8. Install quarter-waveplate Alignment Aid so that the primary measurement beam passes through the hole of the Alignment Aid (see *Figure 6-45*).

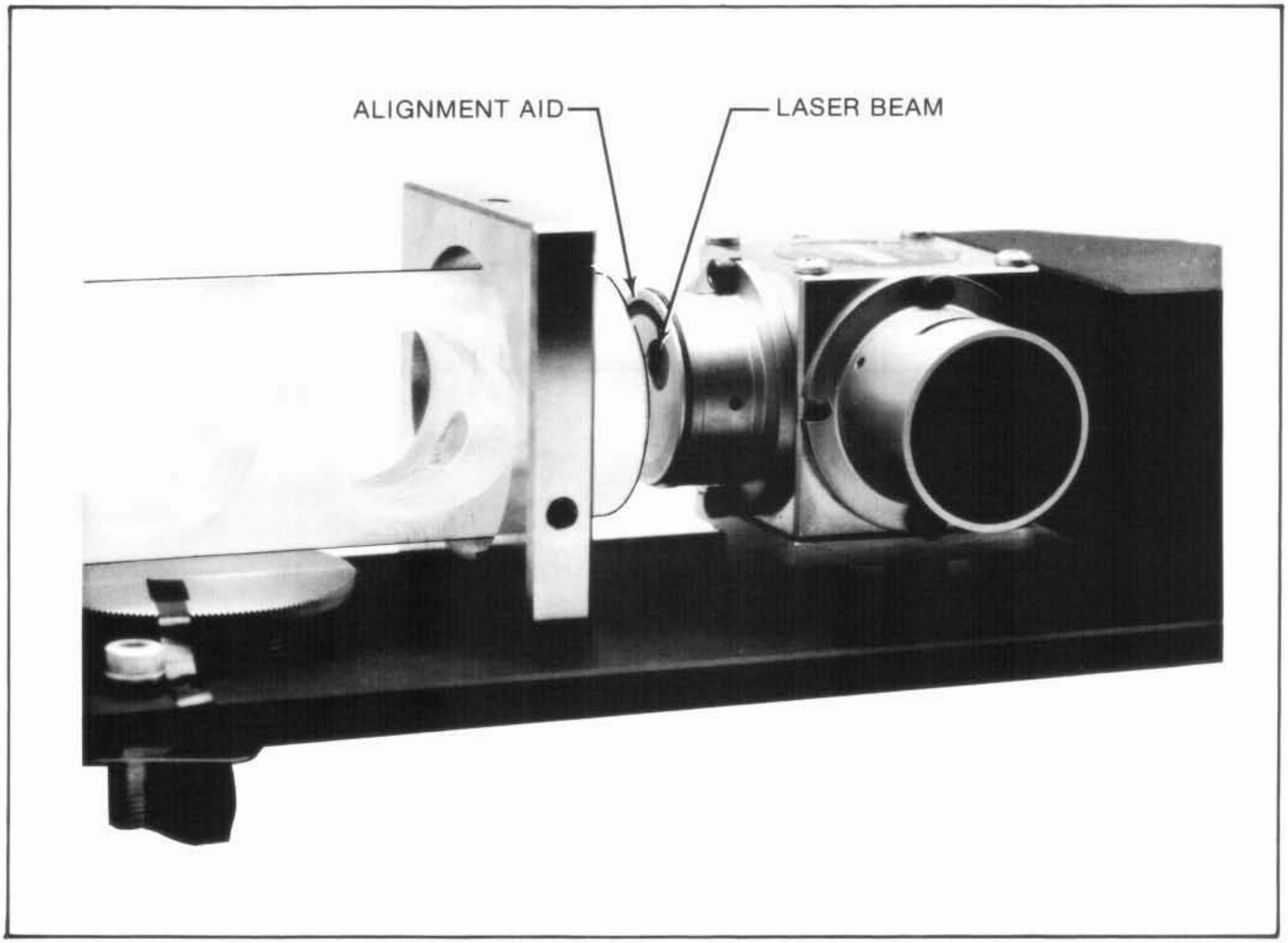


Figure 6-45. Installation of Alignment Aid

NOTE

Standard input aperture for the Wavelength Tracker is "A" (positive sense). If the input beam goes to aperture "B", then direction sense changes (negative sense). See Section IV-K regarding Wavelength Tracker direction sense change using the *WRL mnemonic. Refer to Section V of this manual for details on the direction sense for the Wavelength Tracker.

9. Remove translucent tape from differential interferometer input aperture.

10. Select the small aperture of the laser head.

11. Rotate pitch adjustment screw (see *Figure 6-44*) until the laser beam autoreflects back to the laser head so that the beam is symmetric about the output beam in the vertical axis. Adjust baseplate back and forth in yaw until the autoreflected beam is concentric with the laser head aperture.

3. Remove the three hitch-pin clips by pulling on the red tape.

4. Tighten front mounting screw (*Figure 6-44*) until slight resistance is sensed.

5. Place a piece of translucent tape over the differential interferometer's "A" input aperture (see *Figure 6-44*). Flatten tape tight against input "A" aperture to obtain a high resolution outline of the input aperture and a well defined laser pattern is visible on the tape.

6. Rotate vertical translator adjustment screw (see *Figure 6-44*) until the input beam is symmetric about the input aperture in the vertical axis. At the same time, translate in the horizontal direction to center laser beam in horizontal plane.

7. Tighten down front mounting screw (see *Figure 6-44*) finger-tight when laser beam is concentric to input aperture.

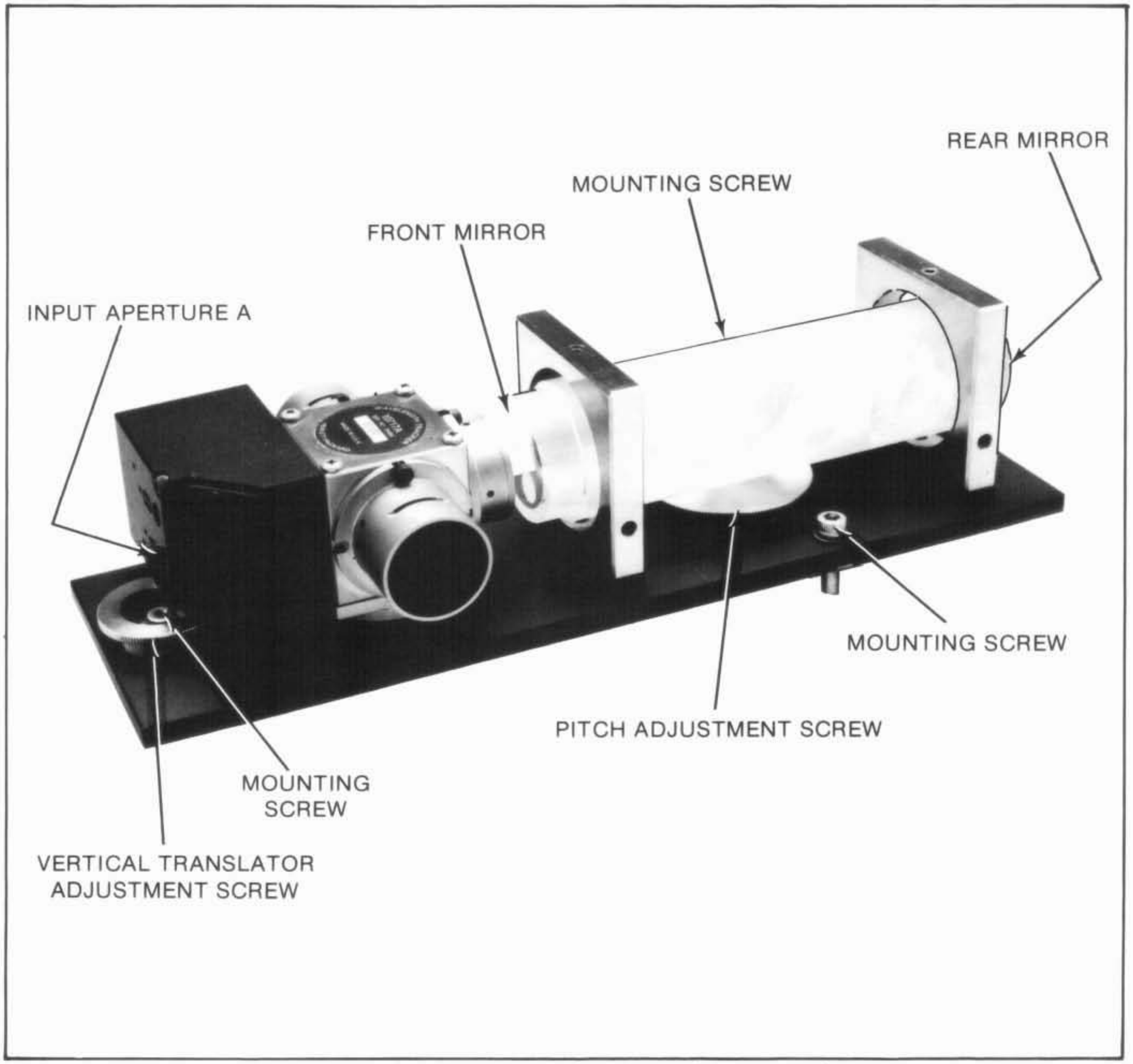


Figure 6-44. HP 10717A Wavelength Tracker Adjustment Hardware

21. Remove beam blocking device. The voltmeter should now read at +0.7 Vdc. If the measured voltage is below +0.7 Vdc, the Wavelength Tracker and/or the receiver is not properly aligned. If after repeating the receiver alignment (steps p through u), the voltage measured at the test point is still below +0.7 Vdc, the entire alignment procedure must be repeated until the misalignment is corrected.

22. Remove voltmeter from receiver's test point. All alignment and adjustment procedures are complete.

NOTE

After the Wavelength Tracker and receiver have been properly aligned in the measurement system, it is recommended that the vertical translator adjustment screw (see *Figure 6-44*) be locked in place. This will prevent possible cosine error in the Wavelength Tracker due to thread clearance between the adjustment screw and the baseplate. A suitable low strength, wicking adhesive (Locktite #425) is recommended. In vibration-free environments, this precaution may not be necessary.

Receiver — Alignment and Gain Adjustment Procedure

The following procedure aligns and adjusts the 10780B Receiver for optimum performance.

1. Align the optics on the machine in the desired configuration. See alignment procedures applicable to the interferometer(s) installed in your system.

2. Run the system stage out to its limit such that the retroreflector or plane mirror for one axis is furthest from the interferometer.

3. Mount the HP 10780B Receiver on that axis.

4. Connect a DVM or Oscilloscope to the test point on the back of the receiver.

5. Align the position of the receiver for a maximum positive voltage on the test point. It may be necessary to adjust the gain potentiometer to keep the test point voltage out of saturation and in the linear region (0.1 to 0.8V).

NOTE

A simple way to align the receiver is use a gage block to autoreflect the beam. Keep in mind that the objective is to position the receiver such that the beam enters the aperture perpendicular to the receiver's front face and that the beam is centered in the receiver aperture. Hold the gage block against the receiver front face and adjust the receiver position and angular orientation so that the beam is autoreflected, i.e., coincident upon itself at the laser head.

6. Rotate the GAIN potentiometer fully clockwise.

12. Tighten all three mounting screws (see *Figure 6-44*) until just finger-tight. Tighten three screws alternately until snug. Now tighten screws applying a torque of 0.9 Newton-meter (8 inch-pounds). Maintain proper autoreflection as screws are tightened. If change occurs, correct by readjusting Wavelength Tracker in pitch and yaw until the laser beam is autoreflected back into the laser head. This insures proper angular alignment.

NOTE

Tightening the mounting screws unevenly or exceeding the specified torque specification will disrupt alignment and degrade overall system performance.

13. Remove Alignment Aid.

14. Return laser head turret to its larger aperture. Two parallel unclipped beams should now enter and exit the differential interferometer.

15. Check for a circular, unclipped laser beam. As long as the two beams are not clipped, the alignment of the Wavelength Tracker is adequate.

16. **Alignment of the receiver** is accomplished by translating it perpendicularly and angularly (relative to the beam axis) to center the beam on the receiver's lens. Coarse beam alignment is achieved by using the snap-on Alignment Target fixture (P/N 10780-40003) supplied with the receiver. (See *Figure 6-10*.) For the Wavelength Tracker, this target is used only to align the receiver to the incident beam.

17. To check the final optical alignment of the Wavelength Tracking Compensation system, place a rectangular gage block over the lens of the receiver (and pressed against the receiver's case) and autoreflect the beam back toward the differential interferometer of the Wavelength Tracker. When the receiver is mounted properly (which occurs when the beam enters the receiver's aperture perpendicular to the plane on which the aperture is mounted) the autoreflected beam will be coincident on itself back to the laser head. Refer to the receiver alignment procedures discussed earlier in this section for additional alignment information.

    After optical alignment of the receiver, the gain of the receiver is adjusted. This procedure ensures that the leakage signal from one or the other beams isn't sufficient to turn on the receiver. The following procedure sets the gain just below the optical leakage threshold.

18. Install a fast responding voltmeter to the test pin located on the receiver.

19. Block one of the two beams incident on the **front** etalon mirror (see *Figure 6-44*) with a piece of paper. Be sure to block only one beam at a time. Observe the voltmeter reading. If the reading is greater than +0.1 Vdc, turn the gain adjustment screw counterclockwise until the voltage reads +0.1 Vdc.

20. Block one of the two beams incident on the **rear** etalon mirror (see *Figure 6-44*) with a piece of paper. Again, be sure to block only one beam at a time. If the measured voltage is greater than +0.1 Vdc, turn the gain adjustment screw counterclockwise until the reads +0.1 Vdc.

e. Install the HP 10723A High Stability Adapter in place of the removed reference cube corner. Either set of mounting slots may be used to attach the High Stability Adapter to the interferometer.

f. Refer to *Figure 6-46*. Locate and remove the PLANE MIRROR CONVERTER.

g. The black plastic bezel under the plane mirror converter must be removed to allow access for an Alignment Aid during setup. The bezel is secured with silicone adhesive but can be easily removed. Place the blade of a small screwdriver under the lip of the bezel and pry the bezel out. PRY THE SCREWDRIVER AWAY FROM THE BEAM SPLITTER GLASS TAKING CARE NOT TO COME IN CONTACT WITH OR SCRATCH THE OPTIC. Discard the bezel.

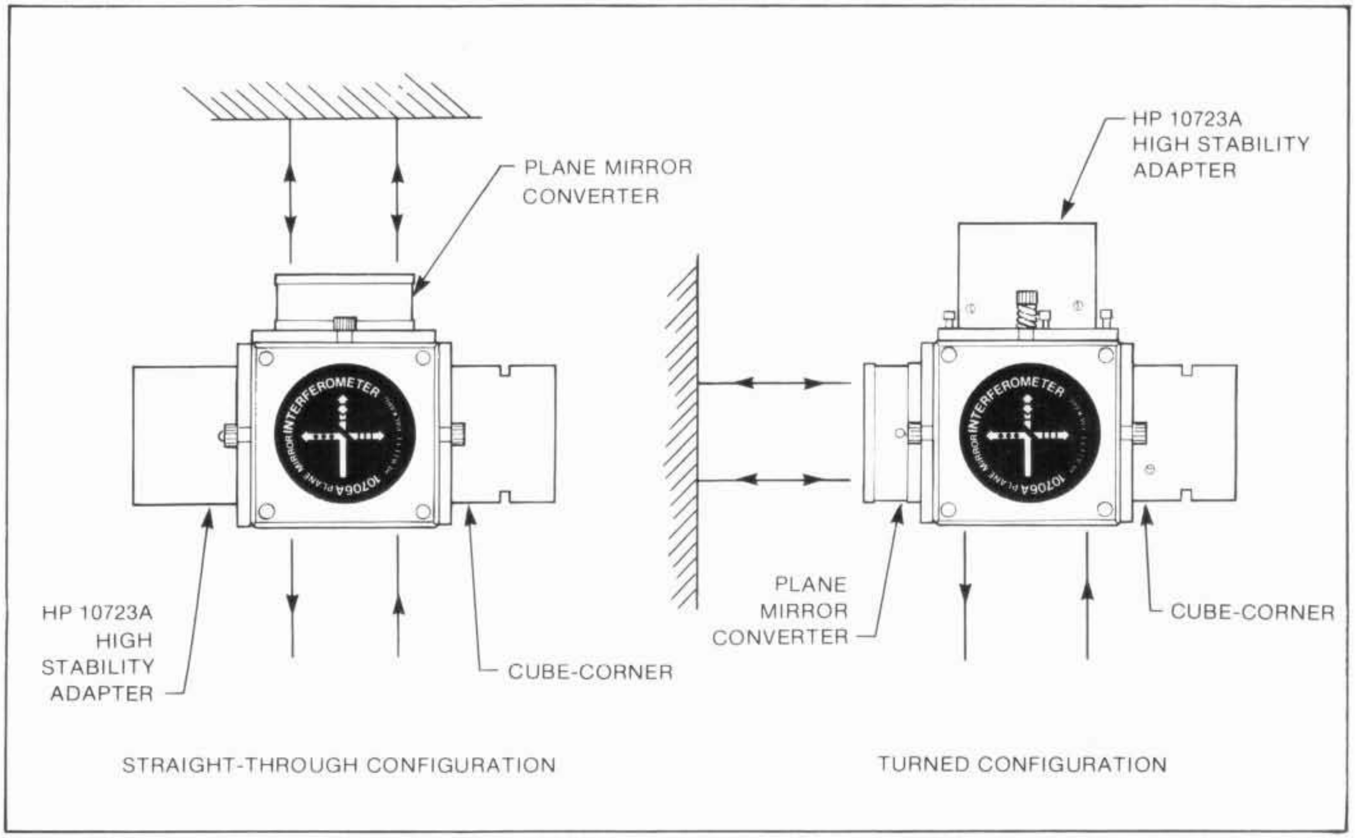


Figure 6-46. HP 10706A Conversion Using the HP 10723A

h. Replace the plane mirror converter that was removed in step d.

i. This completes the conversion. The converted interferometer must be realigned as described in the alignment sections for the HP 10706B High Stability Plane Mirror Interferometer.

High Stability Plane Mirror Interferometer, HP 10706B

The alignment procedure for the HP 10706B High Stability Plane Mirror Interferometer is similar to the HP 10706A, except for an additional alignment of the High Stability Adapter.

Before proceeding with the alignment procedures, reconfiguring of the interferometer and alignment aids will be covered.

7. Block the measurement beam (the beam between the interferometer and the retroreflector or one of the beams between the interferometer and the plane mirror).

8. Adjust the GAIN potentiometer counter-clockwise until the test point voltage drops below 0.1V.

9. Unblock the measurement beam. The test point voltage should be at least 0.7V.

NOTE

Record the voltage reading at the beam monitor test point for use as an axis reference for future troubleshooting.

High Stability Adapter, HP 10723A

The HP 10723A High Stability Adapter converts an HP 10706A Plane Mirror Interferometer into an improved thermal stability version equivalent to the HP 10706B High Stability Plane Mirror Interferometer. The adapter replaces the REFERENCE cube-corner on the HP 10706A Plane Mirror Interferometer.

INSTALLATION

To convert an HP 10706A Plane Mirror Interferometer to the HP 10706B configuration, proceed as follows:

NOTE

The HP 10723A MUST be installed in place of the REFERENCE cube corner on the HP 10706A. If it is inadvertently installed on the other side, the thermal errors will become worse rather than better. Be certain to refer to *Figure 6-46* for the proper installation orientation.

a. Refer to *Figure 6-46* and positively identify the position to install the HP 10723A. Note that in either configuration, the HP 10723A replaces the REFERENCE CUBE-CORNER (HP 10703A Retroreflector).

b. Remove the REFERENCE CUBE-CORNER and store it in a safe place.

c. Refer to *Figure 6-46*. If the interferometer is in the straight through configuration, proceed to step e and install the HP 10723A using the mounting screws that were used to mount the Reference Cube-Corner.

   If the interferometer is in the turned configuration, use the new hardware supplied with the HP 10723A to mount the HP 10723A as described in step d.

d. Using the hex key provided, install the four 2-56 × 3/16" long screws into the holes on the flange of the HP 10723A housing. Be sure that they do *not* protrude through the flange.

   Equip both 4-40 × 1/2" long mounting screws with a compression spring and use them to install the HP 10723A in place of the removed Reference Cube-Corner. Either set of mounting slots may be used to attach the High Stability Adapter to the interferometer.

   Tighten both mounting screws until the head of each just begins to compress the spring. Then tighten each screw *two* turns to properly compress each spring.

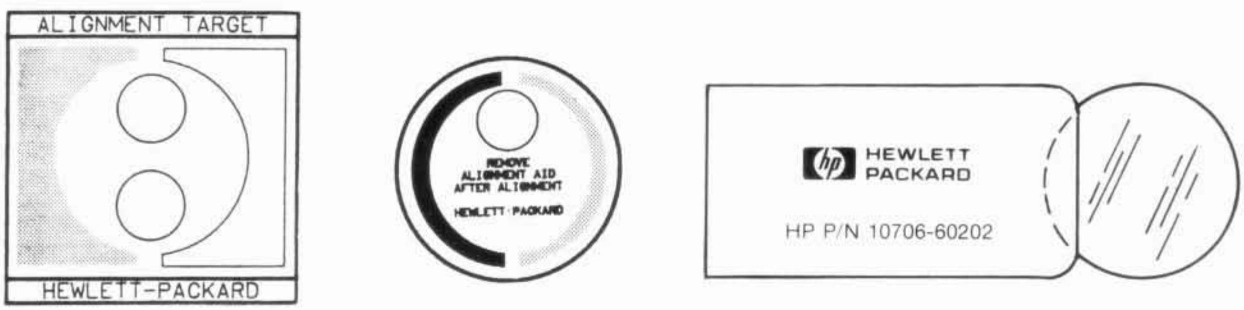
   Continue on to step f.

ALIGNMENT AIDS

The HP 10706B High Stability Plane Mirror Interferometer is supplied with the alignment aids shown in *Figure 6-48.*

- Alignment Aid, P/N 10706-60001
- Alignment Target, P/N 10702-60001
- Alignment Aid, P/N 10706-60202

The first two alignment aids are the same as used on the HP 10706A Plane Mirror Interferometer. Refer to the "Alignment Aids" for the Plane Mirror Interferometer in this section for a further discussion of their use.



ALIGNMENT TARGET
HP P/N 10702-60001

ALIGNMENT AID
HP P/N 10706-60001

ALIGNMENT AID
HP P/N 10706-60202

Figure 6-48. HP 10706B Alignment Aids

Alignment Aid P/N 10706-60202 facilitates autoreflection alignment for the high stability adapter to achieve minimal thermal drift. It contains a quarter-wave plate to reflect the reference beam back on itself and return it to the laser head without offset. *Figure 6-49* illustrates how the aid is positioned between the beam splitter and the high stability adapter during alignment.

ALIGNMENT PROCEDURES

Two alignment procedures are given for the High Stability Plane Mirror Interferometer:

- the straight through configuration (as shipped) in a single-axis application
- the turned configuration for two axis X-Y stage applications

STRAIGHT THROUGH CONFIGURATION, SINGLE AXIS ALIGNMENT PROCEDURE

The following procedure describes the alignment of the HP 10706B high stability plane mirror interferometer used in the straight through configuration. Before proceeding, review the "Alignment Principles" given earlier in this section.

Objective

This procedure minimizes cosine error and the thermal drift coefficient of the HP 10706B, and maximizes the signal strength at the receiver. Two separate autoreflection/adjustment steps are performed using the two alignment aids.

STRAIGHT THROUGH CONFIGURATION

The HP 10706B High Stability Plane Mirror Interferometer is shipped in the straight-through configuration as shown in *Figure 6-47*. Note the location of the plane mirror converter and high stability adapter with respect to the graphics on the label.

TURNED CONFIGURATION

The HP 10706B can be configured to turn the beam to reduce the number of beam bending optics as shown in *Figure 6-47*. This is done by interchanging the high stability adapter and the plane mirror converter and adding new mounting and adjusting hardware for the High Stability Adapter. Note the location of the plane mirror converter and high stability adapter with respect to the graphics on the label.

The new mounting and adjusting hardware is contained in a bag shipped with the HP 10706B.

Using the hex key provided, install the four 2-56 × 3/16" long screws into the holes on the flange of the High Stability Adapter housing. Be sure that they do *not* protrude through the flange.

Equip both 4-40 × 1/2" long mounting screws with a compression spring and use them to mount the High Stability Adapter in place of the plane mirror converter as shown in *Figure 6-47*.

Tighten both mounting screws until the head of each just begins to compress the spring. Then tighten each screw *two* turns to properly compress each spring.

NOTE

Changing to the turned configuration changes the measurement direction sense. (See Section V). If the High Stability Adapter is installed in the wrong location, the interferometer will have worse thermal stability.

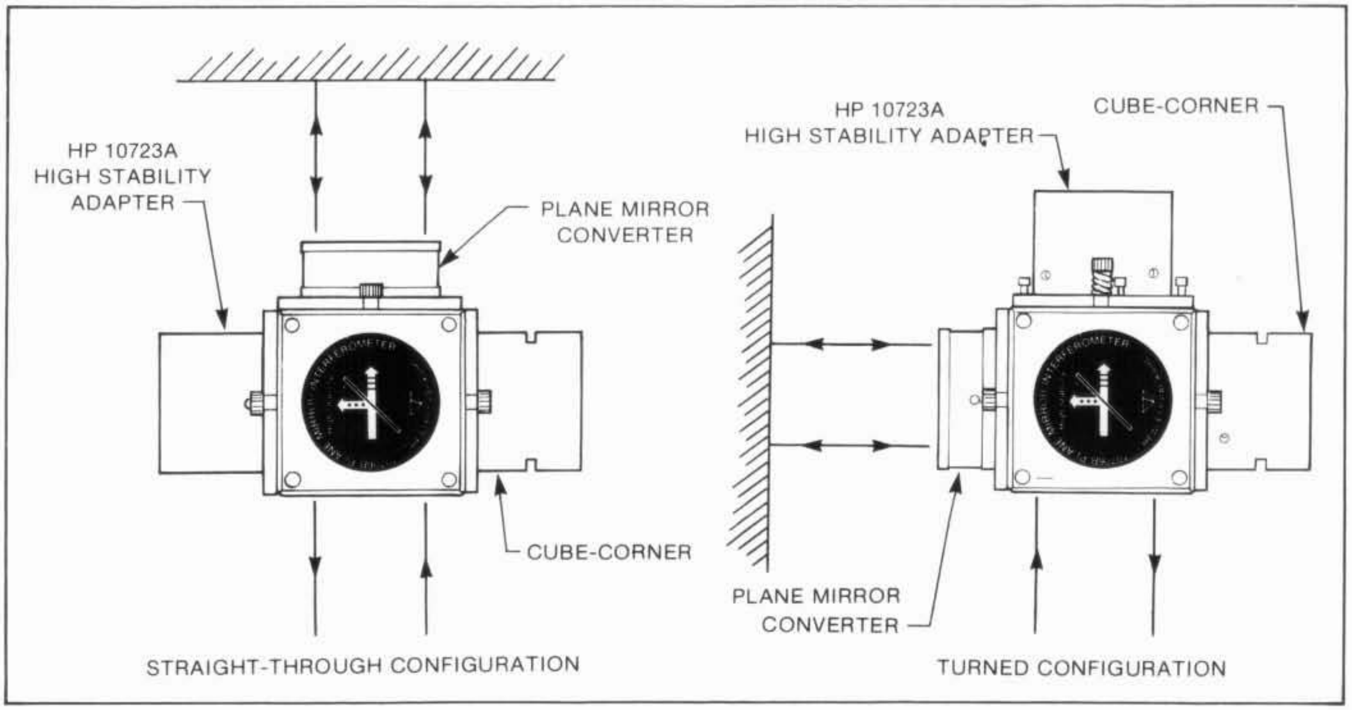


Figure 6-47. HP 10706B Configurations

5. Angularly adjust the laser beam until the beam reflected from the measurement mirror returns upon itself, through the interferometer and back to the small aperture of the laser head. Translate the laser head or the interferometer to keep the laser beam centered on one hole of the Alignment target. Clamp down the laser and/or the beam steering optics.

NOTE

For high accuracy alignment or for installations where there is less than 0.5 metres (20 inches) between the laser and mirror, perform steps 6 through 8.

6. Remove the alignment target (P/N 10702-60001) and rotate the turret of the laser head to select the large aperture. Do not remove the alignment aid (P/N 10706-60001) on the output side of the interferometer. Center the output beams on the receiver aperture by translating the receiver. Translucent tape over the receiver aperture will help to observe when the beam is centered.

7. Connect a fast responding voltmeter (preferably a meter type) to the receiver test point. Fine adjust the laser beam angularly until a signal is received. This is indicated by the voltmeter suddenly jumping to a value greater than 0.25 volts. This adjustment is critical and may require considerable care to achieve the desired result.

8. Peak the voltmeter reading (which will be fluctuating) by fine adjusting the laser beam in both angular axes. Carefully readjust the interferometer until the voltage reading suddenly drops back to about 0.3 Volts.

NOTE

Proper alignment is achieved when the voltage reading from the receiver test point is just below the sudden jump up in voltage. If the alignment is fixed to sustain the peaked voltage, the system operation will be degraded.

This aligns the laser beam to within ± 1.2 arcminutes to the direction of travel, resulting in a cosine error of approximately 0.05 parts per million (0.05 micrometres per metre of travel or 0.05 microinches per inch).

9. Remove the alignment aid (P/N 10706-60001) from the interferometer. Also, remove the plane mirror converter from the interferometer. Switch to the small aperture on the laser head. Block the measurement beam by placing something between the interferometer and the measurement mirror.

10. Insert the HP 10706B alignment aid (P/N 10706-60202) between the beam splitter and the high stability adapter as shown in *Figure 6-49*. This allows the reference beam to be autoreflected from the high stability adapter back towards the small aperture of the laser head.

11. Observe the reflection of the reference beam back at the laser head. Pitch and yaw the interferometer until this reflection is returned back into the small aperture of the laser head.

12. Lock down the interferometer pitch and yaw adjustments.

13. Remove the HP 10706B alignment aid (P/N 10706-60202) from between the beam splitter and the high stability adapter. Replace the plane mirror converter. Remove the material from between the interferometer and measurement mirror.

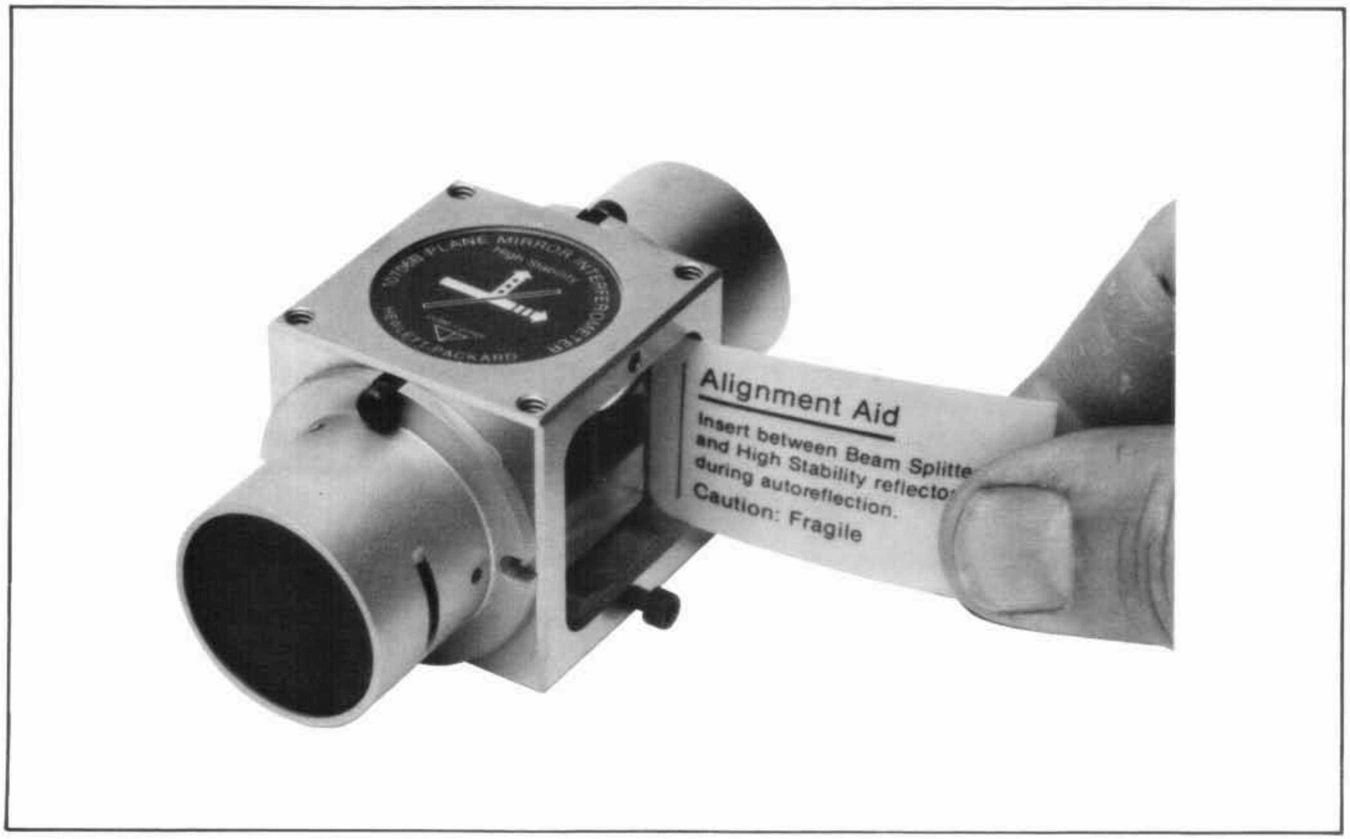


Figure 6-49. Using the HP 10706-60202 Alignment Aid.

Procedure

1. Translate the stage to its furthest point from the laser head. Align the laser beam perpendicular to the measurement mirror by autoreflection.

2. Position the HP 10706B in the beam path between the laser head and the measurement mirror.

3. Place the interferometer alignment target (P/N 10702-60001) on the laser side of the interferometer. Place the alignment aid (P/N 10706-60001) on the output side of the interferometer in the correct orientation. Select the small aperture on the front turret of the laser head.

4. Translate the interferometer until the beam passes through the center of one hole on the alignment target and through the hole on the alignment aid and strikes the measurement mirror. Use translucent tape over the target aperture to observe when the beam is centered.

NOTE

If the distance between the laser head and the reflector is greater than 0.5 metres (20 inches), the formula given in the paragraph on Overlapping Dots determines the cosine error based on the offset of the return beam at the laser head. For example, with a distance between the laser head and reflector of 0.5 metres and an offset of the return beam at the small aperture of the laser of 500 micrometres (0.0202 inches), the cosine error is approximately 0.12 parts per million.

Procedure

NOTE

Steps 1 through 17 constitute the Y-axis alignment.

1. Send the beam through the center of the 50% beam splitter. Align the Y-Axis laser beam parallel to the plane of the stage and measurement mirror by translating and angularly adjusting the laser head. This ensures that the interferometer turns the beam 90 degrees. Using an optical square or pentaprism is helpful. Lock down the laser head.

2. Position the HP 10706B in the beam path to turn the beam 90 degrees towards the measurement mirror. Place the alignment target (P/N 10702-60001) on the laser side of the interferometer. Place the alignment aid (P/N 10706-60001) on the output side of the interferometer in the correct orientation. Select the small aperture on the front turret of the laser head.

3. Translate the interferometer until the beam passes through the center of one hole on the alignment target and through the hole on the alignment aid and strikes the measurement mirror. Use translucent tape over the target aperture to observe when the beam is centered.

NOTE

If the distance between the laser head and the reflector is greater than 0.5 metres (20 inches), the formula given in the paragraph on Overlapping Dots determines the cosine error based on the offset of the return beam at the laser head. For example, with a distance between the laser head and reflector of 0.5 metres and an offset of the return beam at the small aperture of the laser of 500 micrometres (0.0202 inches), the cosine error is approximately 0.12 parts per million.

4. Angularly adjust the interferometer until the beam reflected from the measurement mirror returns upon itself, through the interferometer and back to the small aperture of the laser head. Once this autoreflection is achieved, lock down the interferometer making sure not to disturb the alignment.

NOTE

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

5. Remove the plane mirror interferometer alignment target and rotate the turret of the laser head to select the large aperture. Do not remove the plane mirror interferometer alignment aid on the output side of the plane mirror interferometer. Center the output beams on the receiver aperture by translating the receiver. Translucent tape over the receiver aperture will help to observe when the beams are centered.

6. Connect a fast responding voltmeter (preferably a meter type) to the Y-axis receiver test point. Fine adjust the interferometer angularly until a signal is received. This is indicated by the voltmeter suddenly jumping to a value greater than 0.25 volts. This adjustment is a critical and may require considerable care to achieve the desired result.

14. The reference and measurement beams must be centered on the receiver aperture. Use translucent tape over the receiver aperture to observe the beams. Translate the receiver to center the beams on the receiver aperture.

15. Place the alignment aid (P/N 10706-60001) back on the output side of the interferometer and switch to the large aperture on the laser head. Connect a fast responding voltmeter to the receiver test point. Monitor the voltage reading along the complete travel of the stage. The voltage should not jump up to the previously peaked voltage reading. If so, readjust the laser beam as in step 5 until the voltage reading suddenly drops back down to about 0.3 volts.

16. If readjustment of the laser head or beam steering optics is required in step 15 then return to step 9 and repeat the procedure.

17. Remove the interferometer alignment aid.

18. Rotate the turret on the laser head to the large aperture. Verify that the LED indicator on the receiver is illuminated and the voltage at the receiver test point is between 0.6 and 1.3 volts dc.

TURNED CONFIGURATION (X-Y STAGE EXAMPLE) ALIGNMENT PROCEDURE

The following procedure describes the alignment of HP 10706B interferometers used in an X-Y stage application as shown in *Figure 6-50*. Before proceeding, review the "Alignment Principles" given earlier in this Section.

Objective

This procedure minimizes cosine error and the thermal drift coefficient of the HP 10706B, and maximizes the signal strength at the receiver. Two separate autoreflection/adjustment steps are performed using the two alignment aids.

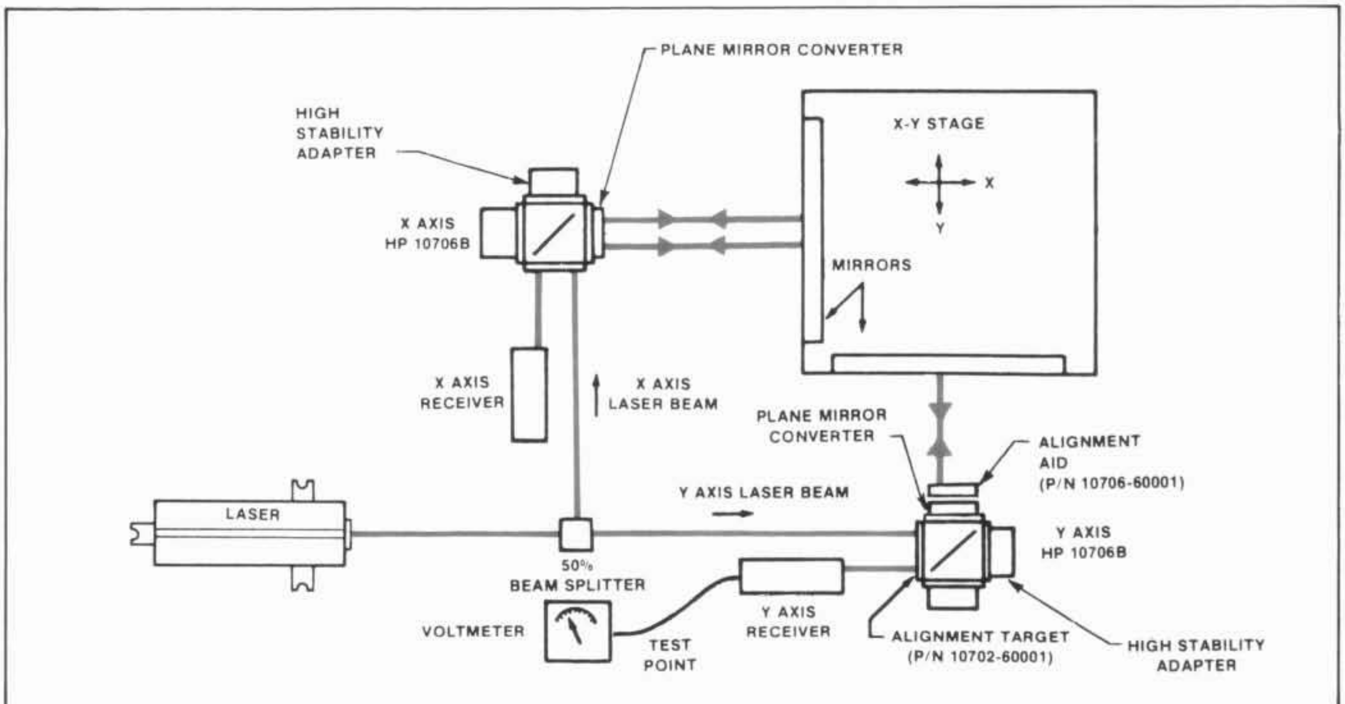


Figure 6-50. HP 10706B High Stability Plane Mirror Interferometer in an X-Y Stage Application

NOTE

Steps 18 through 34 constitute the X-axis alignment.

18. Align the X-Axis laser beam parallel to the plane of the stage and measurement mirror by adjusting the pitch and yaw of the 50% beam splitter (do not adjust the laser head). This ensures the interferometer turns the beam 90 degrees. Using an optical square or pentaprism is helpful. Lock down the 50% beam splitter.

19. Place the HP 10706B in the beam path to turn the beam 90 degrees towards the measurement mirror. Place the alignment target (P/N 10702-60001) on the laser side of the interferometer. Place the alignment aid (P/N 10706-60001) on the output side of the interferometer in the correct orientation. Select the small aperture on the front turret of the laser head.

20. Translate the interferometer until the beam passes through the center of one hole on the alignment target and through the hole on the alignment aid (P/N 10706-60001) and strikes the measurement mirror. Use translucent tape over the aperture of the alignment target to observe when the beam is centered.

NOTE

If the distance between the laser head and the reflector is greater than 0.5 metres (20 inches), the formula given in the paragraph on Overlapping Dots determines the cosine error based on the offset of the return beam at the laser head. For example, with a distance between the laser head and reflector of 0.5 metres and an offset of the return beam at the small aperture of the laser of 500 micrometres (0.0202 inches), the cosine error is approximately 0.12 parts per million.

21. Angularly adjust the interferometer until the beam reflected from the measurement mirror returns upon itself, through the interferometer and back to the small aperture of the laser head. Once autoreflection is achieved, lock down the interferometer, making sure not to disturb the alignment.

NOTE

For high accuracy alignment or for installation where there is less than 0.5 metres (20 inches) between the laser and mirror, perform steps 22 through 24.

22. Remove the alignment target (P/N 10702-60001) and rotate the turret of the laser head to select the large aperture. Do not remove the alignment aid (P/N 10706-60001) on the output side of the interferometer. Center the output beams on the receiver aperture by translating the receiver. Translucent tape over the receiver aperture will help to observe when the beam is centered.

23. Connect a fast responding voltmeter to the receiver test point. Fine adjust the plane mirror interferometer angularly until a signal is received. This is indicated by the voltmeter suddenly jumping to a value greater than 0.25 volts. This adjustment is critical and may require considerable care to achieve the desired result.

24. Peak the voltmeter reading (which will be fluctuating) by fine adjusting the interferometer in both angularaxes. Carefully readjust the interferometer until the voltage reading suddenly drops back down to about 0.3 Volts.

7. Peak the voltmeter reading (which will be fluctuating) by fine adjusting the interferometer in both angular axes. Carefully readjust the interferometer until the voltage reading suddenly drops back to about 0.3 Volts.

NOTE

Proper alignment is achieved when the voltage reading from the receiver test point is just below the sudden jump up in voltage. If the alignment is fixed to sustain the peaked voltage, the system operation will be degraded.

This aligns the laser beam to within ± 1.2 arcminutes to the direction of travel, resulting in a cosine error of approximately 0.05 parts per million (0.05 micrometre per metre of travel or 0.05 microinches per inch).

8. Lock down the interferometer (Y-axis) securely, making sure the alignment is not disturbed.

9. Remove the alignment aid (P/N 10706-60001) from the interferometer. Also, remove the plane mirror converter from the interferometer. Switch to the small aperture on the laser head. Block the measurement beam by placing something between the Y-axis interferometer and the measurement mirror.

10. Insert HP 10706B alignment aid (P/N 10706-60202) between the beam splitter and the high stability adapter as shown in *Figure 6-49*. This allows the reference beam to be autoreflected from the high stability adapter back towards the small aperture of the laser head.

11. Observe the reflection of the reference beam back at the laser head. Adjust two of the four alignment set screws until the beam autoreflects into the small aperture of the laser head. Once autoreflection is achieved, gently snug the two remaining set screws. Be careful not to disturb the autoreflected alignment.

12. Remove the HP 10706B alignment aid (P/N 10706-60202) between the beam splitter and the high stability adapter. Replace the plane mirror converter. Remove the material from between the interferometer and the measurement mirror.

13. The reference and measurement beams must be centered on the receiver aperture. Use translucent tape over the receiver aperture to observe the beams. Translate the receiver to center the beams on the receiver aperture.

14. Place the alignment aid (P/N 10706-60001) back on the output side of the interferometer and switch to the large aperture on the laser head. Connect a fast responding voltmeter to the receiver test point. Monitor the voltage reading along the complete travel of the stage. The voltage should not jump up to the previously peaked voltage reading. If so, readjust the interferometer as in step 4 until the voltage reading suddenly drops back to about 0.3 volts.

15. If readjustment of the interferometer is required in step 14 then return to step 9 and repeat the procedure.

16. Remove the alignment aid (P/N 10706-60001).

17. Rotate the turret on the laser head to the large aperture. Verify that the LED indicator on the receiver is illuminated and the voltage at the receiver test point is between 0.6 and 1.3 volts dc.

High Resolution Interferometer

The objective of these procedures is to align the HP 10716A to make measurements with a minimum of cosine error and thermal drift and for maximum signal strength at the HP 10780B Receiver.

The following procedure assumes that the plane mirror reflector is the movable optic and has been installed perpendicular to the axis of travel (see below for the HP 10724A installation procedure).

Before proceeding with the alignment procedures, details on interferometer configurations, plane mirror reflector mounting, and alignment aids are covered.

CONFIGURATIONS

There are two configurations available for the High Resolution Interferometer allowing flexibility in optical layout of a measurement system. They are:

- Standard
- Turned (Option 001)

Figure 6-51 illustrates the location of the measurement beams for each configuration.

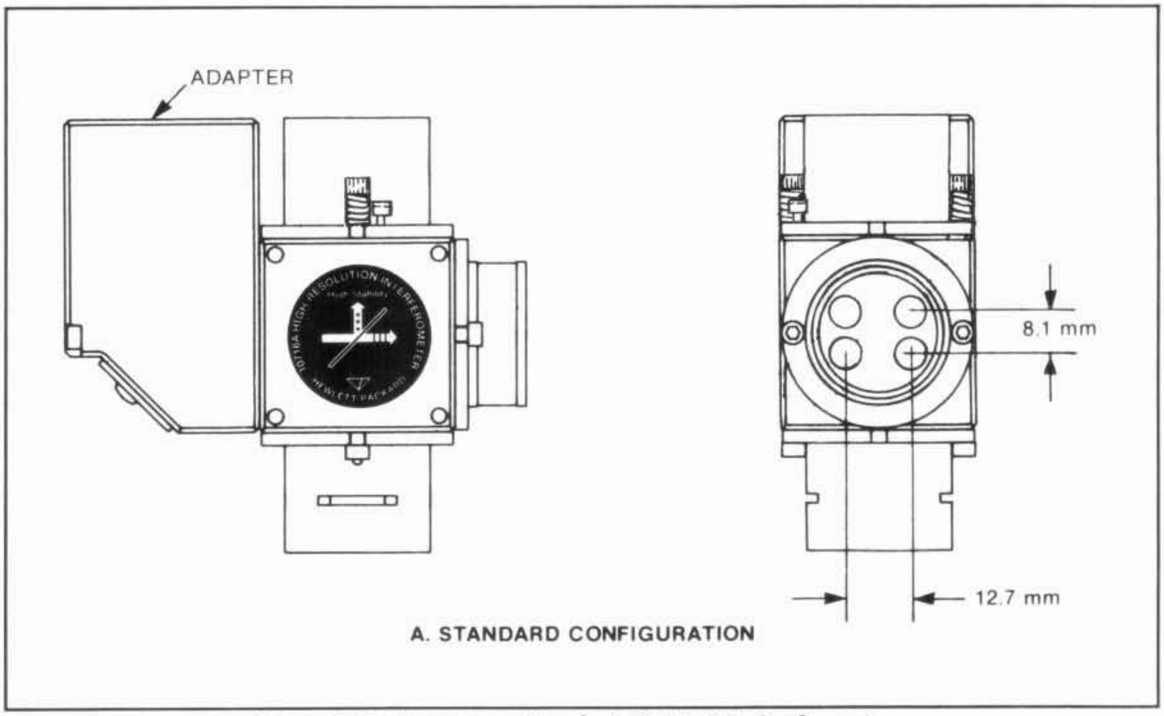


Figure 6-51. Beam Locations for HP 10716A Configurations

NOTE

Proper alignment is achieved when the voltage reading from the receiver test point is just below the sudden jump up in voltage. If the alignment is fixed to sustain the peaked voltage, the system operation will be degraded.

This aligns the laser beam to within ± 1.2 arcminutes to the direction of travel, resulting in a cosine error of approximately 0.05 parts per million (0.05 micrometre per metre of travel or 0.05 microinches per inch).

25. Lock down the interferometer (X-axis) securely. Make sure the alignment is not disturbed.

26. Remove the alignment aid (P/N 10706-60001) from the interferometer. Also, remove the plane mirror converter from the interferometer. Switch to the small aperture on the laser head. Block the measurement beam by placing something between the interferometer and the measurement mirror.

27. Insert HP 10706B alignment aid (P/N 10706-60202) between the beam splitter and the high stability adapter as shown in *Figure 6-49*. This allows the reference beam to be autoreflected from the high stability adapter back towards the small aperture of the laser head.

28. Observe the reflection of the reference beam back at the laser head. Adjust two of the four adjustment screws until the beam autoreflects into the small aperture of the laser head. Once autoreflection is achieved, gently snug the two remaining set screws. Be careful not to disturb the autoreflected alignment.

29. Remove the HP 10706B alignment aid (P/N 10706-60202) from between the beam splitter and the high stability adapter. Replace the plane mirror converter. Remove the material from between the interferometer and the measurement mirror.

30. The reference and measurement beams must be centered on the receiver aperture. Using translucent tape over the receiver aperture to observe the beams, translate the receiver to center the beams.

31. Place the interferometer alignment aid (P/N 10706-60001) back on the output side of the interferometer and switch to the large aperture on the laser head. Connect a fast responding voltmeter to the receiver test point. Monitor the voltage reading along the complete travel of the stage. The voltage should not jump up to the previously peaked voltage reading. If so, readjust the interferometer as in step 21 until the voltage reading suddenly drops back to about 0.3 volts.

32. If readjustment of the interferometer is required in step 31, return to step 26 and repeat the procedure.

33. Remove the interferometer alignment aid.

34. Rotate the turret on the laser head to the large aperture. Verify that the LED indicator on the receiver is illuminated and the voltage at the receiver test point is between 0.6 and 1.3 volts dc.

ALIGNMENT AIDS

The HP 10716A High Resolution Interferometer is supplied with two of the alignment aids shown in *Figure 6-48*.

- Alignment Aid, P/N 10706-60001
- Alignment Aid, P/N 10706-60202

Alignment Aid P/N 10706-60202 facilitates autoreflection alignment for the high stability adapter to achieve minimum thermal drift and maximum signal strength. It contains a quarter wave plate to reflect the reference beam back on itself and return it to the laser head without offset. *Figure 6-49* illustrates how the aid is positioned between the beam splitter and the high stability adapter during alignment.

ALIGNMENT OVERVIEW

The alignment procedure consists of a five part process.

- Alignment of the laser beam perpendicular to the plane mirror reflector using autoreflection.

NOTE

For a review of autoreflection techniques, see page 6-37.

- Alignment of the HP 10716A Interferometer to the beam using a reflective gage block and autoreflection.
- Realignment of the laser beam to correct for slight angular beam deviation caused by the interferometer.
- Alignment of the reference reflector in the interferometer for minimum thermal drift and maximum signal strength.
- Installation of the HP 10780B/C/F Receiver to properly receive the reference and measurement beams.

ALIGNMENT PROCEDURE

The following alignment procedure is for the "Standard Configuration" with the laser beam entering the interferometer in aperture B. The alignment procedure for the "Turned Configuration" is similar except it is more sensitive to angular alignment of the interferometer.

NOTE

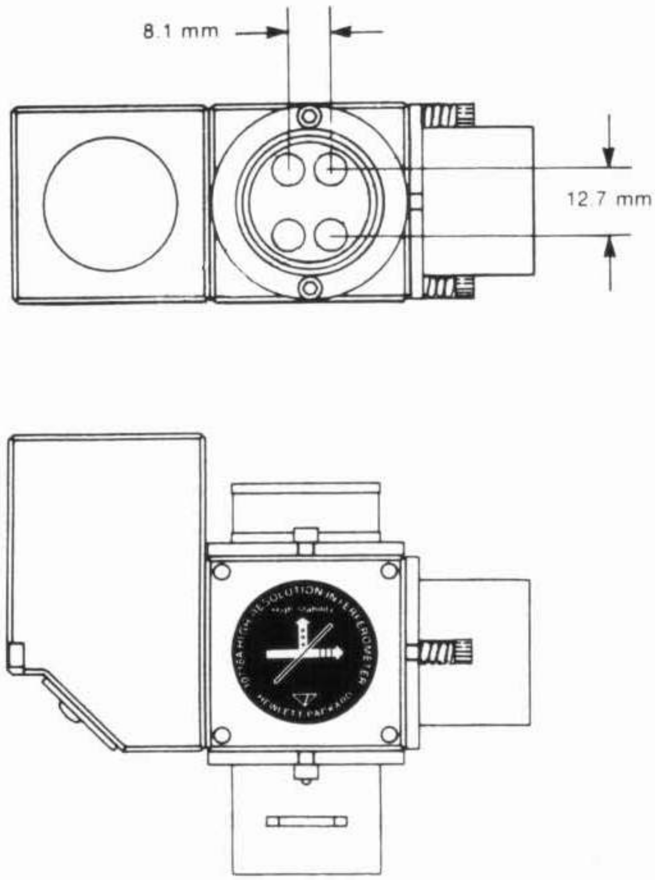
Either port A or B of the interferometer may be used for the input port, the remaining port is the output.

a. Select the small aperture on the laser head.

b. The laser beam for each axis should be aligned perpendicular to the measurement mirror. This is done by autoreflecting off this mirror and adjusting the laser head or beam bender until the reflected beam is centered in the small aperture on the laser head.

c. Translate the interferometer so that the laser beam enters the input aperture (aperture B, this example).

d. Place a rectangular gage block over the input aperture so that it reflects the laser beam back toward the laser. (See *Figure 6-52*.)



B. TURNED CONFIGURATION (OPTION 001)

Figure 6-51. Beam Locations for HP 10716A Configurations (Continued)

h. Select the small aperture on the front turret of the laser head. The return beam from the moving plane mirror will no longer precisely autoreflect back to the small aperture of the laser head as it did in step e. This must be corrected. Adjust the laser beam until the laser beam is autoreflected back through the small aperture of the laser head. This ensures that the beam is perpendicular to the measurement mirror. This step requires pitching and yawing the laser head, beam benders, or beam splitters depending on optical layout.

i. If substantial adjustment of the laser beam was required in step h, the interferometer will have to be repositioned so that the beam goes through the center of the input port. Repeat steps a through e and secure the interferometer to the machine bed.

NOTE

The High Resolution Interferometer is now aligned for minimum cosine error. The final steps (j through w) will align the reference reflector for minimum thermal drift coefficient and maximum signal strength.

j. Remove the Plane Mirror Converter assembly (i.e., the quarter waveplate) from the measurement side of the interferometer by loosening one cap screw and removing the other.

k. Block the measurement beam and switch to the small aperture on the laser head.

l. Insert alignment aid (P/N 10706-60202) between the now exposed glass beam splitter and the reference reflector (the one with the four adjustment cap screws and two springs). See Figure 6-49. This will allow the reference beam to autoreflect back towards the small aperture on the laser head.

m. Return light will not be visible from this reflector near the laser output aperture.

n. Now adjust TWO of the small cap screws on the housing so that this return beam autoreflects back into the small output aperture of the laser.

o. GENTLY snug the other two cap screws while observing the return beam on the output aperture. Make certain not to disturb the beam alignment.

p. Remove the mica alignment aid (P/N 10706-20202) and replace the Plane Mirror Converter.

q. Unblock the measurement beam.

r. Verify autoreflection of the measurement beam by attaching the magnetic alignment aid to the output (measurement) side of the interferometer and observing the autoreflected beam on the laser aperture. Remove the magnetic alignment aid.

s. Verify that you now see four unclipped spots in a rectangular pattern on the face of the measurement plane mirror. (The room lights may have to be dimmed to see these spots of weakly scattered light.)

t. Install the HP 10780B/C/F Receiver so that light from the top port ("A" port) of the interferometer enters the center of the lens, parallel to the optic axis of the lens.

u. Verify with a piece of translucent tape over the lens that the spots from Reference and Measurement beams overlap adequately.

v. If these spots do not overlap at the receiver, the alignment should be rechecked. It may be necessary to slightly tweak the Reference Reflector adjustment screws to improve overlap.

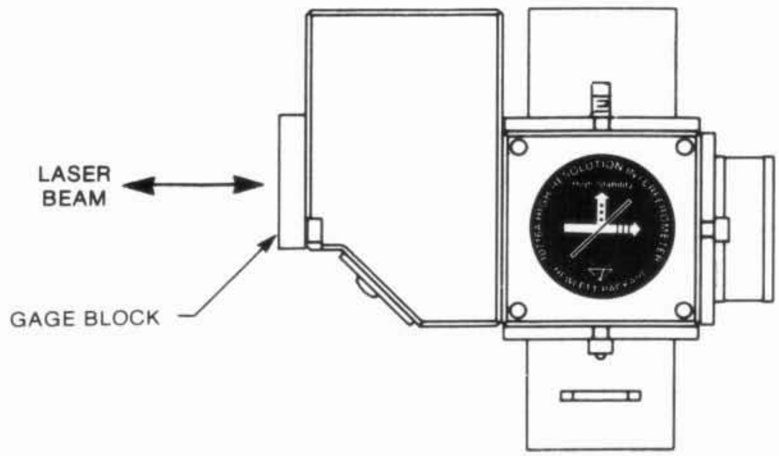


Figure 6-52. HP 10716A with Gage Block Attached

e. Adjust the interferometer in pitch and yaw until the laser beam is auto-reflected back into the laser head. This ensures proper angular alignment. It may be necessary to translate the interferometer again to center the laser beam on the input aperture. Use a piece of translucent tape to help observe the beam.

f. Remove the gage block.

It should be noted that the previous autoreflection procedure is used only to reduce clipping and is not as critical as the autoreflection procedure used to reduce cosine error. As long as the four beams are not clipped, the alignment of the interferometer is adequate.

The next steps refine the alignment to reduce cosine error.

g. Place the alignment aid (P/N 10706-60001) over the output aperture (plane mirror converter) on the interferometer such that the measurement beam passes through the aperture on the alignment aid. (See *Figure 6-53*.)

Figure 6-53. HP 10716A with Alignment Aid Attached over Measurement Beam

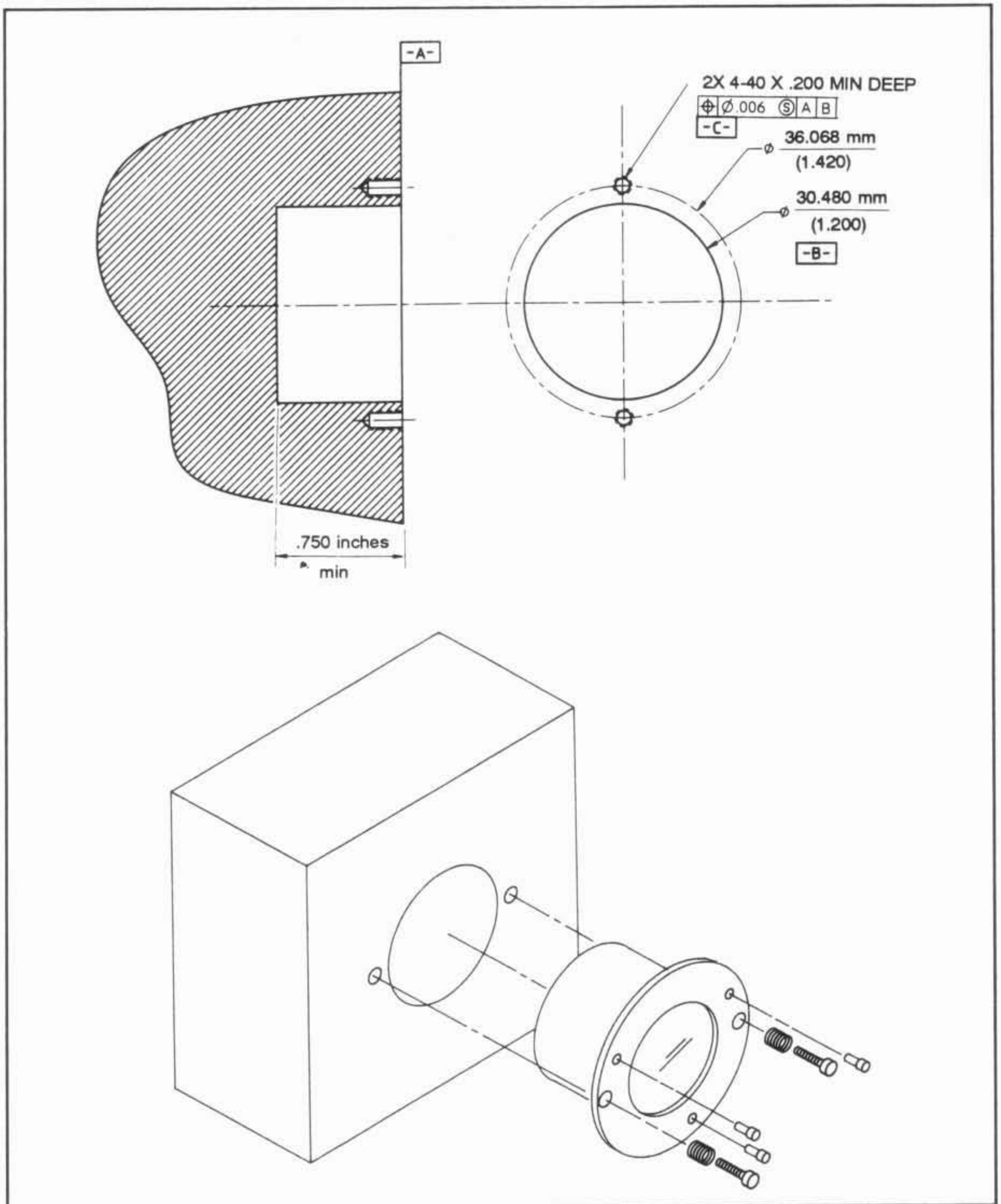


Figure 6-54. HP 10724A Mounting Requirements and Installation Drawing

w. Select the large aperture at the output of the laser head and traverse the full travel at the machine. Verify that the LED indicator on the receiver is illuminated through the full travel and the voltage measured at the receiver test point is between 0.6 and 1.3 volts dc.

Plane Mirror Reflector Mounting (HP 10724A)

If you use the HP 10724A Plane Mirror Reflector with the HP 10716A, the following instructions give the details for mounting and installation.

The HP 10724A is designed to be mounted into a hole or pocket on the stage (moving object). The mounting surface which is machined to accept the HP 10724A should be closely perpendicular to the axis of machine travel. Figure 6-54 shows the mounting hole details. Provision is made to lift the flange slightly off of the mounting surface thereby allowing pitch and yaw corrections to be made to align the HP 10724A exactly perpendicular to the axis of machine travel.

To install the HP 10724A, proceed as follows:

a. Install three #2-56 cap screws into the flange form the mirror side, but do not let the screws protrude through the flange.

b. Insert the labeled end (non-flange end) of the HP 10724A into the mounting hole or pocket. Start the two #4-40 cap screws through the compression springs and the clearance holes in the flange and then into the mounting surface. (See *Figure 6-54*.)

c. Tighten the #4-40 screws so that they contact but do not compress the springs.

CAUTION

In the following steps (d through g), take care not to distort the mirror by overcompressing the springs.The springs should never be tightened down solid; leave at least 0.001 clearance between the coils at all times. This may be checked by passing a piece of paper (about 0.001 inch thickness) through the coils.

d. Tighten each of the #4-40 screws one and a half turns. The springs are now initially compressed.

e. Advance the three #2-56 screws until they just contact the mounting surface. Then tighten each by one and a half turns to lift the housing off the mounting surface and further compress the springs.

f. Adjust the mirror in the pitch and yaw plane until it is perpendicular to the machine axis of travel by unscrewing the #2-56 cap screws. An auto collimator or prealigned laser beam may be used for this purpose.

g. Again confirm that the springs have not been compressed solid by passing a piece of paper (about 0.001 inch thickness) through the coils.

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SECTION VII
SYSTEM THEORY AND TROUBLESHOOTING

SECTION VII CONTENTS

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SECTION VII
SYSTEM THEORY AND TROUBLESHOOTING

SYSTEM THEORY

The basic HP 5527A Laser Position Transducer system consists of laser, optics, measurement receiver(s), air and material temperature sensor(s), the HP 5507A electronics, and a system controller. The laser serves as the light beam and reference frequency source. The optics and the measurement receiver use the laser beam to generate the measurement signal. The reference and measurement signals, along with the environmental sensor signals, are used by the electronics to generate linear displacement information. The system controller can read and display this displacement information. In addition, the controller can send destination input data to the HP 5507A electronics which outputs a real time error signal representing the difference between the destination and the actual position. This error signal can be used in the customer's servo electronics to drive a stage's positioning motors. Refer to *Figure 7-30* ("HP 5527A Laser Position Transducer System Block Diagram") while reading the theory of operation.

A low-power helium-neon laser emits a coherent light beam composed of two slightly different optical frequencies, f_1 and f_2, of orthogonal linear polarizations. (Refer to *Figure 7-1* "Typical HP Laser Position Transducer Block Diagram".) Before exiting the laser assembly, the beam passes through a beam splitter where a small fraction of the beam is sampled. This portion of the beam is used both to generate a reference frequency and to provide an error signal to the laser cavity tuning system. The difference in the amplitudes of f_1 and f_2 is used for tuning while the difference in frequency between f_1 and f_2 (about 1.8 MHz for the HP 5517A and 2.1 MHz for the HP 5517B) is used for the reference signal.

The major portion of the beam passes out of the laser head (HP 5517A, 5517B, or 5518A) to an interferometer. The interferometer is a polarizing beam splitter that reflects one polarization (frequency) and transmits the other. The beam splitter is oriented such that the reflected and transmitted beams are at right angles to each other. The reflected beam (f_2) is reflected off a fixed retroreflector, usually mounted directly on the interferometer. The transmitted frequency (f_1) passes through the interferometer and is reflected back to the interferometer by a movable retroreflector. (See Section II, "Fundamental Measurement Concepts" for a more detailed description.) If the distance between the interferometer and the movable retroreflector remains fixed, the difference frequency (f_2-f_1) equals the reference signal. Under these conditions the HP 5507A Laser Position Transducer Electronics detects no change in relative position of the interferometer and the movable retroreflector. When the movable retroreflector changes position relative to the fixed interferometer, a doppler frequency shift occurs. This Doppler-shifted frequency becomes $f_1 \pm \Delta f_1$ depending on the direction of reflector movement. The two frequency components, f_1 and f_2, exit the interferometer as a coincident beam.

The coincident beam is directed to a receiver (e.g., HP 10780B) where the two frequency components interfere (mix) at the receiver's polarizing plate. This produces a difference frequency which is detected by the receiver's photodetector and converted to an electrical signal. The receiver circuitry then amplifies the signal which becomes the measurement frequency. Displacement information is obtained in the HP 5507A electronics by a comparison of both the measurement and reference signals.

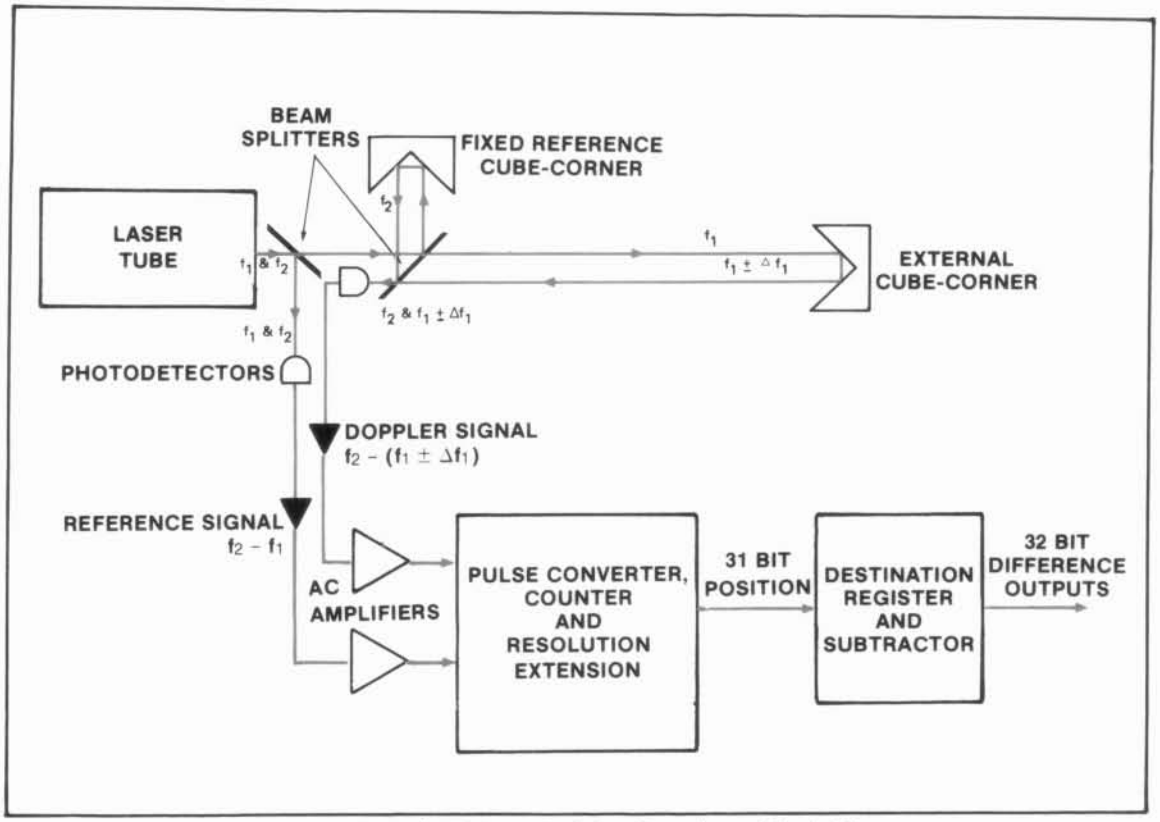


Figure 7-1. Typical HP Laser Position Transducer Block Diagram

SYSTEM CONTROLLER

The HP 5507A Laser Position Transducer Electronics require a digital computer to act as the system controller. The system controller sends commands via HP-IB to the HP 5507A to allow the computer to read position information, send destination data, and use the extensive built-in diagnostics. The HP 5507A is designed to meet IEEE-488, IEEE-728, and IEEE-P754 standards for general purpose instrument programming.

HP 5507A LASER POSITION TRANSDUCER ELECTRONICS

The HP 5507A Laser Position Transducer Electronics is used with an HP laser head (HP 5517A, 5517B, or 5518A) and HP Optics. The system serves as the position feedback element in both closed-loop servo control systems and open-loop precision measuring systems. It consists of a main chassis, a power supply, an HP-IB Interface board, and a ventilating fan. The main chassis serves as a backplane for interconnecting up to six function boards and the HP 10946B Automatic Compensation board, with the HP-IB board and power supply.

Transducer Backplane

The transducer backplane provides power and signal flow paths (busses) for the boards installed in the system frame. It consists of 8 data lines, 14 address lines, and several bus control lines. There are additional lines that supply the reference frequency and the buffered X32 REF signal, the latter of which is used for resolution extension in the Axis board electronics. The bus is bidirectional and is similar in detail to commonly used microprocessor busses. The backplane facilitates communication between boards by effectively becoming an extension of the controller board's memory space. For a more detailed description of the backplane and its associated signals, see Section III of this manual.

HP-IB Interface Board

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

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

HP-IB CIRCUITRY

The HP-IB board accepts command and data mnemonics accompanied by numeric data from the HP-IB Bus, and channels the data or commands to the appropriate HP 5507A boards. The board's microprocessor is responsible for translating incoming HP-IB messages into addresses and data compatible with the internal backplane. It also generates system status information and performs error reporting functions. Internal software closely monitors the servo loop, checking for errors, sampling strobes, and position null indications reported by other boards.

REFERENCE PHASE-LOCKED LOOP MULTIPLIER

The Reference Phase-Locked Loop multiplies the reference frequency signal from the HP 5517A/5517B/5518A Laser Head by a factor of 32. The multiplied reference signal is buffered onto the backplane and used by the resolution extension circuitry on the axis function boards. Noise errors in the laser reference signal are detected in the multiplier circuit which then notifies the on-board microprocessor.

HP 10932A Axis Board

The Axis board receives the measurement signal from a receiver and the reference signal from a laser head and translates the fringe counts into velocity, position and position error signals. The measurement signal is produced by either the HP 10780B Receiver or the measurement channel of an HP 5518A Laser Head. The reference signal is generated by the laser head (HP 5517A, HP 5517B, or HP 5518A), frequency multiplied by 32 on the HP-IB board, and routed to all function boards via the HP 5507A backplane. Every Axis board connected to the HP 5507A backplane is individually programmed and operates independently.

Most of the actual position measurement is accomplished on two custom VLSI integrated circuits (ICs). A housekeeping microprocessor performs data conversions for Input/Output over the backplane, controls the measurement ICs, performs power-up self tests, and handles error reporting.

INPUT SOURCE-SELECTION LOGIC

This circuitry selects a measurement input from five signal sources: the rear-panel receiver input jack, the HP 5518A Laser Head's internal measurement receiver (if the 5518A is used), or test frequencies of 1.0, 1.5, or 2.0 MHz.

RESOLUTION EXTENSION

Resolution extension is fixed at times 32, giving resolutions of $\lambda/64$ or $\lambda/128$, depending on the optics used. The resolution extension IC creates the five lowest bits of (extended) positional data. It uses the multiplied reference frequency signal (X32 Ref) provided by the HP-IB board to digitally extract phase information from measurement transitions.

COUNTER-SUBTRACTOR

Basically, the counter-subtractor IC is a 26-bit synchronous up/down counter and 32-bit subtractor. The 26-bit output of the counter along with the five resolution extended position bits from the resolution extension IC are used to generate a 31-bit current position input to the subtractor. The subtractor's other input is the on-chip 31-bit destination register, which may be loaded by the housekeeping microprocessor.

The results of the position minus destination subtraction appear in parallel on 32 Position Error output lines (Sign, BO-B30). These lines change synchronously with the Error Clock (1.5 to 3.0 MHz depending on laser head) generated by the resolution extension IC and can be in signed-magnitude or two's-complement format. The least-significant Position Error bit represents a displacement of $\lambda/256$ when using high resolution optics, $\lambda/128$ when using plane mirror optics, and $\lambda/64$ with cube-corner optics.

ANALOG VELOCITY GENERATOR

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

Output scaling is 0.394 V/cm/s when using $\lambda/256$ optics, 0.197 V/cm/s when using $\lambda/128$ optics and 0.098 V/cm/s with $\lambda/64$ optics. Residual offset at zero velocity is less than 10 mV, and in-band noise for lambda 64 resolution is less than 40 mV for slew rates below 0.05 cm/second. The output is filtered with two poles at 10 kHz, and has a 464 Ohm series resistance for short circuit protection. See Section VIII ("Specifications") for more details.

HOUSEKEEPING MICROPROCESSOR

The onboard microprocessor circuitry is responsible for transferring data to and from the counter-subtractor IC and formatting the information so that it may be used by the HP-IB board. All of the HP-IB axis programming functions pass through the mailbox and into the microprocessor.

At least 500 times a second, the microprocessor executes its main program loop: positional information is read out from the counter-subtractor IC, converted to floating point form, multiplied by conversion and compensation numbers, and then stored in the mailbox. Next, the status flag bits present on the input port are read to see if any error conditions have occurred since last checked, or if the mailbox has been written to by a backplane controller board. If any of these conditions are true, the microprocessor services them. The microprocessor is then free to repeat the loop.

BACKPLANE INTERFACE (Mailbox)

The Axis board shares 512 bytes of RAM with the backplane. This RAM is referred to as the mailbox, and is used for passing data and messages between a backplane controller and the Axis board microprocessor.

HP 10934A A-Quad-B Axis Board

The A-Quad-B Axis Board receives the measurement signal from a receiver and the reference signal from a laser head. It translates the fringe-count information into A-Quad-B or Up/Down pulse output signals. The measurement signal is produced by either the HP 10780C/F Receiver or the measurement channel of an HP 5518A Laser Head. The reference signal is generated by the laser head (HP 5517A/B/C or HP 5518A). This signal is multiplied by 32 on the HP-IB board, and routed to all function boards via the 5507A/B backplane. The position measurement calculations are performed by two custom VLSI integrated circuits (ICs).

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

- Axis Circuits
- Data Conversion
- Pulse Generation
- Backplane Interface
- Processor Core
- I/O Circuits

AXIS CIRCUITS/DATA CONVERSION BLOCKS

Reference (from a laser head) and measurement (from a laser receiver) signals enter the Axis Circuits block where they are used to derive a raw laser-position signal. Generation of this signal is identical to the generation of the position error signal on the HP 10932A/B Axis Board. This signal is routed to the Data Conversion block, conditioned with units conversion and compensation, and sent to the Pulse Generation block.

PULSE GENERATION BLOCK

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

BACKPLANE INTERFACE BLOCK (Mailbox)

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

PROCESSOR CORE BLOCK

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

I/O CIRCUITS BLOCK

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

HP 10936A/B Servo-Axis Board

The Servo-Axis board receives the measurement signal from a receiver and the reference signal from a laser head and translates the fringe counts into position information and motor drive signals. The measurement signal is produced by either the HP 10780C/F Receiver or the measurement channel of an HP 5518A Laser Head. The reference signal is generated by the laser head (HP 5517A/B/C or HP 5518A), frequency multiplied by 32 on the HP-IB board, and routed to all function boards via the HP 5507A/B backplane. The position measurement is accomplished on two custom VLSI integrated circuits (ICs).

An onboard microprocessor does power-up self tests and then is ready to:

- execute commands received through the backplane mailbox,
- execute commands received over the binary interface,
- execute a servo control algorithm that generates a motor drive signal.

While waiting for any of the above, the microprocessor checks for errors, controlling the measurement ICs, and converting raw data into compensated units.

INPUT SOURCE-SELECTION LOGIC

This circuitry selects a measurement input from nine signal sources: the rear-panel receiver input jack, the HP 5518A Laser Head's internal measurement receiver (if the 5518A is used), or test frequencies of 0.75, 0.86, 1.0, 1.2, 1.5, 2.0 or 3.0 MHz.

RESOLUTION EXTENSION

Resolution extension is fixed at times 32, giving resolutions of $\lambda/64$ or $\lambda/128$, depending on the optics used. The resolution extension IC creates the five lowest bits of (extended) positional data. It uses the multiplied reference frequency signal (X32 Ref) provided by the HP-IB board to digitally extract phase information from measurement transitions.

COUNTER-SUBTRACTOR

Basically, the counter-subtractor IC is a 26-bit synchronous up/down counter and 32-bit subtractor. The 26-bit output of the counter along with the five resolution extended position bits from the resolution extension IC are used to generate a 31-bit current position input to the subtractor. The subtractor's other input is the on-chip 31-bit marker register, which may be loaded by the microprocessor. The results of the position minus marker subtraction generate the Threshold and Window Outputs.

MICROPROCESSOR

The microprocessor controls everything on the Servo-Axis board. Its main loop reads the position from the custom ICs, converts it to compensated units, puts the result in the mailbox, reads status information and reports any errors, tests for and services any input through the mailbox, and tests for and services any I/O over the binary interface.

Simultaneously, a timer is running that will interrupt the microprocessor at programmed intervals, causing it to execute the selected servo control algorithm. This algorithm calculates the motor drive value based on current position, desired position, and specified velocity, acceleration, and delta acceleration terms. The motor drive value is written to the appropriate output and then control returns to the main loop program.

BACKPLANE INTERFACE (Mailbox)

The Servo-Axis board shares 512 bytes of RAM with the backplane. This RAM is referred to as the mailbox, and is used for passing data and messages between a backplane controller and the Servo-Axis board microprocessor.

BACKPLANE CONTROLLER

The Servo-Axis board can take control of the Backplane, and read and write data to another function board's mailbox. This capability allows the Servo- Axis board to direct commands received over the binary interface to other function boards in the HP 5507A/B.

MASTER/SLAVE LOGIC

The master/slave logic either generates (when set up as master) or receives (when set up as slave) the servo-sample clock and sync pulses. These signals are used to coordinate multiaxis moves. Two mnemonics (*SVC and *CLK) control a board's Master/Slave status.

BINARY INTERFACE

The 16-bit binary interface is controlled entirely by the onboard microprocessor. There are 16 input lines, 16 output lines, and 3 handshake lines. The falling edge of the HS. IN- line indicates that the system control computer wants to send or receive some data as indicated by the DIRECTION line.

When the Servo-Axis board is ready to respond, it will lower the HS. OUT- line and the transfer will be completed by the computer raising the HS. *IN- line. If the board is expecting a command, then the data item is executed as a command. Otherwise the board stores/sends data associated with a previous command. The timing diagrams in Section III illustrate the handshake signals in detail.

The output lines are dual purpose. Besides being the binary interfaces' output, they are also the 16-bit Motor Drive output lines. If the latter operation is selected with a *OUT4, *OUT5, *OUT6, or *OUT7 mnemonic, then no output can be done through the binary interface.

MOTOR DRIVE OUTPUTS

These outputs go directly to the power amplifier that drives an axis motor. The motor drive value calculated by the microprocessor is sent to one or more of the three available outputs. The analog output uses a 16-bit digital-to- analog converter to generate its signal. The pulse-width modulated output generates either an up or down pulse with the motor drive value specifying the pulse width. The 16-bit two's-complement output uses the binary interface's output lines and just outputs the motor drive value (no handshaking used).

HP 10946B/C Automatic Compensation Board

Accurate measurements with the Laser Position Transducer system require compensation for the following:

Material expansion and contraction due to temperature changes, and

Wavelength change due to differing mediums through which the laser beam must travel.

An on board microprocessor does power-up self tests and then is ready to

- execute commands received through the backplane mailbox,
- execute commands received over the binary interface,
- execute a servo control algorithm that generates a motor drive signal.

While it is waiting for any of the above, it is checking for errors, controlling the measurement ICs, and converting raw data into compensated units.

INPUT SOURCE-SELECTION LOGIC

This circuitry selects a measurement input from nine signal sources: the rear-panel receiver input jack, the HP 5518A Laser Head's internal measurement receiver (if the 5518A is used), or test frequencies of 0.75, 0.86, 1.0, 1.2, 1.5, 2.0 or 3.0 MHz.

RESOLUTION EXTENSION

Resolution extension is fixed at times 32, giving resolutions of $\lambda/64$ or $\lambda/128$, depending on the optics used. The resolution extension IC creates the five lowest bits of (extended) positional data. It uses the multiplied reference frequency signal (X32 Ref) provided by the HP-IB board to digitally extract phase information from measurement transitions.

COUNTER-SUBTRACTOR

Basically, the counter-subtractor IC is a 26-bit synchronous up/down counter and 32-bit subtractor. The 26-bit output of the counter along with the five resolution extended position bits from the resolution extension IC are used to generate a 31-bit current position input to the subtractor. The subtractor's other input is the on-chip 31-bit marker register, which may be loaded by the microprocessor. The results of the position minus marker subtraction generate the Threshold and Window Outputs.

MICROPROCESSOR

The microprocessor controls everything on the Servo-Axis board. Its main loop reads the position from the custom ICs, converts it to compensated units, puts the result in the mailbox, reads status information and reports any errors, tests for and services any input through the mailbox, and tests for and services any I/O over the binary interface.

Simultaneously, a timer is running that will interrupt the microprocessor at programmed intervals, causing it to execute the selected servo control algorithm. This algorithm calculates the motor drive value based on current position, desired position, and specified velocity, acceleration, and delta acceleration terms. The motor drive value is written to the appropriate output and then control returns to the main loop program.

BACKPLANE INTERFACE (Mailbox)

The Servo-Axis board shares 512 bytes of RAM with the backplane. This RAM is referred to as the mailbox, and is used for passing data and messages between a backplane controller and the Servo-Axis board microprocessor.

BACKPLANE CONTROLLER

The Servo-Axis board can take control of the Backplane, and read and write data in another function board's mailbox. This capability allows the Servo-Axis board to direct commands received over the binary interface to other function boards in the HP 5507A.

MASTER/SLAVE LOGIC

The master/slave logic either generates (boards set up as masters) or receives (boards set up as slaves) the servo sample clock and the sync pulses. These signals are used to coordinate multiaxis moves. Two mnemonics (*SVC and *CLK) control a board's Master/Slave status.

BINARY INTERFACE

The 16-bit binary interface is controlled entirely by the onboard microprocessor. There are 16 input lines, 16 output lines, and 3 handshake lines. The falling edge of the HS. IN- line indicates that the system control computer wants to send or receive some data as indicated by the DIRECTION line. When the Servo-Axis board is ready to respond, it will lower the HS. OUT- line and the transfer will be completed by the computer raising the HS. IN- line. If the board is expecting a command, then the data item is executed as a command. Otherwise the board stores/sends data associated with a previous command. The timing diagrams in Section III illustrate the handshake signals in detail.

Note that the output lines have a dual purpose. Besides being the binary interfaces' output, they are also the 16-bit Motor Drive output lines. If the latter operation is selected with a *OUT4, *OUT5, *OUT6, or *OUT7 mnemonic, then no output can be done through the binary interface.

MOTOR DRIVE OUTPUTS

These outputs go directly to the power amplifier that drives the stage's motor. The motor drive value calculated by the microprocessor is sent to one or more of the three available outputs. The analog output uses a 16-bit digital-to-analog converter to generate its signal. The pulse-width modulated output generates either an up or down pulse with the motor drive value specifying the pulse width. The 16-bit two's-complement output uses the binary interface's output lines and just outputs the motor drive value (no handshaking used).

HP 10946B Automatic Compensation Board

Accurate measurements with the Laser Position Transducer system require compensation for the following:

Material expansion and contraction due to temperature changes, and

Wavelength change due to differing mediums through which the laser beam must travel.

All materials expand and contract with changes in temperature. If a "workpiece" is measured at two different temperatures, two different measurements will result. Material expansion of the "workpiece" depends on its temperature and Thermal Expansion Coefficient.

The speed of light changes as light travels through mediums of differing densities. The laser beam travels through air which has a density that varies with changes in temperature, pressure, and humidity. This change in the speed of light changes the wavelength of the laser light which correspondingly changes the number of wavelength fringes counted along a given distance.

The HP 10946B Automatic Compensation Board, in conjunction with off-board sensors (that supply analog temperature, pressure, and humidity information) or the Wavelength Tracker (that supplies wavelength change information), allows the user to continuously compensate for wavelength and material temperature.

BASIC OPERATION

After completing power-up self tests, the compensator configures itself to provide a wavelength-of-light (WOL) compensation number. All sensor channels with a signal voltage within the range of the A/D converter (± 1 Volt) are automatically enabled.

The compensator's A/D converter converts all enabled input channels and then calculates a WOL compensation number (*CNV) using the values obtained and/or the following default values for any disabled channel:

Air Humidity	50%
Air Temperature:	20°C
Air Pressure:	760 mm Hg
Material Temperature Average:	20°C
Thermal Expansion Coefficient:	0 ppm/°C

NOTE

There is a small warm up time required for the HP 10751A/B Air Sensor. Thus, the compensation number *CNV should not be used for about 5 minutes after power-up.

With the Wavelength Tracking function disabled (factory setting), the compensator repeatedly calculates *CNV. However, if Wavelength Tracking is enabled (*WTE = 1), then, in addition to the above calculations, it also accumulates phase changes between an HP 10780B measurement signal and the laser head's reference signal. These phase changes correspond to changes in the wavelength of light (see paragraphs on HP 10717A in Section II). The accumulated phase is used to update the Wavelength Tracker Compensation number (*WTC). The *WTC value includes material temperature compensation if the expansion coefficient has been set.

The compensator can be programmed by the operator when more than simple compensation is required. The operator can read/overwrite sensor data, directly enable/disable sensors, enable/disable material temperature compensation, enable/disable the compensation number change alert feature, or enable/disable the Wavelength Tracking function. Refer to Section IV (Subsection K) for more Automatic Compensation board programming details.

SENSOR RANGES

There are three ranges for the sensor channels. The A/D hardware range, approximately ±1 Volt, is used to determine if a sensor is connected to the HP 5507A rear panel. The conversion range, listed with each mnemonic, generates an error if exceeded. Finally, the sensors have a calibrated measurement range. For example, the calibrated range of the HP 10751A/B air pressure measurement is 517.2 to 775.7 mm Hg.

The compensator checks each sensor reading to make sure that the sensor is operating within the conversion range. When a reading exceeds the range, the error is reported and the sensor variable is not updated. The last valid reading is retained. The compensator will continue to read the sensor in the normal sequence; that is, it will not automatically disable the sensor. See Section IV, Subsection K, for HP 10946B Automatic Compensation Board programming information.

WAVELENGTH TRACKER

The Wavelength Tracking function operates by digitally measuring the phase angle between the reference and measurement signals once per millisecond. Each measurement is compared with the one before and the difference (assumed to be less than 180°) used to update a software counter. This counter is combined with the etalon length, the vacuum wavelength, the initial *WTC value and the material temperature and expansion coefficient value, to calculate the Wavelength Tracking Compensation number. See Section II for more detailed theory.

BACKPLANE INTERFACE (Mailbox)

A dual-port RAM, also referred to as the mailbox, interfaces the HP 10946B Automatic Compensation Board with the HP 5507A backplane. The Mailbox RAM contains a table of mnemonics for the compensator and memory locations for data associated with the mnemonics. The mnemonic table tells the HP 5507A HP-IB board what type of data is associated with each mnemonic and where in Mailbox RAM the data is located. The HP-IB board makes the mnemonics available to the HP-IB controller.

HP 10941A Prototyping Kit

The HP 10941A Prototyping Kit (*Figure 1-7*) consists of a Prototyping board, an extender board, and two interconnect cables. Approximately 219 square centimetres (34 square inches) of usable "breadboard" area is available for adding custom circuitry to the HP 5507A Laser Position Transducer Electronics. Additionally, up to 64 input and 64 output lines are supported by HP-IB via a factory loaded backplane interface circuit. (Customer must supply appropriate latches/buffers for all I/O lines used.)

BACKPLANE INTERFACE

This circuitry connects user-added circuits to the HP-IB interface. It performs all of the handshaking, instruction and address decoding, and buffering required by the HP 5507A backplane.

INPUT/OUTPUT LINES

The backplane interface on the Prototyping board supplies eight negative-true TTL compatible input strobes and eight similar output strobes. The strobes may be used with readily available, user supplied ICs to construct a customized I/O interface. All strobes are true (low) for approximately 330 nanoseconds.

SENSORS

HP 10751A/B Air Sensor

The HP 10751A/B Air Sensor measures air temperature and pressure, and has the provision for manually setting in a factor for low, mid, and high humidity. These are supplied in signal form (AP, AT, and AH) to the compensator board of the HP 5507A. The compensator board converts this information into wavelength-of-light or total compensation number data for use with the rest of the HP 5507A Laser Position Transducer system. The difference between the A and B models is the cable length: the HP 10751A has a cable length of 5 m (16 feet) while the 10751B has a cable length of 15 m (49 feet).

HP 10757A/B/C Material Temperature Sensor

The HP 10757A/B/C Material Temperature Sensor is used to compensate for thermal expansion or contraction of the material being measured by the HP 5507A. The 10757A/B/C contains a thermistor-type temperature sensor mounted in a remote oil immersible "button" with a magnetic base. The sensor output, in signal form (MT1 or MT2, depending on which HP 5507A rear connector the sensor is attached) is supplied to the compensator board of the HP 5507A. The compensator board converts this information into total compensation number data for use with the rest of the HP 5527A Laser Position Transducer system. The difference between the A, B, and C models is the cable length: the HP 10757A cable length is 5 metres (16 feet), the 10757B cable length is 15 metres (49 feet), the 10757C cable length is 25 metres (82 feet).

LASER HEADS

The wavelenth of light from the laser head is used as length standard for the HP 5527A Laser Position Transducer system. The head generates a coherent (all light waves in phase), collimated (all waves traveling parallel to one another) light beam consisting of two orthogonally polarized frequency components that is used by the laser transducer system to generate measurement displacement signals (MEASure FREQuency). In addition to this beam, the laser head generates an electrical reference signal (REFerence FREQuency).

HP offers three models of laser heads (e.g., HP 5517A, 5517B, and 5518A) to fill a variety of customer requirements. The following paragraphs provide a basic description of each model. Additional information on the different laser heads can be found in Section's I and II.

HP 5501A Laser Head (Discontinued)

The major structures of the HP 5501A Laser Head include the laser tube assembly, regulator circuits (that ensure optimum laser operation), and diagnostic circuits. Power requirements are ±15 Vdc, supplied by the HP 5527A system power supply.

NOTE

The HP 5527A system power supply is located within the HP 5507A Laser Position Transducer Electronics package.

The laser head emits a laser beam, containing a vertically polarized component F_1 (the lower of the two frequencies) and a horizontally polarized component F_2, that is used by the HP 5527A Laser Position Transducer system to generate displacement measurement signals. In addition to this beam, the laser head generates an electrical reference (REF @ ~1.8 MHz) signal, and accepts and produces interface and diagnostic signals for accessory equipment.

A beam splitter diverts a small portion of the output beam and routes this sample to a polarizing beam splitter. This splitter partially separates and applies the F_1 and F_2 signals to the PZT control circuit. The PZT control circuit compares the signal level of the F_1 and F_2 samples. If the levels of these samples are not equal, an appropriate (dc) PZT control voltage is generated to tune the laser tube and equalize the F_1 and F_2 components. In addition to providing this automatic tuning control, the control circuits extract the difference between F_1 and F_2 and generate an electrical reference measurement signal for use by the transducer accessory equipment.

HP 5517A/B Laser Head

The major structures of the HP 5517A/B Laser Head include the control electronics, the laser assembly, the sampler assembly, the reference receiver, and the high voltage power supply. All of the necessary control signals for the operation of the HP 5517A/B are generated internally. Power requirements are ± 15 Volts dc and is supplied by the HP 5527A system power supply.

The laser head emits a laser beam, containing a vertically polarized component F_2 (the higher of the two optical frequencies) and a horizontally polarized component F_1. A portion of the emitted beam is directed to the sampler assembly. Most of this sample feeds into the reference receiver and the remainder of the sample is used to control laser tuning. The reference receiver generates the reference frequency signal by mixing the two laser frequencies. The reference frequency is in the range of 1.5 to 2.4 MHz and is a TTL-level square wave. When the laser tuning stabilizes, the reference frequency is sent to the system electronics.

The main portion of the beam is directed by system optics to an external receiver where a measurement signal is generated. The measurement and reference signals are compared by the HP 5527A Laser Position Transducer system to generate a displacement measurement signal.

The difference between the A and B model is size. The B model matches the HP 5501A/B footprint, but has the accuracy and stability of the HP 5517A. The reference frequency for the HP 5517A is 1.5 to 2.0 MHz and 1.9 to 2.4 MHz for the HP 5517B.

HP 5518A Laser Head

The major structures of the HP 5518A are the control electronics, the laser assembly, the sampler assembly, the turret optics, the measurement receiver, and the reference receiver. The HP 5518A requires only power input from the HP 5527A system power supply. All control signals are internally generated. The HP 5518A output signal, called REFerence FREQuency, is enabled when the laser tuning is stabilized. Laser tuning is stabilized by the control electronics. The output signals, MEASurement FREQuency and Beam Strength, require proper alignment of measurement optics in addition to stable tuning.

The control electronics control the tuning of the laser assembly to ensure an accurate laser wavelength. When properly tuned, the laser assembly outputs two laser frequencies. One laser frequency, F_1, is polarized horizontally (or parallel to the bottom of the HP 5518A chassis). The other laser frequency, F_2, is polarized vertically (or perpendicular to F_1). The wavelengths of the two frequencies differ only slightly since the frequency difference between F_2 and F_1 is small when compared to their optical frequencies.

Before the laser light is emitted from the HP 5518A, a portion of it is sampled by the sampler assembly. Most of this sample is fed into the reference receiver and the remainder of the sample is used to control laser tuning.

The reference receiver generates the TTL-level square wave signal, REFerence FREQuency, by mixing the two laser frequencies. The reference frequency is the difference in frequency between the two laser frequencies. The reference frequency is 1.7 to 2.4 MHz for HP 5518As with serial number 2532A02139 and above. For previous HP 5518As, the frequency is 1.5 to 2.0 MHz. The measurement receiver generates the TTL-level square wave signal, MEASurement FREQuency, by mixing the two laser frequencies after they have returned from the measurement optics. The measurement and reference frequency signals are transmitted to the HP 5507A in differential form.

RECEIVERS

HP 10780B Receiver

The HP 10780B Receiver converts the Doppler-shifted laser light into electrical signals that can be processed by the rest of the laser system. A lens located on the front end of the receiver focuses the laser light onto a silicon PIN photodiode. Between the lens and the diode is a small piece of polarizing material oriented at 45° to the horizontal and vertical axes of the receiver. When the receiver is mounted properly — vertical axis parallel or perpendicular to the axes of the laser head — the polarizer passes one-half the incident power from each of the two incoming orthogonally polarized components of the received laser beam. The resulting power on the photodiode chip is an amplitude-modulated sine wave; its frequency is the Doppler-shifted split frequency, and its amplitude is proportional to the product of the incident powers of the two orthogonal components. The photodiode generates an ac current, which is converted to an ac voltage at a frequency of 100 kHz to 5 MHz.

The detected signal voltage goes through an impedance transformation stage, two gain stages, and a level translation stage. The result, a TTL-level signal, goes to a TTL differential line driver, which is ac-coupled to the rest of the HP 5527A by a shielded twisted-pair cable. The output is a differential square wave at the Doppler-shifted split frequency.

The difference between the A and B model is the increased sensitivity of the B model to laser light. The maximum sensitivity of the HP 10780B is 1.5 μW (factory set at 5 μW) and can be adjusted via an externally accessible potentiometer using the adjustment procedures found in Section VI of this manual.

HP 5518A Internal Measurement Receiver

The HP 5518A internal measurement receiver amplifies and converts the difference frequency of the laser beam (returned by the system optics) to TTL levels and supplies the signal to the HP 5507A.

During a measurement, the vertical and horizontal components pass through the turret and measurement optics and return to the measurement receiver. The difference between their frequencies will change whenever the measurement optics are moving. The laser light returning from the measurement optics is directed through a polarizer and onto a photodiode. Because of the polarizer orientation, the beam power past the polarizer varies sinusoidally at the difference frequency of the two laser frequency components. The beam power at the difference frequency is converted to TTL levels. The frequency of the TTL output is the measurement frequency.

SYSTEM OPTICS

The laser system measures displacements by looking at the Doppler shift induced by the motion of the displacements. Both frequencies of laser light originate at the laser head and travel to the interferometer, where the beams are optically separated. One of the two frequency components is directed toward the object whose motion is being measured. There it is reflected by a mirror or retroreflector (cube-corner) and returned to the interferometer. The other frequency component travels a fixed path through the cube corner mounted directly to the interferometer, where both components recombine into a single beam. Both cube-corner retroreflectors offset their corresponding beams and return them parallel to the incoming beam path. Small rotations or perpendicular movements will not affect the accuracy of the measurement. Each system axis must have an interferometer and retroreflector. Machine design considerations determine which type of interferometer is optimum. The choice of the interferometer for each axis usually specifies the retroreflector for that axis.

The HP 10717A Wavelength Tracker is an interferometer and etalon combination that measures change in laser wavelength, not displacement. It measures apparent change in a fixed distance, which is interpreted as a variation in the laser wavelength.

For more detailed information on the individual optical components available from HP, refer to Section II of this manual.

INTRODUCTION TO SYSTEM TROUBLESHOOTING

This section provides assistance in the identification of defective components in the HP 5527A Laser Position Transducer system should a failure occur. It will help determine whether the fault is in the HP 5507A electronics, environmental sensor, laser head, receiver, or one of the HP 107XX optical components.

Component-level troubleshooting and calibration should be performed by Hewlett-Packard technicians only. However, component-level troubleshooting and calibration information is provided for selected assemblies. This section is structured as indicated in *Table 7-1*.

Table 7-1. Troubleshooting Section Content Summary

INSTRUMENT	TYPE OF INFORMATION
HP 5507A	Subassembly-level troubleshooting to isolate the fault to the power supply or circuit board.
	Component-level troubleshooting except for those assemblies on the Exchange Program (i.e., Axis, Automatic Compensation, HP-IB boards, and power supply. (See "Exchange Assemblies" for more details.)
	Power supply adjustment procedures.
Laser Heads	System-level troubleshooting for isolating the fault to the laser head.
HP 10751A/B	Subassembly-level troubleshooting and Air Sensor calibration procedures.
HP 10757A/B/C Material Temperature Sensors	Calibration procedures. (See Note 1).
HP 10780B	Receiver System-level troubleshooting for isolating the fault to a receiver.
HP 107XX Optics	System-level troubleshooting for isolating the fault to the optical assemblies. (See Note 2).

Note 1: The HP 10757A/B/C Material Temperature Sensors are on the BLUE STRIPE PROGRAM. The entire instrument is replaced when it is determined the unit is defective. See "Exchange Assemblies" paragraphs of this section for details.

Note 2. The HP 107XX optics are repairable only by Hewlett-Packard.

NOTE

The HP 5501A/B Laser Heads are not recommended for use with the HP 5527A Laser Position Transducer system because they would degrade the HP 5527A system performance. HP 5501A information has been left in this section to aid in troubleshooting. The HP 5501A is no longer manufactured by Hewlett-Packard.

Additional information is provided in the manuals that are supplied with each instrument. *Table 7-2* describes each manual and what information is found in each one.

Table 7-2. Supplementary Manuals

INSTRUMENT	TYPE OF INFORMATION	NAME OF MANUAL	CURRENT HP PART NUMBER (See Note 1)
HP 5501A Laser Head	Component-level Troubleshooting and Adjustments	5501A Laser Laser Head Operating and Service Manual	05501-90025 (HP 5501A)
HP 5517A/B Laser Head	Component-level Troubleshooting and Adjustments	Model HP 5517A (or HP 5517B) Laser Head Operating and Service Manual	05517-90007 (HP 5517A)
HP 5518A Laser Head	Component-level Troubleshooting and Adjustments	5528A Laser Measurement System Service Manual	05528-90016
HP 10780B Receiver	Component-level Troubleshooting and Adjustments	10780B Receiver Operating and Service Manual	10780-90015
Note 1: The HP part number of a manual is subject to change when the manual is updated.			

Troubleshooting Assumptions

The troubleshooting procedures make the following assumptions:

a. That the system controller is operating properly. Before connecting the HP-IB cable (HP 10833A/B/C/D) from the system controller to the HP 5507A, check the controller by

   1. booting the unit up and verifying appropriate responses,
   2. running your own known good programs, and
   3. executing any controller diagnostics unique to your particular controller.

b. That all system controls have been double-checked to verify that they are in the proper positions. This includes the correct setting of all circuit board address and test switches. (See "Preliminary Checks" in this section.)

c. That all system cabling is configured correctly and that they are making proper electrical connection.

d. That the system optics are clean. Refer to "Procedures for Cleaning Measurement Optics" in this section.

e. That power to the system is removed prior to replacing any units or circuit boards.

f. That the precautions outlined in "Electrostatic Discharge (ESD)" found in this section are adhered to.

g. That any repair to the circuit board component level, be accomplished by a Hewlett-Packard technician.

h. That the troubleshooting procedures cannot cover all possible malfunctions or combination of malfunctions. However, at the very minimum, these procedures will direct you to the general area of the problem.

WARNING

USE OF CONTROLS, ADJUSTMENTS, OR PROCEDURES OTHER THAN THOSE SPECIFIED HEREIN MAY RESULT IN HAZARDOUS LASER LIGHT EXPOSURE OR EXPOSURE TO HIGH VOLTAGES.

ELECTROSTATIC DISCHARGE (ESD)

Electronic components and assemblies can be permanently damaged by electrostatic discharge. To avoid damage caused by ESD, follow the following precautions:

a. ENSURE that static sensitive devices or assemblies are serviced at static-safe work stations providing the proper grounding for personnel (e.g., table mat with wrist strap).

b. ENSURE that static sensitive devices or assemblies are stored in static-shielding containers (e.g., antistatic poly bags).

c. DO NOT wear clothing subject to static charge build-up, such as wool or synthetic materials.

d. DO NOT handle components or assemblies in carpeted areas.

e. DO NOT remove the component or assembly from its static protective container until you are ready to install it.

f. AVOID touching component leads or assembly edge connectors with your fingers.

TROUBLESHOOTING INFORMATION

The possible system problems that can occur can be divided into the following areas:

a. Malfunction of the laser head.
b. Malfunction of one or more receiver.
c. Malfunction, misalignment, or improper application of the optical devices.
d. Malfunction of the system controller or its improper programming.
e. Malfunction of the HP 5507A (plus any options) system electronics.

If one of these areas is suspect as the source of the trouble, refer to the appropriate troubleshooting information and flowcharts for that particular area.

Required Test Equipment

The equipment required to maintain the HP 5507A is listed in *Table 7-3*. Other equipment may be substituted if it meets or exceeds the critical specifications listed in the table. Refer to *Table 7-20* for a list of test equipment required for the calibration of both environmental sensors (HP 10751A/B Air Sensor and 10757A/B/C Material Temperature Sensor).

Table 7-3. Recommended Test Equipment

INSTRUMENT	REQUIRED CHARACTERISTICS	HP MODEL NO.
Laser Power Meter	Range: 1 microwatt to 1 milliwatt Accuracy: ±10%	United Detector Technology (Model 40X with 6328A Filter)
Digital Voltmeter	Range: −15V to +15V ±0.01 Vdc (See Note 1) ±0.000001 Vdc (See Note 2)	HP 3456A
Logic Probe	TTL Level	HP 545A
Oscilloscope	Ability to display signals between dc and 100 MHz.	No Recommendation
Clip-on DC Milliammeter	DC Current Range: 1 mA to 10A (full scale) Accuracy: ±3% of full scale ±0.15 mA	HP 428B
Note 1: Accuracy of ±0.01 Vdc required for voltage adjustments. Note 2. Accuracy of ±0.000001 Vdc (1 μV) required for HP 5507A calibration.		

Laser Head Troubleshooting

HP 5501A LASER HEAD

The following symptoms indicate problems with the HP 5501A Laser Head. If one or more of these symptoms are observed, use the troubleshooting flowchart (*Figure 7-31*) to assist in determining if the HP 5501A is actually at fault. A detailed repair procedure is outlined in the HP 5501A Laser Transducer (Laser Head) Operating and Service Manual.

a. No laser light being emitted from the laser head exit port.

b. Laser beam flashing.

c. Low power output from the laser head as measured with a laser power meter filtered for 6328 Å [e.g., United Detector Technology (Model 40X Meter with filter)].

d. Laser head will not tune. If the RETUNE FAILURE indicator is lit, depress the RETUNE pushbutton. The RETUNE FAILURE indicator should extinguish immediately while the RETUNE indicator extinguishes approximately nine seconds later.

e. POWER ON indicator is not lit.

f. LASER CURRENT indicator is lit.

g. Absence of reference signal or bad reference signal.

h. +15 UNBAL or −15 UNBAL indicator is lit.

i. +15 FUSE or −15 FUSE indicator is lit.

HP 5517A/B LASER HEAD

The following symptoms indicate problems with the HP 5517A/B Laser Head. If one or more of these symptoms are observed, use the Troubleshooting Tree, *Figure 7-32*, to assist in determining if the HP 5517A/B is actually at fault. Detailed repair procedures are outlined in each laser head's respective operating and service manual.

a. No laser light being emitted from the laser head exit port.

b. Laser beam flashing.

c. Low power output from the laser head (as measured with a laser power meter filtered for 6328 A [e.g., United Detector Technology (Model #40X Meter with filter)].

d. LASER ON indicator not lit.

e. READY indicator does not illuminate as expected. Normally, the indicator will start to blink on and off within three minutes of applying power to the laser head. This indicates that the laser head is in the process of warming up. When the HP 5517A/B is ready for use, the indicator assumes a steady on condition (after a 10 minute warm-up period).

f. Absence of reference signal or bad reference signal.

g. HP 5517B's +15V POWER ON or –15V POWER ON indicator is not lit.

HP 5518A LASER HEAD

The following symptoms indicate problems with the HP 5518A Laser Head. If one or more of these symptoms are observed, use the troubleshooting flowchart (*Figure 7-33*) to assist in determining if the HP 5518A is actually at fault. A detailed repair procedure is outlined in the HP 5528A Laser Measurement System Service Manual.

a. No laser light being emitted from the laser head exit port.

b. Laser beam flashing.

c. Low power output from the laser head as measured with a laser power meter filtered for 6328 A [e.g., United Detector Technology (Model 40X Meter with filter)].

d. LASER ON indicator not lit.

e. READY indicator does not illuminate as expected. Normally, the indicator will start to blink on and off within three minutes of applying power to the laser head. This indicates that the laser head is in the process of warming up. When the HP 5518A is ready for use, the indicator assumes a steady on condition (after a 10-minute warm-up period).

f. Absence of reference signal or bad reference signal.

g. SIGNAL indicator does not light (see the HP 5518A Laser Head internal receiver troubleshooting information found in this section).

h. No measurement signal or bad measurement signal (see the HP 5518A Laser Head internal receiver troubleshooting information found in the this section).

Receiver Troubleshooting

HP 10780B RECEIVER

NOTE

Allow the laser head sufficient time to complete its tuning cycle prior to determining whether or not the HP 10780B is working properly.

When the receiver photodetector receives an adequate laser beam signal, the LED indicator illuminates (located on the Receiver's top surface) and the DC voltage at the external beam monitor test point is greater than +0.7. (See "Receiver — Alignment and Adjustment Procedure" in Section VI for procedures to adjust this test point voltage.)

If the MEASUREMENT SIGNAL ERROR indicator on the HP 5507A front panel illuminates, the problem may be with one of the system's measurement axis receivers. If a SYSTEM ERROR indicator illuminates and the system is equipped with a Wavelength Tracking Compensation system, the problem could be with the Wavelength Tracker axis receiver or the overall alignment of the Wavelength Tracking Compensation system components. By sending an error message query (ERRM?) to the HP 5507A Laser Position Transducer Electronics via the system controller, the system will respond indicating which axis is generating the error message.

Improperly aligned optical devices in either a measurement or a Wavelength Tracking axis can also cause a receiver to appear bad. Check for this by either placing the receiver directly in the laser beam path from the laser head, or by reflecting the laser beam onto the receiver's photodetector using a retroreflector. This isolates all other optical devices from the system. Most systems contain more than one axis and, consequently, more than one receiver. If trouble is suspected with one particular receiver, exchange it with another receiver to verify the suspected malfunction. If you suspect problems with the alignment of a receiver, refer to Section VI of this manual for the appropriate alignment procedures.

The receiver LED indicator may remain on even if the beam between the interferometer and the retroreflector is blocked. This can occur occasionally with correct optical alignment if the measurement path is very short and few optical devices are used in the measurement path. If this situation occurs, refer to the HP 10780B Operating and Service Manual.

The troubleshooting trees of *Figure 7-34* and *Figure 7-40* will help you determine if the HP 10780B Receiver or HP 10717A Wavelength Tracker is faulty. *Table 7-4* provides the HP 5507A rear panel measurement and Wavelength Tracking Compensator receiver input signal/pin identification. Repair of the HP 10780B is outlined in the HP 10780B Operating and Service Manual.

Table 7-4. HP 10780B Receiver Signal Chart

RECEIVER		HP 5507A REAR PANEL RECEIVER INPUT CONNECTORS (See Note 1)		SIGNAL NAME
INPUT	**OUTPUT**	**MEASUREMENT AXIS**	**WAVELENGTH AXIS** RECEIVER	
	J1-1	A2W1J1(1)	A8W1J1(1)	$\overline{\text{MEAS}}$ Referred to as MEAS FREQ- within the HP 5507A.
	J1-2	A2W1J1(2)	A8W1J1(2)	MEAS Referred to as MEAS FREQ within the HP 5507A.
J1-3		A2W1J1(3)	A8W1J1(3)	+15V Return RET
J1-4		A2W1J1(4)	A8W1J1(4)	+15V

PIN	WIRE COLOR	SIGNAL
1	BLK	MEAS FREQ-
2	WHT	MEAS FREQ
3	WHT/GRA	+15V RETURN
4	WHT/GRA/GRN	+15V

HP 5507A Rear Panel Receiver Cable Connectors (A2W1J1 and A8W1J1)

Note 1: See Figure 7-35 for more HP 5507A signal flow detail.

NOTE

A dash (—) following a signal name indicates a negative-true signal.

The receivers should be inspected at least twice a year, depending on its operating environment. Inspect as follows:

- VISUAL INSPECTION — Inspect the unit for indication of mechanical and electrical defects. Look for signs of overheating, corrosion, accumulations of dust, oil, loose electrical connections, or broken parts.
- REPAIR AND CLEANING — Repair any obvious defects; and if necessary, clean the unit with dry, clean compressed air. Clean optics as outlined in the —'Operator's Maintenance" paragraphs of this section.

Periodically you may wish to verify proper beam alignment. Refer to the Section VI of this manual for this procedure.

HP 5518A LASER HEAD INTERNAL RECEIVER

The HP 5518A Laser Head contains its own measurement receiver. The SIGNAL indicator is on when sufficient laser beam signal is received through one of two turret optics ports: the laser exit port (top) used as a destination of the laser return beam for straightness measurements, and laser return port (bottom) used for destination of laser return beam for distance, velocity, and angular measurements.

Improperly aligned optical devices can cause the receiver to appear defective. To check:

a. Set the HP 5518A turret assembly to the OTHER position. Both aperture shutters should be open.

b. Wait for the HP 5518A READY light to remain on. At power-up, the laser tube begins a tuning cycle to stabilize its reference frequency. Halfway through the stabilization cycle, the READY light will start flashing; when the cycle has completed, the READY light will stay on continuously.

c. Use a clean linear retroreflector (HP 10767A) to reflect the laser beam 180° back through the laser return port (bottom). If the SIGNAL indicator lights, indicating that the return laser beam is strong enough for a measurement, then the system optics need to be aligned. Otherwise, the problem is with the HP 5518A.

Optical Device Troubleshooting

Problems with the optical devices are usually caused by their misalignment. Refer to the alignment procedures in Section VI for further information. Air turbulence caused by ventilation equipment or temperature gradients near the laser beam path can also cause measurement problems. If this is suspected, shield the area around the laser beam and optical devices with cardboard tubing, plastic sheet, or other suitable material. Some problems with sporadic counting and drift can be traced to air turbulence around the measurement path. This should be considered as a possibility before troubleshooting other parts of the system.

NOTE

If the problem is traced back to dirty optics, refer to "Procedures for Cleaning Measurement Optics", prior to attempting to clean them.

Defective measurement optics should be returned to Hewlett-Packard where they will be evaluated for repair. Follow the procedures outlined in the Installation section of this manual for packaging methods and procedures.

Wavelength Tracker Troubleshooting

Troubleshooting the HP 10717A Wavelength Tracker involves proper interpretation of the HP 5507A Laser Position Transducer Electronics front panel annunciators, system- and board-level self tests, and knowing when the Wavelength Tracker requires realignment to the system optics. The main system problems that could occur include:

- Misalignment of the Wavelength Tracker, the receiver, the system optics, and system laser source.
- Improper programming of system
- Malfunction of the receiver
- Malfunction of the HP 5507A system electronics (i.e., HP 10946B Automatic Compensation Board)

The troubleshooting information for the Wavelength Tracker, receiver, system optics, and the HP 10780B and HP 10717A Troubleshooting Trees (*Figures 7-34* and *7-40* respectively) will help you determine if the HP 10780B Receiver or HP 10717A Wavelength Tracker is faulty.

The front panel LEDs, combined with the error messages listed in Appendix B, provide assistance with both programming and hardware problems. The SYSTEM ERROR LED illuminates when a problem occurs in the measurement or reference path of the Wavelength Tracker axis or when incorrect programming strings have been sent by the system controller. By sending an error message query (ERRM?) to the HP 5507A electronics via the system controller, the system will respond indicating which board address is generating the error message, and provide a brief description of the error.

At power-up or following a "hard reset", the HP 10946B Automatic Compensation Board will perform an internal self-test to verify proper operation of the processor, RAM, ROM, Mailbox RAM and control electronics. The results of these tests are reported by the two LEDS (DS1 and DS2) mounted the HP 10946B board. At the end of the tests, these LEDs should be off. Also, the SYSTEM ERROR LED on the HP 5507A front panel turns on if any of the board's self tests fail.

After passing the self tests mentioned above, the 10946B tests its measurement functions. The SYSTEM ERROR LED will also indicate measurement function test fauilures. In addition, there is a set of self-test error codes (see Appendix B) unique to the measurement function self tests. These error codes are accessible by setting the *TST mnemonic to one and by sending an error message query (ERRM?).

The HP 10717A Wavelength Tracker is an optical device and is pre-aligned at the factory. If found defective it should be returned to Hewlett-Packard where it will be evaluated for repair. Follow the procedures outlined in Section VI of this manual for packaging methods and procedures.

HP 5507A Laser Position Transducer Electronics Troubleshooting

The following paragraphs describe the methods for isolating a problem within the HP 5507A to a given printed circuit (P.C.) board assembly. The following topics are discussed in detail:

- Interpretation of the Front Panel Annunciators
- Power-up Self Tests
- Preliminary Checks (Includes Printed Circuit Board Address Switch Position Description)
- HP 5507A Failure Symptoms and Their Probable Causes
- Prototyping Board Troubleshooting

HP 5507A FRONT PANEL ANNUNCIATORS

The front panel annunciators (LEDs), combined with the error messages listed in Appendix B, provide assistance with both programming and hardware problems. A description of LED indications and sequences are covered briefly in the following paragraphs.

LASER ON (Yellow)	Monitors the HP 5507A +15V power supply line. This line supplies power whenever the front panel line switch is in the ON (depressed) position. The yellow indicator alerts the system operator that the laser head is energized and emitting a beam.
LASER LOCKED (Green)	When the laser head is supplying a stable reference signal [after the laser head has reached its operating temperature (as indicated the by HP 5517A or HP 5518A READY indicators being on)] and the HP 5507A has locked on to this signal, the green indicator illuminates. As the laser head is warming up, this indicator flashes once and then remains off until a stable reference signal is received and the HP 5507A Phase-Locked Loop (PLL) circuit has locked onto it.
MEASUREMENT SIGNAL ERROR (Red)	Indicates a problem in the measurement signal path.
SYSTEM ERROR (Red)	Indicates errors caused by reference signal glitches, incorrect programming strings, etc.
TALK (Green)	Indicates the HP 5507A is addressed to talk and is currently transmitting data.
LISTEN (Green)	Indicates the HP 5507A is addressed to listen and is currently receiving data.
SRQ (Green)	Indicates a service request condition exists.

HP 5507A FRONT PANEL ANNUNCIATOR POWER-UP SEQUENCE

At power-up or following a "hard reset", the LEDs will undergo the following unique sequencing cycle:

Power-up or "Hard Reset"	All front panel LEDs turn on and off, with the LASER LOCKED LED remaining on a bit longer than the other LEDs. After the above LEDs (except the LASER LOCKED LED) extinguish, the HP-IB indicators will flash on and off sequentially one time. The SRQ LED stays on for approximately ten seconds, before turning off. Then the TALK, LISTEN, and SRQ indicators begin to cycle sequentially until a stable reference signal is received from the laser head and the HP 5507A PLL locks onto this signal.
Laser Warm-up Period	The HP-IB board's self tests are complete and the TALK, LISTEN, and SRQ LEDs are cycling (in sequence). The cycling of the LEDs continues until (1) the laser head reaches its operating temperature, and (2) the HP 5507A receives and locks onto a stable reference signal.
Laser Reference Stability	When the laser head reaches proper operating temperature and the HP 5507A locks on a stabilized laser reference signal, the LASER LOCKED LED illuminates and the TALK, LISTEN, and SRQ LEDs no longer blink sequentially. The HP-IB now performs a "soft reset" to initialize all boards.

HP 5507A POWER-UP SELF TESTS

At power-up or following a BOOT command ("hard reset"), the HP-IB, Axis, and Automatic Compensation board perform an internal self-test to verify proper operation. (See "HP 5507A HP-IB Interface" in Section IV.) The longest self test, that of the HP-IB board, takes about 15 seconds to complete. During this time, the HP 5507A front-panel LEDs will flash to indicate the progress of the test. If any of the LEDs fail to turn on, or if the SYSTEM ERROR LED is on and the TALK, LISTEN, or SRQ LEDs do not flash as described earlier, an HP-IB board or front-panel board hardware failure is indicated.

If the SYSTEM ERROR LED is on, but the TALK, LISTEN, and SRQ LEDs are off or flashing, one of the boards other than the HP-IB board is not functioning properly. The faulty board may be pinpointed by sending CNFG? to the HP 5507A over HP-IB and reading the resulting configuration string, or by removing the HP 5507A top cover and checking the self-test indicator LEDs on the Automatic Compensation and Axis boards. The Axis and Automatic Compensation boards both have two LEDs (DS1 and DS2) located at the top edge of their respective PC boards. These LEDs report the results of the power-up self tests as they cycle on and off, as portions of the tests are completed. At the end of the self tests, approximately 8 seconds after power-up, both LEDs should be off. The SYSTEM ERROR LED on the HP 5507A front panel turns on if any of the board's self tests fail.

During the system self-test period, the HP-IB board will not respond to HP-IB inputs. Fifteen seconds after power-up, the system is completely initialized and then waits for the laser head to output a stable reference signal. During this waiting period, the front panel TALK, LISTEN, and SRQ LEDs will cycle. This continues until the HP 5507A's PLL receives and locks onto a stable reference signal. During this waiting period, transfer operations are reduced to two string transfers per second.

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

PRELIMINARY CHECKS

WARNING

WHEN THE HIGH VOLTAGE SHIELD (MP8) IS REMOVED FROM THE HP 5507A, LINE VOLTAGES ARE EXPOSED WHICH ARE DANGEROUS AND MAY CAUSE SERIOUS INJURY IF TOUCHED. DO NOT REMOVE THE HIGH VOLTAGE SHIELD UNLESS IT IS NECESSARY AND ONLY WHEN THE UNIT IS DISCONNECTED FROM THE POWER MAINS.

a. Check that the power line selector on the HP 5507A rear panel is set to the correct line voltage.

b. Check that the fuse located within the power module is OK. Refer to "AC Line Fuse Replacement" to gain access to the power module.

c. Check that the three fuses located on the HP 5507A backplane are OK. Refer to "Disassembly and Assembly" to gain access to the the backplane fuses.

d. Check that the following cables are making proper electrical connection. If any are suspect, remove each cable from its respective connector and clean the electrical contacts thoroughly. Cleaning and reseating the connectors removes any dirt and oxidation from the contacts.

NOTE

A 50/50 solution of isopropyl alcohol and water (de-ionized preferably) applied with a lint-free cotton cloth is recommended for cleaning gold contacts.

1. W2. Connects the power supply to the HP 5507A backplane. (Refer to *Figure 7-11* or *7-16* for cable location.)
2. W3. Connects the internal fan to the HP 5507A backplane. (Refer to *Figure 7-11* or *7-15* for cable location.)
3. A2W1. Connects axis board to the rear panel receiver BNC-type connector. (Refer to *Figures 7-11* or *7-17* for cable location.)
4. A8W1. Connects the Automatic Compensator board to the rear panel Wavelength Tracking RECEIVER BNC-type input connector. (Refer to *Figure 7-17* for cable location.)
5. A9W1. Connects the compensator connector board to the Automatic Compensation board. (Refer to *Figure 7-17* for cable location.)
6. A10W1. Connects the Laser Connector Board to the HP 5507A backplane. (Refer to *Figure 7-17* for cable location.)
7. A11W1. Connects the front panel board to the HP-IB board. (Refer to *Figure 7-11* or *7-15* for cable location.)

e. Check the address switch (DIP) and jumpers on the HP-IB board.

1. Jumper JMP1 must be installed.
2. Address Switch SW2 (Normal Setting). The TEST switches must be set to zero during normal operation. The ADDRESS switches may be set as desired.

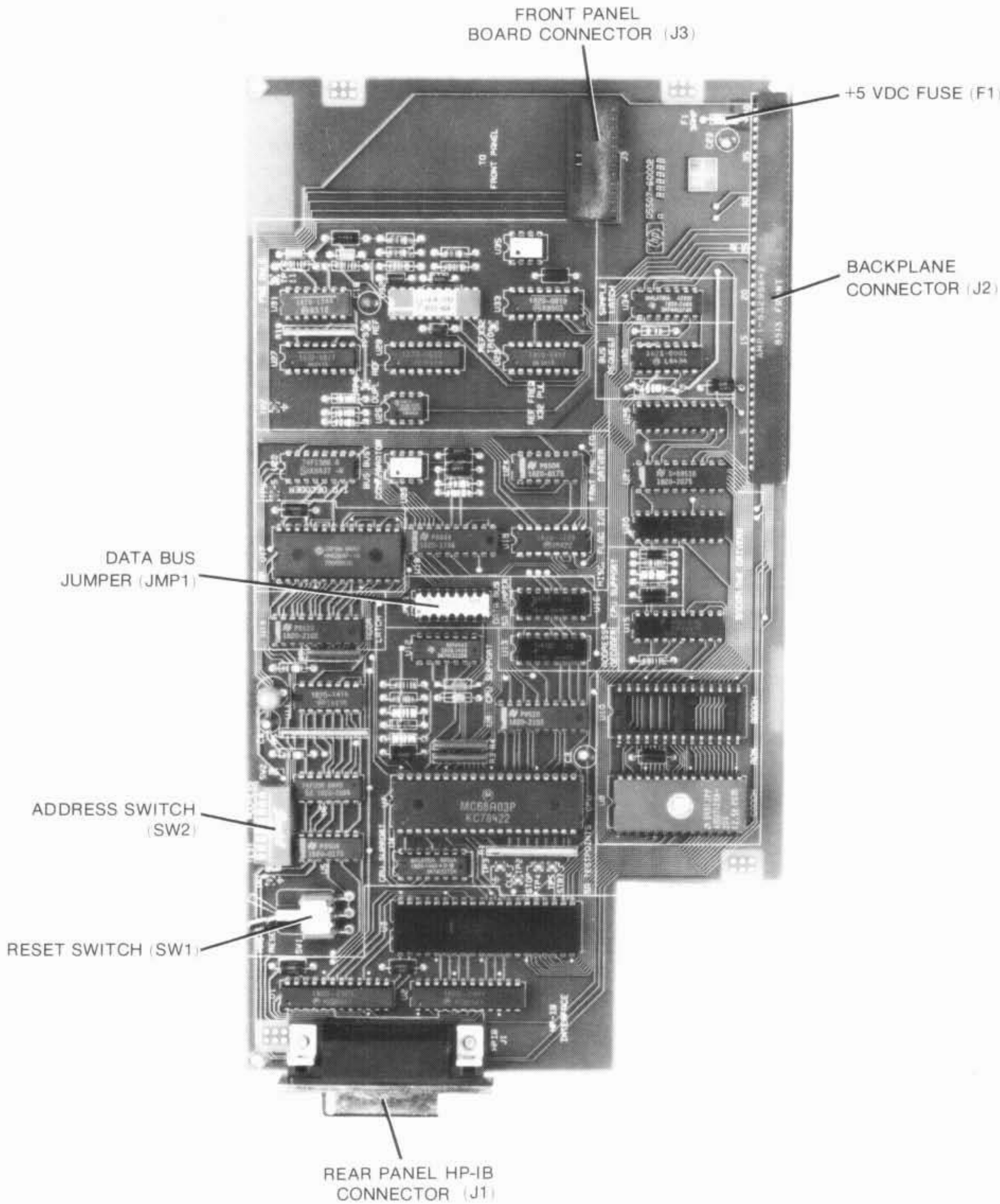
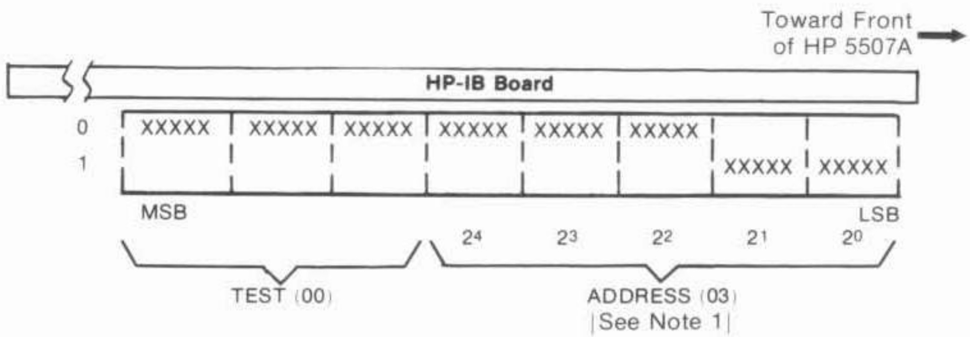


Figure 7-2. A1 HP-IB Interface Board



Note 1. The HP-IB board's address may be set from 0 to 31 by setting the desired binary address on this switch. Refer to Section IV for information on how these addresses are used.

Figure 7-3. HP-IB Board Address Switch Setting

f. Check the address switch (DIP) and Jumpers on the Axis board.

1. Jumper JMP1 must be installed.

2. Address Switch SW1 (Normal Setting). The TEST switches must be set to zero during normal operation. The ADDRESS switches may be set as desired.

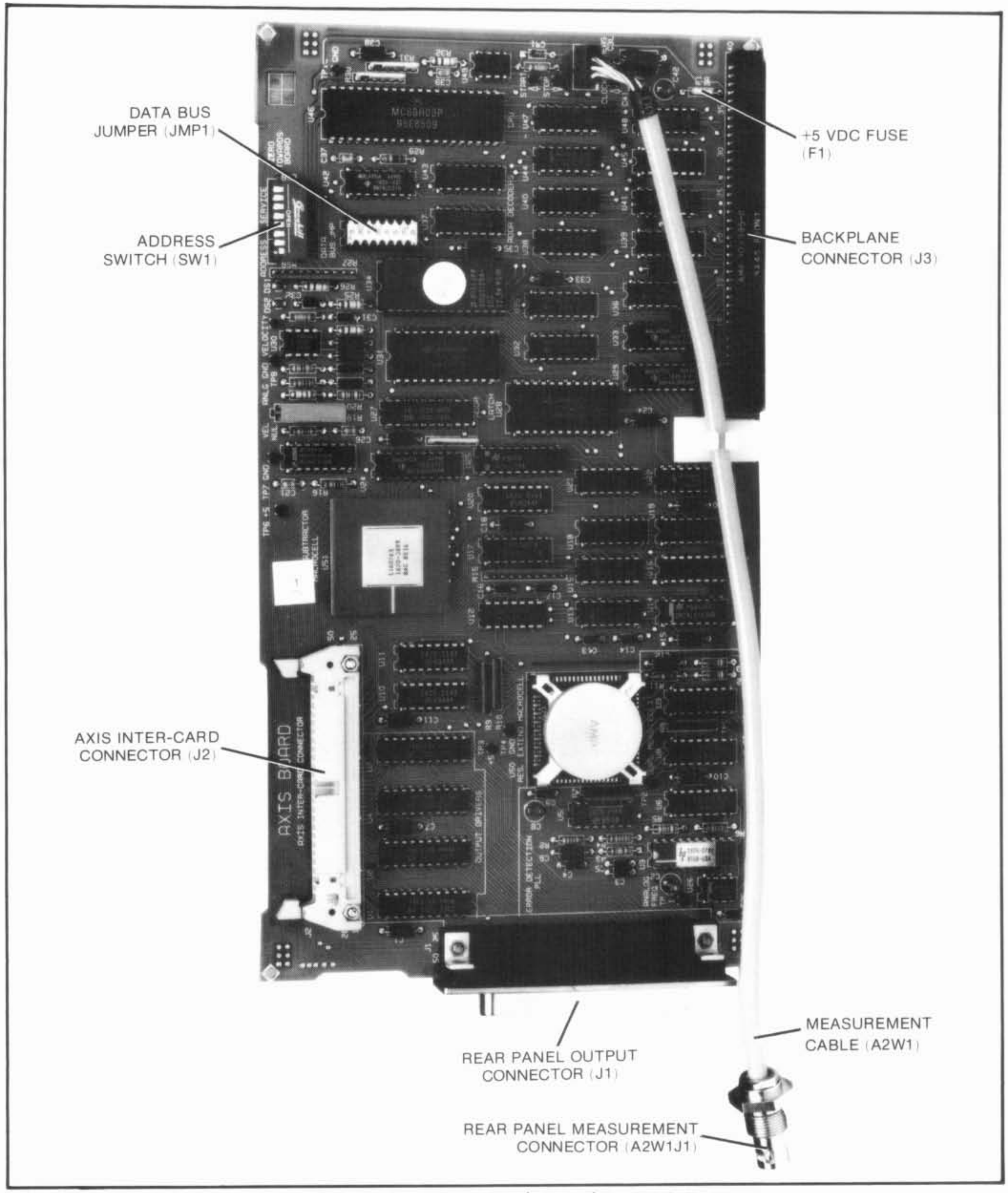
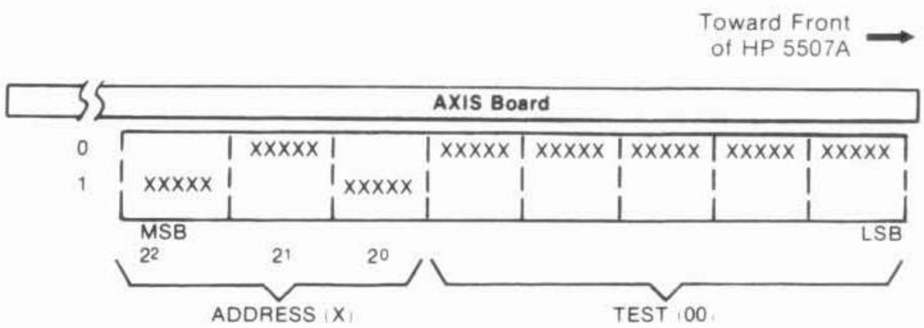


Figure 7-4. A2 Axis Board (Part of Option 032)



NOTE

The other possible Axis board switch settings are as follows.

Switch Setting 2^2	2^1	2^0	Corresponding Mnemonic Prefix
0	0	0	S
0	0	1	T
0	1	0	U
0	1	1	V
1	0	0	W
1	0	1	X
1	1	0	Y
1	1	1	Z

Figure 7-5. Axis Board Address Switch Setting

f0.1 Check the DIP switch and jumpers on the A-Quad-B Axis board.

1. The address , Setup Enable, and Baud Rate settings on the address (DIP) switch SW1 should be set as desired (see *Table 6-1*). The Setup enable and Test switches should be off (0).

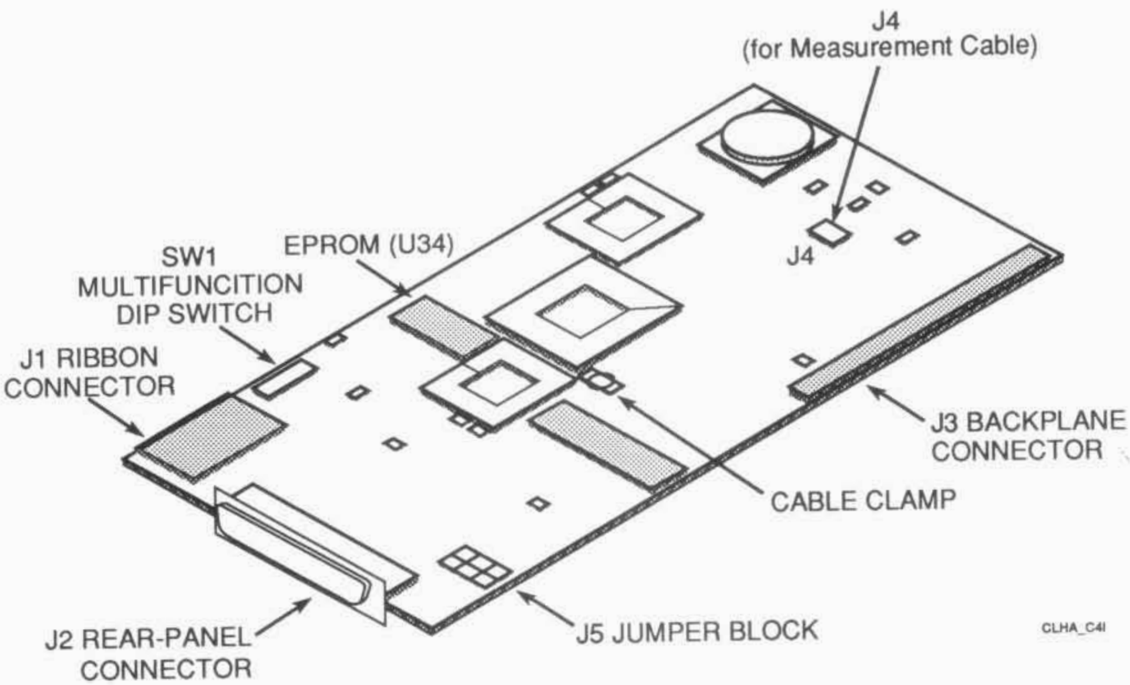
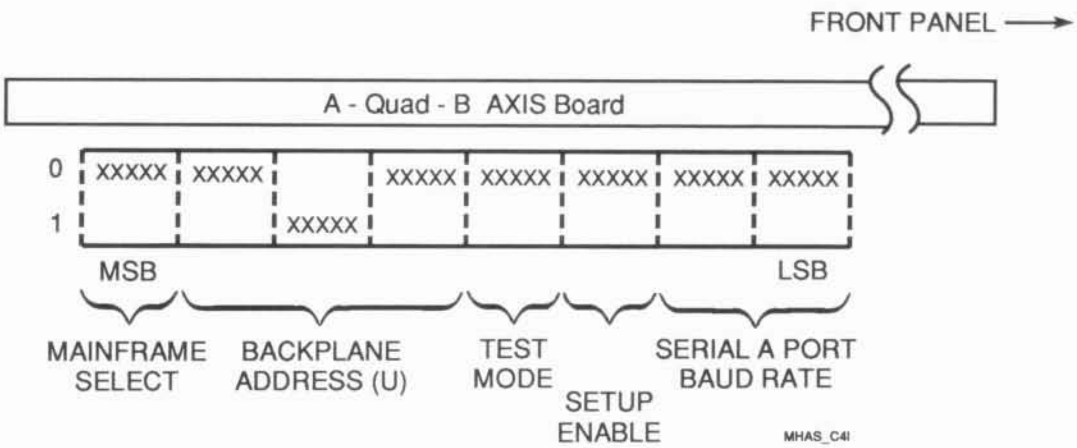


Figure 7-5.1. A-Quad-B Axis Board



NOTE

The other possible A-Quad-B Axis board switch settings are as follows:

Switch Setting			Corresponding Mnemonic Prefix
2^2	2^1	2^0	
0	0	0	S
0	0	1	T
0	1	0	U
0	1	1	V
1	0	0	W
1	0	1	X
1	1	0	Y

Figure 7-5.2. A-Quad-B Axis Board Switch Setting

f1. Check the address switch (DIP) on the Servo-Axis board.

1. Address Switch SW1 (Normal Setting). The TEST switches must be set to zero during normal operation. The address switches may be set as desired (See *Table 6-1*).

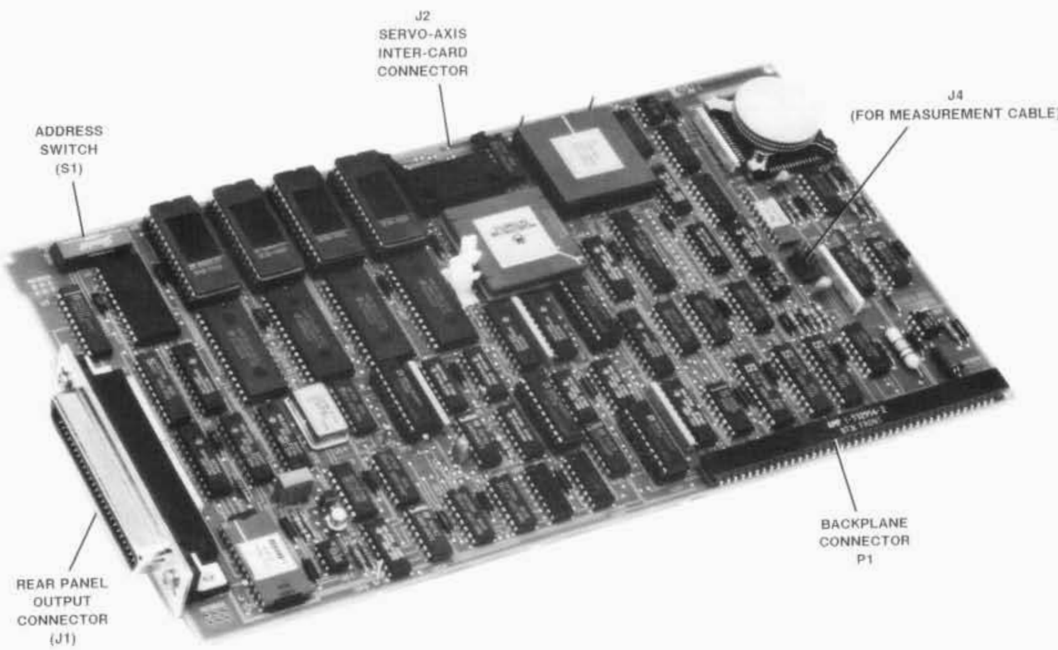
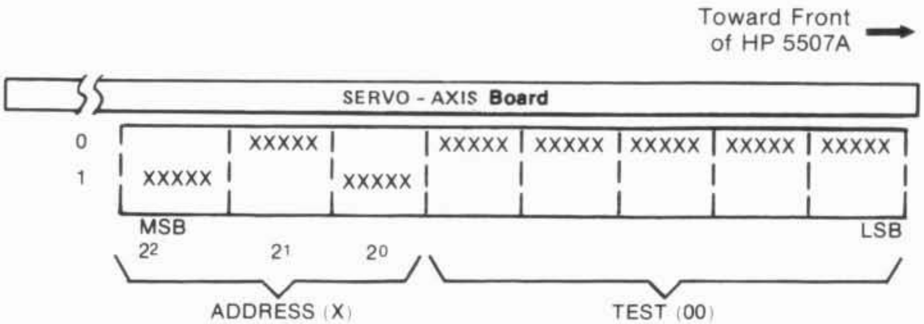


Figure 7-5a. A15 Servo-Axis Board (Part of Option 036)



NOTE

The other possible Servo-Axis board switch settings are as follows.

Switch Setting 2^2	2^1	2^0	Corresponding Mnemonic Prefix
0	0	0	S
0	0	1	T
0	1	0	U
0	1	1	V
1	0	0	W
1	0	1	X
1	1	0	Y
1	1	1	Z

Figure 7-5b. Servo-Axis Board Switch Setting