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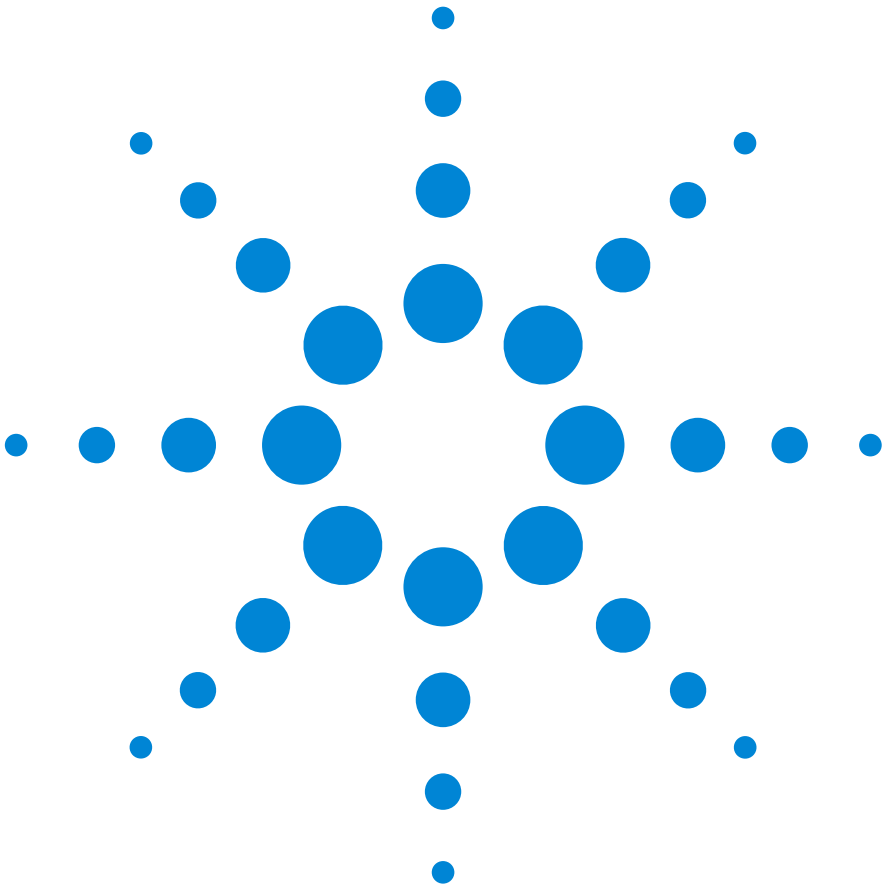
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Agilent E1710A Angular Encoder System
Agilent E1720A Linear Encoder System

Agilent E1711A Sensor Head
Agilent E1712A Scale
Agilent E1713A Scale Servo Axis Board
Agilent E1714A Master Arm Assembly

User's Manual



Agilent Technologies

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User's Manual

Agilent E1710A Angular Encoder

Agilent E1720A Linear Encoder

The E1710A and E1720A encoders do not have serial numbers.

The individual components that have serial numbers are:

Agilent E1711A Sensor Head

SERIAL PREFIX NUMBER:

This manual applies to E1711A Sensor Heads with Serial Prefix Number 3701A.

Agilent E1713A Scale Servo Board

SERIAL PREFIX NUMBER:

This manual applies to E1713A Scale Servo Boards with Serial Prefix Number 3705A.

Agilent E1714A Master Arm Assembly

SERIAL PREFIX NUMBER:

This manual applies to E1714A Master Arm Assemblie with Serial Prefix Number 3701A.

Agilent E1710A Angular Encoder System
Agilent E1720A Linear Encoder System

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Manual part number E1710-90006

Certification and Warranty

Certification

Agilent Technologies certifies that this product met its published specification at the time of shipment from the factory. Agilent further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology (formerly National Bureau of Standards), to the extent allowed by the Institute's calibration facility, and to the calibration facilities of other International Standards Organization members.

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Safety Considerations

General

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

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

Before Applying Power

Verify that the product is set to match the available line voltage and the correct fuse is installed. Refer to instructions in Chapter 1 of the Manual.

Before Cleaning

Disconnect the product from operating power before cleaning.

Safety Earth Ground

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

Warning Symbols That May Be Used In This Book



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



Indicates hazardous voltages.

Safety Considerations (contd)



Indicates earth (ground) terminal.



or



Indicates terminal is connected to chassis when such connection is not apparent.



Indicates Alternating current.



Indicates Direct current.

WARNING

BODILY INJURY OR DEATH MAY RESULT FROM FAILURE TO HEED A WARNING. DO NOT PROCEED BEYOND A WARNING SIGN UNTIL THE INDICATED CONDITIONS ARE FULLY UNDERSTOOD AND MET.

CAUTION

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For additional safety and acoustic noise information, see back matter.

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1

Introduction

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Where to Find It

This manual is designed for those who will assemble, install, program, maintain, and operate angular and linear encoder systems incorporating the Agilent E1710A Angular Encoder System and applicable options, or the Agilent E1720A Linear Encoder System and applicable options. This manual also applies to the subsystems Agilent E1711A, Agilent E1712A, Agilent E1713A, and Agilent E1714A. This manual contains the following chapters:

Chapter 1, Introduction, introduces the Agilent E1710A Angular Encoder System, the Agilent E1720A Linear Encoder System, and their options.

Chapter 2, Installing Encoder Systems, shows you how to assemble and install Agilent E1710A and Agilent E1720A system components and applicable options. The chapter also provides information on software installation and system verification.

Chapter 3, Getting Started with TUNE1713, shows you how to install the TUNE1713 software and how to determine approximate servo coefficients for a PID controller.

Chapter 4, TUNE1713 Parameters Reference, provides detailed information on the TUNE1713 software.

Chapter 5, Getting Started with Programming, shows you how to program the Agilent E1713A with its supplied command set.

Chapter 6, Register Operation and Command Description, is a reference to the Agilent E1713A command set.

Chapter 7, Profiling, describes how the Agilent E1713A generates position reference data.

Chapter 8, Maintenance and Troubleshooting, deals with problem solving, ordering replacement parts, and handling system components.

Chapter 9, Encoder System Components, contains descriptions of the individual system components and operating theory and specifications for the Agilent E1713A.

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Introduction to the Encoder Systems

System designers installing and using the Agilent E1710A or Agilent E1720A systems and their options, and those involved in assembling and maintaining them, should be familiar with lasers, optics, electronics, PC computers, and computer programming languages.

System Usage

These Agilent encoder systems may be used in any application where you need to precisely position, or determine the position of, mechanical systems or parts.

The Agilent E1710A Angular Encoder System may be used in any application where you wish to establish a precise location on an arc. For example, the Agilent E1710A provides hard-disk drive manufacturers with the metrology needed to precisely position disk drive read/write heads over blank disk platters.

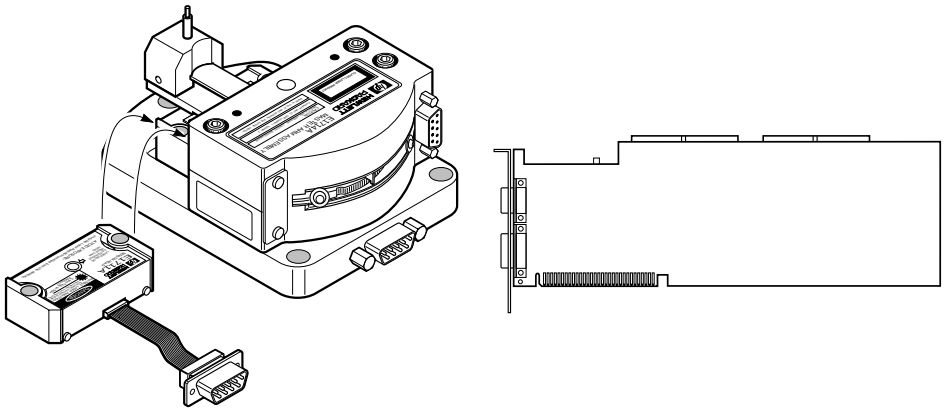


Figure 1-1. Agilent E1710A Angular Encoder System

The Agilent E1720A Linear Encoder System may be used in any application where you wish to establish a precise position on a straight line. The differences between the Agilent E1720A Linear Encoder System and the Agilent E1710A Angular Encoder System are described below.

System Structure

This section lists the components in the Agilent E1710A and Agilent E1720A systems and their options.

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Angular Encoder System (Agilent E1710A)

A complete angular encoder system, suitable for disk drive manufacturing applications consists of the following components and options (see Chapter 9 for descriptions of individual components):

- Agilent E1710A Angular Encoder System (includes the following):
  - Agilent E1711A Sensor Head
  - Agilent E1713A Scale Servo Axis Board
  - Agilent C2932A Sensor Head Cable
  - Agilent E1714-60203 Servo Motor Cable
  - Agilent E1714A Master Arm Assembly (can also be ordered as Agilent E1710A, Opt. 001, with Agilent E1711A Sensor Head and Agilent E1712A, Opt. 038 Angular Scale installed)
  - Agilent E1712A, Opt. 038 Angular Scale, 38.2 mm radius
  - Mechanical Push Pin, Opt. 002
  - Agilent E1710A, Opt. 101 Agilent E1710A/E1720A Encoder Systems User's Manual, which includes the Agilent E1713-13401 3.5-inch system software disk

The Agilent E1711A Sensor Head, Agilent E1714A Master Arm Assembly with Agilent E1712A Angular Scale, and Agilent E1713A Scale Servo Axis Board comprise a closed-loop encoder positioning system.

Linear Encoder System (Agilent E1720A)

A complete linear encoder system consists of the following components and options (see Chapter 9 for descriptions of individual components):

- Agilent E1720A Linear Encoder System (includes the following):
  - Agilent E1711A Sensor Head
  - Agilent E1713A Scale Servo Axis Board
  - Agilent E1712A, Opt. 011, Linear Scale
  - Agilent C2932A Sensor Head Cable
  - Agilent E1720A, Opt. 101, Agilent E1710A/E1720A Encoder Systems User's Manual, which includes the Agilent E1713-13401 3.5-inch system software disk

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System Performance

The Agilent E1710A Angular Encoder System provides digital measurements of angular position over a range of ± 20 º with a LSB resolution of 8 nanoradians (0.0016 arcsec). This corresponds to a linear displacement resolution of 0.3 nanometer at a radius of 38.2 mm (1.504 inches). The system's high resolution and immunity to turbulence make it suitable for use at track densities ranging from 10,000 to 25,000 TPI.

Operating in linear motion, the Agilent E1720A Linear Encoder System provides a displacement LSB resolution of 0.3 nanometer (0.012 µin).

System Theory of Operation

Refer to Figure 1-2, below, which illustrates a typical angular encoder system. A linear encoder system operates in a similar manner, using a linear scale rather than an angular scale carried on a rotating arm.

The sensor head (**1**) contains a laser light source and detector array. The angular scale (**2**) and the mechanical push pin (**3**) are carried on the master arm (**4**) of the master arm assembly (**5**).

The laser beam from the sensor head illuminates the scale. Reflected light is collected and focused via a lens system onto the detector array in the sensor head. The detector array reads the interference pattern between the ± 1 orders diffracted from the scale and measures linear displacement of the scale relative to the sensor head. Knowing the scale radius allows computation of the relative angular displacement.

Measurement signals from the detector array in the sensor head are sent to the Scale Servo Axis board (**6**), where they are compared with previously programmed position parameters. The position a error signal developed is then processed by a PID or IIR control equation.

The output of the control equation goes to a D/A converter, which produces an analog control voltage which is sent to the master arm assembly. There, the voltage is amplified and sent to the master arm servo motor, which is contained in the master arm assembly. In a typical servo writer application, the servo motor drives the master arm and with it, the mechanical push pin. The mechanical push pin positions a disk drive read/write head.

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1 Sensor Head

2 Angular Scale

3 Mechanical Push Pin

4 Master Arm mounted on Master Arm Assembly

5 Master Arm Assembly and base

6 Servo Axis Board

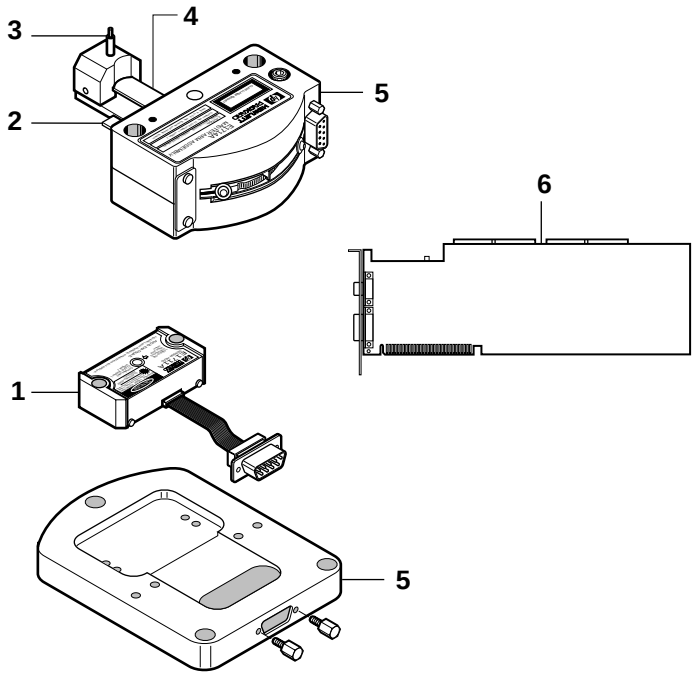


Figure 1-2. Agilent E1710A Angular Encoder System, Operation

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Ordering Encoder Products

These are the standard ways to order **angular encoder** products:

1. Order the Agilent E1710A Angular Encoder System, which includes:
   - Agilent E1711A Sensor Head
   - Agilent E1712A, Opt. 038 Angular Scale, 38.2 mm Radius
   - Agilent E1713A Scale Servo Axis Board
   - Agilent C2932A Sensor Head Cable
   - Agilent E1714-60203 Servo Motor Cable
2. Order a complete, tested system, consisting of the Agilent E1710A Angular Encoder System installed on the Agilent E1714A Master Arm Assembly by ordering Agilent E1710A, Opt. 001. To order a complete positioner system, add the Agilent E1710A, Opt. 002 (Mechanical Push Pin).

   To add the Agilent E1710A/E1720A Encoder Systems User's Manual, which includes the Agilent E1713-13401 3.5-inch system software disk, order Option 101 with item 1 or item 2.
3. Order any angular encoder component individually. For example, order the Scale Servo Axis Board by ordering the Agilent E1713A. Use option code Opt. 038 to order the angular scale.

These are the standard ways to order **linear encoder** products:

1. Order the Agilent E1720A Linear Encoder System, which includes:
   - Agilent E1711A Sensor Head
   - Agilent E1712A, Opt. 011 Linear Scale.
   - Agilent E1713A Scale Servo Axis Board
   - Agilent C2932A Sensor Head Cable

   To include the Agilent E1710A/E1720A Encoder Systems User's Manual and 3.5-inch software disk, add Option 101. To order the linear scale specify option code Opt. 011. You may order custom linear scales by contacting your Agilent Sales Office.
2. Order any of the linear encoder components listed above as an individual item.

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Laser Safety

The Agilent E1711A Sensor Head contains a powerful laser diode that emits invisible infrared light. Do not under any circumstances look directly at the laser light source or allow the laser beam to be directed or reflected into your eyes. You will find the warning labels illustrated below fixed to any device that contains a laser or that may direct a laser beam into your eyes.

You will find a Class I label fastened to the Agilent E1714A Master Arm Assembly. A Class I label is used with components for which there is no need to access the laser beam by either users or service persons.

The Agilent E1711A Sensor Head carries a Class III label. Note that the Class III label carries information that describes the type of laser diode, its continuous wave power, and the wavelength of the beam. When handling a Class III device, no user or service person may take any action that might or will expose the laser beam.

For the Agilent E1711A:

- The scale and the arm carrying the scale must be in place over the laser beam aperture in the sensor head before the system is powered up.
- The unit should never be operated or serviced without the scale in place and covering the laser beam aperture in the sensor head.
- The arm carrying the scale must not be moved in such a way as to expose the laser beam.
- While assembling a system, take no action that will expose anyone to the laser beam.



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2

Installing Encoder Systems

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Introduction

Unpacking and Inspection

CAUTION

Always use Electrostatic Discharge (ESD) precautions when handling electronic components, such as circuit boards and integrated circuits, outside of their protective packing materials.

If the shipping carton is damaged, ask that the carrier's agent be present when the product is unpacked. Inspect the product for damage. If the product is damaged or fails to meet electrical or mechanical specifications, notify the carrier and the nearest Agilent Sales and Service office immediately.

Retain the shipping carton and padding material for the carrier's inspection. The Sales and Service office will arrange for the repair or replacement of your product without waiting for the claim against the carrier to be settled. Also, refer to the section titled *Storage and Shipment*, in Chapter 8.

Laser Safety

The Agilent E1711A Sensor Head contains a powerful laser diode that emits invisible infrared light. Do not under any circumstances look directly at the laser light source or allow the laser beam to be directed or reflected into your eyes. You will find the warning label, shown on the following page, fixed to any device that contains a laser or that may direct a laser beam into your eyes.

You will find a Class I label fastened to the Agilent E1714A Master Arm Assembly. A Class I label is used with components for which there is no need to access the laser beam by either users or service persons. Both angular scales (used in the Agilent E1710A systems) and linear scales (used in the Agilent E1720A systems) must be installed in Class I devices in such a way that no one can access the laser beam.

The Agilent E1711A Sensor Head carries a Class III label. Note that the Class III label carries information that describes the type of laser diode, its continuous wave power, and the wavelength of the beam. When handling a Class III device, no user or service person may take any action that might or will expose the laser beam.

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For the Agilent E1711A:

- The scale and the arm carrying the scale must be in place over the laser beam aperture in the sensor head before the system is powered up.
- The unit should never be operated or serviced without the scale in place and covering the laser beam aperture in the sensor head.
- The arm carrying the scale must not be moved in such a way as to expose the laser beam.
- While assembling a system, take no action that will expose anyone to the laser beam.



Encoder System Installation Overview

Installation procedures depend on the type of encoder system involved (angular or linear), and whether components were purchased as an assembled system or as individual components. If you purchased individual system components, refer to Chapter 9, *Encoder System Components*. Installation of an assembled system consists of:

- Assembling and attaching an angular or linear encoding system to the device to be measured
- Setting address switches on the Agilent E1713A Scale Servo Axis Board and installing it in a PC
- Attaching the appropriate cable(s)
- Installing the system software on the PC

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Installing the Assembled Angular Encoder System

If you purchased the Agilent E1710A Angular Encoder System with Option 001 (Agilent E1714A Master Arm Assembly) fully assembled:

1 Mount the assembled system so that the Master Arm Assembly with attached Scale and Sensor Head are physically connected to the device whose position is to be controlled or measured. Alignment of the system and device is critical.

The following example applies to a disk drive, but you may apply the principle to any device that rotates around a fixed point.

In the case of a disk drive, the master arm may control the position of a read/write head through the use of the mechanical push pin. See Figure 2-1. Note that the travel of the master arm is limited by two stops located on the Master Arm Assembly. Use a 2 mm Allen wrench to adjust these stops.

2 The complete assembly must be mounted relative to the measured or controlled device so that the axis of rotation of the master arm coincides with the axis of rotation of the arm carrying the device.

In Figure 2-1, note the system datum hole located in the Master Arm Assembly. The system datum is the point around which the master arm rotates. The distance between this datum point and the alignment mark on the angular scale is 35.66 mm (1.404 in.).

The system datum hole is tapped for a 5-40 pin that can fit into a disk drive arm bearing, thus establishing alignment between the angular scale and the disk drive arm.

3 After attaching the angular scale to the device, go to the section titled *"Installing the Agilent E1713A Scale Servo Axis Board" on page 2-8*.

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1 System Datum (center of rotation for master arm)

2 System Datum Pin

3 Agilent E1714A Master Arm Assembly

4 Agilent E1712A Angular Scale

5 Agilent E1711A Sensor Head

6 Ribbon Cable and DB9 Connector

7 Sensor Head Alignment Holes

8 Master Arm Assembly Base

9 Master Arm Assembly Alignment Holes

10 4-40 Screwlocks, Washers, and Nuts

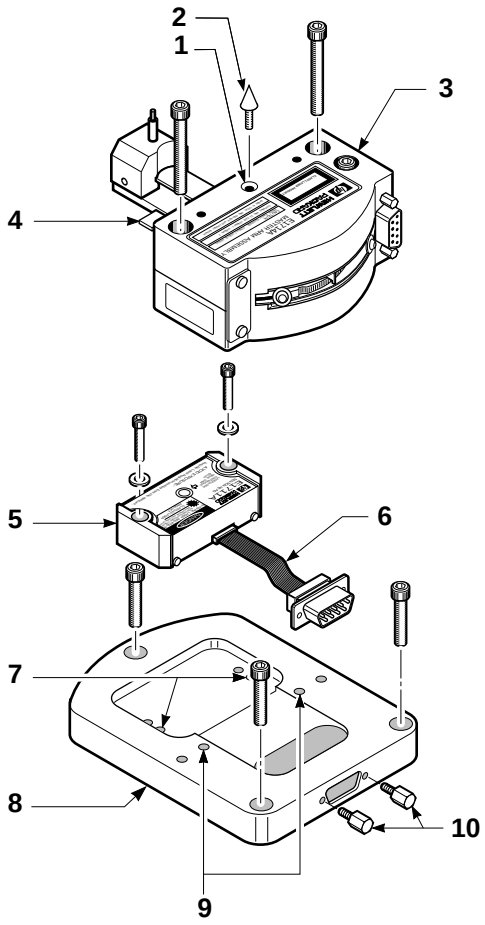


Figure 2-1. Exploded View, Angular Encoder System

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Installing the Agilent E1720A Linear Encoder System

The Agilent E1720A Linear Encoder System consists of the Agilent E1711A Sensor Head, the Agilent E1713A Scale Servo Axis Board, the Agilent E1712A, Opt. 011 Linear Scale, and a Sensor Head Cable. The linear scale must be mounted only in Class I systems, and mounted in a way that anyone using or servicing the system cannot be exposed to the laser beam. Before installing an Agilent E1720A system, refer to the section "Laser Safety" on page 2-3. Agilent E1720A installation consists of:

1 Attaching the linear scale to a mechanical device whose position is being controlled or measured. Refer to Chapter 9 for information on tolerances and spacing considerations.

2 Precisely placing the sensor head relative to the linear scale so that the position resulting from the linear motion of the mechanical device is correctly recorded. Refer to Chapter 9 for information.

3 After attaching the linear scale to the device, go to the section titled *"Installing the Agilent E1713A Scale Servo Axis Board" on page 2-8.*

Installing Angular and Linear Encoder Components

You may purchase individual angular and linear encoder system components. For information on assembling these components, refer to Chapter 9.

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Installing the Agilent E1713A Scale Servo Axis Board

Safety Precautions

When installing the Agilent E1713A in a PC, observe the following precautions:

- Always turn off and unplug the PC before removing the cover(s).
- Carefully read your PC user's guide for safety precautions specific to your PC. Also look for and observe any caution notices printed inside the PC.
- When working inside the PC, be sure to wear a grounding strap and observe standard grounding procedures to prevent electro-static discharge (ESD) and possible damage to the Agilent E1713A board or your PC.

Unpacking and Inspection

CAUTION

Always use Electrostatic Discharge (ESD) precautions when handling the Agilent E1713A board outside of its protective packing materials.

The Agilent E1713A Scale Servo Axis Board Package

When you order the Agilent E1710A with Opt. 101 or the Agilent E1713A with Opt. 101, the board is shipped with the following items:

- Agilent E1710A/E1720A Encoder Systems User's Manual.
- 3.5-inch disk with software programs (Agilent E1713-13401).

Installation Overview

Installing the Agilent E1713A consists of two steps:

1. Setting the Agilent E1713A board I/O address
2. Installing the Agilent E1713A board in the PC.

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Addressing the Agilent E1713A Servo Axis Board

The Agilent E1713A board appears as 32 I/O locations on the PC I/O backplane. The board uses backplane address lines A0 through A12.

Address lines A2–A9 are compared to the board's address switch to decode the board, while A0–A1 and A10–A13 are used to select the various registers. The Base Address is determined by multiplying the value set on address switch by four. The value of the address switch can be determined by picturing the switch as a binary number where a switch in the up position corresponds to a one and a switch in the down position corresponds to a zero.

For example, an address switch set like this:

		I						
ON	I		I	I	I	I	I	I
	A9	A8	A7	A6	A5	A4	A3	A2

corresponds to the binary value 01000000, which is equal to a decimal value of 64 and a base I/O address decimal value of 256. The decimal value of the base I/O address is equal to the decimal value of the switch setting multiplied by 4 ($64 \times 4 = 256$). The factory default setting for the switch is decimal 65 (binary 01000001), which equals a base I/O address (decimal) value of 260.

Record your address switch setting here for future reference:

Address Switch: _____

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Setting the I/O Address

WARNING **UNPLUG THE POWER CORDS TO PREVENT PERSONAL INJURY AND DAMAGE TO THE ELECTRONICS.**

The 8-bit I/O address switch sets the board's base address in the PC's I/O memory. See Figure 2-2 for location of the I/O address switches.

1 60-pin connector, reserved for future product enhancements; Agilent Part Number 1252-1642 (Mating Connector 3M 7960-6500 EC; 3334-xxxx Series or equivalent)

2 Analog Output (SMB Male Connector)

3 Factory Use Only

4 Rear Panel 9 Pin D Connector (Sensor Head)

5 Rear Panel 25 Pin D Connector. Analog Out: Pin 14 Analog Gnd: Pins 1, 2 Digital Gnd: Pin 15

6 Base I/O Address Switch. In the example, the switch is set for an I/O address of 260 which corresponds to a setting of decimal 65 on the address switch

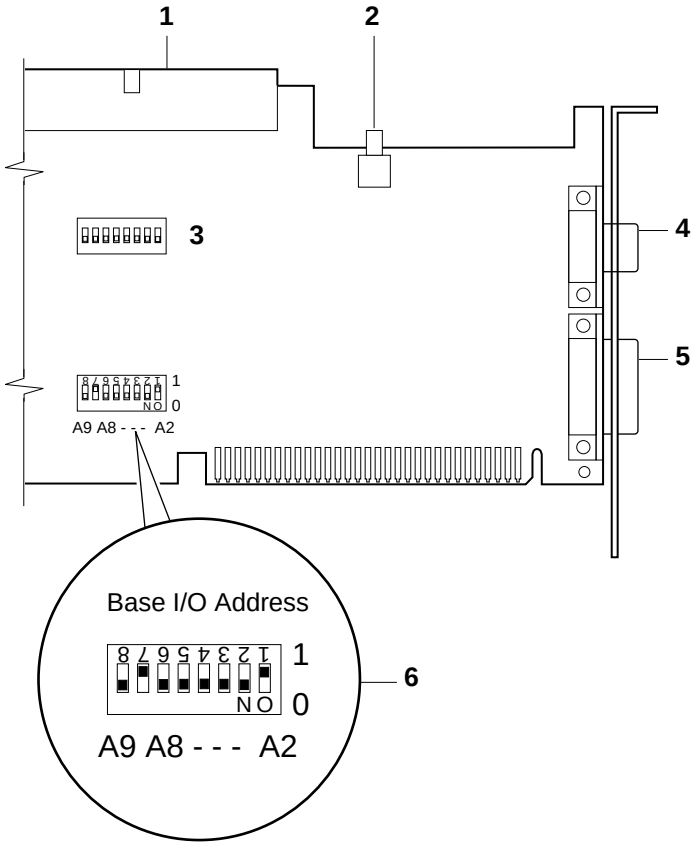


Figure 2-2. Agilent E1713A Address Switches

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Installing the Board in Your PC

Ensure that correct power and cooling will be supplied to the board before installation. (For power requirements, refer to the Agilent E1713A specifications in Chapter 9.) The board (and the voice coil motor mounted in the Agilent E1714A Master Arm Assembly) receives power from the PC backplane. Use the procedure described below to install the board into the desired slot of your PC.

CAUTION The board may be damaged by static discharge. Carry out board installation only in static safe work areas and observe ESD handling procedures.

1. Remove the PC's case covers.
2. Select an empty 8- or 16-bit slot.
3. Remove the slot's cover plate and save the retaining screw.
4. Align the board with the slot's card guide.
5. Slide the board into place.
6. Firmly seat the board in the backplane connector. Make sure that the board connectors are firmly seated without binding or jamming.
7. Secure the board in place with the retaining screw.
8. Replace the PC's case covers.

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Connecting the Cables

The connections between the Scale Servo Axis Board and the Angular Encoder System consist of a Sensor Head Cable (Agilent C2932A) and a Servo Motor Cable (Agilent E1714-60203). Both cables are supplied with the Agilent E1710A. See Figure 2-3.

The Sensor Head Cable is also supplied with the Agilent E1711A Sensor Head when this item is ordered separately, and with the Agilent E1720A Linear Encoder System. The Servo Motor Cable is supplied with the Agilent E1714A Master Arm Assembly when this item is ordered separately.

Sensor Head Cable Connection

The sensor head signal is brought out to a male DB9 connector attached to a ribbon cable. Use a DB9 female-to-male cable to attach this connector to the female DB9 detector connector located on the Scale Servo Axis Board mounting plate. See Figure 2-3.

Servo Motor Cable Connection

The servo motor signal is brought out to a female DB9 connector located on the base of the Master Arm Assembly. Use a DB9 male-to-DB25 male cable to connect the servo motor signal to the female DB25 connector located on the Scale Servo Axis Board mounting plate. See Figure 2-3. The DB25 female connector on the board also supplies +12 VDC to the servo amplifier and servo motor located in the Master Arm Assembly.

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1 Agilent E1713 Scale Servo Axis Board

2 Female DB9 Connector

3 Male DB9 Connector

4 Agilent C2932A Sensor Head Cable

5 Female DB9 Connector

6 Male DB9 Connector

7 Agilent E1711A Sensor Head

8 Female DB9 Connector

9 Male DB25 Connector

10 Agilent E1714-60203 Servo Motor Cable

11 Male DB9 Connector

12 Female DB9 Connector

13 Agilent E1714A Master Arm Assembly

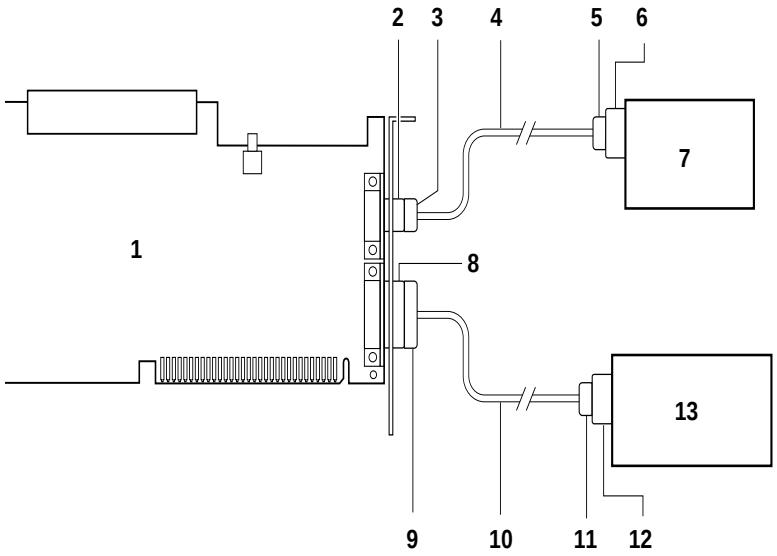


Figure 2-3. Agilent E1710A to Agilent E1713A Cable Connections

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Servo Motor Drive Output Cable Connection

The ±10-volt analog output is available both inside the PC at the SMB connector, and at the 25-pin rear-panel connector. (The shell is analog ground.) On the rear panel 25-pin D connector, pin 14 is the ±10 Volt signal. Pins 1 and 2 are analog ground. You can connect the ±10 volt output to a power-amplifier's control input. The output signal is protected by a 100-ohm series resistor and cannot drive a motor directly.

The two 60-pin board edge connectors (J2 and J3) on the top of the Agilent E1713A provide a 32-bit position output. They may also be used for future product enhancements. Looking at the backside of the board, pin one is designated by a square footprint and sequential pins (2, 3, 4, …) proceed in alternating order. Raw position output is also provided on these connectors, and you may find them useful for custom applications. Contact Agilent for your requirements. See Chapter 9, Agilent E1713A specifications for J2 and J3 pinouts.

Connector	Agilent Part Number	Manufacturer's Part Number	Manufacturer
60-pin Board Edge Connector*	1252-1642	7960-6500 EC	3M Company
SMB Male Connector	1250-1368	51-053-0129	Sealectro Corp.

* Mating connector is 3M Company 3334-XXXX series

Installing the Software

The software is supplied on the 3.5 in. program disk (Agilent E1713-13401). Refer to Chapter 3, *Getting Started with TUNE1713*, for information on installing and running the software.

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3

Getting Started with TUNE1713

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Introduction

The DOS based TUNE1713 software is a basic design, testing, and troubleshooting tool used for observing and improving the performance of closed loop control systems used with the Agilent E1713A Scale Servo Axis Board.

You use TUNE1713's Front Panel Display to enter and edit setup and servo parameters and to command moves. Completion of a move brings up the Results Display, which displays position error, reference position, feedforward, and servo parameters along a time axis.

Running TUNE1713 from the DOS prompt, you can:

1. Verify that the sensor head/scale and signal processing circuits in the Agilent 1713A are producing valid measurements;
2. Select a PID ([Proportional Integral Derivative] with or without feedforward) or IIR (Infinite Integral Response) filter, then set coefficients, sample rate and polarity;
3. Select step size;
4. Initiate a step and immediately observe a graphed response of position error vs. time;
5. Return to the TUNE1713 Front Panel display from any TUNE1713 screen by pressing any key.
6. View graphs of feedforward, reference position, and servo voltage vs. time by selecting the relevant function key.

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Installing the TUNE1713 Program

To run TUNE1713 from your hard drive, you must have the TUNE1713 executable file and several Borland Graphics Interface (BGI) files installed on your hard drive.

Installing TUNE1713

To install the TUNE1713 program on your hard drive, copy the TUNE1713.EXE executable file from the diskette supplied with this manual to the directory on your hard drive from which you will run TUNE1713.

You may run TUNE1713 directly from the root directory on your hard drive, or you may use the DOS MKDIR command to create a separate directory.

For information on creating directories, refer to your DOS documentation or DOS Help.

TUNE1713 uses the Borland Graphics Interface files (LITT.CHR, ATT.BGI, CGA.BGI, EGAVGA.BGI, HERC.BGI, IBM8514.BGI, PC3270.BGI). These files are located on the diskette provided with this manual, in the directory named TC\BGI. You may copy these files to your hard drive's root directory, to the directory that contains TUNE1713.EXE, or to a directory named TC\BGI. See *Installing Graphics Interface Files*, below.

Installing Graphics Interface Files

To install the Borland Graphics Interface files on your hard drive:

1. You may use the DOS MKDIR command to create the \TC\BGI directory on your hard drive unless you prefer to copy the graphic interface files to the root or TUNE1713 directory.

2. Use the DOS command XCOPY to copy all the files in TC\BGI on the software disk to your hard disk, putting them either in the root directory, the TUNE1713 directory, or the TC\BGI directory.

TUNE1713 should be now properly installed.

Before starting TUNE1713, the Agilent E1713A board must be installed in your PC and connected to the encoder system as described in Chapter 2.

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TUNE1713 Screens

The TUNE1713 program has four screens, the TUNE1713 Initial screen, the Front Panel Display screen, the Results Display screen, and the Step Response screen.

TUNE1713 Initial Screen

When you start the TUNE1713 program, the TUNE1713 Initial screen is displayed. After you respond to the prompt for the Agilent E1713A board's I/O address, the Front Panel Display screen is displayed.



Figure 3-1. TUNE1713 Initial Screen

Front Panel Display Screen

The Front Panel Display screen (see Figure 3-2) contains a number of fields in which you can enter and display TUNE1713 parameters. These parameters and their default values are summarized in Table 3-2, below. Also see Table 6-1 in Chapter 6, *Register Operation and Command Description*, for additional information about the parameters, including data type, units, range, and default values.

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HELP text is located at the bottom of the screen, just above the line of soft function key labels (softkeys). The HELP text changes with the location of the highlighted entry field and whenever a softkey is selected.

The softkey labels are located at the bottom of the display, and change when either the **SHIFT**, **CTRL** or **SHIFT+CTRL** keys on the computer keyboard are pressed. The softkeys and the functions they initiate are summarized below and fully described in Table 3-3.

Unshifted Keys	F2:DrvOff	F3:ClrPOS	F4:RdBrd	F5:ClrErr	F6: Move	F7: Step	F8:Replot
Shift	F2:Drv ON	F3:ClrNul	F4:Rd Rev		F6:MltMov	F7:MvToDH	
Shift+Control			F4: CODE				
Control	F1:LL	F2:LL 2nd					F8:PIDIIR

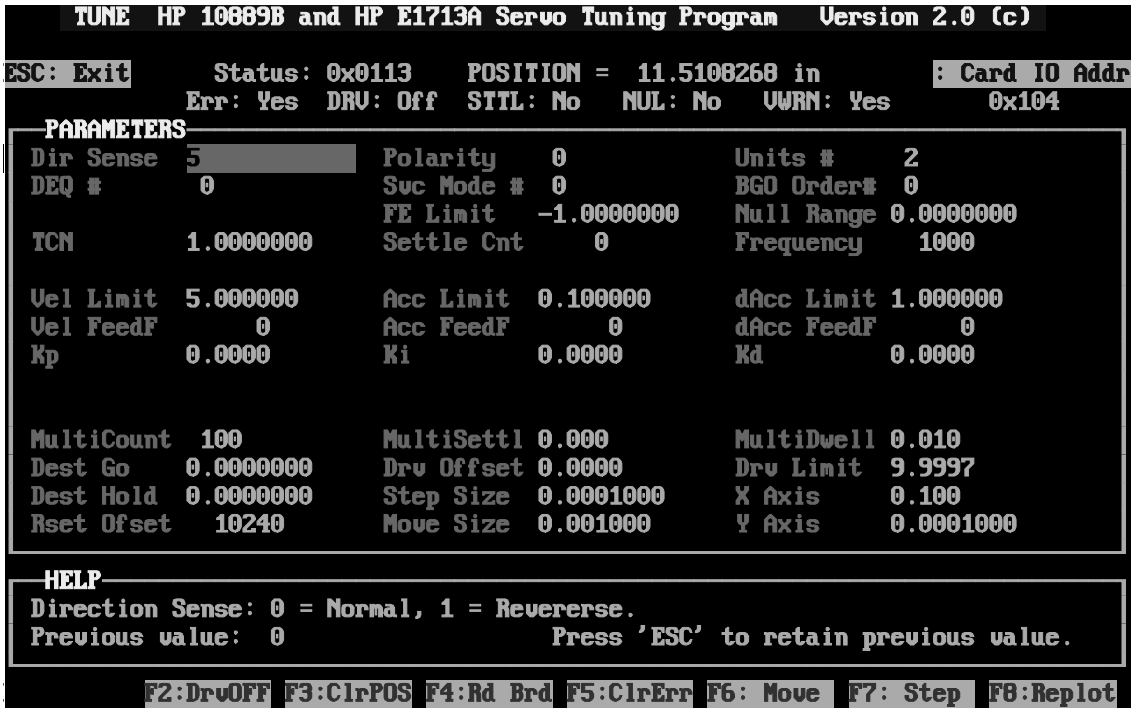


Figure 3-2. TUNE1713 Front Panel Screen

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TUNE1713 Front Panel Display Screen Details

The Front Panel screen is divided into several sections. The information in the PARAMETERS box is described in Table 3-1, below. The information in the upper section of the screen and in the HELP box at the bottom of the screen are also described in Table 3-1.

For Status Line 2, each item indicates the status of a status bit in the Agilent E1713A board's status register. See Chapter 6, *Register Operation and Command Description*, for more information.

Table 3-1. Front Panel Display Screen Details

Lines	Functions
Line 1: Program Title	Displays program title and code revision
Line 2: Status	**ESC: EXIT**; to exit the program, press the keyboard's ESC key. **Status:** Information in this field is for factory use only. **POSITION = 0.0000 in**; indicates a linear position reading in units of inches, millimeters, or counts; unit type is selected in the PARAMETERS box. **F9: Card IO Address**; if your system has two or more Agilent E1713A boards, pressing the computer keyboard's F9 function key lets you change the I/O address of the card currently in use.
Line 3: Status	**Err**: Yes or No. Indicates if any error conditions exist on the board. **DRV:** On or Off. Indicates whether the difference equation is running or not. **STTL**: Yes or No. Indicates if the position error has been within the null size window for settle count servo sample periods after the last profiled move. **NUL:** Yes or No. Indicates if the position error is less than the programmed null size. **VWARN**: Yes or No. Indicates if the stage velocity has approached the velocity limit. **0x000**: Hexadecimal address of the Agilent E1713A board in the PC's I/O backplane.

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Table 3-1. Front Panel Display Screen Details (Continued)

Lines	Functions
HELP Box: The following errors will be high-lighted if they occur	**Code Err**: The board has experienced a firmware code error and must be rebooted; use **SHIFT+CTRL+F5** to reboot. **XYLow:** Amplitude of laser beam returned from scale is too low to give accurate readings; check scale cleanliness and alignment; check amplitude of X and Y signals at TP(X) and TP(Y). **VelErr:** Scale velocity limit has been exceeded. **OverFlow:** The position counter has overflowed. **NullErr:** The position error has exceeded the programmed null size since the last Clear Null Error command. You can clear the Null Error by pressing **SHIFT+F3: ClrNul**. **FollowErr:** The position error has exceeded the programmed maximum following error. **TimeOut**: The board took too long to respond when the program tried to read or write a value. **RangeErr**: A value has been sent to the board that is out of range for the specified parameter. **Note** Issuing a board reset command (**F5: ClrErr**) will clear all errors except the out-of-null error (**NULER**), which must be cleared with **SHIFT+F3: ClrNul**.

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TUNE1713 Front Panel Display Screen Parameters

The Table 3-2 lists Front Panel Display screen parameters and their default values. See Chapter 4 for a description of each parameter.

Table 3-2. Front Panel Display Screen Parameters

Parameter	Default Value	Parameter	Default Value
Dir Sense	0	Ki	0
DEQ #	0 (PID)	MultiSettl	-
TCN	1.00000000	Drv Offset	0
Vel Limit	5 in/sec	Step Size	-
Vel FeedF	0	Move Size	-
Kp	0	Units #	2
MultCount	-	BGO Order	0
Dest Go	0	Null Range	0
Dest Hold	0	Frequency	10,000 (1k Hz)
Rset Offset	-	dAcc Limit	1
Polarity	0	dAcc FeedF	0
Svc Mode #	0	Kd	0
FE Limit	-1	MultiDwell	-
Settle Cnt	0	Drv Limit	32767 (10 V)
Acc Limit	0.1	X Axis	-
Acc FeedF	0	Y Axis	-

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TUNE1713 Function Keys

The TUNE1713 program supports four sets of function keys, each selected by a different combination of the **SHIFT** and **CTRL** keys. The list below summarizes the operation of each function key. Refer to Chapter 4 for a detailed description of each function key.

Table 3-3. TUNE1713 Function Keys

Key	Function
F2:DrvOFF	Turn OFF the servo drive output.
F3:ClrPos	Reset the position counter to zero.
F4:RdBrd	Read all setup parameters from the board and update the display.
F5:ClrErr	Reset any errors on the board.
F6: Move	Perform a profiled move and display the resulting move data.
F7: Step	Perform a step move and display the resulting step response data.
F8:Replot	Replot the last graph with the current graph scaling.
SHIFT+F2:Drv ON	Set destination to current position & turn on the servo drive.
SHIFT+F3:ClrNul	Clear the out-of-null error bit (**NULER**).
SHIFT+F4:Rd Rev	Read and display the boards firmware revision code.
SHIFT+F6:MltMov	Start the multiple move function.
SHIFT+F7:MvToDH	Initiate a move to the **Dest Go** parameters value.
CTRL+F1:LL	Enter Gain, Zero, and Pole for Lead-Lag filter. Calculate and download IIR filter coefficients.
CTRL+F2:LL 2nd	Enter Gain, Zeros, and Poles for 2nd order Lead-Lag filter. Calculate and download IIR filter coefficients.
CTRL+F8:PIDIIR	Converts current PID coefficients to corresponding IIR coefficients. Loads these new IIR coefficients. Switches to IIR equation if current equation is PID.
SHIFT+CTRL+F4: CODE	Downloads new firmware code. Prompts for name of DOS file containing firmware code. This file must be located in the same directory from which TUNE1713 was started.
SHIFT+CTRL+F5: BOOT	Reboot board and set all parameters to default power up values.
F9	Enter new card address switch setting. (I/O address/4)
SHIFT+F9	Enter new card address switch setting. (I/O address/4)
CTRL+F9	Enter new card address switch setting. (I/O address/4)
SHIFT+CTRL+F9	Enter new card address switch setting. (I/O address/4)

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TUNE1713 Results Display Screen

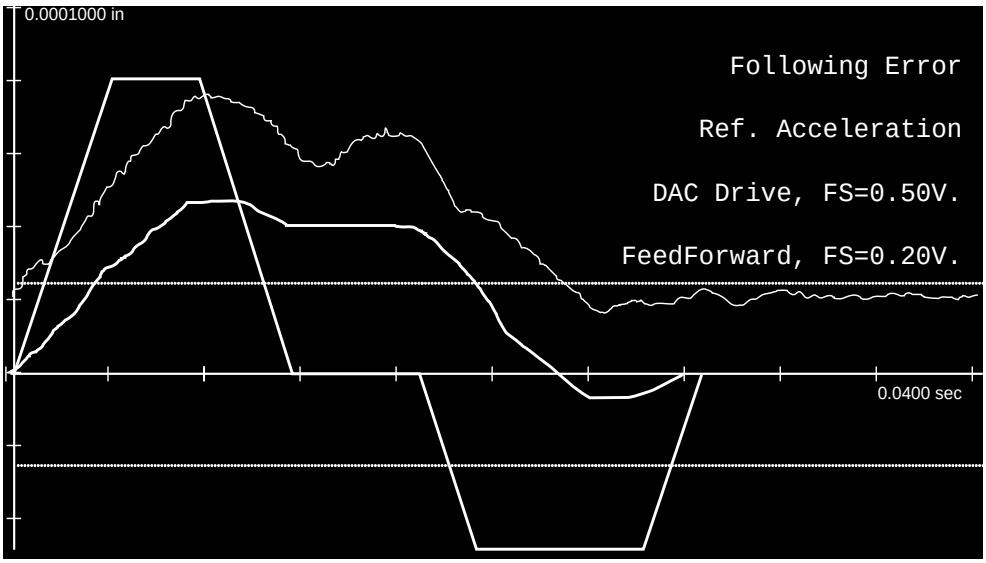


Figure 3-3. TUNE1713 Results Display Screen

The Results Display screen (see Figure 3-3) shows closed-loop step responses and move responses. This screen is automatically enabled only after a step (**F7: Step**) or a move (**F6: Move**) is commanded **and** the stage has settled within the specified settle count and null range. When the null range or settle count are too small, TUNE1713 will prompt you to press any key to enable the Results Display screen even though the stage did not meet your specified settling requirements.

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TUNE1713 Step Response Screen

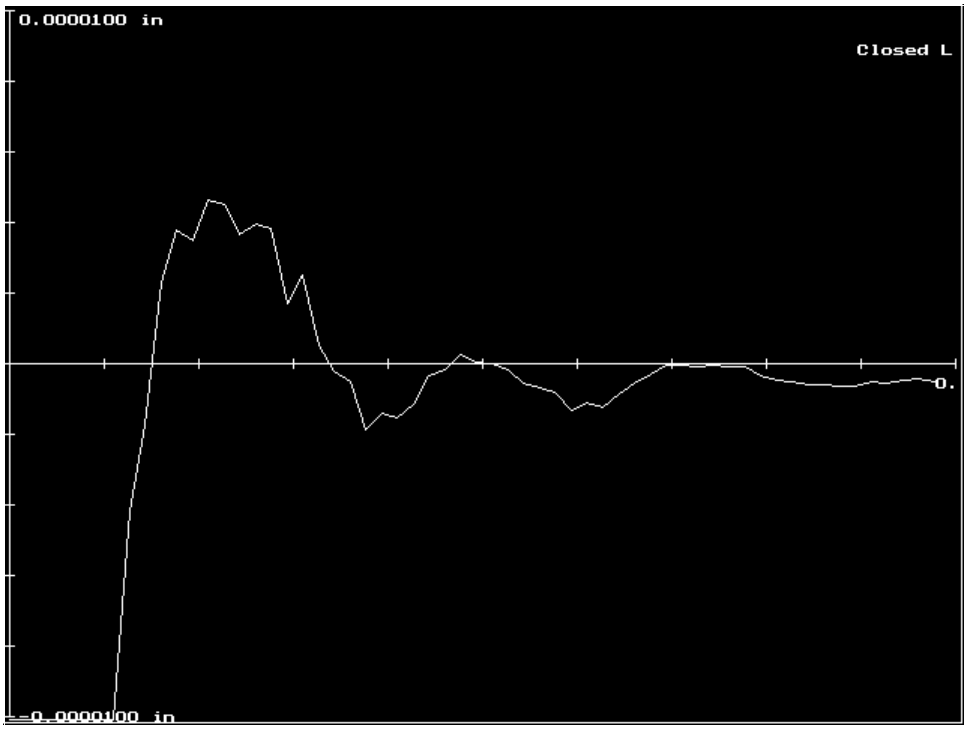


Figure 3-4. Step Response Screen

This screen displays the system's step response using the current servo coefficients. Refer to the section in this chapter titled *Viewing Step Response*, for information on the use of this screen.

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Starting TUNE1713

To start the TUNE1713 program:

1 In the directory containing TUNE1713.EXE, enter **TUNE1713** at the DOS prompt. You will see the TUNE1713 Initial Screen (Figure 3-1).

2 The TUNE1713 program prompts for the board's I/O address switch setting. For information on this setting, refer to the section "*Installing the Agilent E1713A Scale Servo Axis Board*" in Chapter 2.

The board's I/O address switch setting is the board's true I/O address setting divided by four. If you are using the factory default setting, enter the number "65." Do not enter the quote marks.

Possible Error Messages

Table 3-4 describes the sense of possible startup error messages and steps you can take to correct them.

Table 3-4. Startup Error Messages and Corrective Actions

Error Message	Corrective Action
Tells you the Agilent E1713A board cannot be found.	Check the I/O address switch settings on the Agilent E1713A. See Chapter 2.
Tells you that the Graphic files cannot be found.	Check the root or TC/BGI directories for the presence of the graphic files. See *Installing Graphics Interface Files* in this chapter.

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3 If TUNE1713 starts properly, you will see the Front Panel Display.

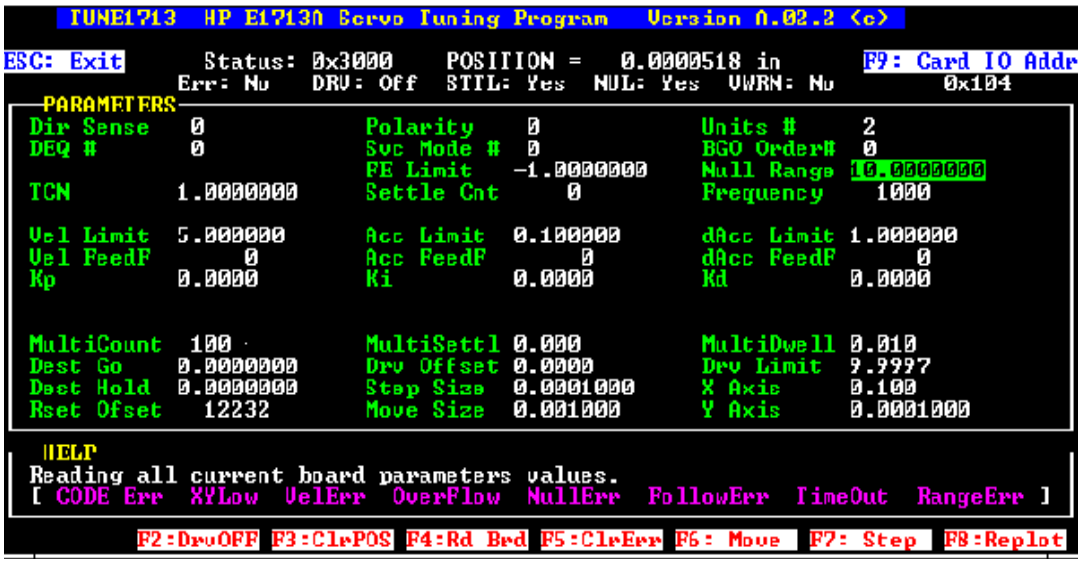


Figure 3-5. TUNE1713 Program Front Panel Display

NOTE

The Front Panel Display may come up with an **Err:** status of **YES** and the **OverFlow** code at the bottom of the screen flashing **NullErr**. If so, check the value of the **Null Range** field (in the right-hand column of parameters). If the value is zero, move the highlighted cursor to the field, enter a small value, such as 0.1, then press **Shift+F3** to clear the **Null Err** message and **Shift+F5** to clear the **Err:** field.

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TUNE Program Basics

TUNE program operation follows these rules:

- Pressing the **ESC** key quits the current operation and returns you to the Front Panel screen or to the DOS prompt.
- A single line of help text for the current highlighted entry field is displayed near the bottom of the screen.
- The cursor keys move the highlighted entry field around the screen.
- The **SHIFT** and **CTRL** keys change what the function keys do.
- A line at the bottom of the screen displays the current function keys' operation.
- Pressing **ENTER** or a number key starts the entry mode for the value in the current highlighted entry field.
- Pressing **ENTER** or **ESC** ends the current entry mode.

To exit the TUNE program, Press the **ESC** key (You may have to press it twice if in data entry mode).

Moving Around in the Displays

Enter or change setup and servo parameters and command moves in the Front Panel (see Figure 3-5). After you command a move and it is successful, TUNE1713 brings up the Results Display, which displays position error and reference position along a time axis (see Figure 3-6). Use the appropriate function keys to observe feedforward and servo motor drive.

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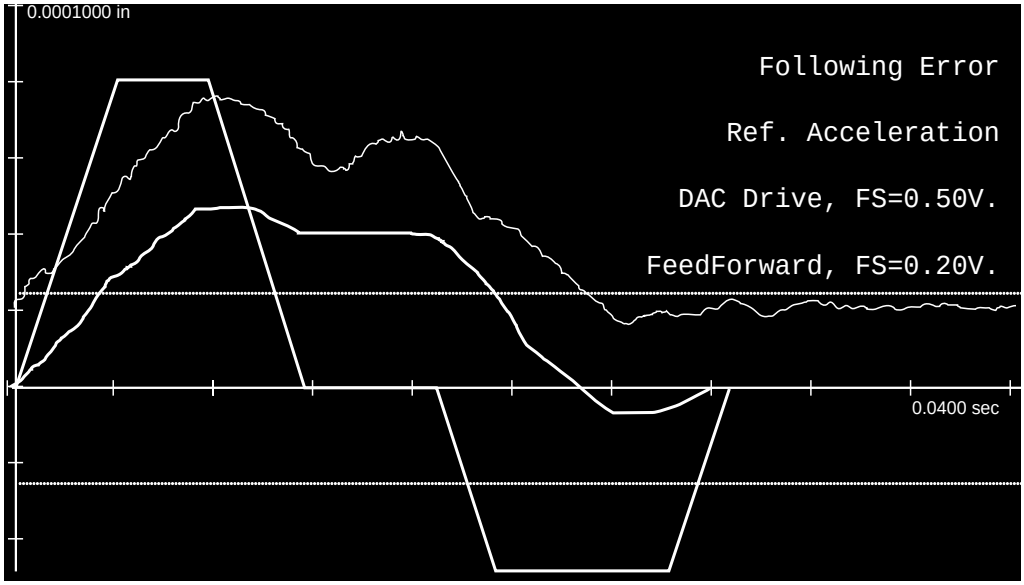


Figure 3-6. TUNE1713 Program Results Display

Moving Between Screens

From the Results Display, you toggle back to the front panel screen by hitting the spacebar on your keyboard. From the Front Panel, you can view any previous results display by hitting the **F8: Replot** function key. This is useful if you want to review the results of the last move after changing the X-axis parameter.

Moving Around in the Front Panel Screen

Use your keyboard's arrow keys (up/down/left/right) to move around in the Front Panel's **PARAMETERS** box. The cursor position is indicated by a highlighted entry field. The **HELP** box at the bottom of the screen provides a one line description on any highlighted entry fields in the **PARAMETERS** box.

Changing Parameter Values

To change a parameter's value, move the cursor to the entry field directly to its right. Type in the new value and press **RETURN** or **ENTER**. To cancel the new value and retain the old value, press the **ESC** key instead of **RETURN** or **ENTER.** Refer to Chapter 4 for complete descriptions of the parameters.

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Using TUNE1713 Function Keys

You can access frequently used TUNE1713 commands at the bottom of the TUNE1713 Front Panel where they are displayed as function keys. (See Table 3-3 on page 3-11). You can access additional sets of command functions by depressing the **SHIFT** key, the **CTRL** key, or the **SHIFT+CTRL** keys. To use these other function keys, press your keyboard's **SHIFT** (or **CTRL** or **SHIFT+CTRL**) at the same time you press the function key (**F1** through **F8**).

See Chapter 4, TUNE1713 Parameters Reference, for complete descriptions of the TUNE1713 function keys.

Executing a Function Key Function

1. Hold down **SHIFT**, **CTRL**, **SHIFT+CTRL**, or neither key to select the desired group of function keys. (The labels at the bottom of the display change to reflect the selected group of function keys.)

2. Press the desired function key while holding down the appropriate keys described in step 1.

3. Look at the **HELP** section on the screen for information on the selected function key.

Changing to Another Board at a Different I/O Address

You will need this function if you have more than one Agilent E1713A installed in your system.

1. Press function key **F9**.

2. Enter the switch setting of another board (which is its I/O address divided by four). TUNE1713's front panel screen pops up and you are now ready to tune the new board.

3. If TUNE1713 has started correctly, you will see the Front Panel Display (see Figure 3-2).

Exiting TUNE1713

To exit TUNE1713, press the **ESC** key. If you are in data entry mode, you may have to press **ESC** twice.

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Viewing Step Response

To generate and display the system's step response using the current servo coefficients, press the **F7: Step** function key. This key clears the board's errors and the servo turns on. Then the difference equation is given a step input of the size specified by the **Step Size** value on the Front Panel screen. As the servo system responds to the step, the board captures the position data, which is then graphed for the time specified by the **X Axis** value. The **Y Axis** value specifies the ± axis limits for the graph.

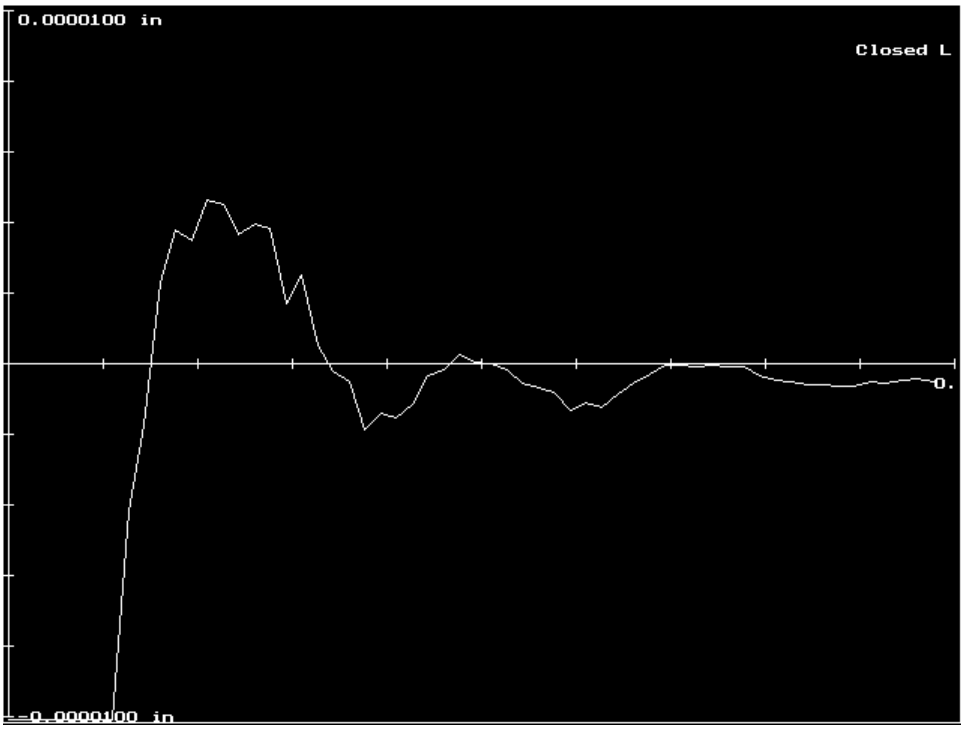


Figure 3-7. Step Response Screen

To return to the Front Panel screen after viewing the graph, press the spacebar. If the graph scales were not appropriate for the system, they can be changed by adjusting the **X Axis** and **Y Axis** values. The same data can then be replotted with the new scaling by pressing the **F8:Replot** function key. You do not have to reinitiate the step.

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Viewing Profiled Moves

To generate and view the results of a profiled move, press the **F6: Move** function key after setting the **X Axis**, **Move Size**, and **Y Axis** values to appropriate values. The stage will first move back to the **Move Size** value, and then capture data when returning to the original location. The position error (or following error) will be plotted along with the reference position's acceleration profile, the drive output voltage, and feedforward's contribution to the drive output voltage. See *Tuning the Servo System: Determining Coefficients*, in this chapter, and Agilent Application Note 325-10 *Sub-micron Positioning* (Agilent publication number 5952-7942) for details on interpreting the resulting graph.

NOTE

If the program gets stuck waiting for the stage to settle, press any key to disable the settling requirement and view the profiled move response.

Press any key to return to the Front Panel screen after viewing the graph.

Executing a Profiled Move to an Arbitrary Location

1. Set the servo coefficients to reasonable values (see *Tuning the Servo System: Determining Coefficients*, in this chapter).
2. Ensure the drive is on (Press **SHIFT+F2**)
3. Move the highlighted entry field to the **Dest Go** parameter.
4. Type in the desired location and press **ENTER**.

Making Multiple Moves

The TUNE program supports repeated moves to simulate some applications. The **MultiCount** value specifies how many times to make moves of the distance **Move Size** before returning to the initial location and repeating the process. After each profiled move, the program will wait **MultiSettl** seconds for the stage to settle (see Settle CountSTLE and Null SizeNUL), and then wait an additional **MultiDwell** seconds before starting the next move. Pressing the **SHIFT+F6:MltMov** function key initiates the multimove function.

The program updates the displayed loop count status after each move.

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If the out-of-null error bit, **NULER**, goes true during the MultiDwell time period, the program displays the loop count and error status, and asks if you want to continue or exit.

To exit the multimove function, press the **ESC** key.

Pressing the **F8:Replot** function key immediately after exiting the multimove function causes the last multimove move to be graphed as if it had been captured with the **F6: Move** function key.

Using IIR Filters

The TUNE1713 program uses three function keys to simplify using the IIR Filter. All are accessed by holding down the **CTRL** key. After pressing one of the function keys, the help text line will request the additional information required to carry out the desired task. Enter the requested information and press **ENTER**.

When all terms have been entered, the program will calculate the IIR coefficients for the desired filter and download them to the board. It will also set the difference equation type to IIR and turn off the servo if the equation type had been PID.

See Agilent Application Note 325-10 *Sub-micron Positioning* (Agilent publication number 5952-7942) for additional information on using the IIR filter.

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Tuning the Servo System: Determining Coefficients

Many methods exist for optimizing servo systems operation. This procedure produces sufficient performance for many applications. Some systems may require more thorough and/or analytical techniques. Application note 325-10, *Sub-micron Positioning* (Agilent publication number 5952-7942), discusses some examples and techniques that can be applied. Also, many text and reference books discuss closed-loop systems in detail.

The PID equation will be used in the following example of Getting Started With TUNE1713. Figure 3-2 shows some suggested values to use in the **PARAMETERS** box: Do not enter coefficient values (**Vel FeedF**, **Acc FeedF**, **dAcc FeedF**, **Kp**, **Ki**, **Kd**) just yet.

In the following procedure, you may want to change some of the suggested values if you know the move size your application typically requires.

Setting Up

1. For purposes of tuning and familiarization, enter a move size and Step size 100 times larger than your typical move.

2. Set an X axis time value about ten times longer than your application's typical settling time.

3. Choose a Null Range and Y axis about 100 times larger than the expected size of your settling size window.

4. These are all starting values that will be decreased once you begin tuning your system.

Determining Differential Gain, Kd

1. Press function key **F7: Step** and examine the graphed response. You should see little or no movement, since all servo coefficients are zero. Press any key to return to TUNE1713's main screen.

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2 Increase **K_d** and repeat step 1 until the arm or stage (device carrying the angular or linear scale*) begins to be unstable. The arm will begin to be unstable when the Following Error starts to ring. You may need to adjust **Drive Offset** to center the graphed response.

* All ensuing references to "arm" include the term "stage."

3 Set **K_d** to one third of the final value in step 2.

Determining Proportional Gain, K_p

1 Press function key **F7: Step** and examine the graphed response. Press any key to return to TUNE1713's main screen.

2 Increase **K_p** and repeat step 1 until the desired rise time, overshoot, and settling performance is achieved. For a starting value, set **$K_p = K_d/15$**.

Acquiring Lock

With these K_p and K_d values, you have enough gain in your system to move. Before tuning the remaining coefficient values, try to acquire servo control lock. To do this:

1 Reset the Position by pressing **F3: ClrPos.**

2 Clear any errors on the board by pressing **F5: ClrErr.**

3 Look at the status line above the **PARAMETERS** box. **Error: No** will indicate that you have cleared all errors on the board. (If you do not see this, look at the **HELP** box for indication of what errors are still present and refer to Chapter 4, *TUNE1713 Parameters Reference*, for further information).

4 With all errors cleared, press **Shift+F2: DrvOn.** The arm should now be locked onto its current position.

5 Physically check the arm or stage for position lock or note that **DRIVE: On** above the **PARAMETERS** box indicates lock. **DRIVE: Off** indicates no lock (meaning the servo application is not running).

6 With lock acquired, move the arm to a reasonable location to perform tuning. Sometimes tuning can be difficult when you are trying to tune at the far end of an arm's range, so position the arm mid-range.

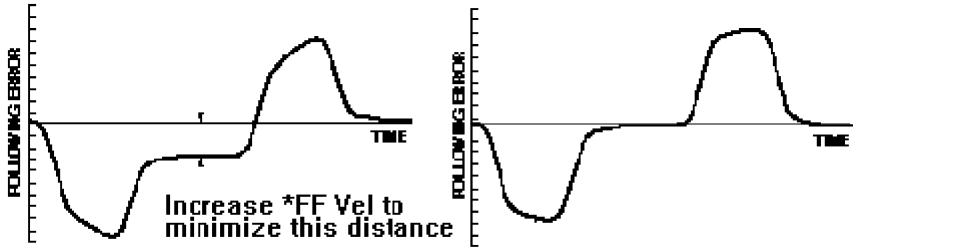
To move the arm using TUNE1713 in the front panel screen, enter the desired destination in the **Dest Go** field entry. The arm will move to the desired position when you press **Enter**. If the arm loses lock, check that **Direction** is properly set.

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Determining Feedforward Terms: Vel FeedF, Acc FeedF, and dAcc FeedF

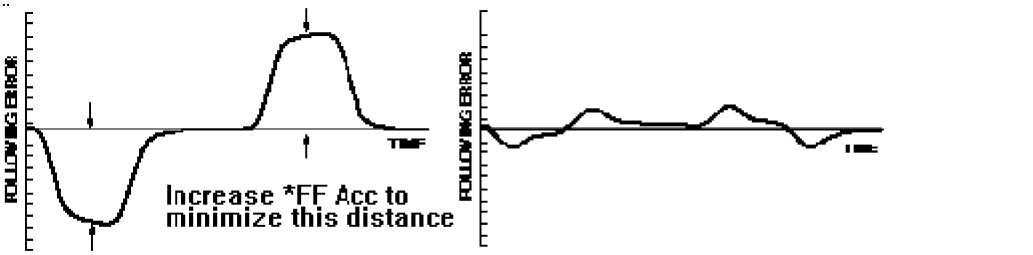
1. Press function key **F6: Move** and examine the graph. Note the Following Error curve. Before starting this procedure, you should see a display similar to that in Figure 3-6.

2. Adjust the **Vel FeedF** and repeat Step 1 until the vertical center of the Following Error plot crosses and is centered around a Following Error of zero.



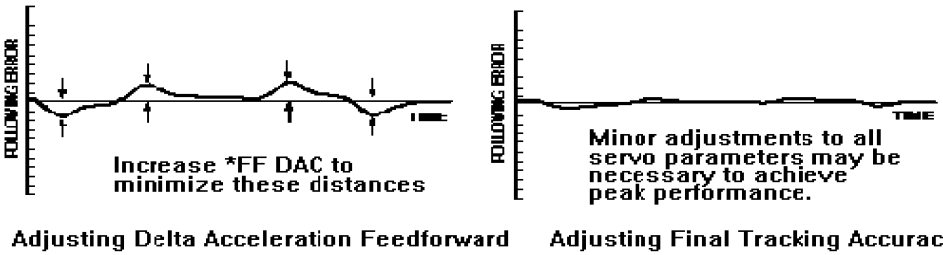
Adjusting Velocity Feedforward Adjusting Acceleration Feedforward

3. While repeating step 1, adjust **Acc FeedF** until the flat tops of the plot are crossing and centered on zero. Note that the left graph below is the same as the right graph in step 2.



Adjusting Acceleration Feedforward Adjusting Delta Acceleration Feedforward

4. While repeating step 1, adjust **dAcc FeedF** until the transition areas are as close to zero as possible. Note that the left graph below is the same as the right graph in step 3.



Adjusting Delta Acceleration Feedforward Adjusting Final Tracking Accuracy

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Determining Integral Gain: K_i

After tuning **K_d**, **K_p**, **Vel FeedF**, **Acc FeedF**, and **dAcc FeedF**, increase the **K_i** coefficient value slowly to integrate position error out of the system. After increasing Ki a little bit, command another **F6: Move** and examine the response. Continue to increase **K_i** until you are satisfied with the accuracy.

This completes the basic tuning procedure. Additional adjustments may be necessary to further improve performance.

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Difference Equation

The difference equation is an integral part of the closed-loop response control to calculate the feedback output signal. It is a function of position error. Position error equals reference position minus actual position. In the Agilent E1713A board, a difference equation is selected using one of the following Difference Equation Number commands:

- Proportional-Integral-Differential (PID)
- Infinite Impulse Response (IIR)
- Custom Downloaded Equation

The PID or IIR equations require coefficients for each of its terms. For the PID equation, three are used. For a second-order IIR equation, five coefficients can be used. The most intuitive and easiest to use equation is the PID, which is the Agilent E1713A's power-up default equation.

PID Equation

The input to the PID difference equation is position error. The output of the equation is the sum of three gain terms: proportional, integral, and differential. Each term has a corresponding coefficient: K_p, K_i, and K_d. The proportional term is position error multiplied by K_p. The integral term is K_i multiplied by the integral of position error. The differential term is K_d multiplied by the derivative of position error. Every sample period, the sum of these three terms, plus any programmed drive offset, is used to produce the final servo output signal. See Figure 3-8.

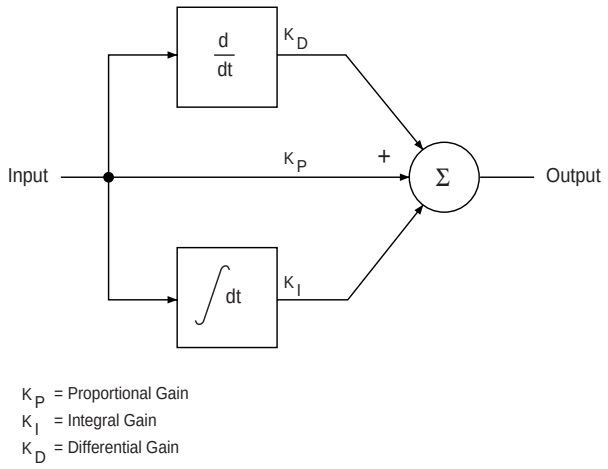


Figure 3-8. PID Difference Equation

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IIR Equation

The IIR equation is commonly used to implement most digital filters. See Figure 3-9, where Z-1 represents a time delay of one sample period. The Agilent E1713A board has a second- and third-order IIR filter. Any s-plane filter can be implemented using an IIR filter given that the order of the IIR filter is high enough. For example, the PID equation has its equivalent IIR representation when the five IIR coefficients are set as follows:

Kx0 = Kp + Ki + Kd
Kx1 = - (Kp + 2Kd)
Kx2 = Kd
Ky1 = 1
Ky2 = 0

For a 2nd order IIR filter, the transfer function is:

$$\frac{C(z)}{E(z)} = \frac{K_{x0}z^2 + K_{x1}z^2 + K_{x^2}}{Z^2 - K_{y1}z - K_{y2}}$$

For a 3rd order IIR filter, the t: $\frac{C(z)}{E(z)} = \frac{K_{x0}z^3 + K_{x1}z^2 + K_{x_2}z + K_{x3}}{Z^3 - K_{y1}z^2 - K_{y2}z - K_{y3}}$

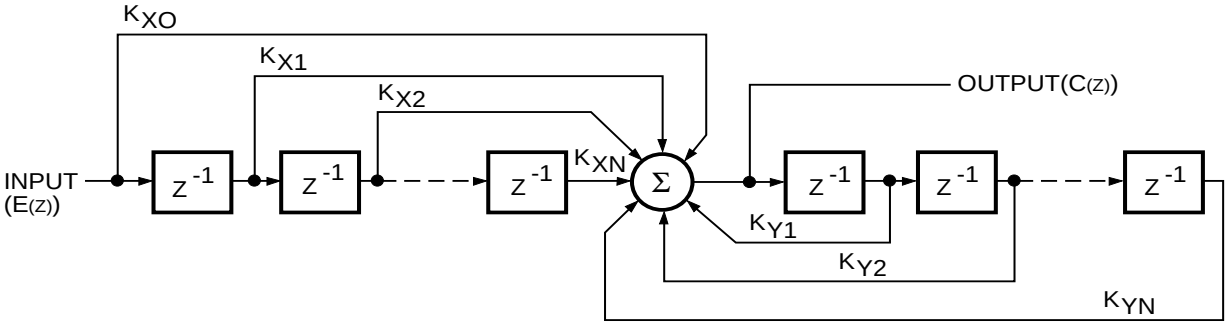


Figure 3-9. Nth Order IIR Difference Equation

See Agilent Application Note 325-10, *Sub-micron Positioning* (Agilent publication number 5952-7942), for more information and detailed analysis on both the PID and IIR equations.

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Putting Everything Together

The Agilent E1713A Scale Servo-Axis Board is a powerful tool, offering numerous options. The best way to move up the learning curve rapidly is to initially work with the TUNE1713 program and with only one axis at a time.

- Determine the direction sense by moving the stage manually and reading position values.
- Verify proper feedback polarity by monitoring the motor drive output line while manually moving the stage. To do this, connect the amplifier input to a variable voltage source, set K_p to a small value, such as 0.1, and send an Acquire Lock command to turn on the motor drive output signal.

  If you move the stage in a direction which you consider positive (to the right, for example) and you get a negative output signal, then the feedback is backwards. To fix this, either swap the motor leads or set the Polarity Parameter to one (1).

- Connect the motor drive output signal to the power amplifier, closing the feedback loop.
- Leave the remaining parameters at default values.
- Roughly tune this axis by following the empirical tuning procedure outlined in Tuning The Servo System. You can use the TUNE program to do this or see Programming Trace Functions for details about getting the data on your own to plot step response.
- Repeat the above for all axes.

Now, some of the more involved options can be explored.

- Experiment with other Sample Period, Velocity Profiling Limit, Acceleration Profiling Limit, and Delta Acceleration Profiling Limit values and see how they affect performance. (Changing Sample Period affects the gain of K_i and K_d). Again use the TUNE program or trace to plot system response.
- Program a buffered filter stimulus signal and trace actual position. The open-loop transfer function can be calculated from this data.
- Program a buffered post-filter injection signal and trace difference equation output. The closed-loop transfer function can be calculated from this data.

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Putting Everything Together

Finally, with the information and experience gathered above, go back and set all parameters to the “optimal” values. Fine tune the servo system, using the difference equation that provides the required system performance. Use the table at the beginning of this chapter for quick reference.

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TUNE1713 Parameters Reference

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TUNE1713 Parameters and Function Keys

The TUNE1713 program has numerous parameters and function key combinations. This section provides a reference for each parameter to its command name. Complete command information is in Chapter 6. Condensed descriptions of each parameter is provided for your convenience. Descriptions of the function keys follow the parameter descriptions.

Table 4-1. The TUNE1713 Parameters Command Names

Command	Meaning	Command	Meaning	Command	Meaning
Dir Sense	Direction Sense	**Polarity**	Polarity of Servo Output	**Units**	Units Type
DEQ	Difference Equation Number	**Svc Mode**	svc	**BGO Order #**	Go Buffered Reference
		FE Limit	Following Error Limit	**Null Range**	Null Range Distance
TCN	Total Compensation Number	**Settle Cnt**	Settle time Count	**Frequency**	Sample Period
Vel Limit	Velocity Profiling Limit	**Acc Limit**	Acceleration Profiling Limit	**dAcc Limit**	Delta Acceleration Profiling limit
Vel FeedF	Feedforward Velocity Coefficient	**Acc FeedF**	Feedforward Acceleration Coefficient	**dAcc FeedF**	Feedforward Delta Acceleration Coefficient
Kp	Difference Equation Coefficient	**Ki**	Difference Equation Coefficient	**Kd**	Difference Equation Coefficient
MultiCount	—	**MultiSettl**	—	**MultiDwell**	—
Dest Go	Go Destination	**Drv Offset**	Drive Offset	**Drv Limit**	Drive Limit
Dest Hold	Destination Hold	**Step Size**		**X Axis**	—
Preset Pos	Preset Position Counter	**Move Size**	—	**Y Axis**	—

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TUNE1713 Parameters

See Table 6-1 for a list of parameter units and ranges.

Acc FeedF

Feedforward Acceleration Coefficient: This value is used to provide forward (not part of the closed loop control) gain based on acceleration results.

Acc L

Limit Acceleration Profiling Limit: This value is used to limit the stage's acceleration.

BGO Order

Go Buffered Reference: This controls and initiates buffered reference moves.

dAcc FeedF

Feedforward Delta Acceleration Coefficient: This value is used to provide forward (not part of the closed loop control) gain based on delta acceleration results.

dAcc Limit

Delta Acceleration Profiling Limit: This value is used to limit the stage's delta acceleration.

DEQ

Difference Equation Number: This number selects a specified difference equation.

Dest Go

Go Destination: This initiates an immediate move to the specified value. The drive must be on in order for the stage to move.

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Dest Hold

Destination Hold: This value is sent to the board for delayed moves. The move is initiated by the **SHIFT+F7: MvToLP** function key.

Polarity

Polarity of Servo Output: This changes the sign of the output signal.

Drv Limit

Drive Limit: This sets the maximum level of the servo output.

Drv Offset

Drive Offset: Adds this offset to the servo output every sample period.

FE Limit

Following Error Limit: At this following error value, the drive shuts off. A negative value disables this feature.

Frequency

Sample Period Count: This value passed in TUNE1713 is the sampling frequency (Hz). Depending on your programming approach, values may be different than what you enter in TUNE1713.

Move Size

The **Move Size** TUNE1713 parameter specifies the size of a profiled move initiated by pressing the **F6: Move** function key or the **SHIFT+F6: MltMov** function key. Appropriate values depend on the function selected. For Move and determining the feedforward coefficients, **Move Size,** should be set in conjunction with the motion profile terms as shown in Agilent Application Note 325-10, *Sub-micron Positioning* (Agilent publication number 5952-7942). For the Multiple Move function, **Move Size**, should be set similar to what will be used in the final application.

MultiCount

The **MultiCount** value specifies how many profiled moves of **Move Size** will be done in each cycle of the multiple move function.

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MultiDwell

The **`MultiDwell`** value specifies how many seconds to wait after the stage has settled before testing for an Out-of-null error NULER during each move of the TUNE1713 program's multiple move function.

MultiSettl

The **`MultiSettl`** value specifies how many seconds to wait for the stage to settle during each move of the TUNE1713 program's multiple move function. When this value is set to zero, the program will wait until the settled bit in the board's status word goes true.

Null Range

Null Range Distance: When position is within this +/- range value of the current destination, the INNUL bit will set.

Preset Pos

Preset Position Counter: This value is used to preset the position value to some specific location.

Settle Cnt

Settle Time Count: This value represents the number of consecutive sample periods required that the stage must be within the Null Range in order for the stage to be "settled". When the stage settles, the STTL bit is set. Depending on your programming approach, values may be different than what you enter in TUNE1713.

Step Size

The **`Step Size`** TUNE1713 parameter specifies how large a step to input into the servo system when the **`F7: Step`** function key is pressed. Its value should be set to twice the distance moved in one servo sample period (maximum stage velocity) divided by the servo sample period (servo sample frequency). For example, if the maximum stage velocity is 18 inches per second (457 m/s) and the servo sample frequency is 10 kHz, the Step Size is 2*(18 ips/10000 Hz) = 0.0036 inch (0.09144 mm).

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Svc Mode

Service Mode: This value specifies the type of profiling.

TCN

Total Compensation Number: This number is used for compensation. The default is 1. The range is 0.99 to 1.01. Use the default unless you wish to change the scale factor.

Units

Units Type: This value specifies what units the TUNE1713 distance or position values will be in.

Vel FeedF

Feedforward Velocity Coefficient: This value is used to provide forward (not part of the closed loop control) gain based on velocity results.

Acc Limit

Acceleration Profiling Limit: This value is used to limit the stage's acceleration.

Vel Limit

Velocity Profiling Limit: This value is used to limit the stage's velocity.

X Axis

The **`X Axis`** TUNE1713 parameter specifies the maximum time value used when plotting the results of a **`F7: Step`** or **`F6: Move`** operation Its value can be changed and then the **`F8: Replot`** key pressed to view the same data with a different time scale.

Y Axis

The **`Y Axis`** TUNE1713 parameter specifies the maximum following error scale value used when plotting the results of a **`F7: Step`** or **`F6: Move`** operation. Its value can be changed and then the **`F8: Replot`** key pressed to view the same data with a different scale.

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TUNE1713 Function Keys

F2:DrvOFF

This function key turns off the motor drive output voltage and stops the difference equation, thus opening the servo loop. See Cmd# 131—Drive Off in Chapter 6.

F3:ClrPOS

This function key sets the position and the reference position to zero. See Cmd# 132—Reset Position Counter in Chapter 6.

F4:Rd Brd

This function key reads all setup parameters from the board and updates the Front Panel screen display.

F5:ClrErr

This function key initiates a soft reset, clearing any errors on the board and setting the position to zero if there was a measurement error. See Cmd# 128—Soft Reset in Chapter 6.

F6: Move

This function key initiates a profiled move of **`Move Size`**. Results of the move are captured and then plotted to the screen so the feedforward terms can be adjusted. The **`X Axis`** and **`Y Axis`** terms specify the maximum graph coordinates.

F7: Step

This function key initiates tracing a step input to the servo system. The **`Step Size`** value specifies how large a step, the **`X axis`** value specifies how much data to graph, and the **`Y Axis`** value specifies the scaling to use when plotting the step response results.

F8:Replot

This function key replots the last graph at the current **`X Axis`** and **`Y Axis`** scale values. Thus the last step or move graph can be re-sized for better viewing.

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Shift + F2:Drv ON

This function key turns on the motor drive output voltage and starts the difference equation, thus closing the servo loop. If the board has a measurement error, then the drive will remain off. Use the **F5: ClrErr** function key to clear the errors first. See Cmd# 130—Drive On in Chapter 6.

Shift + F3:ClrNul

This function key clears only the Null Error bit in the board's status word. See Cmd# 134—Clear Null Error in Chapter 6.

Shift + F4:Rd Rev

This function key reads and displays the board's firmware revision string. See Cmd# 137—Read Revision in Chapter 6.

Shift + F6:MltMov

This function key starts the TUNE1713 program's multimove function. The stage will do **MultiCount** profiled moves of **Move Size**. After each move, the program will wait **MultiSettl** seconds for the stage to settle, and then wait an additional **MultiDwell** seconds. The out-of-null error NULER bit is cleared after settling, and then tested after dwelling. If an error is detected, the program halts and asks the operator to continue or not. Choosing not to continue and then pressing **F8: Replot** displays the move data that caused the error.

Shift + F7:MvToDH

This function key initiates a move to the current **Dest Hold** location. See Cmd# 138—Go Destination Hold in Chapter 6.

Ctrl + F1:LL

This function key requests the Gain, Zero, and Pole for a lead-lag filter. The function then calculates the appropriate IIR coefficients to implement the filter and downloads them to the board. The Difference Equation type will be changed to IIR and the servo loop turned off if the type had been PID.

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Ctrl + F2:LL 2nd

This function key requests the Gain, Zeros, and Poles for a second order lead-lag filter, then calculates the appropriate IIR coefficients to implement the filter and downloads them to the board. The Difference Equation type will be changed to IIR and the servo loop turned off if the type had been PID.

Ctrl + F8:PIDIIR

This function key takes the current PID coefficients and calculates equivalent IIR coefficients. This effectively converts your PID filter to an IIR filter. These IIR coefficients are loaded, and the difference equation is set to IIR. During this conversion, the drive is shut off to avoid undesirable servo responses.

Shift + Ctrl + F4: CODE

This function key allows you to download new firmware to the board. To do this, first make sure a copy of the firmware DOS file is in the same directory where TUNE1713 resides. Upon pressing this function key, you are prompted to enter the filename (include the file extension). After new firmware code has been loaded, TUNE1713 will bring up its startup screen, prompting you for your board's I/O switch setting. When you download new firmware, TUNE1713 will detect the different firmware revision and will let you know this by initially displaying a firmware revision error message. Ignore this message. Press any key to continue using TUNE1713. Keep in mind that downloaded firmware code will be erased any time the Agilent E1713A board is powered off.

Shift + Ctrl + F5: BOOT

This function key initiates a hard reset operation, setting all parameters to their power-up default values and re-loading any on-board firmware. See Cmd# 135—Boot in Chapter 6.

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5

Getting Started with Programming

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Introduction

This chapter provides basic programming information and examples (using C function calls) for most operations on the Agilent E1713A board. Before programming the board for the first time, review the material in this chapter at least through Example 2: Making a Single Move.

You can program the Agilent E1713A in either of two ways:

- using C language functions.
- writing directly to the board registers at their I/O addresses.

Usage of the Agilent E1713A C language functions are shown in text formatted like this: **`text`**. C functions and the header file for all Agilent E1713A board commands are supplied on the 3.5-inch diskette (Agilent E1713-13401).

Function Call Nomenclature

All function names begin with **`e17_`** or **`hp89_`** followed by an abbreviation of the command name. The character(s) appended after this determine what type of operation is done by the function:

`e17_abcde < addr>`	Function sends a command typically requiring no data other than the board address
`e17_abcde_w (<addr>, parameter1, parameter2, ...)`	Function writes parameter values to the board
`e17_abcde_r (<addr>, &parameter1, &parameter2,..)`	Function reads a parameter value from the board

Where **`abcde`** is an abbreviation of the command name and <addr> is the board I/O address.

Initializing and Initiating Moves

When designing your control program, first initialize your parameters, then initiate the move. Wait for your stage to settle from any previous move before initiating another move (by using **`e17_wait_for_stage_to_settle`**, for example). Use the lists below as a guide.

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Initialization Parameters

System	Profiling	Position Monitoring
Drive limit	Delta acceleration	Marker
Drive offset	Acceleration	Marker window
Units Type	Feed forward delta acceleration	
	Feed forward acceleration	
	Feed forward velocity	
	Sample Period	

Commands that Initiate Moves

Command	Mode
Go Destination	internal profiling
Go Destination Hold	used with Destination Hold in internal profiling
Go Buffered Reference	buffered reference profiling
Velocity	velocity profiling

Parameter Value Units

In most cases the parameter values you pass to the functions are the same as the values you use in the TUNE program. In low-level programming of the registers, though, some parameters are different. For example, setting sampling frequency using register-based programming requires specifying **`period`** in 100-ns units instead of directly specifying **`period`**. See the function definitions in E1713F2.C for specifications of the units.

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Single Command Operations

The following four examples show, step-by-step, how to program single command operations using the C functions. An Agilent E1713A board base address of 260 is assumed for all examples. These four examples also assume that the board is in a ready state to receive any command.

Example 1: Set up a sampling frequency of 10 kHz

To use the provided Agilent E1713A functions, you would call this function, pass the double value 0.0001, and check for a zero return value indicating successful command execution:

```
e17_sample_period_w(260, 0.0001);
```

Example 2: Set current units to inches

After using this function check for a zero return value, which indicates successful command execution.

```
e17_units_type_w(260, 2);
```

Example 3: Acquire servo lock at the current stage position

After using this function check for a zero return value, which indicates successful command execution.

```
e17_acquire_lock(260);
```

Provided your stage and board settings allow servo lock and there are no errors on the board, your board should acquire lock at the current stage position.

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Program Examples

The following example programs in the C programming language are found under the *democode* directory with titles similar to MYMAIN*x*.C. Each program includes header file E1713F2.H and was compiled in the DOS environment in a project file titled like EX*x*.PRJ. Each project file included the pre-compiled functions file E17F1.OBJ. These functions were created in Borland Turbo C, version 3.0.

Each program is preceded by a brief description of what the program does and a discussion of which parameters you might change to meet your own stage requirements and configuration.

The sample programs use tuning parameters suited to the Agilent E1714A Master Arm Assembly. Your application may require different values.

Program 1: Read Position

This is a simple program that reads and displays the position measured by the Agilent E1713A board. You can run this program to quickly check your board's operation with your optics system setup. See Figure 5-1 for the program listing.

The program first reads what type of units have been set up on the board, then resets the position counter to zero. The program reads position from the board into a variable and displays the value until a key from the keyboard is struck. You should be able to run this program immediately.

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Program Examples

```
/*              ---------------------------------------------------------------
                Agilent E1713A Main Program for Example 1
                Adapted from similiar program for Agilent10889B card
                This program reads and displays position.
                ---------------------------------------------------------------

                Project File Name:      EX1.PRJ
                Project Files:          E1713F2.H
                                        MYMAIN1.C
*/

#include  "e1713f2.h"                   /*  Agilent E1713A functions header file  */
#include  <stdio.h>
#include  <conio.h>
#include  <string.h>
#include  <process.h>
#include  <stdlib.h>

#define   my_board_addr   260           /*  Agilent E1713A board's base address  */


void main(void)  {

double position;                        /*  Variable to hold position read from Agilent 10889B board  */
char units;                             /*  Variable to hold units read from Agilent 10889B board  */
char units_label[30];                   /*  String for units type label  */


                if ( hp89_ready(my_board_addr) )  {             /*  Check if board is ready to receive first command  */
                        printf("Error.  Board not ready.\n");   /*  and exit if board is not responding  */
                        exit(0);
                }

                if ( hp89_units_type_r(my_board_addr, &units) )  {/*  Read units type  */
                        printf("Error.  Board not responding.\n");      /*  and exit if board is not responding  */
                        exit(0);
                }

                if (units == 0)                                 /*  Store units type label in string  */
                        strcpy(units_label, "raw lambda units");
                else
                        if (units == 1) strcpy(units_label, "lambda compensated units");
                else
                        if (units == 2) strcpy(units_label, "inches");
                else
                        strcpy(units_label, "mm");

                hp89_zero_position(my_board_addr);          /*  Reset current position to zero  */

                clrscr();                                   /*  Clear screen  */
                _setcursortype(_NOCURSOR);                  /*  Turn cursor off  */

                while (!kbhit())  {                         /*  Read and display position until a keyboard key
stroke.  */
                        gotoxy(1,1);
                        printf("Press any key to stop...");
                        gotoxy(5,1);
                        hp89_position_r(my_board_addr, &position);
                        printf("\n\nPosition =   %+f  %s     \n", position, units_label);
                }

                _setcursortype(_NORMALCURSOR);              /*  End of demo.  Turn cursor back on.  */
}
```

Figure 5-1. Program Listing of MYMAIN1.C

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Program 2: Making a Single Move

This program (shown in Figure 5-2) initializes parameters, homes in at one end of the arm's range, makes a single move forward to establish a starting position for future moves. The PID difference equation is used. To run this program with your stage, you should look at all initialization parameters and make adjustments to their values accordingly. The PID coefficients are most critical. Unsuitable coefficient values can prevent servo lock or can cause the drive to shut off after limits are exceeded. Use the TUNE1713 program to determine what PID coefficients are appropriate for your stage.

Two procedures are included in this program: **`e17_home()`** and **`e17_wait_for_settle()`**. They are part of the MYMAIN2.C file on your disk.

The **`e17_home()`** procedure moves the arm very slowly to the most negative position in the swing range, establishing a home position. When you use this procedure, be sure that you replace the destination value passed in **`e17_go_dest_w(my_board_addr, -10)`** with a distance greater than your arm's maximum travel to ensure travel to the farthest end of its range. You should also adjust the drive limit value passed in **`e17_drive_limit_w(my_board_addr, 5000)`** with a value just large enough to move your arm. The drive limit value should be large enough to move your arm but not so large that the stage comes to a loud 'stop' as it hits the table's physical limit.

The **`e17_wait_for_settle()`** procedure is required to allow the stage to settle because the board can be ready to receive another command while a move is still in process. If you are waiting for your stage to settle and want to improve the control speed of your program, consider using the **`e17_dest_hold()`** and **`e17_go_dest_hold()`** functions.

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Program Examples

```
/*                  ------------------------------------------------------------
                    Agilent E1713A Program for Example 2
                    This program adapted from program for Agilent10889B
                    This program initializes parameters, moves the stage
                    to one extreme of position, then makes moves.
                    ------------------------------------------------------------

                    Project File Name:      EX2.PRJ
                    Project Files:          E1713F2.H
                                            MYMAIN2.C
*/

#include      "e1713f2.h"
#include      <stdio.h>
#include      <dos.h>
#include      <process.h>
#include      <stdlib.h>
#include      <conio.h>

#define  my_board_addr  260                 /*  Agilent E1713A board's base address  */

short hp89_wait_for_settle(short hp89_addr); /*  Stage settle procedure  */
short hp89_home(short hp89_addr);            /*  Stage homing procedure  */


void main(void)  {

double position;

clrscr();
printf ("\n* * * * Starting program * * * *\n\n");

/*                  ----------------------------------------------------
                    Check if the Agilent E1713A board is present and
                    responding.  Exit if it is not.
                    ----------------------------------------------------
*/
                    if ( hp89_ready(my_board_addr) )  {
                              printf("\nError.  Board not ready.\n");
                              exit(EXIT_SUCCESS);
                    }

/*                  ----------------------------------------------------
                    Initialize parameters
                    ----------------------------------------------------
*/
/*      System related parameters  */

                    hp89_drive_limit_w(my_board_addr, 10.0);       /*  10 volts  */
                    hp89_drive_offset_w(my_board_addr, 0.0);       /*  0 volts  */
                    hp89_units_type_w(my_board_addr, 2);          /*  English (inches)  */

/*      Profiling related parameters  */

                    hp89_sample_period_w(my_board_addr, 0.0001);/*  Sample period  */
                    hp89_service_mode_w(my_board_addr, 0);     /*  Stand alone internal positioning profile  */
                    hp89_daccel_w(my_board_addr, 20.0);          /*  Delta acceleration value  */
                    hp89_accel_w(my_board_addr, 0.05);           /*  Acceleration value  */
                    hp89_velocity_w(my_board_addr, 0.15);        /*  Velocity limit value  */
                    hp89_diff_eqn_number_w(my_board_addr, 0);/*  Equation #0:  PID  */
                    hp89_diff_eqn_coef_w(my_board_addr, 0.085, 0, 1);/*  Coefficient 1:  Kp  */
                    hp89_diff_eqn_coef_w(my_board_addr, 0.0001, 0, 2);/*  Coefficient 2:  Ki  */
                    hp89_diff_eqn_coef_w(my_board_addr, 1.27, 0, 3);/*  Coefficient 3:  Kd  */
                    hp89_diff_eqn_coef_w(my_board_addr, 0.0, 0, 0);/*  Use this bank of coefficients  */
                    hp89_feedf_daccel_w(my_board_addr, 0);       /*  Feedforward delta acceleration  */
                    hp89_feedf_accel_w(my_board_addr, 0);        /*  Feedforward acceleration  */
                    hp89_feedf_velocity_w(my_board_addr, 0);     /*  Feedforward velocity  */
```

Figure 5-2. Program listing of MYMAIN2.C

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Program Examples

```
/*      Position monitoring features  */

                hp89_following_error_limit_w(my_board_addr, 0.2);/*  0.2 inches  */
                hp89_marker_w(my_board_addr, 0.0);              /*  0 inches  */
                hp89_marker_window_w(my_board_addr, 0.0);       /*  0 inches  */

                hp89_null_range_w(my_board_addr, 0.000050);    /*  50 uinches  */

                hp89_settle_time_w(my_board_addr, 0.03);       /*  30 milliseconds  */

/*              ---------------------------------------------------
                Check if the board is ready, then rotate arm on Voice Coil motor
                counter-clockwise until arm touches the stop at end of travel, then
                reset counter to zero, then move arm clockwise 5 degrees and
                establish this as position zero.  Then turn servo off.
                ---------------------------------------------------
*/

/*   Start of Demo Program   */

                if ( hp89_ready(my_board_addr) )  {             /*  Is the board ready ?  */
                        printf("Error.  Board not ready.\n");
                        exit(EXIT_SUCCESS);
                }

                printf("\n\nFinding home...");                  /*  Establish home position  */
                if ( ! hp89_home(my_board_addr) )  {
                        printf("\n\nError.  Could not home.\n");
                        exit(EXIT_SUCCESS);
                }
                printf("found");

                printf("\n\nMoving arm clockwise 5 degrees ...");/*  Move 0.1 inches  */
                hp89_go_dest_w(my_board_addr, 0.131);       /*  .131 inches at radius of 38.2 mm = 5 degrees  */
                if ( ! hp89_wait_for_settle(my_board_addr) )  {
                        printf("\n\nError.  Stage did not settle.\n");
                        exit(EXIT_SUCCESS);
                }
                printf("settled");

                hp89_position_r(my_board_addr, &position);   /*  Read position  */
                printf("\n\nPosition = %f", position);

                printf("\n\nZeroing position counter...");
                hp89_zero_position(my_board_addr);           /*  Zero position counter  */
                hp89_position_r(my_board_addr, &position);   /*  Read position again  */
                printf("\n\nPosition = %f\n", position);


/*              ---------------------------------------------------
                End of demo.
                ---------------------------------------------------
*/
```

Figure 5-2. Program listing of MYMAIN2.C (Continued)

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Program 3: Trace and Feedforward

This program (shown in Figure 5-3) makes a 0.0254-mm (0.001-inch) move with and without feedforward. Trace is turned on to record reference and stage positions during each move. Trace data is then copied to a DOS file and imported to a spreadsheet application where position and following error data is plotted for analysis.

Feed forward reduces following error during moves and allows the arm to settle. You can use trace in your program to monitor the effects of feedforward or use the TUNE program to evaluate feedforward effects for your system.

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Program Examples

```
/*              ------------------------------------------------------------
                Agilent E1713A Program for Example 3
                This program adapted from similiar example used with Agilent E1713A
                This program initializes parameters, homes in at one stage
                end, and traces two 0.001 inch moves with and without
                feedforward.
                ------------------------------------------------------------

                Project File Name:      EX3.PRJ
                Project Files:          E1713F2.H
                                                MYMAIN3.C
*/

#include        "e1713f2.h"
#include        <stdio.h>
#include        <dos.h>
#include        <process.h>
#include        <stdlib.h>
#include  <conio.h>

#define          my_board_addr        260                          /*  Agilent E1713A board's base address
*/

short hp89_wait_for_settle(short hp89_addr);                        /*  Stage settle procedure  */
short hp89_home(short hp89_addr);                                   /*  Stage homing procedure  */
                                                                    /*  Copy trace data to DOS file procedure
*/
short hp89_copy_trace_to_file(short hp89_addr, const char *filename, short items);

/*  Start of demo program  */


void main(void)  {

double position;

clrscr();

/*              ----------------------------------------------------
                Check if the Agilent E1713A board is present and
                responding.  Exit if it is not.
                ----------------------------------------------------
*/
                if ( hp89_ready(my_board_addr) )  {
                        printf("\nError.  Board not ready.\n");
                        exit(0);
                }

/*              ----------------------------------------------------
                Initialize parameters
                ----------------------------------------------------
*/
/*              System related parameters  */
                hp89_drive_limit_w(my_board_addr, 10.0);    /*  10 volts  */
                hp89_drive_offset_w(my_board_addr, 0.0);    /*  0 volts  */
                hp89_units_type_w(my_board_addr, 2);        /*  English (inches)  */

/*              Profiling related parameters  */

                hp89_sample_period_w(my_board_addr, 0.0001); /*  Sample period  */
                hp89_service_mode_w(my_board_addr, 0);    /*  Stand alone internal positioning profile  */
                hp89_daccel_w(my_board_addr, 20.0);       /*  Delta acceleration value  */
                hp89_accel_w(my_board_addr, 0.05);        /*  Acceleration value  */
                hp89_velocity_w(my_board_addr, 0.15);     /*  Velocity limit value  */
                hp89_diff_eqn_number_w(my_board_addr, 0);/*  Equation #0:  PID  */
                hp89_diff_eqn_coef_w(my_board_addr, 0.085, 0, 1); /*  Coefficient 1:  Kp = 0.6  */
                hp89_diff_eqn_coef_w(my_board_addr, 0.0001, 0, 2);/*  Coefficient 2:  Ki = 0.03  */
                hp89_diff_eqn_coef_w(my_board_addr, 1.27, 0, 3);  /*  Coefficient 3:  Kd = 8  */
                hp89_diff_eqn_coef_w(my_board_addr, 0., 0, 0);  /*  Use this bank of coefficients  */
                hp89_feedf_daccel_w(my_board_addr, 0);    /*  Feedforward delta acceleration  */
                hp89_feedf_accel_w(my_board_addr, 0);     /*  Feedforward acceleration  */
                hp89_feedf_velocity_w(my_board_addr, 0);  /*  Feedforward velocity  */
```

Figure 5-3. Partial listing of MYMAIN3.C Showing Traced Moves With and Without Feedforward

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Program Examples

```
/*              Position monitoring features  */

                hp89_following_error_limit_w(my_board_addr, 0.2);/*  0.2 inches  */
                hp89_marker_w(my_board_addr, 0.0);              /*  0 inches  */
                hp89_marker_window_w(my_board_addr, 0);         /*  0 inches  */
                hp89_null_range_w(my_board_addr, 0.000050);   /*  50 uinches  */
                hp89_settle_time_w(my_board_addr, 0.03);     /*  30 milliseconds  */

/*              ------------------------------------------------------
                Home and establish position "zero".  See MYMAIN2.C for
                comments.
                ------------------------------------------------------
*/
                if ( hp89_ready(my_board_addr) )  {             /*  Ready for command?  */
                        printf("Error.  Board not ready.\n");
                        exit(0);
                }
                printf("\n\nFinding home...");                  /*  Establish home position  */
                if ( ! hp89_home(my_board_addr) )  {
                        printf("\n\nError.  Cound not home.\n");
                        exit(0);
                }
                printf("found");
                printf("\n\nMoving forward 0.1 inches...");     /*  Move 0.1 inches  */
                hp89_go_dest_w(my_board_addr, 0.1);
                if ( ! hp89_wait_for_settle(my_board_addr) )  {
                        printf("\n\nError.  Stage did not settle.\n");
                        exit(0);
                }
                printf("settled");
                hp89_position_r(my_board_addr, &position);
                printf("\n\nPosition = %f", position);
                printf("\n\nZeroing position counter...");      /*  Zero position counter  */
                hp89_zero_position(my_board_addr);
                hp89_position_r(my_board_addr, &position);
                printf("\n\nPosition = %f\n", position);

/*              ------------------------------------------------------
                Trace a 0.001 inch move.
                ------------------------------------------------------
*/
                hp89_trace_mode_w(my_board_addr, 67);     /*  Turn trace on  */
                printf("\n\nMoving 0.001 inches...");
                hp89_go_dest_w(my_board_addr, 0.001);     /*  Go to destination 0.001"  */
                if ( ! hp89_wait_for_settle(my_board_addr) )  {
                        printf("\n\nError.  Could not settle.\n");
                        exit(0);
                }
                printf("settled\n");
                delay (1000);
                printf("Writing trace data to file EX3_MOVE.TXT\n\n");
                hp89_transfer_trace(my_board_addr, 16);     /*  Transfer 16 pages of data  */
                hp89_copy_trace_to_file(my_board_addr, "EX3_MOVE.TXT", 500);  /*  Copy to my DOS file  */
                printf("\n\nMoving back to home...");
                hp89_go_dest_w(my_board_addr, 0.0);         /*  Go back to starting position  */
                if ( ! hp89_wait_for_settle(my_board_addr) )  {
                        printf("\n\nError.  Could not settle.\n");
                        exit(0);
                }
                printf("settled");

/*              ------------------------------------------------------
                Add feedforward and trace another 0.001 inch move.
                ------------------------------------------------------
*/
                hp89_feedf_daccel_w(my_board_addr, 20);    /*  Feedforward delta acceleration  */
                hp89_feedf_accel_w(my_board_addr, 40);     /*  Feedforward acceleration  */
                hp89_feedf_velocity_w(my_board_addr, 550); /*  Feedforward velocity  */
```

Figure 5-3. Partial Listing of MYMAIN.C Showing Traced Moves with and Without Feedforward (Continued)

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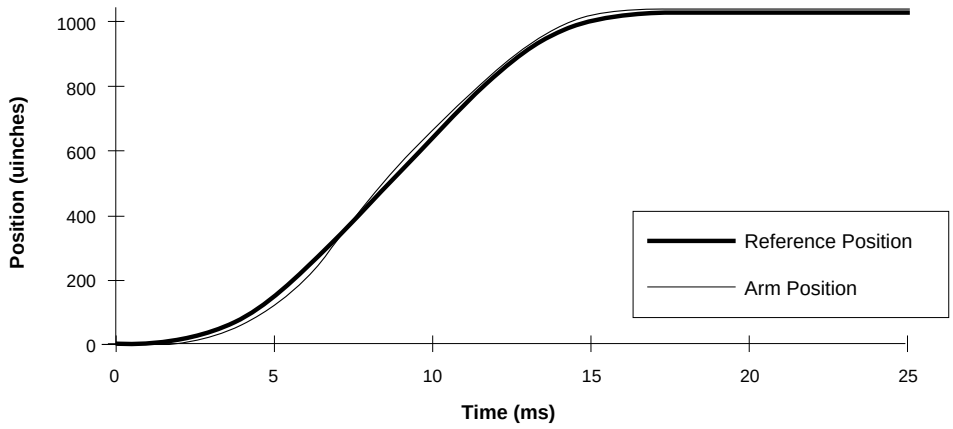
```
                hp89_trace_mode_w(my_board_addr, 67);                   /*  Turn trace on  */
                printf("\n\nAdded feedforward and moving another 0.001 inches...");
                hp89_go_dest_w(my_board_addr, 0.001);                   /*  Go to destination 0.001"  */
                if ( ! hp89_wait_for_settle(my_board_addr) )  {

                        printf("\n\nError.  Could not settle.\n");
                        exit(0);
                }
                printf("settled\n\n");
                printf("Writing trace data from move with feedforward\n");
                printf("to file EX3_FF.TXT in current directory.\n\n");
                delay (1000);
                hp89_transfer_trace(my_board_addr, 16);                 /*  Transfer 16 pages of data  */
                hp89_copy_trace_to_file(my_board_addr, "EX3_FF.TXT", 500);  /*  Copy to my DOS file  */

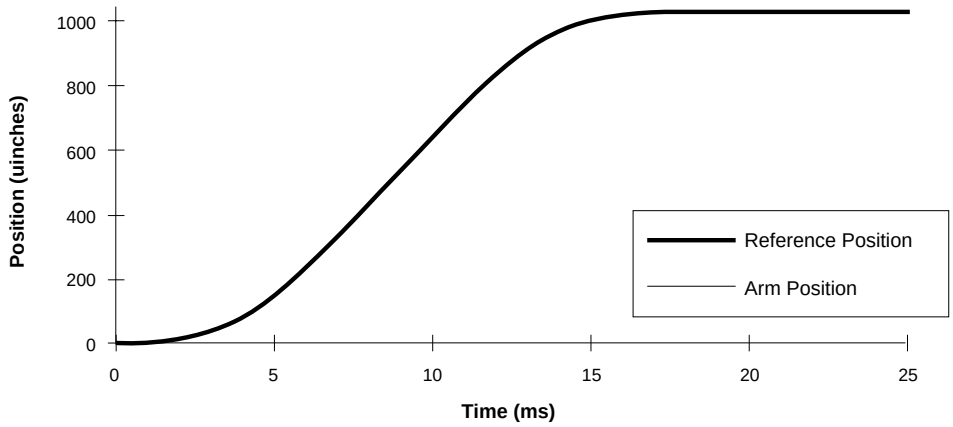
/*              ---------------------------------------------------------
                End of demo.
                ---------------------------------------------------------
*/
                printf("End of demo, turning drive off\n");
                hp89_drive_off(my_board_addr);                          /*  Turn the drive off.  */
}
```

Figure 5-3. Partial Listing of MYMAIN.C Showing Traced Moves with and Without Feedforward (Continued)

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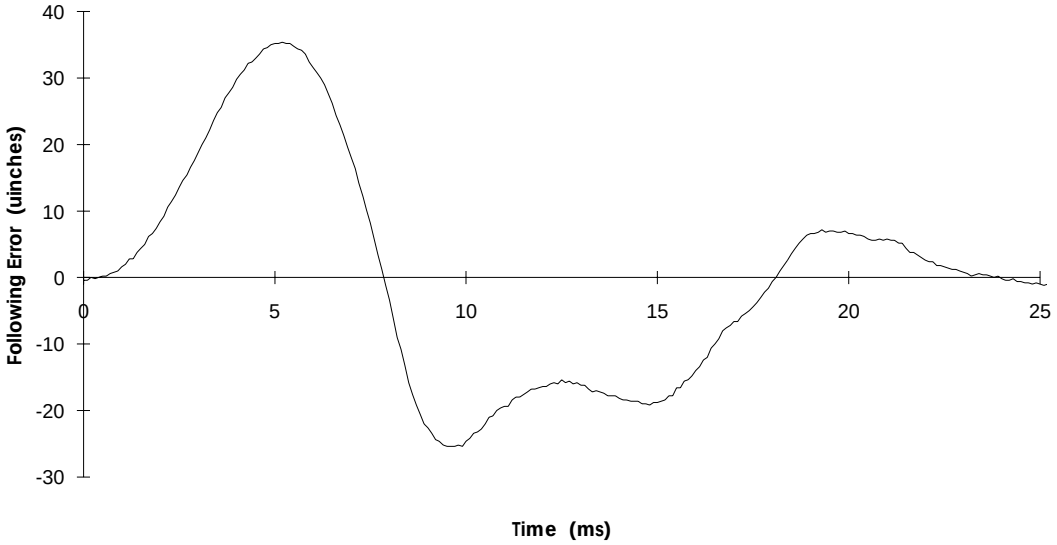
Above: Without Feedforward



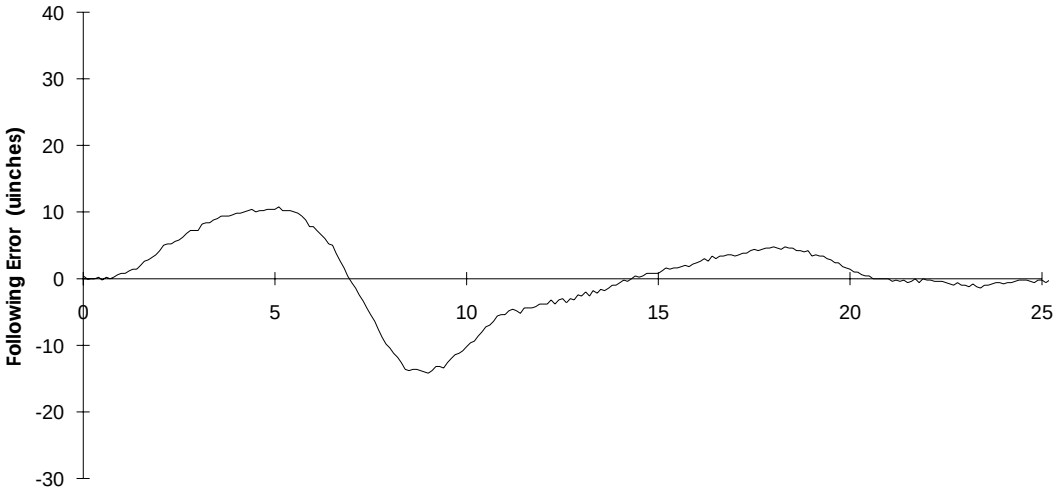
Above: With Feedforward

Figure 5-4. Sample Profile of a 0.001-Inch Move With and Without Feedforward

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Above: Without Feedforward



Above: With Feedforward

Figure 5-5. Sample Following Error With and Without Feedforward

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Program 4: Using External Positioning Profiling To Step Move

This program (shown in Figure 5-6) makes a step response move using external positioning profiling. External positioning profiling service mode immediately makes any destination value sent to the board the immediate reference position. Trace is also used in this example to record the step response of this move. Step moves are useful in evaluating the dynamic performance of your system. The **`e17_step()`** procedure shows you one way to make a step move using the provided Agilent E1713A functions.

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Program Examples

```
/*              ---------------------------------------------------------------
                Agilent E1713A Program for Example 4
                This program adapted from similiar program used with Agilent 10889B
                This program initializes parameters, homes in at my stage's
                end, and traces a step response move.
                ---------------------------------------------------------------

                Project File Name:      EX4.PRJ
                Project Files:          E1713F2.H
                                        MYMAIN4.C
*/

#include        "e1713f2.h"
#include        <stdio.h>
#include        <dos.h>
#include        <process.h>
#include        <stdlib.h>
#include <conio.h>

#define         my_board_addr       260                     /*  Agilent E1713A board's base address
*/

short hp89_wait_for_settle(short hp89_addr);                /*  Stage settle procedure  */
short hp89_home(short hp89_addr);                           /*  Stage homing procedure  */
                                                            /*  Copy trace data to DOS file procedure
*/
short hp89_copy_trace_to_file(short hp89_addr, const char *filename, short items);
                                                            /*  Step move procedure  */
short hp89_step(short hp89_addr, double stepsize);


void main(void)  {

double position;

clrscr();

/*              ---------------------------------------------------
                Check if the Agilent E1713A board is present and
                responding.  Exit if it is not.
                ---------------------------------------------------
*/
                if ( hp89_ready(my_board_addr) )  {
                        printf("\nError.  Board not ready.\n");
                        exit(0);
                }

/*              ---------------------------------------------------
                Initialize parameters
                ---------------------------------------------------
*/
/*              System related parameters  */
                hp89_deadpath_w(my_board_addr, 0.);         /*  No deadpath--not using compensation
*/
                hp89_drive_limit_w(my_board_addr, 10.0);    /*  10 volts  */
                hp89_drive_offset_w(my_board_addr, 0.0);    /*  0 volts  */
                hp89_units_type_w(my_board_addr, 2);        /*  English (inches)  */
                hp89_sample_period_w(my_board_addr, 0.0001);

/*              Profiling related parameters  */
                hp89_service_mode_w(my_board_addr, 0);      /*  Stand alone internal positioning profile
*/
                hp89_daccel_w(my_board_addr, 20.0);         /*  Delta acceleration value  */
                hp89_accel_w(my_board_addr, 0.05);          /*  Acceleration value  */
                hp89_velocity_w(my_board_addr, 0.15);       /*  Velocity limit value  */
                hp89_diff_eqn_number_w(my_board_addr, 0);   /*  Equation #0:  PID  */
                hp89_diff_eqn_coef_w(my_board_addr, 0.085, 0, 1);   /*  Coefficient 1:  Kp  */
                hp89_diff_eqn_coef_w(my_board_addr, 0.0001, 0, 2);  /*  Coefficient 2:  Ki  */
                hp89_diff_eqn_coef_w(my_board_addr, 1.27, 0, 3);    /*  Coefficient 3:  Kd  */
                hp89_diff_eqn_number_w(my_board_addr, 0);   /*  Use this bank of coefficients  */
                hp89_feedf_daccel_w(my_board_addr, 0);      /*  Feedforward delta acceleration  */
                hp89_feedf_accel_w(my_board_addr, 0);       /*  Feedforward acceleration  */
                hp89_feedf_velocity_w(my_board_addr, 0);    /*  Feedforward velocity  */
```

Figure 5-6. Partial listings of MYMAIN4.C Showing a Step Move

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Program Examples

```
/*              Position monitoring related parameters  */
                hp89_following_error_limit_w(my_board_addr, 0.2);/*  0.2 inches  */
                hp89_marker_w(my_board_addr, 0.0);              /*  0 inches  */

                hp89_marker_window_w(my_board_addr, 0);         /*  0 inches  */
                hp89_null_range_w(my_board_addr, 0.000050);     /*  50 uinches  */
                hp89_settle_time_w(my_board_addr, 0.03);    /*  30 milliseconds  */

/*              ---------------------------------------------------
                Home, and establish starting position "zero"
                ---------------------------------------------------
*/
                if ( hp89_ready(my_board_addr) )  {
                        printf("Error.  Board not ready.\n");
                        exit(0);
                }
                printf("\n\nFinding home...");                      /*  Establish home position  */
                if ( ! hp89_home(my_board_addr) )  {
                        printf("\n\nError.  Could not home.\n");
                        exit(0);
                }
                printf("found");
                printf("\n\nMoving forward 0.1 inches...");         /*  Move 0.1 inches  */
                hp89_go_dest_w(my_board_addr, 0.1);
                if ( ! hp89_wait_for_settle(my_board_addr) )  {
                        printf("\n\nError.  Stage did not settle.\n");
                        exit(0);
                }
                printf("settled");
                hp89_position_r(my_board_addr, &position);
                printf("\n\nPosition = %f", position);
                printf("\n\nZeroing position counter...");
                hp89_zero_position(my_board_addr);
                hp89_position_r(my_board_addr, &position);
                printf("\n\nPosition = %f\n", position);

/*              ---------------------------------------------------
                Trace a step response move of 0.001 inch.
                ---------------------------------------------------
*/
                hp89_trace_mode_w(my_board_addr, 67);       /*  Turn trace on  */
                printf("\n\nStepping now...");
                if ( hp89_step(my_board_addr, 0.001) )  {       /*  Step  */
                        printf("\nCould not step properly\n");
                        exit(0);
                }
                printf("stepped successfully\n");
                hp89_transfer_trace(my_board_addr, 16);
                printf("Writing trace data to file EX4_STEP.TXT\n\n");
                /*  Transfer trace data to file */
                hp89_copy_trace_to_file(my_board_addr, "EX4_STEP.TXT", 500);     /*  Copy to a DOS file  */

                printf("End of demo, turning drive off.\n\n");
                hp89_drive_off(my_board_addr);                  /*  Turn drive off.  */
}
```

Figure 5-6. Partial listings of MYMAIN4.C Showing a Step Move (Continued)

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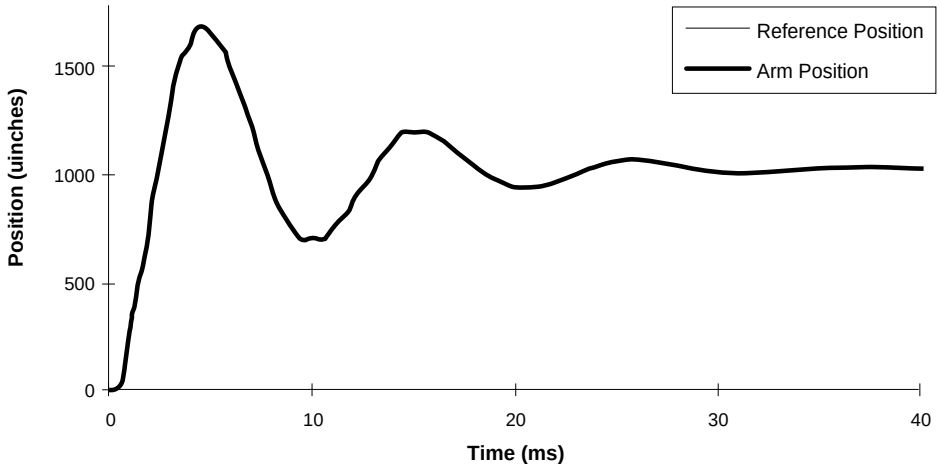


Figure 5-7. Sample Results of a 0.001-Inch Step Move

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Program 5: A Custom Position Profile Move

This program (shown in Figure 5-8) uses Buffered Reference Position Profile service mode to make sinusoidal position-profiled moves. The program first creates the custom reference positions and loads them into the Agilent E1713A board's trace buffer before sending a buffered reference "go" command. This custom profiled move is repeated several times with different interpolation counts by changing the count value passed to function **`e17_buff_ref_interp_w()`**. Trace is used to record results from each move.

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Program Examples

```
/*              ---------------------------------------------------------------
                Agilent E1713A Program for Example 5
                This program adapted from a similiar program for Agilent 10889B
                This program initializes parameters, homes in at one stage
                end, creates an array of sinusoidal position values, and makes
                custom profiled move using buffered reference position
                profiling and different interpolation values.
                ---------------------------------------------------------------

                Project File Name:      EX5.PRJ
                Project Files:          E1713F2.H
                                        MYMAIN5.C
*/

#include        "e1713f2.h"
#include        <stdio.h>
#include        <dos.h>
#include        <process.h>
#include        <stdlib.h>
#include        <math.h>
#include <conio.h>

#define          my_board_addr        260                          /*  Agilent E1713A board's base address
*/
#define  PROFILE_COUNT  100

short hp89_wait_for_settle(short hp89_addr);                        /*  Stage settle procedure  */
short hp89_home(short hp89_addr);                                   /*  Homing procedure  */
                                                                    /*  Copy trace data to DOS file procedure
*/
short hp89_copy_trace_to_file(short hp89_addr, const char *filename, short items);
                                                                    /*  Copy array items to DPM buffer
procedure  */
short hp89_load_DPM_buff(short hp89_addr, double array[], short array_count);
                                                                    /*  Create an array of reference positions
procedure  */
void create_sine_profile(double array[], short array_count, double amplitude);



void main(void)  {

double position, profile[PROFILE_COUNT];

                clrscr();

                printf("Start of demo\n");

/*              ---------------------------------------------------
                Check if the Agilent E1713A board is present and
                responding.  Exit if it is not.
                ---------------------------------------------------
*/
                if ( hp89_ready(my_board_addr) )  {
                        printf("Error.  Board not ready.\n");
                        exit(0);
                }

/*              ---------------------------------------------------
                Initialize parameters
                ---------------------------------------------------
*/
/*              System related parameters  */
                hp89_deadpath_w(my_board_addr, 0.);          /*  No deadpath--not using compensation  */
                hp89_drive_limit_w(my_board_addr, 10.0);      /*  10 volts  */
                hp89_drive_offset_w(my_board_addr, 0.0);      /*  0 volts  */
                hp89_units_type_w(my_board_addr, 2);          /*  English (inches)  */
```

Figure 5-8. Partial listings of MYMAIN5.C Showing a Buffered Reference Move

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```
/*              Profiling related parameters  */
                hp89_sample_period_w(my_board_addr, 0.0001);    /*  Sample period  */
                hp89_service_mode_w(my_board_addr, 0);     /*  Stand alone internal positioning profile  */
                hp89_daccel_w(my_board_addr, 20.0);          /*  Delta acceleration value  */
                hp89_accel_w(my_board_addr, 0.05);           /*  Acceleration value  */
                hp89_velocity_w(my_board_addr, 0.15);          /*  Velocity limit value  */
                hp89_diff_eqn_number_w(my_board_addr, 0);      /*  Equation #0:  PID  */

                hp89_diff_eqn_coef_w(my_board_addr, 0.085, 0, 1); /*  Coefficient 1:  Kp  */
                hp89_diff_eqn_coef_w(my_board_addr, 0.0001, 0, 2); /*  Coefficient 2:  Ki  */
                hp89_diff_eqn_coef_w(my_board_addr, 1.27, 0, 3);   /*  Coefficient 3:  Kd  */
                hp89_diff_eqn_number_w(my_board_addr, 0);   /*  Use this bank of coefficients  */
                hp89_feedf_daccel_w(my_board_addr, 0);      /*  Feedforward delta acceleration  */
                hp89_feedf_accel_w(my_board_addr, 0);       /*  Feedforward acceleration  */
                hp89_feedf_velocity_w(my_board_addr, 0);    /*  Feedforward velocity  */

/*              Position monitoring related parameters  */
                hp89_following_error_limit_w(my_board_addr, 0.2);/*  0.2 inches  */
                hp89_marker_w(my_board_addr, 0.0);            /*  0 inches  */
                hp89_marker_window_w(my_board_addr, 0);       /*  0 inches  */
                hp89_null_range_w(my_board_addr, 0.000050);    /*  50 uinches  */
                hp89_settle_time_w(my_board_addr, 0.03);    /*  30 milliseconds  */

/*              ------------------------------------------------------
                Establish home and position zero on my stage.
                ------------------------------------------------------
*/
                if ( hp89_ready(my_board_addr) )  {
                        printf("Error.  Board not ready.\n");
                        exit(0);
                }

                printf("Finding home...");                          /*  Establish home position  */
                if ( ! hp89_home(my_board_addr) )  {
                        printf("\n\nError.  Cound not home.\n");
                        exit(0);
                }
                printf("found");

                printf("\n\nMoving forward 0.1 inches...");        /*  Move 0.1 inches  */
                hp89_go_dest_w(my_board_addr, 0.1);
                if ( ! hp89_wait_for_settle(my_board_addr) )  {
                        printf("\n\nError.  Stage did not settle.\n");
                        exit(0);
                }
                printf("settled");

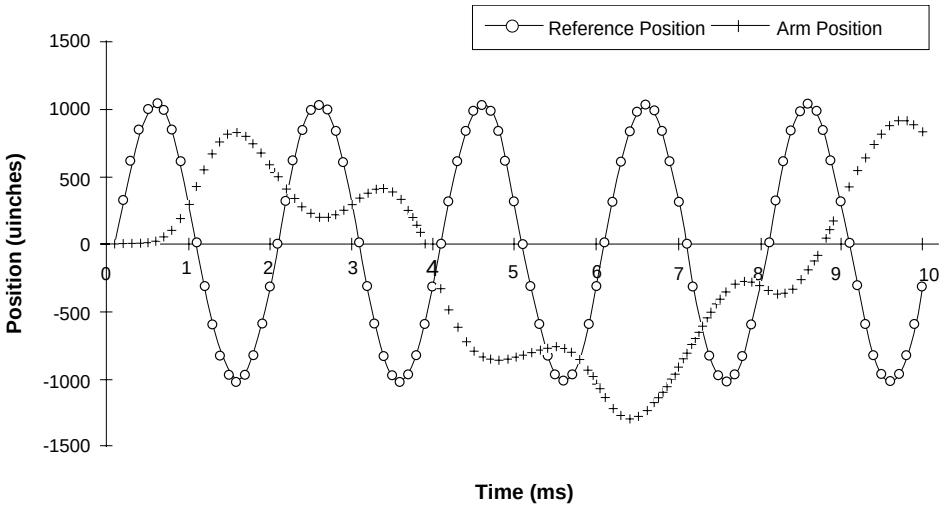
                hp89_position_r(my_board_addr, &position);
                printf("\n\nPosition = %f", position);

                printf("\n\nZeroing position counter...");
                hp89_zero_position(my_board_addr);
                hp89_position_r(my_board_addr, &position);
                printf("\n\nPosition = %f\n", position);

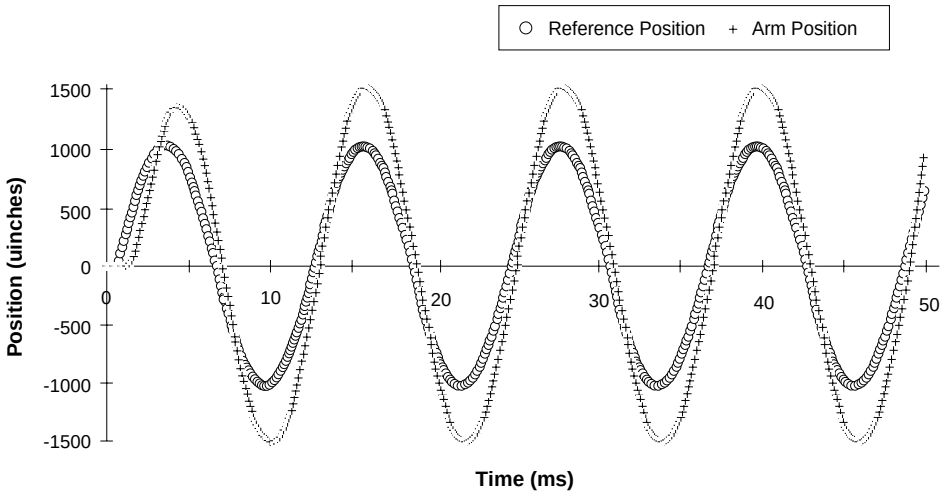
/*              ------------------------------------------------------
                Make and trace a custom position profiled move.
                with and without interpolation between reference position data.
                ------------------------------------------------------
*/
```

Figure 5-8. Partial listings of MYMAIN5.C Showing a Buffered Reference Move (Continued)

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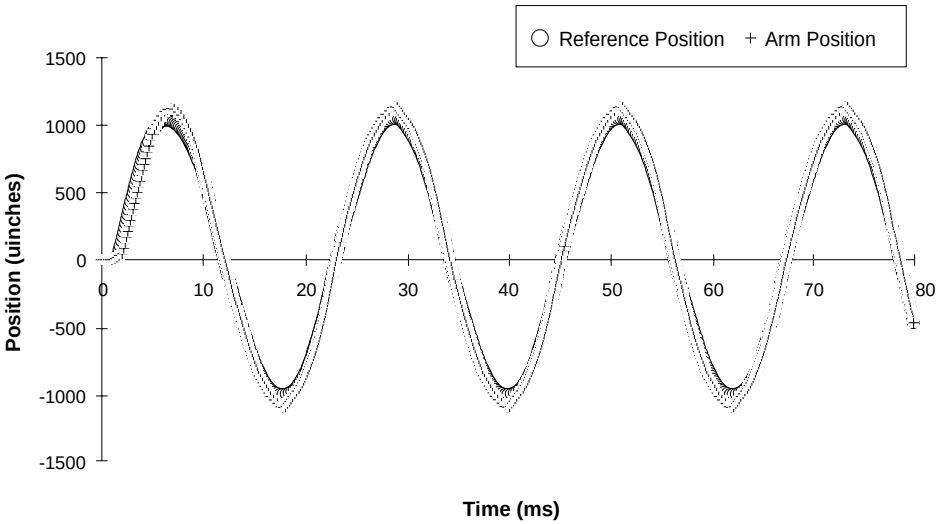
Above: No Interpolation Used



Above: Interpolation Count of 5 Used

Figure 5-9. Sample Results of 0.001-Inch Sinusoidal Moves Using Interpolation

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Above: Interpolation Count of 10 Used

Figure 5-9. Sample Results of 0.001-Inch Sinusoidal Moves Using Interpolation (Continued)

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6

Register Operation and Command Description

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Addressing the Agilent E1713A Board

The Agilent E1713A board appears as 32 I/O locations on the PC backplane. The board uses backplane address lines A0 through A12.

Address lines A2–A9 are compared to the board's address switch to decode the board, while A0–A1 and A10–A12 are used to select the various registers. The Base Address is determined by multiplying the decimal value of the address switch by four. The value of the address switch can be determined by picturing the switch as a binary number where a switch in the up position corresponds to a one and a switch in the down position corresponds to a zero.

For example, an address switch set like this

		I						
ON	I		I	I	I	I	I	I
	A9	A8	A7	A6	A5	A4	A3	A2

would correspond to the binary value 01000000, which is equal to 64 and a base address of 256.

The Agilent E1713A board's 32 registers appear as eight groups of four contiguous I/O locations separated by 1024 bytes starting at the base address. The following table shows the Agilent E1713A board's registers and their locations relative to the base address.

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Table 6-1. Agilent E1713A Registers and Address Offsets

Register	Address Offset
Command Register	0
Buffer Data Register	1
Buffer Address Low Register	2
Buffer Address High Register	3
PC IRQ Enable Register	1024
Clear PC IRQ	1025
PC IRQ Control Register	1026
Reserved	1027
Command Status Register	2048
User Status Register	2049
Error Status Register	2050
System Status Register	2051
Command Extension byte 0	3072
Command Extension byte 1	3073
Command Extension byte 2	3074
Command Extension byte 3	3075
Command Data Space byte 0	4096
Command Data Space byte 1	4097
Command Data Space byte 2	4098
Command Data Space byte 3	4099
Command Data Space byte 4	5120
Command Data Space byte 5	5121
Command Data Space byte 6	5122
Command Data Space byte 7	5123
Command Data Space byte 8	6144
Command Data Space byte 9	6145
Command Data Space byte 10	6146
Command Data Space byte 11	6147
Command Data Space byte 12	7168
Command Data Space byte 13	7169
Command Data Space byte 14	7170
Command Data Space byte 15	7171

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Communication Protocol

The Agilent E1713A board is always commanded through byte valued Command Numbers. These numbers are written to the Command Register for read, write, or command operations.

Read, write, and command operations share a common programming protocol that is described below. Exceptions to any general operation or programming protocol will be stated in the descriptions. You will find a complete listing of all Command Numbers at the end of this section.

Commands are issued to the Agilent E1713A board by writing a Command Number to the Command Register. The Command Register also functions as a ready indicator in that when the Command Register is zero, the Agilent E1713A board is ready to receive a command.

Before writing a Command Number to the Command Register, the PC must first verify that the Command Register is zero. The PC then writes the Command Number to the Command Register. The Command Register is continually monitored. When the Command Register becomes non-zero, the Agilent E1713A board executes the command indicated by the command number that was written. When the Agilent E1713A board finishes executing the command, it will update the Command Status Register and then return the Command Register to zero.

After issuing a command, the PC monitors the Command Register. When the PC reads a zero value, the command has been completed. The PC may then read the Command Status Register to check for successful completion of the command. A zero value in the Command Status Register indicates success, non-zero values indicate otherwise. If the command returns data, such as a position read command, the data may read at this time.

Many commands require supplemental data in the Command Extension space, Command Data space, Buffer Data space or, any combination of the three. This data must be written before writing the Command Number to the Command Register for these commands.

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Data Formats

Unless otherwise indicated, data written to and read from the Agilent E1713A board is processed least significant byte first. The Agilent E1713A board uses the following four data types:

- byte (8-bit)
- word (16-bit)
- long word (32-bit)
- Real (IEEE double precision floating point) (64-bit)

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Sending a Write Command

You must supply appropriate parameter values to the Agilent E1713A board when programming it using the registers. The Write Data Command Numbers are used to write most parameter values to the board. Typically, you follow the steps below when using them.

Writing Data to the Agilent E1713A Board

- Write the parameter value you want to set up to the Data Space in correct units and data type
- Write the associated Command Number to the Command Register

The Command Register will return to a value of zero once the Agilent E1713A board completes execution of this command operation.

Note that the required parameter value is written to the Data Space before the Command Number is sent to the Command Register. When you write data to the Data Space, the least significant byte is always in the lowest byte of the Data Space (PC I/O offset location 4096). Higher order bytes progress up from this lowest byte location.

Example: Write Null Range Distance Value

For example, to set up a Null Range of 10 µinches, follow these steps:

- Check that the command register is zero
- Write 0.000010 (real data type = 8 bytes) to the Data Space
- Write 8 (i.e., Cmd# 8—Null Range Distance) to the Command Register
- Check the command register. When the register contains zero the command has completed. Then check the command status register for a zero value, indicating that the command has completed successfully. A non-zero value indicates the occurrence of an error.

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Example: Write Null Range Distance Value

In Table 6-2, Command #99, Units Value, is listed with a value range of 0–3. Referring to the section on Command Descriptions (see below), you find that a value of 2 corresponds to units in inches. To set a value of 2, follow these steps:

- Check that the command register is zero
- Write 2 (byte) to Data Space Register 4352 (256 + 4096)
- Write Command #99 (byte) to Command Register 256 (256 + 0)
- Check the command register. When the register contains zero the command has completed. Then check the command status register for a zero value, indicating that the command has completed successfully. A non-zero value indicates the occurrence of an error.

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Sending a Read Command

Cmd# 127—Read is the command number you use most often to read data from the board. Typically, you follow the steps listed below.

Reading Data from the Agilent E1713A Board

- Write the associated command number of the parameter value you want read to the Command Extension Space
- Write the Read command number 127 to the Command Register
- Wait until the Agilent E1713A board is finished executing this read command (check the command register for a value of zero)
- Read the parameter value from the data space in the correct units and data type form

The Command Register will return to a value of zero once the Agilent E1713A board completes execution of this command operation. The units, data type, and Command Number are provided in Table 6-2 in this chapter.

Note that the associated command number of the parameter value you want to read is written to the Command Extension Space first. Command numbers are always byte values. Whenever you write data to the Command Extension space, you always start with the lowest byte of the space, PC I/O offset location 3072. So, for most read operations, you simply write the parameter's command number to location 3072 plus your board's base address.

After writing the Read command number 127 to the Command Register, you must wait until the board has finished executing the command. (This requires time to load the parameter value into a space you can read from). The board indicates that it has completed a command by returning the Command Registers value to a value of zero. Monitor this register for a value of zero after writing any Command Number there.

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When the board has completed executing the command, read the parameter value from the Data Space. The lowest byte of the data is located at the lowest addressed byte of the Data Space (board base address + 4096) with higher order bytes progressing up from this address.

Example: Read Null Range Distance Value

For example, to read what the current Null Range value is, you would follow these steps:

- Write 8 (i.e., Cmd# 8—Null Range Distance) to the Command Extension Space
- Write 127 (Cmd# 127—Read Value) to the Command Register
- Read the Command Register until its value is zero
- Read the data (real data type = 8 bytes) from the Data Space starting with the address location equal to the board base address + 4096

For additional examples, see the source code file E1713F2.C on the program disk supplied with this manual.

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Sending a Command

Some Command Numbers (128 and above) command the Agilent E1713A board to immediately perform a specific operation or activity. Typically, when using any of these command numbers, you simply write the Command Number to the Command Register.

Commanding the Agilent E1713A Board

- Check that the command register content is zero
- Write the command number of the command operation to the Command Register
- Check that the command register content is zero indicating that the command has completed
- Check the command status register. A zero value indicates successful completion of the command; if you see a non-zero value, see “System Status Register,” below. Try rebooting the board, using the Boot command

The Command Register will return to a value of zero once the Agilent E1713A board completes execution of this command operation.

Example: Reset the Agilent E1713A Board

To perform a soft reset of the Agilent E1713A board, do the following:

- Check that the command register content is zero
- Write 128 (i.e., Cmd# 128—Soft Reset) to the Command Register
- Check that the command register content is zero, indicating that the command has completed
- Check the command register status for a zero(0) value, which indicates successful completion of the command

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Example: Acquire Servo Lock at the Current Stage Position

Command #129—Acquire Lock, requires no additional data. To perform the command:

- Check that the command register content is zero
- Write 129 (byte) to the Command Register 256 (256 + 0)
- Check that the command register content is zero, indicating that the command has completed
- Check the command register status for a zero(0) value, which indicates successful completion of the command

If your stage and board setting allow servo lock and there are no errors on the board, your board should acquire lock at the current stage position.

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Command Numbers Summary

Table 6-2, Table 6-3, and Table 6-4 summarize information on all the Agilent E1713A Command Numbers. The column abbreviations are defined as:

CMD# Command Number. You write to this number to the Command Register

Name Name of command used in Command Number Descriptions and Agilent-supplied programming routines.

Type Type of data you write when setting up the associated parameter's value or when reading the associated parameter's value. Note: Real = 8 bytes, Long = 4 bytes, Word = 2 bytes, Byte = 1 byte

Units Units in which data is read from or written to the board. You use CMD #99 to select units type. Note that the units you choose using CMD #99 affects all data read from or written to the board. For example, writing a value of 2 sets the distance units to English inches. This means that the units for CMD #4 (Go Destination) will be in English inches.

Range Limits of the data you write or read.

Default Power-up (boot) value of parameter

NOTE In Table 6-2, Table 6-4, and Table 6-5, ***commands highlighted in gray*** are part of the command set, but are not used with the Agilent E1713A Scale Servo Axis Board.

NOTE When writing data, the value to be written is first put into the command data space, with the MSB in the lowest address location the proceeding upward. Next, the command number is written to the command register.

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Table 6-2. Command Numbers For Reading/Writing Data

CMD#	Name	Type	Units	Range	Default
1	Delta Acceleration Profiling Limit	Real	g/s	> 0	1
2	Acceleration Profiling Limit	Real	g	> 0	0.1
3	Velocity Profiling Limit	Real	mm/s, inch/s	> 0	5 in/s
4	Go Destination	Real	inch mm counts	±25.8 ±655 $\pm 2^{31}$ = 2,147,483,648	0
5	Destination Hold	Real	see CMD# 4	see CMD# 4	0
6	Total Compensation Number	Real	none	0.99 – 1.01	1.00000000
7	Deadpath Distance				
8	Null Range Distance	Real	inch mm counts	±418 ±10,620 ±2,147,483,648	0
9	Difference Equation Coefficient	Real	none	none	0
10	Following Error Limit	Real	see CMD# 8	see CMD# 8	–1
11	Marker Position				
32	Buffered Reference Interpolation Count	Long	—	0–65535	0
64	Sample Period	Word	100 ns	500 – 40,000	10,000 (1 kHz)
65	Feedforward Delta Acceleration Coefficient	Word	g/sec	0 – 32767	0
66	Feedforward Acceleration Coefficient	Word	g	0 – 32767	0
67	Feedforward Velocity Coefficient	Word	in/sec mm/sec counts/sec	0 – 32767	0

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Table 6-2. Command Numbers For Reading/Writing Data (Continued)

CMD#	Name	Type	Units	Range	Default
68	Drive Limit	Word	0.3052 mV	0 – 32767	32767 (10 V)
69	Drive Offset	Word	0.3052 mV	0 – 32767	0
70	Settle Time Count	Word	sample periods	0 – 65,535	0
71	Read Reset Offset	Word	raw counts	$0 – 2^{14}$	
96	Service Mode	Byte	—	0, 3, 4, 7, 8, 11, 12	0
97	Trace Control Value	Byte	—	1, 2, 4, 8, 16, 32, 64, 128	0
98	Optics Type				
99	Units Value	Byte	—	0 – 3	2
100	Polarity of Servo Output	Byte	—	0, 1	0
101	Difference Equation Number	Byte	—	0 – 2	0 (PID)
102	Go Buffered Reference	Byte	—	0 – 4	0
103	Measurement Select Value				
104	Laser Common Drive Lines				
105	Filter Control				
106	Marker Window Width				
110	Direction Sense		—	0 – 1	0
111	Resolution		—	0, 1 – 2	1

Table 6-3. The Read Command and Its Command Extension Values

CMD#	Name	Command Extension Space Value & Name	Type	Units
127	Read	0: Read Position	Real	inch, mm, λ
		1–106: See Table 6-2	See Table 6-2	See Table 6-2
		128: Read Trip State	Byte	—
		129: Read Drive Value	Word	0.3052 mV
		130: Read Reference Position	Longword	Raw counts*
		131: Read Following Error Limit	Longword	Raw counts*
		132: Read Buffered Reference Index	Word	—
		133: Read Profile Times	Longword	In sample periods (see Sample Period)

* Raw counts is the system resolution = 5 microns/2^{14} .(0.3051758 nm)

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Table 6-4. Command Numbers for Commanding Board

CMD#	Name
128	Soft Reset
129	Acquire Lock
130	Drive On
131	Drive Off
132	Reset Position Counter
133	Preset Position Counter
134	Clear Null Error
135	Boot
136	Transfer Trace Data
137	Read Revision
138	Go Destination Hold
139	Clear Boot Status
140	Load Buffered Reference

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Table 6-5. Command Summary

Full Name	CMD#	C Function Call[1]
acceleration profiling limit	2	accel
acquire lock	129	acquire_lock
boot	135	boot
buffered reference interpolation count	32	buff_ref_interp
clear boot status bit	139	clear_boot_bit
clear null error status bit	134	clear_null_error_bit
deadpath distance		
delta acceleration profiling limit	1	daccel
destination hold	5	dest_hold
difference equation coefficient	9	diff_eqn_coef
difference equation number	101	diff_eqn_number
drive limit	68	drive_limit
drive off	131	drive_off
drive offset	69	drive_offset
drive on	130	drive_on
feedforward acceleration coefficient	66	feedf_accel
feedforward delta acceleration coefficient	65	feedf_daccel
feedforward velocity coefficient	67	feedf_velocity
filter control		
following error limit	10	following_error_limit
go buffered reference	102	go_buff_ref
go destination	4	go_dest
go destination hold	138	go_dest_hold
laser common drive lines		
load buffered reference	140	load_buff_ref
marker position		
marker window width		
measurement select value		

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Table 6-5. Command Summary (Continued)

Full Name	CMD#	C Function Call
null range distance	8	null_range
optics type		
polarity of servo output	100	polarity
preset position counter		
read buffered reference index	127(x132)[2]	buff_ref_index
read drive value	127(x129)[2]	drive
read following error	127(x131)[2]	following_error
read position	127(x0)[2]	position
read profile times	127(x133)[2]	profile_times
read reference position	127(x130)[2]	ref_position
read revision	137	read_revision
read trip state	127(x128)[2]	trip
reset position counter	132	zero_position
sample period	64	sample_period
service mode	96	service_mode
settle time count	70	settle_time
soft reset	128	soft_reset
total compensation number	6	total_comp_number
trace control value	97	trace_mode
transfer trace data	136	transfer_trace
units value	99	units_type
velocity profiling limit	3	velocity

1 All function calls are preceded by “e17_”
2 The letter ‘x’ precedes the command extension space value used with the Read Command number 127.

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Command Descriptions

Acceleration Profiling Limit *Cmd# 2*

Cmd# 2—Acceleration Profiling Limit sets the maximum acceleration used for internal profiled moves. See Chapter 7 for information on internal profiled moves. Units are set using the Units Value command. Default is in/sec^2.

Acquire Lock *Cmd# 129*

Cmd# 129—Acquire Lock acquires or “locks on to” the current stage position and is a friendly way of safely turning on the servo system. It samples the position counter to get its current value, sets the destination equal to that value, turns on the drive on, and starts executing the selected difference equation. This way of acquiring lock prevents the system from receiving a large error signal which can occur when the drive is turned on without setting up the destination value properly. In most instances, Cmd# 129 is the recommended way to turn on the servo. See also Cmd# 130—Drive On.

NOTE Systematic errors or lack of adequate system gain may prevent this command from completing successfully. See Status Registers for information on potential errors that will prevent acquiring lock.

Boot *Cmd# 135*

Cmd# 135—Boot performs either a hard boot from onboard ROM or a soft boot from code downloaded by the PC. To boot from ROM, write a word to the Data Space with a value of zero. Write the ASCII string ‘BOOT’ to the DPM buffer space. Then write the Cmd# 135 to the Command Register. The boot process will take a few hundred milliseconds and the Agilent E1713A board will not respond to the PC during this time.

To boot from new code, write a word value equal to the number of 256-byte pages into the Data Space. This number is obtained from the third and fourth bytes in the code file.

NOTE The value in the code file is written MSB first and the value in the Data Space is LSB first.

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Write the contents of the code file from the fifth byte to the end of the file to the Buffer Space, then write the Cmd# 135 to the Command Register. The Agilent E1713A board will check the data.

Monitor the Command Register. When it returns to zero, read the Command Status Register. If the Command Status Register is zero, the code is checked and ready to boot. At this point the Agilent E1713A board is in a holding state and is monitoring the Command Register. To execute the boot, the PC must now write an additional 135 to the Command Register. Any other non-zero value will cancel the boot command.

Buffered Reference Interpolation Count Cmd# 32

Cmd# 32—Buffered Reference Interpolation Count specifies how many servo sample periods will take place between each buffered reference value in the Buffered Reference Profile mode, service mode 8. (See Cmd# 96—Service Mode). In other words, the Agilent E1713A board will interpolate “Buffered Reference Interpolation Count” times between consecutive buffered reference values. For example, if a count value of 4 is specified, then the reference position will be updated every servo sample period in the following manner:

Servo Sample Period	Reference Position Equals
X	Value (N)
X + 1	Value (N) + 1/5 Delta
X + 2	Value (N) + 2/5 Delta
X + 3	Value (N) + 3/5 Delta
X + 4	Value (N) + 4/5 Delta
X + 5	Value (N + 1)

where X, X + 1, X + 2, X + 3, ... = consecutive servo sample periods
Value[N] = Nth Buffered Reference Value
Delta = Value[N + 1] – Value[N]

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This command is also applicable in Buffered Post Filter Injection mode, service mode 11, and in Filter Stimulus mode, service mode 12. In these modes, the Buffered Reference Interpolation Count value specifies how many times to repeat the signal injection operation associated with those modes. For example, a value of 4 means the buffer data will be looped and injected five times through.

Clear Boot Status *Cmd# 139*

Cmd# 139—Clear Boot Status clears the error status bit BOOT. See System Status Register section in this chapter for information on the BOOT bit.

Clear Null Error *Cmd# 134*

Cmd# 134—Clear Null Error clears the error status bit NULER. Except for a soft reset, this command is the only way to clear this status bit. See System Status Register section in this chapter for information on the NULER bit.

Delta Acceleration Profiling Limit *Cmd# 1*

Cmd# 1—Delta Acceleration Profiling Limit sets the maximum target delta acceleration value for internal profiled moves. See Chapter 7 for information on internal profiled moves.

Destination Hold *Cmd# 5*

Cmd# 5—Destination Hold allows you to load a destination value and hold the value without initiating a move. To initiate a move using this pre-loaded destination value, use Cmd# 138—Go Destination Hold. This feature allows you to pipeline destinations to the Agilent E1713A to perform pre-move calculations.

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Difference Equation Coefficient *Cmd# 9*

Command Register	Command Extension Space				Data Space
	Cmdx0	Cmdx1	Cmdx2	Cmdx3	
9	Difference Equation Coefficient Type #	Coefficient # or Bank Use #	—	—	Floating Point Value

Cmd# 9—Difference Equation Coefficient allows you to store difference equation coefficients and make a particular bank of coefficients the current active set of coefficients to use.

To load coefficients, you must first load the Command Extension Space and the Data Space with the required data before sending Cmd# 9 to the Command Register. The coefficient value is written to the Data Space. The number of the difference equation (for which you are writing coefficients) is written to the first byte of the Command Extension Space. The coefficient number is written to the second byte of the Command Extension Space. The coefficient numbers for up to four banks of coefficients are listed below.

NOTE

To activate a bank of coefficients, write the Bank Use # instead of the coefficient number to the second byte of the Command Extension Space.

	Coefficient #			
PID	Bank 1	Bank 2	Bank 3	Bank 4
Bank Use #	0	4	8	12
Kp	1	5	9	13
Ki	2	6	10	14
Kd	3	7	11	15

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	Coefficient #			
IIR	Bank 1	Bank 2	Bank 3	Bank 4
Bank Use #	0	6	12	18
Kx0	1	7	13	19
Kx1	2	8	14	20
Kx2	3	9	15	21
Ky1	4	10	16	22
Ky2	5	11	17	23

See Agilent Application Note 325-10, *Sub-micron Positioning* (Agilent publication number 5952-7942), for descriptions of the PID and IIR equations.

Difference Equation Number *Cmd# 101*

Cmd# 101—Difference Equation Number selects the difference equation used in closed-loop servo control. To choose a difference equation, you must write the number corresponding to your choice in the Data Space prior to writing Cmd# 101 to the Command Register. The numbers available for internal algorithms at this time are:

0 PID algorithm
1 2nd order (5 coefficients) IIR filter
2 3rd order (7 coefficients) IIR filter

See Agilent Application Note 325-10, *Sub-micron Positioning* (Agilent publication number 5952-7942), for descriptions of the PID and IIR equations. Custom difference equations may be loaded into Difference Equation numbers 128–143.

Direction Sense *Cmd# 110*

This read/write command lets you specify the direction sense of the arm movement. For example, if the arm is rotating clockwise but producing a negative count, use CMD #110 to change the direction sense so the count is positive in the direction of arm motion. The command is a byte variable with a range of 0 or 1 and default value of 0. It does not impact the hardware outputs on the top connector of the Agilent E1713A.

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Drive Limit *Cmd# 68*

Cmd# 68—Drive Limit sets the maximum absolute value written to the DAC on the Agilent E1713A board.

NOTE

You specify this voltage in 0.3052 mV resolution units according to the equation:

Data Space Value = Desired Maximum Positive or Negative Voltage ÷ 0.3052 e -3

Drive Off *Cmd# 131*

Cmd# 131—Drive Off disables the servo drive output, forces the output to zero, and stops executing the difference equation.

Drive Offset *Cmd# 69*

Cmd# 69—Drive Offset sets the voltage offset value for the servo output drive signal.

NOTE

You specify this offset voltage in 0.3052 mV resolution units according to the equation:

Data Space Value = Desired Offset in Volts ÷ 0.3052 e -3

Drive On *Cmd# 130*

Cmd# 130—Drive On enables the drive circuit and starts the difference equation.

NOTE

Systematic errors may prevent this command from completing successfully. See Chapter 8, *Maintenance and Troubleshooting*, for a list of common problems.

Feedforward Acceleration Coefficient *Cmd# 66*

Cmd# 66—Feedforward Acceleration Coefficient sets the amount of acceleration feedforward gain used in calculating the motor drive outputs. See Chapter 7 for more information on feedforward. The Units Value command sets units for this coefficient. Default = in/sec^3.

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Feedforward Delta Acceleration Coefficient Cmd# 65

Cmd# 65—Feedforward Delta Acceleration Coefficient sets the amount of velocity feedforward gain used in calculating the motor drive output every sample period. See Chapter 7 for more information on feedforward. The Units Value command sets units for this coefficient. Default = in/sec^3.

Feedforward Velocity Coefficient Cmd# 67

Cmd# 67—Feedforward Velocity Coefficient sets the amount of velocity feedforward gain used in calculating the motor drive output every sample period. See Chapter 7 for more information on feedforward. The Units Value command sets units for this coefficient. Default = in/sec.

Following Error Limit Cmd# 10

Cmd# 10—Following Error Limit sets the maximum following error limit. Should the actual position differ from the reference position by more than the specified following error limit, an error will be generated in the system status register and the servo drive output will be turned off. Setting up a following error limit outside the specified range (i.e., a negative value) turns off the following error limit function by setting the limit to a value greater than the maximum position error (power-up default). The Units Value command sets units for this coefficient. Default = inches.

Go Buffered Reference Cmd# 102

Cmd# 102—Go Buffered Reference is used with the Buffered Reference Profile mode (service mode 8) and does two things. First, sending this command initiates the Agilent E1713A board to start buffering user specified reference position data. Second, the command also specifies by its value the order and signing convention of how the Agilent E1713A board uses the buffered reference data.

When buffered reference profiling is initiated by this command, the Agilent E1713A board starts adding the buffer values (destination offset values) to the reference position on a sample by sample basis. This operation continues until the end of the buffer is reached. (Linear interpolation between reference positions is performed if an interpolation count value has been set up).

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The Buffer Go Value specifies the order in which the buffer values will be used. These values are defined for the following options:

Buffer Go Value	Option	Definition
1	Forward Positive:	Use first buffer value first (last buffer value last) to produce + move
2	Forward Negative:	Use first buffer value first (last buffer value last) to produce -move
3	Reverse Positive:	Use last buffer value first (first buffer value last) to produce + move
4	Reverse Negative:	Use last buffer value first (first buffer value last) to produce -move

See Cmd# 96—Service Mode, and Cmd# 32—Buffered Reference Interpolation Count for more information. See Chapter 7 for a discussion on buffered reference profiling.

Go Destination *Cmd# 4*

Cmd# 4—Go Destination moves the stage to the destination value you specify in the Data Space area immediately after this command number is written to the Command Register. The Agilent E1713A board calculates adjustments for the current units, compensation value, deadpath distance, and service mode prior to the move. This command is not applicable in Velocity Profile or Buffered Reference Profile modes.

NOTE

Cmd# 132—Reset Position Counter zeroes the destination as well as the position counter.

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Go Destination Hold *Cmd# 138*

Cmd# 138—Go Destination Hold commands the Agilent E1713A board to *immediately* move to the held destination value specified by Cmd# 15—Destination Hold. The difference between using these commands (Destination Hold, Go Destination Hold) and Cmd# 4—Go Destination is that the Destination Hold command allows the Agilent E1713A to pre-calculate profiling parameters. You can use this command for pipelining consecutive move commands. In other words, while the Agilent E1713A board is completing a move or is non-active, you can set up destination values which can be immediately moved to upon the Go Destination Hold command. On the other hand, note that Go Destination commands the Agilent E1713A board to move to a destination; the Agilent E1713A board will require time to calculate profiling parameters before actually moving.

Load Buffered Reference *Cmd# 140*

Cmd# 140—Load Buffered Reference loads buffered reference data from the DPM Buffer to the Agilent E1713A board's buffer. Before performing this command, you must first load the buffered reference data to the DPM Buffer in little endian (LSB first) format. This command then requires the number of buffer items and the type of items to load. Write the number of buffer items (as a word) to the Data Space first, and the value corresponding to the following bit settings to the first byte of Command Extension Space:

Bit	7	6	5	4	3	2	1	0
Function	not used	not used	not used	not used	not used	not used	Item Type	Transfer Mode

Transfer Mode: 0 = initialize trace buffer
1 = append to trace buffer

Item Type: 0 = real (8 bytes)
1 = raw counts (4 bytes)

Then, write the command number to the Command Register. This transfers the buffered reference data from the DPM Buffer to the Trace Buffer. See Chapter 7 for more information on buffered reference operation and programming.

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Null Range Distance *Cmd# 8*

Cmd# 8—Null Range Distance, sets the range value used in monitoring an in-null-range condition used in setting the system and error status bits, INNUL and NULER. An in-null-range condition occurs when the absolute value of [current position minus destination] is less than this Null Range value. For example, if your destination is 1 inch (25.4 mm), and your Null Range value is 0.1 inch (2.54 mm), an in-null-range condition exists whenever the current position is between 0.9 inch and 1.1 inches (22.9 and 27.9 mm).

The system status bit INNUL is set to 1 whenever current position is within the Null Range of destination, and is set to 0 whenever current position is outside of it. This bit is continually updated.

The error status bit NULER is set and latched after any out-of-null range occurrence. This bit is only cleared by Cmd# 134—Clear Null Error Status. You can use this NULER bit to monitor position wandering after a settled condition has been reached To do this, reset this bit after the stage has settled and monitor it.

NOTE

NULER always occurs when a move places the stage outside the null error limits.

Polarity of Servo Output *Cmd# 100*

Cmd# 100—Polarity of Servo Output sets the polarity of the servo output voltage. Value 0 sets the servo output signal positive for positive drive values; the value 1 sets the servo output signal negative for positive drive values.

Read Command *Cmd# 127*

Cmd# 127—Read is used to read most values from the Agilent E1713A board. It is used with one other Command Number (or other defined number) as a value placed in the Command Extension Space to indicate the parameter value to be read. Descriptions of all valid Command Extension Space values follow:

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Command Extension Space Value

0 Read Position

Command Extension Space value 0 when used with Cmd# 127—Read returns the stage position in *current units* as a *real* data type (8 bytes) to the Data Space. All position values except raw units are compensated values using the current total compensation value. See Cmd# 6—Total Compensation Number.

1 to 106 Read Parameter Value

Command Extension Space value 0 through 106, when used with Cmd# 127—Read, returns the chosen parameter's value to the Data Space. The chosen parameter is the parameter associated with the Command Number value indicated in this chapter. The data type and units are the same as the data type and units used in writing the data to the Data Space. See Table 6-2 for data type and units listing.

128 Read Trip State

Command Extension Space value 128, when used with Cmd# 127—Read, returns a byte value representing the current trip state of the current or last move profile when in Position Profile or Velocity Profile modes. When in Buffered Profiling mode, the byte value indicates the type of buffered profiling currently being executed. See Chapter 7 for the trip state values corresponding to the different profiles possible.

129 Read Drive

Command Extension Space value 129, when used with Cmd# 127—Read, returns the current DAC value of the servo drive output signal. The returned data type is word.

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130 Read Reference Position Value

Command Extension Space value 130 when used with Cmd# 127—Read returns the current reference position in raw units only to the Data Space. This value can only be read in raw units. The returned data type is long word.

131 Read Following Error Value

Command Extension Space value 131 when used with Cmd# 127—Read returns the current following error value in raw units to the Data Space. The returned data type is long word.

132 Read Buffered Reference Index

Command Extension Space Value 132 allows you to read the position within the buffer and the interpolation count of the current move while in buffered reference mode. Each value is an unsigned word. The buffer position value is returned in the first two bytes of Data Space and the interpolation count in the next two.

133 Read Profile Times

Command Extension Space Value 133 allows you to read profile times in servo sample periods for the most recent internal profiled move. The profile times are returned to the Data Space as 3 long words (4 bytes each) after this command is received. Delta Acceleration profile time occupies the lowest 4 bytes (PC I/O offset location 4096–4099), Acceleration time occupies the next 4 bytes (PC I/O offset locations 5120–5123), and Velocity profile time occupies the next 4 bytes (PC I/O offset locations 6144–6147).

For internal profiled moves, the total trip time will be equal to (4 × delta acceleration profile time) + (2 × acceleration profile time) + (velocity profile time). See the Trip States section in Chapter 7 for more information on profiling times.

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Read Reset Offset *Cmd# 71*

This read only command is accessed through the general READ command (Cmd# 127). It returns the absolute phase offset at the reset position as an unsigned 16-bit word. The LSB represents 0.30518 nm.

Read Revision *Cmd# 137*

Cmd# 137—Read Revision returns the Agilent E1713A board's software revision date to the DPM buffer. See Chapter 7 for reading from the DPM buffer.

Reset Position Counter *Cmd# 132*

Cmd# 132—Reset Position Counter resets the position counter and destination to zero, re-establishes the total compensation number for deadpath compensation, and stops any current position profiling move in progress.

Resolution *Cmd# 111*

This command can be used to compensate for alternate sensor head/scale combinations that may be offered in the future. Use a value of 1 with the Agilent E1711A Sensor Head and Agilent E1712A Angular Scale.

Sample Period *Cmd# 64*

Cmd# 64—Sample Period sets the servo sample period which controls how often the selected difference equation is run and servo drive output signal is updated. The Sample Period is specified in units of 100 ns. To calculate the appropriate Sample Period value from a desired sampling frequency, use the following equation:

Sample Period Value = 10^7 ÷ Desired Sampling Frequency

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Service Mode *Cmd# 96*

Cmd# 96—Service Mode sets the Agilent E1713A to a particular profiling service mode or a test service mode. The choices for the Service Mode values you write to the Agilent E1713A are listed below. Details of each of these modes can be found in Chapter 7.

Service Mode Value	Service Mode	Master/Slave/Stand Alone
0	Internal Position Profile	Stand Alone
3	External Position Profile	
4	Internal Velocity Profile	Stand Alone
7	External Velocity Profile	
8	Buffered Reference Profile	Stand Alone
11	Buffered Post Filter Injection	Stand Alone
12	Buffered Filter Stimulus	Stand Alone

Settle Time Count *Cmd# 70*

Cmd# 70—Settle Time Count specifies a number of consecutive sample periods required in the Agilent E1713A's determination of a settled condition. A settled condition exists when position has been within the Null Range of the destination for the specified consecutive number of sample periods after a move. The Agilent E1713A board keeps track of this event and updates the system status SETTL bit.

Soft Reset *Cmd# 128*

Cmd# 128—Soft Reset performs a soft reset of the Agilent E1713A board. A soft reset will clear all status errors on the board (except for code failure 'CODE' and boot status 'Boot') and updates all status bits. If a measurement error exists, then the position is reset to zero as well. Soft Reset clears Scale errors and Warnings and resets the position value if XYLOW or VEL errors occur.

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Total Compensation Number *Cmd# 6*

Cmd# 6—Total Compensation Number is a number used internally to multiply raw counts to obtain scale position information. It is also used to compensate values for Cmd# 4—Go Destination, and Cmd# 8—Null Range Distance.

Default = 1.0000000

Trace Control Value *Cmd# 97*

Cmd# 97—Trace Control Value selects which parameters will traced every sample period once tracing begins and sets up the way in which tracing will begin. To use this command, set each bit in the chart below to your needs, then write the resulting Trace Control Value value to the Agilent E1713A board. The Trace Control Value select bits are listed below. As an example, to trace reference position and current position upon sending this command number to the Agilent E1713A's Command Register, select bits 1000 0011 = 131, and write the Trace Control Value value 131 to the Agilent E1713A board.

Bit	7	6	5	4	3	2	1	0
Function	Start Tracing on Cmd# 97	Start Tracing on any move*	not used	not used	Trace Motor Drive	Trace DEQ Output	Trace Current Position	Trace Reference Position
Data Size	—	—	—	—	one word	one word	two words	two words

*Any move can be initiated by either Cmd# 4—Go Destination when in internal profiling mode, Cmd# 3—Velocity Profiling Limit when in velocity profiling mode, or Cmd# 102—Go Buffered Reference when in buffered reference profiling mode.

Reference Position and Current Position values are traced in raw counts. Difference Equation and Motor Drive values are traced in their DAC output values. See Chapter 7 for complete information on programming trace values and buffer utilization.

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Transfer Trace Data *Cmd# 136*

Cmd# 136—Transfer Trace Data transfers trace data from the most recent trace operation to the Buffer Space in the Dual Port Memory.

To transfer trace data, write a word value equal to the number of 256-byte pages you wish to transfer into the Data Space, then write the Cmd# 136 to the Command Register. When the command has completed, the Command Register will return to zero. At this point the command status register may be read, with a zero indicating successful command completion.

The trace data may now be read from the DPM buffer. Note that the trace data is stored in 'big endian' format, or most significant byte first. See Chapter 7 for a discussion of trace operations.

Units Value *Cmd# 99*

Cmd# 99—Units Value, selects the type of units that will be used in for most I/O operations. When you select these units, you write and read position-related and distance parameters in these *current units*. Exceptions will be noted. Choices for the Units Value value you write to the board are:

0	Raw (uncompensated counts)
1	Compensated (counts)
2	English inches (inch)
3	Metric millimeters (mm)

Velocity Profiling Limit *Cmd# 3*

Cmd# 3—Velocity Profiling Limit (Velocity Limit) sets the maximum target velocity value for internal profiled moves. See Chapter 7 for information on internal profiled moves.

This command, when in velocity profiling mode, initiates moves (like the Go Destination command does in internal profiling mode). In velocity profiling, this command stops moves by sending a velocity profile limit of zero.

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Status Registers

These registers are read-only registers that can be polled to check and identify any system errors, Agilent E1713A board errors, or certain positioning related conditions. Do not attempt to write to these registers to clear errors. Refer to the Command Descriptions section for commands that reset errors indicated by these register status bits.

Command Status Register

Offset Value From Base Address: 2048

This register indicates whether a command completed successfully or not. A value of 0 in this register indicates success. A non-zero value in this register indicates an error. Read from this register only after a command has completed. The Agilent E1713A board lets you know that a command has completed by updating the Command Register to value 0 after you have written a Command Number to it. In other words, check the Command Register for value 0, then read from the Command Status Register.

Error Status Register

Offset Value From Base Address: 2050

These status bits are read only. All Error Status Register bits, except the CODE and BOOT bit, are reset by Command Number 128—Soft Reset. BOOT and NULER have separate Command Numbers which allow them to be reset by themselves. A 1 in each bit position below indicates the following occurrences:

Bit	7	6	5	4	3	2	1	0
Function	CODE	BOOT	Reserved	NULER	FELIM	XYLOW	OVFL	VELER

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CODE: A code error has occurred. Possible causes include bus and address errors. This bit cannot be reset. You must reboot the board to clear this bit.

BOOT: The board has been booted since the last reset of this BOOT bit. This bit will let you know if the card has re-booted. Re-boots may occur during Agilent E1713A halts or timeouts. You should clear this bit on initialization so that you can check this bit for potential re-boot occurrences. (See Command Number 139—Clear BOOT Error Bit)

NULER: Measured position has gone out of the Null range since the last NULER reset. This bit can be used to monitor whether stage position has gone out of some pre-specified range To do this, after the stage has settled (see System Status Register SETTL bit), clear this NULER bit (see Command Number 134—Clear NULER bit) so that you can monitor any out-of-null positions.

FELIM: The following error limit has been exceeded. The Following Error Limit (See Command Number 10—Write Following Error Limit) is a programmable value. At any time when following error (Reference Position-Measured Position) exceeds this value, servo motor drive output will shut off.

XYLOW: A Signal Dropout Error has occurred. The input voltages have dropped below a minimum which has been preset to ensure accurate position information. The current position may not be valid. This error automatically turns off the servo.

OVFL : The position counter has overflowed. Any position related information produced by the board may not be valid.

VELER (Velocity Error): A velocity error has occurred. An input signal change indicating a velocity of ±(1.0 ±0.125) m/s has occurred but the board cannot tell the direction of motion. The current position may not be valid. This error automatically turns off the servo.

A Velocity Error will be issued for absolute velocities greater than 0.875 ±0.125 m/s (34.45 ±4.92 inches/s). A Velocity Error will be issued for velocities greater than approximately 1 meter/sec. Depending on absolute phase at any given time, the circuits may generate a Velocity Error with velocities ranging from 0.750 m/s to 1.000 m/s (29.52 to 39.37 inches/s). This status bit is cleared by SOFT RESET (Cmd #128).

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System Status Register

Offset Value From Base Address: 2051

Bit	7	6	5	4	3	2	1	0
Function	Reserved	Reserved	SETTL	INNUL	TRIP	DRIVE	P33	VWARN

These status bits are read only. All System Status Register bits are updated continuously. A 1 in each bit position above indicates the following occurrences:

SETTL: The stage has settled. This means the measured stage position has been in the Null range for the user specified Settle Time (see Command Number 8—Write Null Range and Command Number 70—Write Settle Time).

INNUL: The measured stage position is inside the Null range. When the measured position is outside the Null range, this bit is 0.

TRIP: A 'trip' is in progress. 'Trip' refers to the reference profile path generated by the Agilent E1713A board for moves. Reference position values from this profile generation are used to generate position error calculations during moves. When the board has finished using all generated profile reference values, the trip is finished and this bit will return to zero.

DRIVE: The servo drive output is on. A zero indicates it is off. Turning on the servo drive turns on the current difference equation loaded onto the board. See Command Number 130—Enable Drive and Command Number 131—Disable Drive.

P33: This is the next bit of the extension counter. Each time the counter "rolls" over, this bit is toggled and the OVFL error bit is set. POSITION RESET (Cmd #132) clears this bit to zero.

VWARN: (Latched Velocity Warn): A Velocity Warning indicates that the stage velocity has approached the velocity limit. The stage should be slowed to prevent loss of position information.

A Velocity Warning is issued for absolute velocities greater than 0.875 ±0.125 m/s (34.45 ±4.92 inches/s)—depending on absolute phase at any given time, the circuits may generate a velocity warning with velocities anywhere from 0.750 m/s to 1.000 m/s (29.52 to 39.37 inches/s). This status bit is cleared by SOFT RESET (Cmd #128).

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Agilent 10889B Command Cross Reference

With the exception of several commands, the command sets for the Agilent E1713A and the Agilent 10889B boards are the same. The following table lists the Agilent 10889B commands that are not used with the Agilent E1713A board. It also includes two commands, CMD# 110 and 111 that are used with the Agilent E1713A board but not used with the Agilent 10889B board. Refer to Command Descriptions in this chapter for details of Agilent E1713A board command operations.

Table 6-6. Agilent 10889B Commands Not Used With the Agilent E1713A Servo Axis Board

CMD#	Name	Type	Units	Range	Default
7	Deadpath Distance	Real	inch mm λ	±209 ±5310 ±1,073,741,823	0
11	Marker Position	Real	see CMD# 7	see CMD# 7	0
98	Optics Type	Byte	—	0 – 2	1
103	Measurement Select Value	Byte	—	0, 1, 2	1
104	Laser Common Drive Lines	Byte	—	0, 1	
105	Filter Control	Byte	—	0 – 15	0
106	Marker Window Width	Byte	—	0 – 15	0
110	Direction Sense		—	0 – 1	0
111	Resolution		—	0, 1 – 2	1
133	Preset Position Counter	Command Number for Commanding Board			

NOTE

In Table 6-2, Table 6-4, and Table 6-5, commands ***highlighted in gray*** are part of the command set, but are not used with the Agilent E1713A Scale Servo Axis Board.

In Table 6-6 commands ***highlighted in gray*** are part of the command set, but are not used with the Agilent 10889B PC Servo Axis Board.

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7

Profiling

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Profiling

Profiling refers to the method in which the Agilent E1713A board generates position reference values on a sample-by-sample basis. For a profiled move, the Agilent E1713A uses programmed velocity, acceleration, and delta acceleration values to create a reference position profile vs time.

When you initiate the move, the stage moves in accordance with the reference position profile. The movement of the stage may not exactly follow the profile. The difference between the actual stage position during the move and the profile position is called the “following error.”

This section discusses profiling topics as they apply to the Agilent E1713A board’s profiling algorithms and parameters. Figure 7-1 shows a block diagram of the Agilent E1713A board. Refer to this during profiling and difference equation discussions.

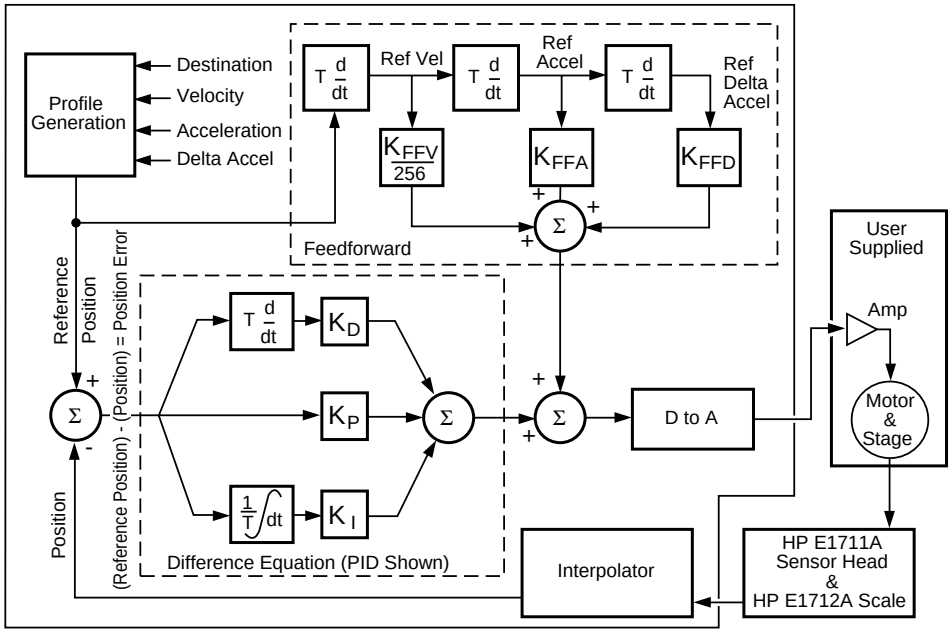


Figure 7-1. Agilent E1713A Servo-Axis Board Block Diagram

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Profiling Limits

In every sample period, a reference position value is generated. This value is used with a stage's actual position to compute a position error value which is processed by the PID or the IIR algorithms. (Figure 7-1 illustrates the PID algorithm.) The reference position value is also input to the feedforward block, generating the feedforward term. The sum drives a D/A converter which produces the servo output voltage. One to three programmed profiling limit values are used to control the internal generation of this reference position value:

Delta acceleration:	Sets the delta acceleration rate in g's per second
Acceleration:	Sets the maximum acceleration (in g's) for both position and velocity profiling
Velocity:	Sets the maximum velocity (in current units) for position profiling, or sets the desired velocity for velocity profiling

These values should be set to correspond to (or be less than) the capabilities of the motor-stage system.

Feedforward

Feedforward attempts to generate most of the servo output from the reference position values instead of the position error. Its function is outside the control loop, and thus does not affect the system's stability. Feedforward offers two benefits. First, proper feedforward helps minimize following error during moves. Second, feedforward can help optimize settling time characteristics. Three programmable feedforward coefficients are available: Feedforward delta acceleration, Feedforward acceleration, and Feedforward velocity. See the TUNE chapters in this manual for more information on how to use them.

Service Modes

The Agilent E1713A board has different profiling options (position and velocity) that are set up using the Service Mode command:

- "Internal" profiling indicates that the reference positions are calculated from the programmed destination, velocity, acceleration and delta-acceleration limit values.

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- "External" profiling indicates that the reference positions are calculated directly from the programmed destination or velocity limit value.
- "Buffered Reference" profiling indicates that the reference positions are user-defined values downloaded to the board. These various profiling methods are described below.

Internal Position Profiling

In internal position profiling, when a move is initiated (by either a Go Destination or Go Destination Hold command), a series of reference positions are internally generated by the board that will move the stage to the desired destination while keeping the delta acceleration, acceleration, and velocity of the stage within their programmed limits specified by their respective commands.

External Position Profiling

In this service mode, the destination value sent with the Go Destination command or specified by the Destination Hold command becomes the reference position immediately after a move is initiated. The delta acceleration, acceleration, and velocity programmed values are ignored.

Internal Velocity Profiling

Internal velocity profiling operates similarly to internal position profiling. However, moves are initiated with the Velocity Profiling Limit command. When a move is initiated, the board's velocity value increases to its limit using the delta acceleration and acceleration programmed values and continues to run at this velocity limit. To terminate the move, another Velocity Profiling Limit command is sent with the velocity limit value of zero. (All Go Destination and Go Destination Hold commands are ignored).

External Velocity Profiling

In this service mode, the velocity value sent with Velocity Profiling Limit command becomes operational instantly. The delta acceleration and acceleration programmed values are ignored.

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Buffered Reference Profiling

In this mode, the trace buffer is filled with position offset values which are added to the reference position on a sample by sample basis after a Go Buffer Reference command is sent. This process continues until the end of the programmed buffer values are reached. See Programming Reference Buffer Operations later in this chapter for more information.

When using the buffer for Buffered Position Profiling the board uses the current Total Compensation Number and Deadpath Distance values to convert to raw counts before adjusting the reference position. Note that the buffer values are offset destinations, meaning all values are relative to the stage position when a Go Buffered Reference command is sent. For Reverse operation, the last value in the buffer is subtracted from all values during the move.

These buffer reference values can be linearly interpolated by a user-defined number of times to increase system flexibility and performance. Setting the interpolation count to a value N using the Buffered Reference Interpolation Count command causes the board to insert N servo sample periods between each buffer value and update the reference position proportionately on each sample period.

Buffered Injection and Filter Stimulus

These modes are useful when determining loop response and tuning the servo system (see Figure 7-2). In either mode, the buffer is filled with the desired test signal. The Go Buffered Reference command causes these stored values to be injected at the specified location.

The post filter (difference equation) injection allows testing closed loop system response or open loop motor-stage response. (Set the coefficients to zero).

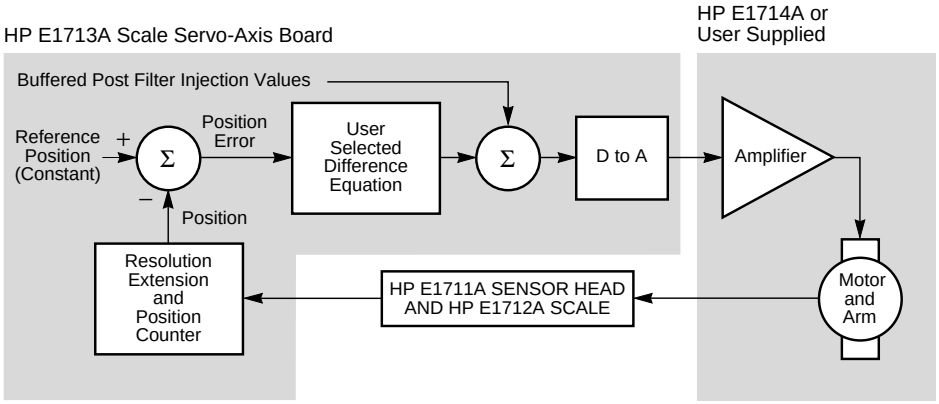
The filter stimulus allows testing the difference equation response and the open loop system response. In this mode, the only input to the difference equation is the stored values). See Figure 7-2.

The Trace function should be used to collect position and difference equation output data with both these modes. See Programming Trace Control later in this chapter for more information.

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Using buffered reference interpolation count in these modes sets up a loop count instead of an interpolation count. Setting the loop count to N causes the board to automatically repeat the Go Buffered Reference command N additional times, thus looping through a buffered injection or filter stimulus operation N times.

Block Diagram For Post Filter Injection



Block Diagram For Post Filter Stimulus

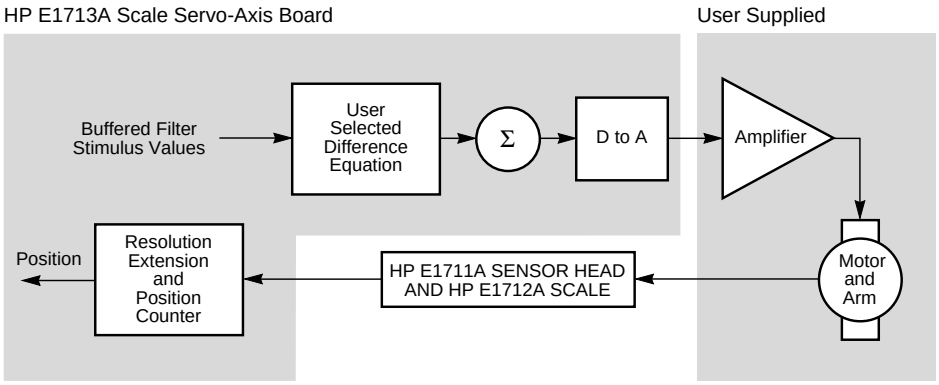


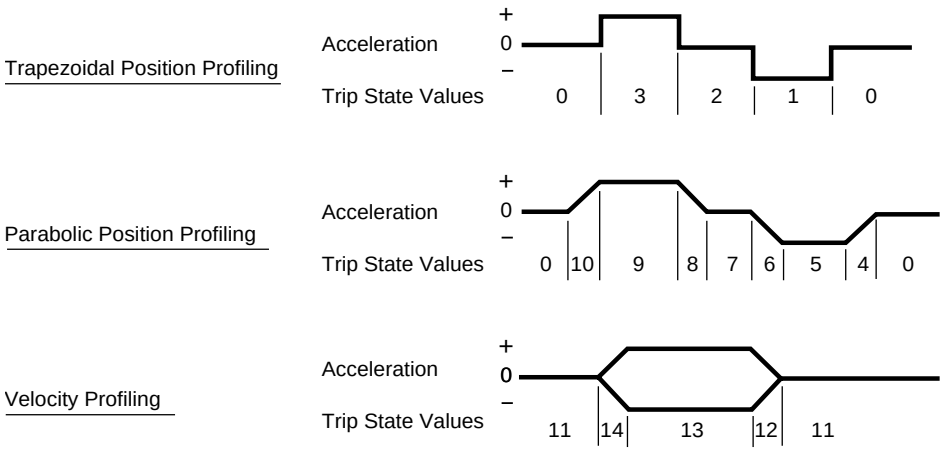
Figure 7-2. Block Diagram for Post Filter Injection and Filter Stimulus

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Trip States

"Trip state" refers to where the Agilent E1713A board is currently in a position or velocity profile. Trip state information is available using the Read Trip State command. Figure 7-3 illustrates the different trip state values as they relate to what occurs during different profiled moves. Note that for buffered reference profiling, trip state values indicates buffer mode operation.

Profiling times refer to the times calculated by the Agilent E1713A board over which profiling is either in a delta acceleration, acceleration, or velocity state. For example, in Parabolic Position Profiling (Figure 7-3), trip state corresponds to the delta acceleration profiling time. Trip states 10, 8, 6, and 4 correspond to this same time. Similarly, trip states 9 and 5 correspond to the acceleration profiling time, and trip state 7 corresponds to the velocity profiling time.



Buffered Profiling

Buffered Reference Trip State Values	Buffered Operation	Buffered Injection Trip State Values
15	Idle	20
16	Positive Forward	21
17	Negative Forward	22
18	Positive Reverse	23
19	Negative Reverse	24

Figure 7-3. Trip States for Different Profiling Modes

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Trace and Buffered Reference

Trace Buffer Utilization

The Agilent E1713A Scale Servo-Axis board has 32000 long (32-bit) words of buffer memory that are shared between trace and buffered reference. This buffer operation scheme maximizes the memory available for trace when buffered reference profiling is not in use. At power up, the board assigns all of this memory as trace data.

Loading reference buffer values using the Load Buffered Reference command causes some user-specified size of trace buffer to be reassigned to store reference buffer data starting at the top of the trace buffer. Read any trace data before loading any reference buffer data!

Each time a trace is performed, any memory not used by the reference buffer is filled with trace data. When buffered reference profiling is not in use, storage of trace data starts at the top of the trace buffer. When transferring trace data with the Transfer Trace Data command, the Agilent E1713A board transfers only traced data.

The Agilent E1713A board stores each reference buffer value as one long word in memory, allowing 32000 positions to be stored. If the interpolation count is set to zero, and the sample period set to 100 (10 kHz), then a 3.2-second journey can be stored. Increasing either the interpolation count or the sample period lengthens this journey time. For example, using a 2 kHz sample rate and an interpolation count of 4, a 64-second journey can be stored.

Each trace data item uses one or less long words of memory. Reference and actual position each use 32 bits, or one long word. Motor drive and difference equation output each use only 16 bits, or 1/2 long word. Tracing all parameters (reference position, actual position, difference equation output, and motor drive) requires three long words per sample period, allowing over 10000 sample periods of tracing, or about 0.53 second of data at the fastest sample rate. Reducing the sample rate or number of parameters traced will increase the maximum trace time. For example, tracing only Actual Position (one long word) with a 2 kHz sample rate results in 16 seconds of trace data.

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When both buffered reference and trace functions are utilized, the times for each should be adjusted accordingly. For example, filling the buffer with 2000 data points, setting an interpolation value of 9, and using a 2 kHz sample rate produces a 10-second stored trip, and allows Actual Position to be traced for 11 seconds. For example, filling the buffer with 2000 data points, setting an interpolation value of 9, and using a 2 kHz sample rate produces a 10 second stored trip, and allows Actual Position to be traced for up to 15 seconds.

Programming Trace Control

Up to four different system signals can be recorded in real-time by the Agilent E1713A Scale Servo Axis Board. There are 32,000 long (32-bit) words of buffer space available for data storage. Part, or all, can be reserved for trace data. The rest is available for buffered reference.

The Trace Control command selects which system signals to store in the buffer, and when to start storing them. Then, once per sample period, the selected signals are recorded for later retrieval. Recording stops when the end of trace buffer memory is reached. Table 7-1 shows the correspondence between the trace control value passed with the Trace Control command and the system signals that are traced.

Table 7-1. Trace Control Values

Bit	Value	Trace Control Feature	Data Length
0	1	Reference Position	32-bit long word
1	2	Actual Position	32-bit long word
2	4	Difference Equation Output	1A-bit word
3	8	Motor Drive DAC	1A-bit word
4	16	Not currently used	—
5	32	Not currently used	—
6	64	Start tracing on either Go Destination, Go Destination Hold, Go Buffered Reference or Velocity command	—
7	128	Start tracing when this Trace Control command is sent	—

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Trace data is stored in the same order as listed above. For example, specifying a trace of all four items with value 79 causes the data to be stored in the following order once a move is initiated:

Reference Data
Actual Position Data
Difference Equation Output
Motor Drive
Reference Data
Actual Position Data
etc.

Additional signals can be calculated by combining two or more of the traced parameters. For example, subtracting Reference from Actual Position yields following error, and subtracting Difference Equation Output from Motor Drive yields Feedforward. Graphing these parameters versus time allows quick analysis of a system's response and greatly reduces the time spent optimizing servo-system performance.

Reading Trace Data

The data recorded during a trace can be read from the DPM buffer. Trace data must first be transferred from the Trace buffer to the DPM buffer using the Transfer Trace Data command. All data will be transferred after this command is sent and completely and successfully executes.

Trace data is stored in the DPM buffer starting at the lowest address in big endian format. Reading data is done one byte at a time by reading from the DPM Buffer Data register.

Programming Reference Buffer Operations

Three service modes use the reference buffer as a data source. One of them treats the data as offset destination values. This mode allows custom motion profiles which can not be generated from the velocity, acceleration and delta acceleration terms. The other two modes treat the data as numeric input to be injected at a specific point in the system. These latter modes are useful when tuning the servo system and determining the open and closed-loop transfer functions. In all modes, reference buffer data must be transferred from the DPM buffer to the Trace buffer using the Load Buffered Reference command before initiating a buffered reference move or signal injection.

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Writing Buffered Reference Data

Values written to the DPM buffer for buffered reference profiling operation are either double (8 byte) or long (4 byte) values in little endian format. (Note that Trace data *transferred* to the DPM buffer is in *big* endian format). The Agilent E1713A board converts each value sent from current units to compensated lambda units when the values are specified as double. The units of the buffer values are user-specified with the Load Buffered Reference command.

For Buffered Post Filter Injection, the board clips the 32-bit compensated lambda value to 16 bits. The maximum or minimum integer is used if the buffer value is outside the 1A-bit integer range. For Buffered Filter Stimulus, the board sends the full 32-bit compensated lambda value to the difference equation in place of position error. To accurately know the injected signal, Agilent recommends programming in raw or compensated lambda units when using Buffered Injection or Filter Stimulus.

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DPM Buffer Registers

The DPM Buffer is used on the Agilent E1713A board for handling large amounts of data. You typically use this area for Trace and Buffered Reference operation, or for downloading new firmware to the board. DPM Buffer data is accessed through these three PC I/O Registers: the DPM Buffer Data Register, the DPM Buffer Low Address Register, and the DPM Buffer High Address Register.

DPM Buffer Data Register

Offset Value From Base Address: 1

This register is used to read data from and write data to the DPM Buffer. This register is byte wide, so reading and writing data is done byte by byte. You must first set up the starting address where the first byte will be read. Generally, but not necessarily, the starting address is 0, the lowest available address in the DPM Buffer. (This starting address is set up in the DPM Buffer Low and High Address Registers). When you read from or write data to this DPM Buffer Data Register, the Agilent E1713A board auto-increments a pointer that points to the next higher byte in the DPM Buffer. This allows you to read the next byte of DPM Buffer data the next time you read from this register, or to write to the next byte of DPM Buffer space the next time you write to this register.

For example, to write to the DPM Buffer starting at address 0, write 0 to the DPM Buffer Low Address Register (register location = your Agilent E1713A base address + 2), then write 0 to the DPM Buffer High Address Register (register location = base address + 3). Now write a byte to the DPM Buffer Data Register (register location = base address + 1). The Agilent E1713A will take that byte of data and write it the DPM address location 0. You write again to the DPM Buffer Data Register (register location = base address + 1) to write the second byte of data to DPM address location 1. Continue to write data to the DPM Buffer Data Register until your writing is complete.

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DPM Buffer Low Address Register

Offset Value From Base Address: 2

This register is used to hold the low byte of the starting address during writing operations to the DPM Buffer. The starting address is two bytes wide and must be set up before any write operations are done. This register, the DPM Buffer Low Address Register, contains the low byte of this starting address, while the DPM Buffer High Address Register contains the high byte of the starting address.

DPM Buffer High Address Register

Offset Value From Base Address: 3

This register is used to hold the high byte of the starting address during reading or writing operations to the DPM Buffer. See description on the DPM Buffer Low Address Register.

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8

Maintenance and Troubleshooting

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Introduction

This chapter provides information on maintenance, troubleshooting, and getting replacement parts for the Agilent E1713A.

Laser Safety

The Agilent E1711A Sensor Head contains a powerful laser diode that emits invisible infrared light. Do not under any circumstances look directly at the laser light source or allow the laser beam to be directed or reflected into your eyes. You will find the warning labels illustrated below fixed to any device that contains a laser or that may direct a laser beam into your eyes.

You will find a Class I label fastened to the Agilent E1714A Master Arm Assembly. A Class I label is used with components for which there is no need to access the laser beam by either users or maintenance persons.

The Agilent E1711A Sensor Head carries a Class III label. Note that the Class III label carries information that describes the type of laser diode, its continuous wave power, and the wavelength of the beam. When handling a Class III device, no user or maintenance person may take any action that might or will expose the laser beam.

For the Agilent E1711A:

- The scale and the arm carrying the scale must be in place over the laser beam aperture in the sensor head before the system is powered up.
- The unit should never be operated or serviced without the encoder scale in place and covering the laser beam aperture in the sensor head.
- The arm carrying the scale must not be moved in such a way as to expose the laser beam.
- While assembling a system, take no action that will expose anyone to the laser beam.



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Maintenance

Occasionally, the surface of the scale and the laser cover window in the Sensor Head may need cleaning. How often depends on the cleanliness of the environment. If measurement results begin to vary from the norm, try cleaning the scale and laser cover window. You may use the following procedure:

1. Fold a piece of lens tissue to a width of about 6 mm (0.25 in). Make sure the folded tissue is no more than 3 mm (0.12 in) thick.
2. Wet the folded lens tissue with acetone.
3. Slide the wetted tissue between the scale and the Sensor Head and across the length of the scale.
4. Make one pass only. Additional passes with the wetted tissue or cleanings with a dry tissue may deposit more contaminant than is removed.

Calibration

The Agilent E1710A and Agilent E1720A systems require no periodic calibration.

Troubleshooting

If a system or component is known to be defective, you can:

- return it to an Agilent Service Center for repair, or
- exchange it by ordering the appropriate exchange part number. See Table 8-1, below, for exchange part numbers.

You may use the following procedure for troubleshooting the Agilent E1713A Servo Axis Board:

1. Ensure that correct board addressing is being executed (base address = 4 × dip switch).
2. Ensure that +5 Vdc (+0.25 V, –0.125 V) is present on the PC backplane at the slot in which the AgilentE1713A board is mounted.
3. Ensure the encoder system is correctly set up.
4. Check the status of the LEDs on the Agilent E1713A board. Any RED LED indicates a problem in the board. The GREEN LED indicates sufficient signal strength at the input to the Agilent E1713A board.

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5 You can verify the presence of the Laser beam using a luminescent card (sensitive to infrared light) slid into the beam. Before doing so, refer to the section above, on laser safety.

6 You also can verify the presence of a beam and the operation of the electronics in the Sensor Head by blocking the beam. The GREEN signal indicator LED on the board will go out. Before doing so, refer to the section above, on laser safety.

7 You can check the operation of the LEDs by disconnecting the cable between the board and the Sensor Head. If the LEDs go out, they are operating properly.

8 If an item fails while under warranty, return it to a Agilent Sales and Service office. If an item fails out of warranty, you may call any of the Agilent Sales and Service offices listed below for information on repairs.

Storage and Shipment

To protect the board during storage or shipment, good antistatic commercial packing methods should be used. Reliable commercial packing and shipping companies have the facilities and materials to adequately repack a product.

NOTE

Before returning a product, contact the nearest Agilent Sales and Service office for instructions.

Conditions during storage and shipment should be limited as follows:

- Maximum altitude: 7,620 meters (25,000 feet).
- Minimum temperature: -40 °C (-40 °F).
- Maximum temperature: +75 °C (+167 °F).

Ordering Replaceable Parts

To obtain replaceable parts, address your order to one of the Agilent Service Centers listed in the Sales and Support page at the end of this manual (follows the index). Identify parts by Agilent part number.

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Agilent E1710A/Agilent E1720A Exchange/Rebuilt Program

To exchange a product under the Exchange/Rebuilt program, you may call any of the Agilent Sales and Service offices listed above. The exchange/rebuilt program is available for the following items:

Table 8-1. Available Exchange/Rebuilt Assemblies

Exchange/Rebuilt Product	Exchange/Rebuilt Part Number
Agilent E1710A, Opt 001 Master Arm Assembly and Sensor Head	Agilent p/n E1710-69201
Agilent E1711A Sensor Head and Sensor Head Cable	Agilent p/n E1711-69201
Agilent E1713A Scale Servo Axis Board (This exchange/rebuilt assembly consists of all the assembly replaceable parts except interconnect cables and manual)	Agilent p/n E1713-69201
Agilent E1714A, Master Arm Assembly with mounted Angular Scale	Agilent p/n E1714-69201

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9

Encoder System Components

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Introduction

You may find individual Agilent E1710A or Agilent E1720A system components useful in custom applications. This chapter describes each system component, and suggested procedures for assembling components into a system. The following components are available:

- Agilent E1711A Sensor Head
- Agilent E1712A, Opt. 038 Angular Scale
- Agilent E1712A, Opt. 011 Linear Scale
- Agilent E1713A Scale Servo Axis Board
- Agilent E1714A Master Arm Assembly
- Agilent E1714A, Opt. 002 Mechanical Push Pin
- Agilent E1710A/E1720A Encoder Systems User's Manual and Agilent E1713-13401 Program Disk (Agilent E1710A, Opt. 101, Agilent E1720A, Opt. 101, or Agilent E1713A, Opt. 101)
- Agilent E1710A/E1720A Encoder Systems User's Manual (only) (Agilent E1711A, Opt. 101 or Agilent E1714A, Opt. 101)

For information on ordering these items individually, contact your nearest Agilent Sales office.

Identification

Each Agilent E1211A, Agilent E1713A, and Agilent E1714A is identified by a serial number in the format 1234A56789. The serial number is on a stick-on label fastened to the item. The four-digit prefix (the first four digits from the left) identifies a group or series of items that have been manufactured to the same specification. The letter indicates the assembly plant location. The five-digit serial number is different for each item.

If the serial prefix of an item differs from that of this manual, there may be differences between this manual and that item. Such differences will be described on Manual Change sheets that may accompany this manual.

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Agilent E1711A Sensor Head

The Agilent E1711A Sensor Head contains a laser diode, preamplifier, and a detector array. The laser beam is emitted from an aperture in the top of the Sensor Head (see Figure 9-1). In a typical installation, an encoder scale (such as an Agilent E1712A, Opt. 038 Angular Scale, or Agilent E1712A, Opt. 011 Linear Scale) is mounted on a movable arm above the Sensor Head.

When the laser beam is reflected from a suitable scale or other diffraction device, an interference pattern is produced, which is read by the detector. The detector puts out a signal which is read as a displacement. The scale must be mounted so that the laser beam illuminates the engraved lines as the scale moves through the beam.

The sensitivity of the detector is sufficient to provide a measurement resolution of up to 0.6 nm with a repeatability of up to ±2 nm or better. The amplified signal from the detector goes to a male DB9 connector. The LSB for the system is approximately 0.3 nm.

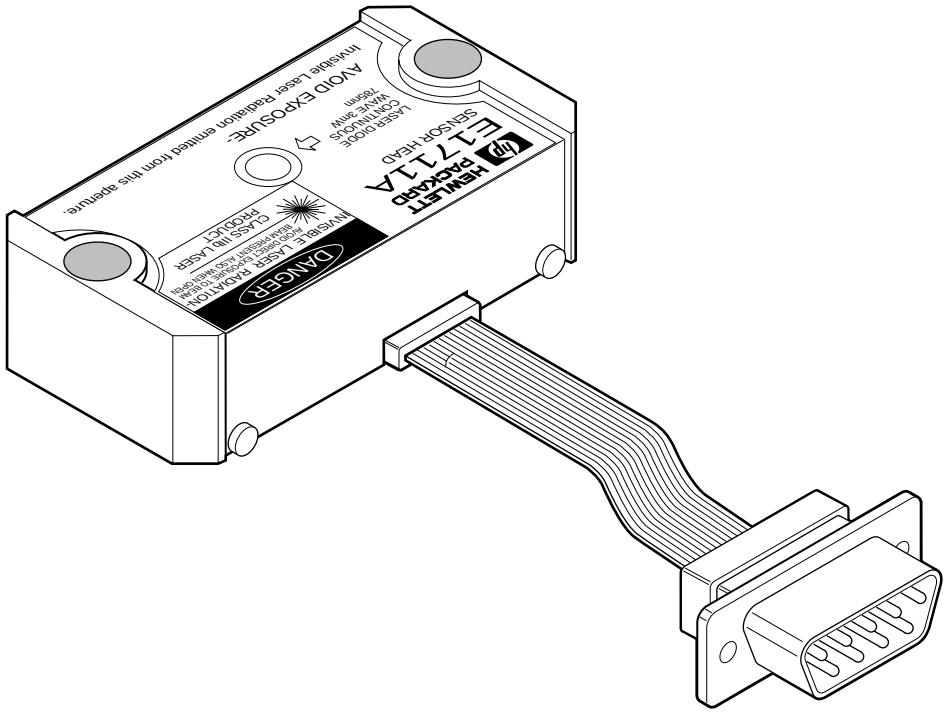


Figure 9-1. Agilent E1711A Sensor Head

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Laser Safety

The Agilent E1711A Sensor Head contains a powerful laser diode that emits invisible infrared light. Do not under any circumstances look directly at the laser light source or allow the laser beam to be directed or reflected into your eyes. You will find the warning labels illustrated below fixed to any device that contains a laser or that may direct a laser beam into your eyes.

You will find a Class I label fastened to the Agilent E1714A Master Arm Assembly. A Class I label is used with components for which there is no need to access the laser beam by either users or service persons. Both angular scales (used in the Agilent E1710A systems) and linear scales (used in the Agilent E1720A systems) must be installed in Class I devices in such a way that no one can access the laser beam.

The Agilent E1711A Sensor Head carries a Class III label. Note that the Class III label carries information that describes the type of laser diode, its continuous wave power, and the wavelength of the beam. When handling a Class III device, no user or maintenance person may take any action that might or will expose the laser beam.

For the Agilent E1711A:

- The scale and the arm carrying the scale must be in place over the laser beam aperture in the sensor head before the system is powered up.
- The unit should never be operated or serviced without the encoder scale in place and covering the laser beam aperture in the sensor head.
- The arm carrying the scale must not be moved in such a way as to expose the laser beam.
- While assembling a system, take no action that will expose anyone to the laser beam.



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Sensor Head Installation Considerations

The Sensor Head is a precisely machined structure designed to maintain the alignment of such critical components as the detector array, laser diode, and the mirrors and prisms in the optical path.

When mounting the Sensor Head to the Agilent E1714A Master Arm Assembly base, alignment pins and alignment pin holes in the Master Arm Assembly base help you precisely align the Sensor Head with the Master Arm Assembly. For optimum accuracy you should remove the alignment pins after mounting the Sensor Head. For additional information, see *"Assembling an Agilent E1710A Positioning System from Components" on page 9-29*.

Custom Sensor Head Base

If you wish to fabricate a base for the Sensor Head for custom installations, you can use the dimensions in Figure 9-2. The dimensions in the drawing use the laser beam aperture for the datum point. The location of the alignment pin holes must be held to within 0.0254 mm (0.001 inch).

You must mount the Angular Scale on the Master Arm so that the surface of the scale and its long axis are precisely positioned relative to the laser beam aperture in the Sensor Head. See Figure 9-4 and Figure 9-5 for the correct dimensions, and also the section titled *"Installing and Aligning Scales" on page 9-9*.

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1 Laser Beam Exit Point, to be established by user

2 Distance from Alignment Pin Hole to Mounting Screw Hole: 7.50 mm (0.295 in)

3 Distance from Laser Beam Exit Point to Alignment Pin Hole: 26.04 mm (1.0252 in)

4 Sensor Head Cable

5 Alignment Pin Hole, 3.175 mm (0.125 in) dia. × 5.08 mm (0.200 in) DP

6 Mounting Screw Hole: M3-.5

7 Sensor Head mounting area width 33 mm (1.3 in)

8 Sensor Head mounting area length 61 mm (2.4 in)

Note: Height of Sensor Head is 17.2 mm (0.677 in)

Note: Tolerances are to 0.0254 mm (0.001 in)

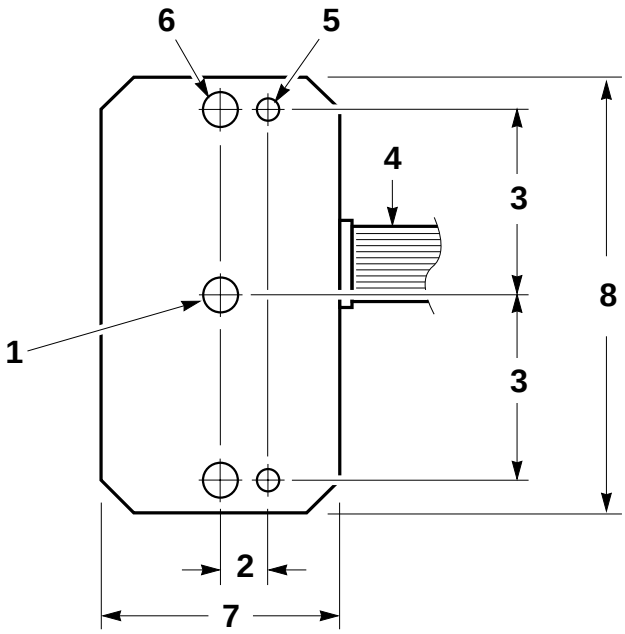


Figure 9-2. Mounting Template for Agilent E1711A Sensor Head

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Encoder Scales

Agilent provides two types of encoder scales: angular and linear. The Agilent E1712A, Opt. 038 Angular Scale is described below. You may order the Agilent E1712A, Opt. 011 Linear Scale cut to your specifications. For information, contact your Agilent Sales Office. Before installing scales, see the section on Laser Safety, above.

Agilent E1712A, Opt. 038 Angular Scale

The Agilent E1712A, Opt. 038 is a 40 º radial scale designed for use at a nominal radius of 1.504 in. (38.2 mm). The scale is approximately 1.2 in. (30.8 mm) long, 0.25 in. (6.4 mm) high, and 0.060 in. (1.5 mm) thick. The width of each radial ruling line is 5 microns and the length of each line is 0.040 in. (1 mm). Note that the distance between the centerline of the angular rulings and the alignment point is 0.100 in (see Figure 9-3).

The pitch of the laser inscribed radial ruling is 10 microns (100 lines/mm) at the nominal radius. Three inscribed registration marks facilitate attachment to a rotating mechanical arm.

Angular scales of other radii can be ordered. Contact your Agilent Technologies Sales Office for information.

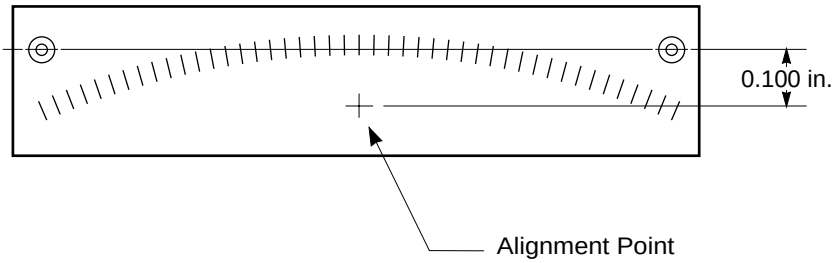


Figure 9-3. Agilent E1712A, Opt. 038 Angular Scale

Scale Installation Considerations

Normally, the angular scale is mounted on an arm or device that rotates (such as the arm of the Agilent E1714A Master Arm Assembly). The linear scale is usually mounted on an arm or device that moves in a straight line. If you are assembling a system of your own, you may mount a scale using a suitable UV adhesive as described in the following installation procedure. Great care must be taken in installing and aligning any scale as mounting tolerances can be as little as 0.0127 mm (1/2000 in).

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NOTE

When handling a scale, it is recommended that you wear surgical gloves.

Installing and Aligning Scales

This section deals primarily with the installation of angular scales, but also includes procedures that may be applicable to installing linear scales (see *Considerations When Working with Linear Scales*, below).

Considerations When Working with Angular Scales

The angular scale consists of a series of lines forming an arc. The center of this arc (intersection of its radii) must coincide with the center of rotation of the part on which the scale is mounted. Any other alignment will cause corresponding systematic eccentricity errors whose magnitude will be comparable to the displacement between the two centers.

This problem does not occur with linear scales. You can position a linear scale precisely by hand to maximize the R, S, and T (or X and Y) signals.

You will need precision mounting jigs and a precision X-Y stage to mount angular scales. The following describes a method for mounting and aligning the Agilent E1712A, Opt. 038 Angular Scale on the rotating arm supplied with the Agilent E1714A Master Arm Assembly. The Agilent E1714A is used only as an example, since the assembly is usually supplied with a scale already installed.

Figure 9-4 and 9-5 provide information on the alignment and clearances between the scale and the Sensor Head. In Figure 9-4, θz, θx, and θy indicate the permissible angular rotation tolerances for the position of the scale relative to the base of the sensor head. In Figure 9-4, θx also indicates the linear direction of the X-axis, θy the linear direction of the Y-axis, and θz the linear direction of the Z-axis.

In Figure 9-4 the Y-axis is in the radial direction and runs through the center of rotation of the scale and the point where the beam from the Sensor Head strikes the scale. The X-axis is perpendicular to the Y-axis and intersects it at the center of rotation of the scale. The Z-axis is orthogonal to the plane of the scale at the scale's center of rotation, and intersects the X and Y axes at that point.

The scale must be mounted so that its bottom surface (on which the encoder lines are engraved) is parallel with the base surface of the Sensor Head. The X-axis of the scale must be parallel with the X-axis of the Sensor Head.

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Considerations When Working with Linear Scales

You can use procedures analogous to those for mounting an angular scale (described below) when mounting and aligning a linear scale. The primary difference is that the linear scale moves in a straight line parallel to the X-axis of the sensor head, whereas the angular scale moves through an arc of a circle that is tangent to the X-axis (see Figure 9-4, below).

WARNING

LINEAR SCALES CAN ONLY BE MOUNTED IN CLASS 1 SYSTEMS. IN A CLASS 1 SYSTEM, NO ONE IS ALLOWED ACCESS TO THE LASER BEAM. BEFORE INSTALLING ANY SCALE, REFER TO THE SECTION ON LASER SAFETY, ABOVE.

The placement of the linear scale along the Y-axis is less critical than with the angular scale. The angular scale must be mounted so that the center of rotation of the scale is coincident with the axis of rotation within a tolerance of 0.05 nm (± 0.002 in). On the other hand, the linear scale may be placed anywhere along the Y-axis as long as the laser beam falls on the diffraction grating. The rulings (lines) of the scale must be parallel to the Y-axis within ± 0.25 °.

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h	specifies the vertical separation between the bottom of the Sensor Head and the ruled side of the scale.
b	indicates the location of the base of the sensor head.
θ***z***	specifies the maximum angle at which the long axis of the encoder may deviate from the long axis of the Sensor Head
θ***x***	specifies the maximum angle within which the encoder must be parallel with the Sensor Head on the long axis.
θ***y***	specifies the maximum angle within which the encoder must be parallel with the Sensor Head of the short axis.

h = 20.2 ± 0.1 mm

θ***z*** = 0 = ± 0.25 degree (± 15 arc min)

θ***x*** = 0 = ± 0.25 degree (± 15 arc min)

θ***y*** = 0 = ± 0.25 degree (± 15 arc min)

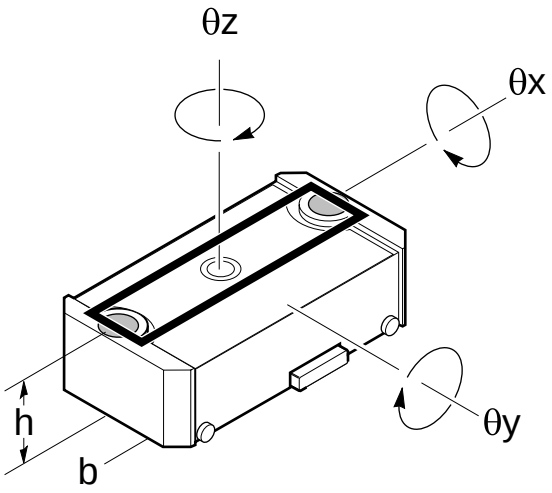


Figure 9-4. Encoder Scale/Sensor Head Alignment

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1 Scale mounting surface

2 Scale, with engraved grid facing top of Sensor Head

3 Sensor Head

4 Sensor Head height: 17.2 mm (0.68 in)

5 Scale bottom to Sensor Head top: 3.0 mm (0.118 in) nominal

6 Critical distance base of Sensor Head (Sensor Head mounting surface) to bottom of scale: 20.2 ± 0.1 mm (0.795 ±0.04 in)

7 Thickness of scale: 1.5 mm (0.060 in)

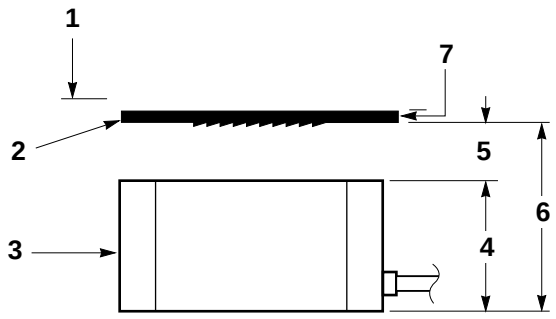


Figure 9-5. Scale to Sensor Head Critical Distance

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Required Equipment for Aligning Scales

- Agilent E1712A, Opt. 038 Angular Scale
- Master Arm (see *"Notes on the Master Arm" on page 9-16*)
- 2 mm Allen wrench
- 20X Microscope with Crosshair Reticle
- XY Translation Stage with Digital Read Out (.0005" resolution minimum)
- XYθ Micropositioning Fixture
- Clamp Fixture
- UV Cement (Dymax 955GEL or equivalent recommended)
- Glue Dispenser
- UV Curing Source

General Description of the Procedure

Use a stationary microscope to locate the master arm axis of rotation. The location of this system datum point on a typical arm (in this example, the Agilent E1714A Master Arm Assembly) is illustrated in Figure 9-6.

In the case of the Agilent E1714A, the travel of the master arm may be restricted by two stops located on the Master Arm Assembly. Use a 2 mm Allen wrench to loosen these stops, then move them to allow free movement of the master arm.

Move the master arm to a position where the Agilent E1712A crosshair alignment feature (see Figure 9-7) is located under the microscope's crosshairs. The scale is then located on the master arm (in this case, a slot), aligned to the microscope crosshair reference, and secured in place with UV cement.

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1 System Datum

2 Servo Motor Connector

3 Sensor Head Connector

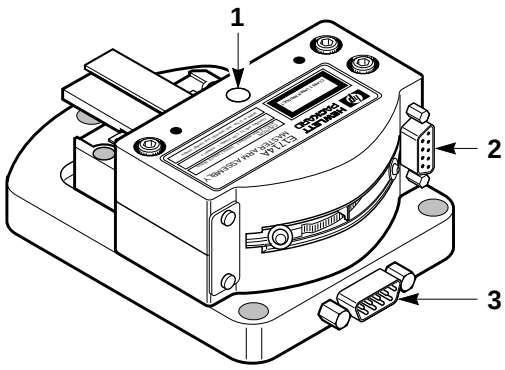


Figure 9-6. System Datum Point, Agilent E1714A Master Assembly

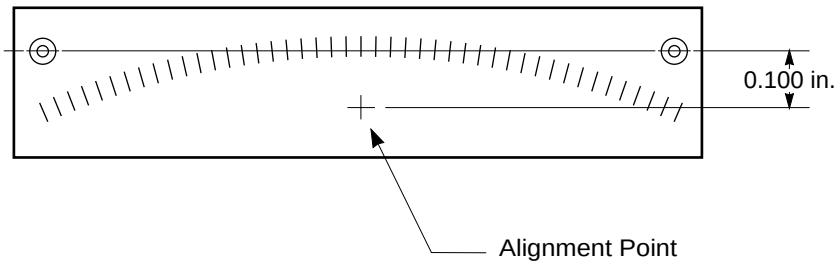


Figure 9-7. Alignment Point, Agilent E1712A Angular Scale

Example Procedure

The following procedure is used at the factory to align the scale to the Agilent E1714A Master Arm Assembly. It is intended as a guideline for customers who wish to align their own encoders.

1 Attach the master arm to the XY stage.

2 Lock the master arm in position.

3 Using the microscope for measurement, align the long edge of the master arm so that it is parallel to the Y-axis to within 0.0127 mm (0.0005 inch).

4 Align the microscope crosshairs to the edge of the master arm.

5 Zero the X-axis DRO.

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6 Move the translation stage in the X-direction (see Figure 9-4) a distance of 1/2 the master arm width. In the case of the Agilent E1714A, this is 12.7000 mm (0.5000 inch).

7 Move the translation stage in the Y-direction (see Figure 9-4) until the top of the bearing hole is in view.

8 Align the microscope crosshairs to top of the bearing hole and record your position.

Top Position: _____

9 Move the translation stage until the bottom of the bearing hole is in view.

10 Align the microscope crosshairs to bottom of the bearing hole and record your position.

Bottom Position: _____

11 Using the values recorded above, move the translation stage to the center of the bearing hole and zero the Y-axis DRO.

12 Move the translation stage 35.66 mm (1.404 inches) in the Y-direction.

13 The microscope crosshairs are now aligned to the virtual center of the scale alignment crosshairs. It is easier to align to the edge of the crosshair. The next step biases the master arm position to allow for alignment to the edge of the crosshair pattern.

14 Move the translation stage 0.0381 mm (0.0015 inch) in the X-direction and -0.0381 mm (-0.0015 inch) in the Y-direction.

15 Place the Agilent E1712A Angular Scale on the master arm.

16 Translate and rotate the scale as necessary until the microscope crosshairs are aligned to the intersection of the bottom and right edges of the alignment crosshair reticle. Clamp the scale in place. Recheck the alignment before proceeding with the next step.

17 Apply three dots of glue along the edge of the scale. **It is very important that the glue neither gets under the scale nor protrudes above the face of the scale.**

18 Cure the glue with the UV source.

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1 Arm Assembly

2 Agilent E1712A, Opt. 038 Angular Scale

3 Scale arm

4 Distance between System Datum (axis of rotation) and alignment point on angular scale: 35.66 mm (1.404 in)

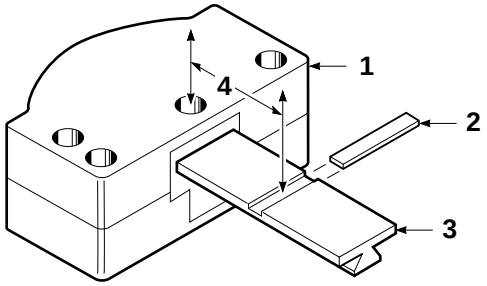


Figure 9-8. Locating the Angular Scale on the Master Arm

Notes on the Master Arm

The above procedure assumes the following about the master arm:

- The mounting surface of the scale is held perpendicular to the center line of the bearing hole to within 0.00762 mm (0.0003 in).
- The distance between the bearing hole (System Datum) and the alignment point on the scale, along the axis of rotation (35.66 mm [1.404 in]), is held to within 0.050 mm (0.002 in).

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Sensor Head/Scale Specifications

The following table lists the electrical and physical characteristics of the Sensor Head with Angular and Linear scales.

Item	Agilent E1710A Angular Scale*	Agilent E1720A Linear Scale
Repeatability	0.05 µrad	± 2 nm
System resolution (LSB)	16 nanoradians	0.6 nm
Track-to-track accuracy	≤ 0.25 µrad	≤ 10 nm (9 µm span)
Long range accuracy	≤ 0.19%** (40° sweep)	± 200 nm
Range	± 20°***	150 mm range***
Sensor Head dimensions	61 mm × 33 mm × 17.2 mm (2.40 in × 1.30 in × 0.677 in)	61 mm × 33 mm × 17.2 mm (2.40 in × 1.30 in × 0.677 in)
Scale dimensions	30 mm × 7 mm × 1.5 mm (1.18 in × 0.275 in × 0.060 in)	155 mm × 6 mm × 3.8 mm (6.1 in × 0.24 in × 0.15 in)
Operating temperature range	15° C to 40° C (59° F to 104° F)	15° C to 40° C (59° F to 104° F)
Velocity	22.2 radians/s	850 mm/s
Power requirements (supplied via Agilent E1713A)****	+ 5 Vdc @ 2 amps +12 Vdc @ 1.2 amps -12 Vdc @ 0.09 amp (with Agilent E1714A attached)	+ 5 Vdc @ 2 amps +12 Vdc @ 1.2 amps -12 Vdc @ 0.09 amp

* For angular system, scale radius = 38.2 mm
** 0.19% = 0.0004% (scale tolerance) + mounting eccentricity
*** Contact your Agilent Sales and Service Office for specific requirements
**** Power for Agilent E1711A Sensor Head and Agilent E1713A Servo Axis Card

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Agilent E1714A Master Arm Assembly

The Agilent E1714A consists of a rotary voice coil motor and master arm, mounted on a base. The master arm carries both the Angular Scale and the optional Mechanical Push Pin. The range of movement of the master arm can be controlled by two limiting stops located on the Master Arm Assembly. These stops may be adjusted using a 2mm Allen wrench.

The Master Arm motor housing contains a system datum for aligning a disk drive arm. This datum consists of a 5-40 tapped hole that is centered precisely on the pivot point of the Master Arm. You can install a System Datum pin in this hole which then fits into a disk drive arm bearing. See Figure 9-13.

The Master Arm Assembly base contains alignment holes for aligning both the Master Arm Assembly and the Sensor head. See Figure 9-2 and Figure 9-13.

The Master Arm motor housing contains an amplifier that boosts the difference signal (provided by the Agilent E1713A Scale Servo Axis Board) to a level sufficient to drive the Master Arm motor. A DB9 connector mounted on the Master Arm motor housing sends the difference signal generated in the Scale Servo Axis Board to the amplifier contained in the Master Arm motor housing. Another DB9 connector, mounted on the Sensor Head, feeds the output of the Sensor Head to the Scale Servo Axis Board.

With the scale mounted on the Master Arm and the Sensor Head mounted on the base, the angular position of the Master Arm can be monitored and controlled to a resolution of 0.016 µrad.

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Master Arm Assembly Specifications

The following table lists electrical and physical specifications for the Master Arm Assembly.

Item	Specification
Track-to-track step and settle time	5 msec typical for 65 µrad step (2.5 µm step at R = 38.2 mm)
Servo bandwidth	200 Hz
Angular range	± 20 °
Mechanical push pin radial location range	15–55 mm
Operating temperature	0 °C to 40 °C (32 °F to 104 °F)
Torque (typical)	0 - 6 V 0.0091 N - m/V 0 - 10 V 0.056 N - m
Power requirements	+ 12 V @ 1 amp (max)

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Agilent E1710A, Opt. 002 Mechanical Push Pin

The Agilent E1710A, Opt. 002 Mechanical Push Pin mounts on the Master Arm of the Agilent E1714A. It can be used to transfer the position of the Master Arm to another device, such as a disk drive read/write arm.

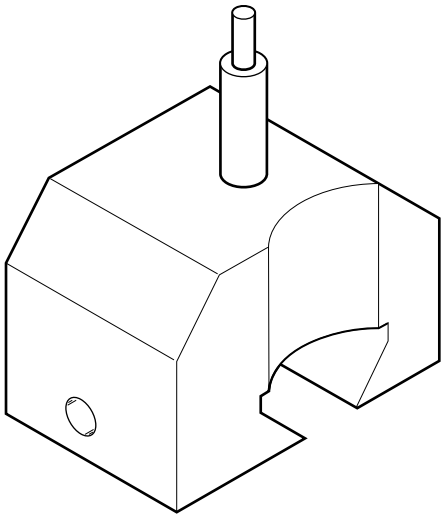


Figure 9-9. Agilent E1710A, Opt. 002 Mechanical Push Pin

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Agilent E1713A Scale Servo Axis Board

The Agilent E1713A is a full length, 8-bit, ISA bus PC-compatible computer board that provides a single-axis position measurement. The board compares a signal from a detector with position information programmed into the board. This position information is used by the Agilent E1713A board, along with software-programmable servo constants, to generate motor drive signals that close the feedback loop between the position measuring device and the user programmed servo constants. The servo signal's motor drive limit is ±10 V. Servo control signals can be updated at a sampling rate of up to a 20 kHz with a resolution of 0.305 mV. A 32-bit position word, updated at 400 kHz is always available at the J2 and J3 connectors located on the top of the board, as well as over the PC backplane.

1 J2 Top connector

2 J3 Top connector

3 P1 Test connector

4 J9 Comm connector

5 J12 Sensor Cable connector, DB9

6 J15 Servo Motor connector, DB25

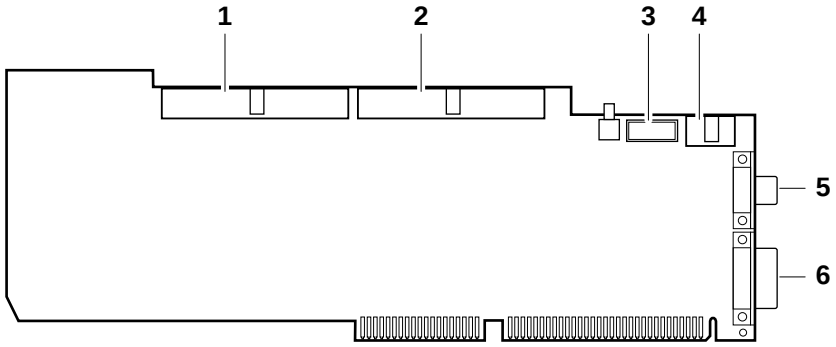


Figure 9-10. The Agilent E1713A Scale Servo Axis Board

Installation Considerations

The Agilent E1713A is a full-length AT-size board and is compatible with most PC-compatible platforms. The board adheres to the ISA specifications and is compatible with most machines that support an 8-bit I/O data transfer cycle and an 8-bit data bus transfers. The Agilent E1713A uses +5V, +12V, and –12V power from the backplane.

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Agilent E1713A Connectors

Figure 9-11, below, illustrates the pin-outs for the two top connectors (J2 and J3). Figure 9-12 illustrates the pinouts for Test Connector (P1), the Communications Connector (J9), the Sensor Cable Connector (J12), and the Servo Motor Connector (J15).

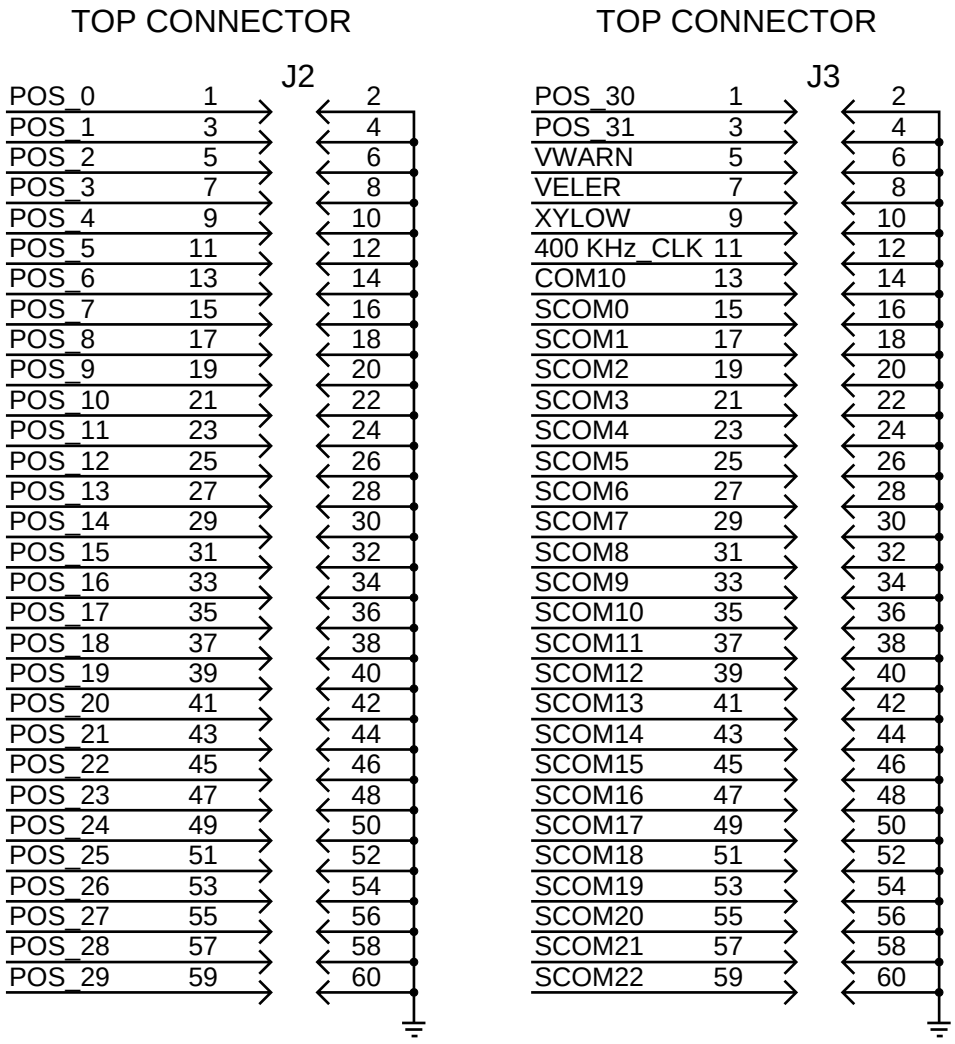


Figure 9-11. Top Connector Pin-Outs

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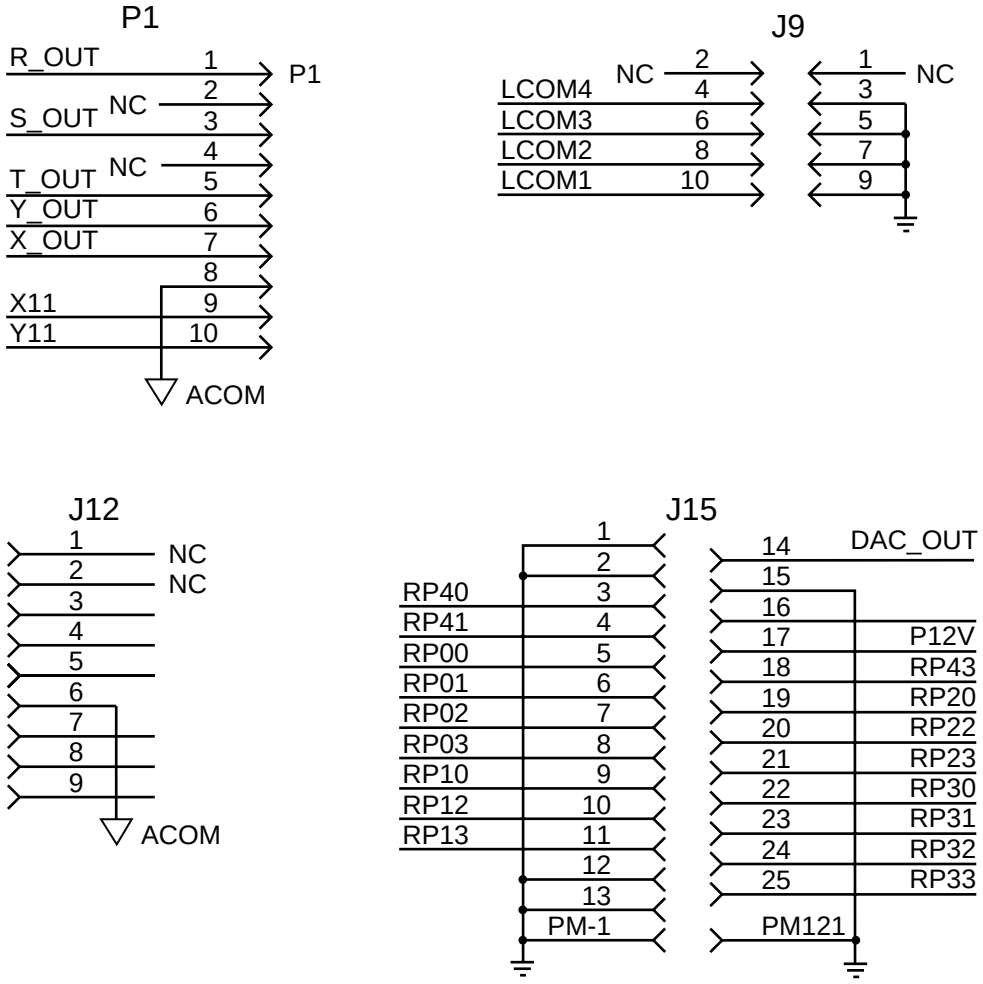


Figure 9-12. Agilent E1713A Connector Pinouts (P1, J9, J12, J15)

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Equipment Supplied

Order the Agilent E1713A with Option 101 to obtain the 3.5-inch program disk (Agilent p/n E1713-13401) that includes the files below. README files are included in some directories to provide information about the software.

- Directory TC/BGI contains a set of seven Borland Graphics Interface files required by the TUNE program.
- The TUNE program helps you tune the Agilent E1713A once you have installed and configured the board and have connected the sensor head and servo control cables.

Directory E17UTL contains the following files:

- CHECK: checks installation of the Agilent E1713A in your PC computer.
- DISPOS: updates and displays position. You can use this to check correct optics setup.
- READREV reads the revision of the Agilent E1713A software.
- LOADFW: allows you to download new firmware to the board when later firmware versions become available.
- E17RWC allows you to perform numerous single read, write, and command operations.

Directory E17USR may contain library routines for advanced users.

Directory DEMOCODE contains C functions covering all Agilent E1713A command operations, and C programs using these functions, as discussed in Chapter 6 of this manual.

Specifications

This section describes the electrical, physical, and programming characteristics of the Agilent E1713A Scale Servo Axis Board.

Power Requirements (typical)

5 Vdc +0.25 V/–0.125 V at 3.0 A
+12 Vdc ±0.5 Vdc at 0.15 A to 1.2 A (with servo motor connected)
–12 Vdc ±0.5 Vdc at 0.05 A

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Weight

0.25 kg (0.55 lb)

Operating Temperature

15–40 °C (59–104 °F)

ISA Compatibility

Standard full-length AT-size board which supports 8-bit data bus transfers.

Cables Required

Refer to Chapter 2 of this manual.

Top Connectors

All of the signals on J2 and some on J3 are enabled. See Figure 9-11, above. These signals are:

Hardware Position

32-bit 2's comp—(LSB)J2-1,3,5,...59,J3-1,3(MSB).

NOTE

Bits 0–13 of the 32-bit position word comprise a phase word that defines the interpolation of the fringes of the encoder signal. When you reset the position word, bits 31 to 14 are set to zero. Bits 0 to 13 are not reset, but are read into a register. The value in the register is subtracted from subsequent readings, resulting in a true zero reading when you read the value from the PC backplane connector. Command 71, Read Reset Offset, reads the value of bits 0–13.

As read from the top connectors (J2 and J3), bits 0–13 are not subtracted from the 32-bit position word. Therefore the position word, as read, does not have the reset offset subtracted from it.

Hardware Status

- Velocity Warn Bit—J3-5—See description in System Status Byte
- Velocity Error Bit—J3-7—See description in Error Status Byte
- XYLow Error Bit—J3-9—See description in Error Status Byte

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Clock Outputs

- 400 kHz (100 ns pulse width)—J3-11
- Hardware Position changes on rising edge of clock.

Other Signals

The Error & Window signals on J3-29 & 31 are not supported.

NOTE All even-numbered pins on both J2 and J3 are GROUND.

Position Outputs

Resolution: 0.30158 mv
Maximum Range: ±655 mm (±25.8 in)
Data Rate: Output updated at sample rate of 400 kHz (at top connectors

Motor Drive Output

±10 V analog with 0.3 mV resolution (DAC OUT and AGND)
Programmable limit (centered on 0 volts)

Programmable Control

Selectable Difference Equation:
PID (Proportional, Integral, Differential)
IIR (Infinite Impulse Response), 2nd order
User-modifiable, downloadable equations
(requires assembly language programming)

Programmable Sample Rate

250 Hz to 20 kHz (depending on equation used)

Programmable Difference Equation Coefficients

3 coefficients for PID
5 coefficients for IIR

Up to 4 sets of coefficients may be stored in the program.

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Programmable Feedforward Terms

Feedforward Velocity
Feedforward Acceleration
Feedforward Delta Acceleration

Programmable Modes

Internal and external Position Profiling
Internal and external Velocity Profiling
Buffered Position Profiling (linear interpolation available)

Programmable Profile Limit Terms

Position Profiling (velocity, acceleration, and delta acceleration)
Velocity Profiling (acceleration and delta acceleration)

Programmable Trace Function

Buffer Size: 32k long words
Data Size:
Reference position and actual position: one long word
Difference equation output, drive signal output: half long word
Position Error = (reference position) – (actual position)

Servo Algorithm Computation Time (Typical)

PID: 12.5 µs
IIR1: 15.5 µs
IIR2: 19.1 µs

Hardware Position Output

Uses PC Internal Ribbon Cable Connector

Data Format

Binary Units: Fractions of a fringe
2's complement: 32-bit parallel binary (from hardware outputs)
Positive Logic
Least Significant Bit (or one count) equals 0.30517578 nm ($5\ \mu m/2^{14}$)
No Reset Zero Offset

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Data Update Rate

400 kHz

Data Age

Typical Variable
150 ns (typical) ambiguity
Assumes sampling is synchronized to the 10 MHz clock

Typical Fixed
Top Connector Data Age: 6.56 µs.

The Top Connector Data is always enabled. This data contains the absolute phase in the 14 least significant bits and is not corrected by the absolute phase at reset. To determine the Offset value, read the Reset Phase Value from the board.

Servo Sample Data Age 4.8 µs to 6.9 µs (from ADC input to servo algorithm output)

Reading Position Over the PC Backplane

Units

English, metric, or fractions of raw counts

Data Update Rate

(Typical, depends on board configuration and PC performance)

Units	386/25 PC	486SX/25 PC
English or millimeters	7 kHz	8 kHz
Uncompensated counts	10 kHz	12 kHz

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Assembling an Agilent E1710A Positioning System from Components

1 Insert the Sensor Head and Master Arm alignment pins in their respective holes in the Master Arm Assembly base. See Figure 9-13, below.

Alignment pins are standard, ground steel dowels of the following dimensions: Sensor Head alignment pins – 1/8 in dia. × at least 3/4 to approx. 2 in.; Master Arm alignment pins – 3/16 in dia. by approx. 2 in.

The lengths of the pins are not critical as long as there is enough pin sticking out of the bottom of the base (or from the base bottom or Master Arm Assembly top in the case of the Master Arm Assembly) to grab with a pliers, so the pin can be removed (see step 2 and step 7, below).

2 Place the Agilent E1711A Sensor Head on the Master Arm Assembly base. Use the alignment pins for correct positioning. When you position the Sensor Head on the base, the alignment pins will protrude from the bottom of the base.

3 Secure the Sensor Head with two M3 × 20 mm Stainless Steel Capscrews and two M3 Stainless Steel Washers.

4 Route the ribbon cable and DB9 connector to the opening in the base.

5 Secure the DB9 connector with two 4-40 screwlocks, washers, and nuts.

6 Place the Master Arm Assembly on the base. Secure it with two M5 × 35 mm Stainless Steel Capscrews. Be careful not to disturb the Sensor mounted on the Master Arm when handling the Master Arm Assembly.

7 Turn the Sensor Head/aster Arm assembly over and withdraw the four alignment pins from the base.

8 Install the Mechanical Push Pin on the Master Arm.

Three M5 × 10 LS Stainless Steel Capscrews are supplied for mounting the hardware to a work bench.

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1 System Datum

2 System Datum Pin

3 Agilent E1714A Master Arm Assembly

4 Agilent E1712A, Opt 038 Angular Scale

5 Agilent E1711A Sensor Head

6 Ribbon Cable and DB9 Connector

7 Master Arm Assembly Alignment Pin

8 Sensor Head Alignment Pin

9 Sensor Head Alignment Holes

10 Sensor Head Alignment Pin

11 Master Arm Assembly Base

12 Master Arm Assembly Alignment Pin

13 Master Arm Assembly Alignment Holes

14 4-40 screwlocks, washers, and nuts

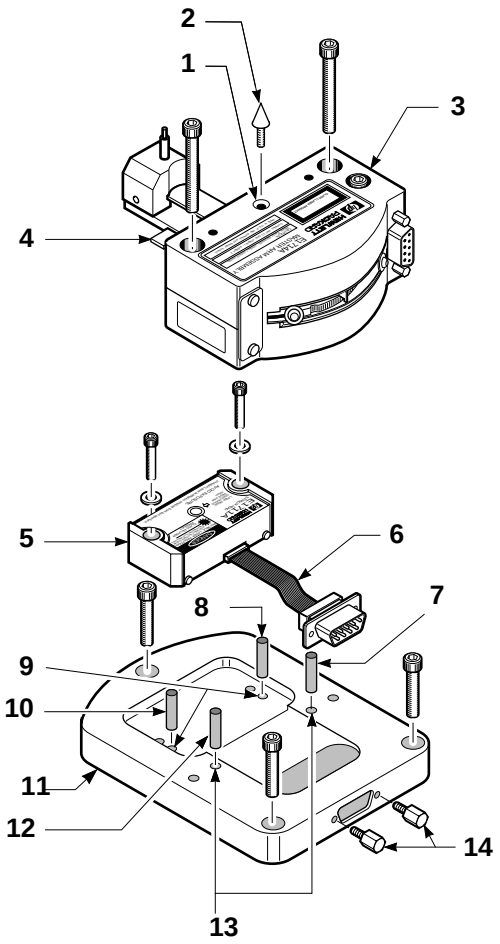


Figure 9-13. Positioning System Assembly

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Verifying an Installation

The following procedure lets you quickly verify the operation of an installed and setup system.

1. Run the DOS file TUNE1713.EXE
2. In the TUNE program front panel display, read the position of the arm carrying the scale.
3. Manually move the arm carrying the scale a known distance.

   Check the new position reading for a match with the movement of the scale.

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DECLARATION OF CONFORMITY

according to ISO/IEC Guide 22 and EN 45014

Manufacturer's Name: Agilent Technologies, Inc.

Manufacturer's Address: Santa Clara Division
5301 Stevens Creek Boulevard
Santa Clara, California 95052-8059
U.S.A.

declares, that the product

Product Name: Encoder System

Model Number:

Agilent E1710A	Encoder System, Angular
Agilent E1711A	Sensor Head
Agilent E1712A	Standard Scale
Agilent E1713A	Servo Axis Board
Agilent E1714A	Master Arm Assembly
Agilent E1720A	Encoder System, Linear

Product Options: This declaration covers all options of the product.

conforms to the following Product Specifications:

Safety: IEC 1010-1: 1990 + A1 / EN 61010-1: 1993
IEC 825-1: 1993 / EN 60825-1: 1994 Class1

EMC:

CISPR 22: 1993 / EN 55022:	1994	Class A
IEC 801-2: 1991 / EN 50082-1:	1992	4 kV CD, 8 kV AD
IEC 801-3: 1984 / EN 50082-1:	1992	3 V/m, 1kHz 80% AM, 26–1000MHz
IEC 801-4: 1988 / EN 50082-1:	1992	500 V Signal Lines
IEC 1000-3-2: 1995 / EN 61000-3-2:	1995	Harmonics
IEC 1000-3-3: 1994 / EN 61000-3-3:	1995	Flicker

Supplementary Information:

The product models listed above comply with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC and carries the CE marking accordingly.

Santa Clara, California, Sept. 3, 1997

Bruce Euler, Quality Engineering Manager

European Contact: Your local Agilent Technologies Sales and Service Office or Hewlett-Packard GmbH, Dept. ZQ/Standards Europe, Herrenberger Straße 130, D-71034 Böblingen (FAX: +49-7031-143143)

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The warranty period begins on the date of delivery or on the date of installation if installed by Agilent. If customer schedules or delays Agilent installation more than 30 days after delivery, warranty begins on the 31st day from delivery.

Warranty does not apply to defects resulting from (a) improper or inadequate maintenance or calibration, (b) software, interfacing, parts or supplies not supplied by Agilent, (c) unauthorized modification or misuse, (d) operation outside of the published environmental specifications for the product, or (e) improper site preparation or maintenance.

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Assistance

Product maintenance agreements and other customer assistance agreements are available for Agilent products.

For any assistance, contact your nearest Agilent Sales and Service Office.

Safety Considerations (contd)

WARNING

ANY INTERRUPTION OF THE PROTECTIVE GROUNDING CONDUCTOR (INSIDE OR OUTSIDE THE INSTRUMENT) OR DISCONNECTING THE PROTECTIVE EARTH TERMINAL WILL CAUSE A POTENTIAL SHOCK HAZARD THAT COULD RESULT IN PERSONAL INJURY. (GROUNDING ONE CONDUCTOR OF A TWO CONDUCTOR OUT-LET IS NOT SUFFICIENT PROTECTION.)

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

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

Instructions for adjustments while covers are removed and for servicing are for use by service-trained personnel only. To avoid dangerous electric shock, do not perform such adjustments or servicing unless qualified to do so.

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

Acoustic Noise Emissions

LpA<47 dB at operator position, at normal operation, tested per EN 27779. All data are the results from type test.

Geräuschemission

LpA<47 dB am Arbeits platz, normaler Betrieb, geprüft nach EN 27779. Die Angagen beruhen auf Ergebnissen von Typenprüfungen.

Electrostatic Discharge Immunity Testing

When the product is tested with 8kV AD, 4kV CD and 4kV ID according to IEC801-2, a system error may occur that may affect measurement data made during these disturbances. After these occurrences, the system self-recovers without user intervention.

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