HP Laser Interferometry:

Replace HP 10946B description with the following text:

HP 10946A Automatic Compensation Board (HP 5507A Option 046) The HP 10946A Automatic Compensation Board interfaces with remote sensors (HP 10751A/B Air Sensor and HP 10757A/B/C Material Temperature Sensor) and provides compensation information for air variations and material temperature. It accommodates one air sensor and two material temperature sensors. Calibration is fast and accomplished through software. Additionally, it can provide an alert when a significant change in index of refraction occurs. The compensation board recognizes mnemonics sent over the HP-IB including functions for:

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

The board also recognizes service related commands that read/write the reference values, read the channel voltages, and calibrate the board. The HP 10946A can also be used for manual compensation. The environmental parameters are input and the HP 10946A derives the compensation information required.

II. Pages 4K-5 through 4K-15 and 4K-18 through 4K-21, Section IV-K, Software Control of the HP 5527A, HP 10946B Automatic Compensation Board:

A. The following mnemonics are unique to the HP 10946B Automatic Compensation Board:

*CMC, *DDV, *DTV, *FTC, *RPC, *WRL, *WTC, *WTE, *WTL, and *WTR.

Table MC-4. HP 10946A Automatic Compensation Board (Continued)

B. The following error messages are unique to the HP 10946B Automatic Compensation Board:

900 through 911

III. Section VII, System Theory and Troubleshooting:

A. Page 7-24, Preliminary Checks

Replace A8 Preliminary Checks with text and figures that follow:

g. Check the address switch (DIP) and jumper JMP1 on the Automatic Compensation Board.

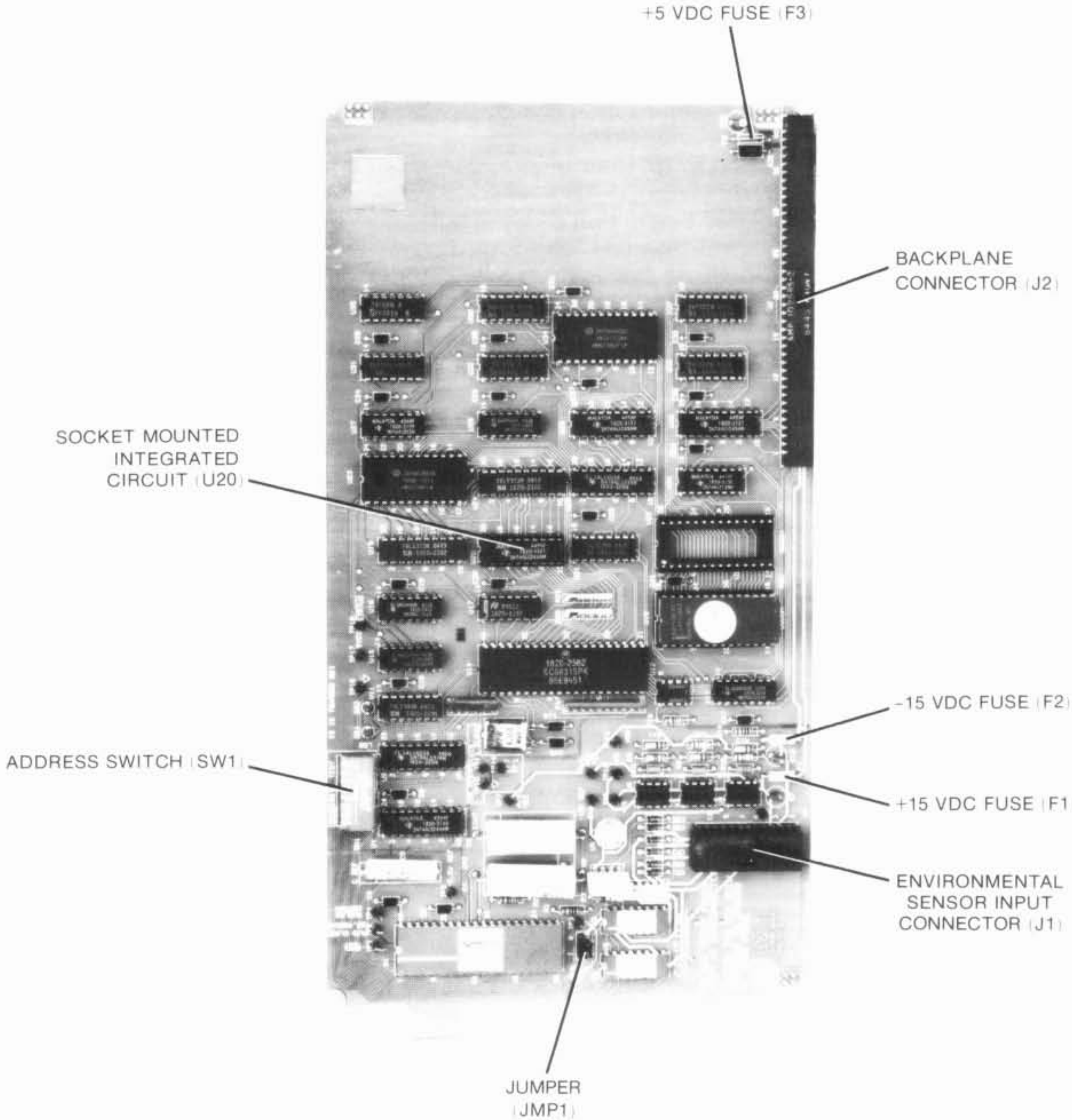


Figure 7-6. A8 Automatic Compensation Board (Part of Option 046)

Table MC-4. HP 10946A Automatic Compensation Board (Continued)

1. Ensure that jumper JMP1 is installed in the run position (see *Figure 7-7*).

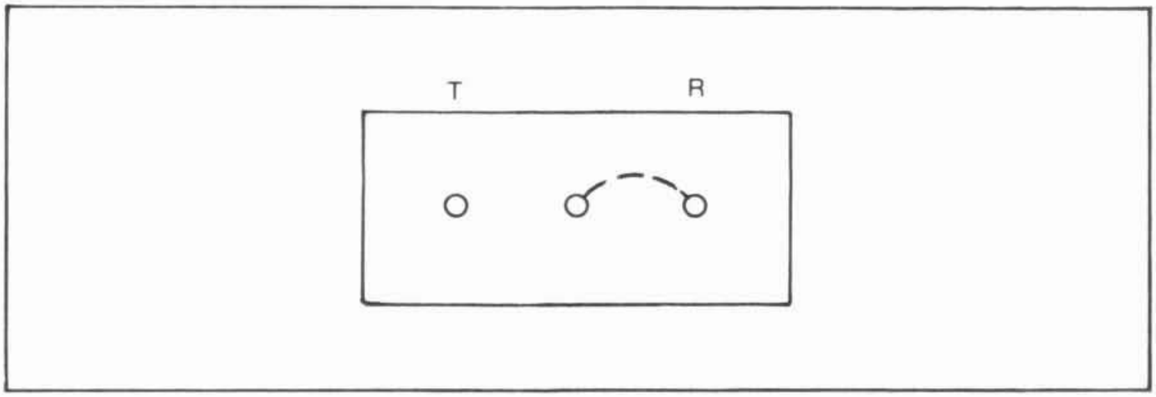


Figure 7-7. JMP1 Normal Position

2. Verify that integrated circuit U20 is properly installed in its socket.

3. Check the address switch (DIP) on the Automatic Compensation board. Address Switch SW1 TEST switches must be set to zero during normal operation. The ADDRESS switches may be set as desired.

Figure 7-8, Automatic Compensation Board Address Switch Setting, is applicable to both the HP 10946A and HP 10946B models.

B. Page 7-76, Table 7-18, HP 10946A Internal Fuse Ratings:

Replace fuse A8F1, A8F2, and A8F3 information with the following:

A8F1, 0.50 Amp, HP Part Number 2110-0297, Protects +15 Vdc
A8F2, 0.50 Amp, HP Part Number 2110-0297, Protects −15 Vdc
A8F3, 1.00 Amp, HP Part Number 2110-0099, Protects +5 Vdc

C. Page 7-76, HP 10946B AUTOMATIC COMPENSATION BOARD CALIBRATION:

1. Calibration Procedure, Step b:

Change first sentence of the second paragraph to read:

If either of the measured voltages are outside of their respective limits, measure the voltage at TP9 (+15V) located on the Automatic Compensator board.

D. Page 7-80, TEMPERATURE CALIBRATION PROCEDURE:

1. Change step m to read:

m. Connect the positive lead of the DVM to HP 5507A rear panel +10V REF OUTPUT, and the negative lead to test point TP4 (Analog Common) located on the HP 10946A.

Table MC-4. HP 10946A Automatic Compensation Board (Continued)

2. Change step s to read:

   s. Connect floating negative terminal of DVM to test point TP4 (Analog Common) and positive terminal of DVM to pin 6 of R4 (AT input from air sensor), both located on the HP 10946A board.

E. Page 7-82, AIR PRESSURE CALIBRATION PROCEDURE:

1. Change step m to read:

   m. Connect floating negative terminal of DVM to test point TP4 and connect positive terminal to R4 (pin 8), both located on the HP 10946A board.

IV. Section VIII, Specifications:

A. Page 8-2, Table 8-1, HP 5527A Laser Position Transducer:

Replace the System "Accuracy" specification with the following:

ACCURACY: The accuracy of the Laser Position Transducer is fundamentally linked to the accuracy of the laser head, the choice of optics and the effects of the environment. In a given system, the absolute accuracy will be the sum of all effects present.

Laser Head Wavelength Accuracy (in vacuum):

HP 5501A: ±0.5 ppm
HP 5517A: ±0.1 ppm

Environmental Effects:

Vacuum: No effect
Atmosphere (with compensation using HP 10751A/B):

Operating Temperature	Range Accuracy
19.5 to 20.5°C	±1.4 ppm
15 to 25°C	±1.6 ppm
0 to 40°C	±2.9 ppm

Interferometer Nonlinearity (worst case potential error due to optical leakage):

Linear or Single Beam:	±2.4 nm	(0.09 μin)
Plane Mirror:	±1.2 nm	(0.05 μin)
Differential:	±6.2 nm	(0.24 μin)

Electronics Accuracy (dependent on least resolution increment):

Linear or Single Beam:	±10 nm	(0.4 μin)
Plane Mirror or Differential:	±5 nm	(0.2 μin)

Table MC-4. HP 10946A Automatic Compensation Board (Continued)

B. Page 8-19, HP 10946B Automatic Compensation Board Specifications:

Replace HP 10946B specifications with the following:

HP 10946A Automatic Compensation Board

Heat Dissipation: 4 Watts (nominal without Sensors)

Power Requirements:
0.7A at +5V
17 mA at +15V
12 mA at −15V

Fuse Ratings:
+5V = 1A
±15V = 0.5A

Calibration Interval: 12 Months (when used with either the HP 10751A/B Air Sensor and/or HP 10757A/B/C Material Temperature Sensor)

Number of Air Sensors: 1
Number of Material Temperature Sensors: 2
Compensation Number Alert Range: ±10 ppm
Expansion Coefficient Value Range:
English: ±100 ppm/°F
Metric: ±180 ppm/°C
Compensation Number Update Rate:
0.5 to 2.5 Hertz (Depending on the number of Sensors used).
Auxiliary Input Range:
±1V nominal
(±2*VREF actual)
Channel protected to ±30V