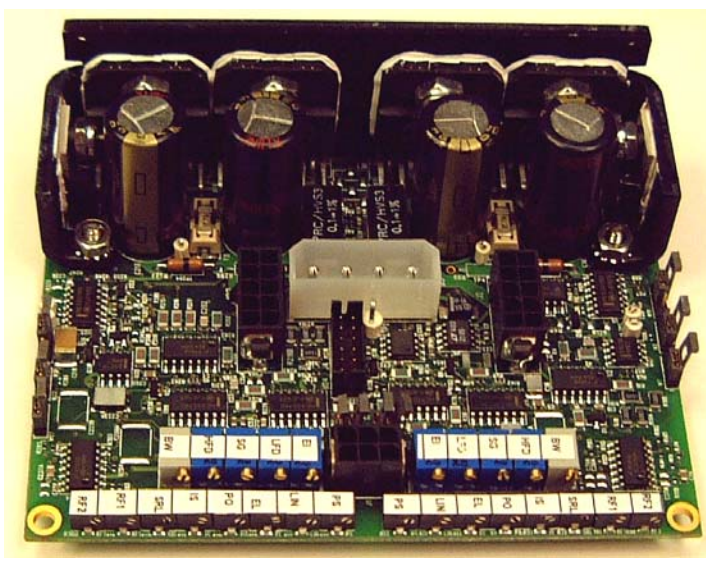
MicroMax™ 673 Series

BOARD LEVEL

DUAL AXIS DRIVER ELECTRONICS



Cambridge Technology

25 Hartwell Avenue, Lexington, MA 02421
Tel. 781-541-1600   Fax. 781-541-1601
www.cambridgetechnology.com

CAMBRIDGE TECHNOLOGY, INC.
25Hartwell Avenue
Lexington, MA 02421
U.S.A.
TEL.781-541-1600
FAX.781-541-1601
www.cambridgetechnology.com

MicroMax is a trademark of Cambridge Technology, Inc.

Lit. No. 673xxManual Rev. 3.4   18 May 2007

Contents

Limited Warranty

CTI warrants that its products will be free of defects in material and workmanship for a period of one year from the date of shipment. CTI will repair or replace at its expense defective products returned by the Customer under a Return Authorization number issued by CTI. This warranty is void if the product is damaged by "misuse" or "mishandling" by any party not under the control of CTI. Misuse or mishandling will be determined by CTI. Misuse includes use of CTI product with incompatible products resulting in damage to the CTI product. The customer is responsible for charges for returning product for repairs. CTI is responsible for charges for shipping product repaired under warranty back to the customer when CTI is allowed to choose the carrier and level of service. The Customer is responsible for repair charges and all shipping charges for non-warranty repairs. CTI's sole liability for any use of its product, regardless of the operating condition of such product, is limited to repair or replacement of the product. The Customer holds harmless and indemnifies CTI from any and all other claims resulting from the use of CTI products.

1.0 MicroMax 673 Series System Overview

1.1 Introduction

The **MicroMax™ Series 673** dual-axis servo driver is designed for applications and mirror positioning systems that require high performance and high accuracy.

The 673 servo driver is used with Cambridge Technology's line of galvanometer type servo motors, also known as scanners. These scanners are available in many sizes ranging from 12.5 grams to 10 kilograms in weight. With a wide range of sizes available, the customer can optimize the package size, system speed, and system cost tradeoffs for mirrors ranging from less than 0.001gm-cm^2 to greater than 100,000 gm-cm^2.

When mated with an appropriate CTI scanner, the Series 673 servo driver becomes a board level, dual-axis, mirror positioning system. The compact size and integrated design of the 673 servo driver simplify the installation process and reduces downtime should the need for replacement arise.

This manual contains the information necessary to install, wire, start up, operate, and tune the MicroMax™ Series 673 servo driver. Please read this manual fully to understand the operation of this mirror positioning system. The optical scanners used in this system are delicate devices and can be damaged if mishandled.

1.2 Safety/Cautions

⚠ **CAUTION** ⚠

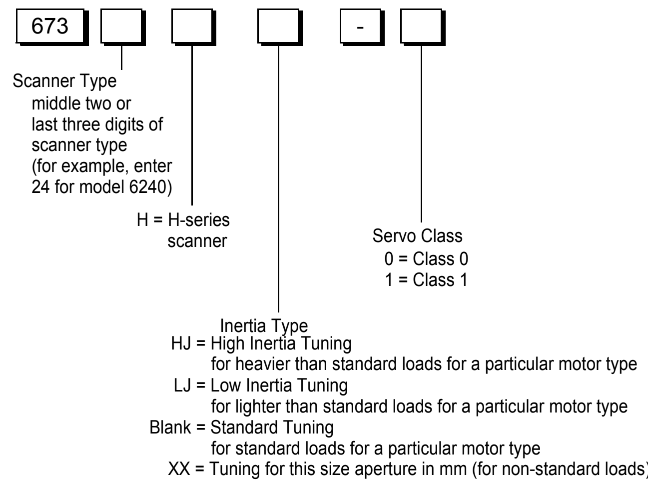
OVERHEATING HAZARD.
Never operate the 671 board without a heatsink! Maintain proper ambient temperature. Refer to the installation section for mounting requirements.

⚠ **CAUTION** ⚠

ESD HAZARD!
The board can be damaged by static electricity.
Use appropriate precautions.

1.3 Part Number Description

The 673 servo board is available in a variety of configurations, as detailed below:



Example #1: Part # 67323H-0
- Servo driver 673
- 6230H Scanner
- Standard Inertia Tuning
- Class 0

Example #2: Part # 673215HHJ-1
- Servo driver 673
- Scanner 6215H
- High Inertia Tuning
- Class 1

Example #3: Part # 67322H10-1
- Servo driver 673
- Scanner 6220H
- Tuning for 10mm mirrors
- Class 1

NOTE: Not all configurations are supported.

1.4 Specifications

All angles are in mechanical degrees. All specifications apply after a 1-minute warm up period.

Table 1: 673 Board Specifications

Parameter	Conditions and Limits	Input Configuration	Units
Command Input Impedance	Differential	200	Kohm
Position Output Impedance	Typ	2	Kohm
Analog Input Range	Max	± 10	Volts
Position Offset Trimpot Range	Typ	± 0.5	Volt
Position Output Scale Factor	Std	0.500	Volts/° mech.
Fault Outputs	Typ	12V CMOS logic through 4.75kohm	-
Temperature Stability	0-50°C Ambient temp	20	ppm/°C
Absolute Maximum Supply Voltage	± 18 to ± 30 Range	30	VDC
	± 15 to ± 18 Range Note #1	30	VDC
Minimum Operating Voltage	± 18 to ± 30 Range	18	VDC
	± 15 to ± 18 Range	15	VDC
Output RMS Current	Typical Note #2	5	A
Output Peak Current	Typical Note #2	11.5	A
Output Peak Current	Guaranteed Note #2	7	A
Supply Current	Without Scanner	± 200	mA
Short Circuit Protection (Fuse)	Typical	Scanner RMS x1.25	A
Over-position Protection	Typical	Scanner Field size + 1°	Deg
Under-voltage Protection	±18 to ±30 ± 15 to ± 18	17 12.5	V
Over-Temperature/Over current Protection	Scanner RMS	1-3	Sec
Ambient Temperature Range	Max limits	0-50	°C
Size	Outside Dimenstions	4.0 x 3.1 x 1.3 10.2 x 7.9 x 3.3	inch cm
Weight	Without cables	5.1 144	oz grams

Note #1: When the jumper is changed from ±18-30V to ±15-18V, the absolute maximum supply voltage does not change, but the Undervoltage Shutdown point does change. A system that was tuned at a higher supply voltage may become unstable while the power is turning off when the under-voltage jumpers are set for ±15 - 18V.

Note #2: Typical and guaranteed peak currents are limited by the 673 board's power output op-amps. Input voltage, power supply capabilities, application waveform, scanner impedance, system step response, etc. all affect the maximum current, voltage, and power the 673 board can deliver.

When driving large loads that demand higher peak current, higher RMS currents, or cause higher temperatures than the 673 servo board can handle, please use the 671 single-axis board with the High Power Option.

1.5 Board Modifications

Please do not attempt to modify or repair the 673 board (except for the Command Input Scale Factor and Over-Position Trip Point resistors) without consulting Cambridge Technology first. Most components are very small (many are 0402 size, which means they are 0.040" by 0.020", or 1mm by 0.5mm) and close together. The traces are narrow and the pads are small. It is difficult even for a skilled technician working with a microscope to change components without damaging the board.

2.0 Installation and Initial Checkout

Step 1: Unpacking and Inspection

IMPORTANT!

Boards and scanners are shipped as matched sets with matching serial numbers. They MUST be kept together or all factory calibration and adjustments will be invalid!

CAUTION

ESD HAZARD!
The board can be damaged by static electricity.
Use appropriate precautions.

1. Unpack the unit and verify that the serial numbers on the serial number tags match the numbers on your purchase order or packing slip.
2. Inspect all components for possible physical damage or discrepancies. If any part of the driver is missing or damaged, notify the carrier and the factory immediately. Shipping damage and unreported shortages are not covered by the product warranty.
3. If the driver will be stored after initial inspection, place it in its original packaging and store it according to the temperature specifications.

Step 2: Mounting

Refer to the 673 Servo Driver Outline Dwg (D05606) sheets 1 and 2 in *"Section 10.0: Appendix E: Drawings" on page 49* for the dimensions and details of its mechanical layout.

1. Determine the location for the board. Provide adequate clearance on all sides to reduce the potential problem of heat generation or shorting to the electrical components.

   If possible, position the unit so all connectors, adjustment potentiometers and test points are easily accessible
   Mount the board to an appropriate heatsink, bracket, or large plate as required to dissipate the high heat generated by the board. Use thermal joint compound. This is essential to protect the board from heat damage.

   IMPORTANT:
   Adequate heatsinking is critical. The size of the heatsink required is application dependent. Several factors such as scanner type, load inertia, command waveform's duty cycle, power supply voltage, etc. are important.

   There are two #4 holes at the left and right ends of the black heatsink bracket, and one #4 hole near the middle of the bracket. The board can be mounted by this heatsink bracket, or it can be mounted by both the front two #4 mounting holes and the heatsink bracket. But in either case, an adequate external heatsink must be attached to the board's bracket or the output stage will quickly overheat.

   IMPORTANT: Minimize the mechanical stress on the board to avoid cracking the surface mount components.

2. Verify Power Supply and Jumper Settings

WARNING

The wiring should be performed only by qualified electrical personnel familiar with the construction and operation of this equipment, the hazards involved, the National Electrical Code (NEC) and local electrical codes. Equipment damage and/or injury could result if these procedures are not observed. The user is responsible for conforming to all applicable local, national and international codes.

Note: This is a two channel board used in X/Y systems. Conventionally the first channel mentioned is the X channel and the second is the Y. When components and jumpers are mentioned in pairs (W3(W23), R13(R213), TP4(TP204)) the first is always the X channel and the second the Y channel, and their function is identical.

1. Ground either the heatsink bracket or one of the two #4 screws that hold the heatsink to the board (see drawing D05606) to chassis ground or the enclosure for best noise rejection. Use a ground strap if necessary to ensure a good connection.
2. Check that the power supply and its output voltage is correct for the system you are installing.
3. Check that the power jumper settings (W1 and W4) exactly match the requirements for your supply voltage:

Table 2: Power Supply Jumper Settings

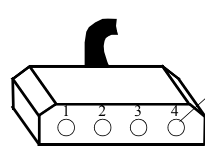
Power Supply Voltage	Jumpers W1 & W4
±18 VDC to ±30 VDC	2+3
±15 VDC to ±18 VDC	1+2

CAUTION

A board operated at a lower supply voltage may behave badly if it was originally tuned at a higher supply voltage. A board jumpered for +/-18V to +/-30V will not work at all below +/-18V because of the undervoltage protection trip point.

4. Check the voltages on the pins of the power supply cable. See *"Section 7.0: Appendix A: Electrical Details" on page 44* for cable construction.

Table 3: Power supply cable pinouts



Pin #	Signal Name	Voltage Range
1	+Supply Voltage	+15 to +18VDC or +18 to +30VDC
2	+Supply Voltage Return	GND (Common)
3	-Supply Voltage Return	GND (Common)
4	-Supply Voltage	-15 to -18VDC or -18VDC to -30VDC

CAUTION

Improper power supply wiring will result in damage to the driver and/or the system.

5. With power off, plug the power supply cable into connector J3.

6. Check/set the jumpers on W3(W23) to match your system's requirements:

Table 4: W3/W23 Signal In Configuration

Input Configuration	Jumpers W3(W23)	Scanner Motion
Differential Non Inverting	1+2, 3+4	Scanner rotates CW for J1-6(J1-4) higher than J1-3(J1-1)
Differential Inverting	1+3, 2+4	Scanner rotates CCW for J1-6(J1-4) higher than J1-3(J1-1)
[If there is no other ground path to the signal source, J3-2 must be connected to signal source ground.]		

7. Check the Command Input Connector wiring [*"Section 7.2: Command Input Wiring" on page 44*] and insert the wired female connector into **J1** on the **673** board.

   Note: Provide separate routing channels for wiring high power signals and wiring command signals. Do not mix power and command signal wiring in the same conduit, duct, or wire tray.

Step 3: Verify system serial numbers and tuning status

Driver, motors, and mirrors are configured, tuned, and shipped with matching serial numbers. If your system was shipped un-tuned, or if you are mixing systems, see *"Section 4.0: Detailed Tuning and Alignment Procedures" on page 14* to tune the board before proceeding to Step 6.

⚠ WARNING

INSTABILITY HAZARD! If the boards, scanners,and loads are mismatched or untuned, there may be serious damage to the system when the power is turned on.

Step 4: Connect the scanner to the board

1. Plug the extension cables, if they are used, into the scanners, and plug the 10-pin connector on the X scanner cable into connector **J2** and plug the 10-pin connector on the Y scanner cable into connector **J22** on the **673** board.
   Be sure that the scanners are connected to the correct channels. If a scanner is connected to the wrong channel, it may be unstable when turned on.

2. If the mirror is not already on the scanner, mount the mirror. [See *"Section 8.0: Appendix B: Mirror Handling and Mounting" on page 46.*]
   Warning: If the mirror is not mounted correctly, the system will be unstable, and there may be serious damage to the system.

   Note: Check that the mirror's angular swing does not allow it to hit any obstruction

3. Set the **Command Input** signal to 0.00volts for both channels so the system will center once powered.

4. Turn the power on and observe the scanner shaft. If either channel is unstable after the startup sequence, or they make whistling, buzzing, or squealing noises, turn the power off immediately, and recheck everything. If the problem persists please call Cambridge Technology for help.
   During a normal startup operation the **673** servo driver goes into the following startup sequence:

   When power is first turned on:
   - The **Output Amplifier** is disabled, effectively disconnecting the scanner coil from the servo output amp.
   - The **Gain** of the servo is reduced, allowing a very small error signal to be sent to the output stage.
   - The **Command Input** signal is disabled.
   - The **Fault Output** signal is active.

   After 1 second:
   - The **Output Amplifier** is enabled, allowing current to pass through scanner.
   - The **Gain** of the servo is increased up to its normal operational value.
   - The scanner is centered in a controlled way, but the input command is blocked.

   After 1 more second (2 seconds from turn-on):
   - The **Command Input** signal is enabled.
   - The **Fault Output** signal de-activates.

5. The scanner will begin to follow the **Command Input** signal which is 0.00V. Hook up an oscilloscope or voltage meter to the Position Output signal at **J4-3(J4-4)**. (For the J4 connector pinout see drawing **D05606**). Use **J4-5(J4-6)** for the ground reference. At this time the voltage should read very nearly 0.00 volts

6. Input a 30 Hz square wave that spans about 0.1° mechanical or about 50 mV on the position signal. For a few very large scanner/mirror systems, 30 Hz may be too fast. For those systems, set the frequency to ~5 Hz.

7. The scanner should immediately start moving in response to this input. Check the Position Out signal or look at the scanner itself and observe that it responds appropriately to the input signal.

8. Change to a sine wave, then gradually increase the amplitude of the Command Input signal until it has almost reached the maximum angle for the application. The system is usually scaled so that the input for the maximum angle is ±10V, but there are exceptions. The system should go into shutdown at the maximum angle, and recover when the input signal is reduced. Do not test the Over-Position shutdown continuously because the scanner is stressed unnecessarily.

Note: If the scanners have been changed to -M scanners with reduced angle bumpers, or the scaling is not standard, the scanner may reach the bumpers before reaching the Over-Position shutdown. Do not test the Over Position shutdown if the scanner hits the bumpers first.

If the bumpers are hit, or if you have changed the bumpers, refer to the Over-Position Chart below as you must change a resistor in the board to set the Overposition Limit Detector correctly.

If the 673 system has passed these checks, it is functioning properly. The scanner will follow any input waveform within the speed, angle, and power limits of the system.

Table 5: Over-Position/Standard Resistor Values

Nominal Field Size Mechanical Degrees	Over-Position Angle Mechanical Degrees P-P	Over-Position Voltage	R90/R290
± 5	± 6	3	33.2K
± 5.5	± 6.5	3.25	30.1K
± 6	± 7	3.5	28.7K
± 6.5	± 7.5	3.75	26.7K
± 7	± 8	4	25.5K
± 7.5	± 8.5	4.25	23.7K
± 8	± 9	4.5	22.6K
± 8.5	± 9.5	4.75	21.0K
± 9	± 10	5	20.0K
± 9.5	± 10.5	5.25	19.1K
± 10	± 11	5.5	18.2K
± 10.5	± 11.5	5.75	17.4K
± 11	± 12	6	16.5K
± 11.5	± 12.5	6.25	16.2K
±12	± 13	6.5	15.4K
± 12.5	± 13.5	6.75	14.7K
± 13	± 14	7	14.3K
± 13.5	± 14.5	7.25	13.7K
± 14	± 15	7.5	13.3K
± 14.5	± 15.5	7.75	13.0K
± 15	± 16	8	12.4K
± 15.5	± 16.5	8.25	12.1K
± 16	± 17	8.5	11.8K
± 16.5	± 17.5	8.75	11.5K
± 17	± 18	9	11.3K
± 17.5	± 18.5	9.25	10.7K
± 18	± 19	9.5	10.5K
± 18.5	± 19.5	9.75	10.2K
± 19	± 20	10	10K
± 19.5	± 20.5	10.25	9.76K
± 20	± 21	10.5	9.53K

⚠ **CAUTION** ⚠

The maximum operating angle for the standard 673 board is ±16.5 degrees. Several components on the board must be changed to operate reliably at angles beyond ± 16.5 degrees. Please consult Cambridge Technology for more information.

Table 6: Current to Voltage and Coil Temperature Calculator Table

	Maximum RMS Current	Conversion Ratio	RMS Volts at Current Monitor at Max RMS Current
6200	1.6A	1V/A	1.6V
6200H	2.2A	1V/A	2.2V
6210	1.6A	1V/A	1.6V
6210H	2.3A	1V/A	2.3V
6215H	3.9A	1V/A	3.9V
6220	2.6A	1V/A	2.6V
6220H	3.7A	1V/A	3.7V
6230	5A	0.5V/A	2.5V
6230H	5A	0.5V/A	2.5V
6231C	5A	0.5V/A	2.5V
6231HC	5A	0.5V/A	2.5V
6240	5A	0.5V/A	2.5V
6240H	5A	0.5V/A	2.5V
6800	1.6A	2V/A	3.2V
6810	2.6A	1V/A	2.6V
6850	4.6A	0.5V/A	2.3V
6860	4.6A	0.5V/A	2.3V
6870	5A	0.5V/A	2.5V
6880	5A	0.5V/A	2.5V
6350	1.1A	2V/A	2.2V
6450	1.77A	2V/A	3.54V
6650	2.83A	1V/A	2.83V
6900	5A	0.5V/A	2.5V
6400	5A	0.5V/A	2.5V

Notes:

1. The maximum RMS current for the 673 board is 5A per channel. If higher currents are needed, please use the 671 single-axis board with the High Power Option.

2. Some of the scanners in the table are included for reference only. Not all combinations are available.

Special Note: A few of the scanners with star (*) numbers have nonstandard coil impedances. The maximum current for these scanners will be different, and the current to voltage ratio may be different. Please check with Cambridge Technology.

3.0 673 System Test and Alignment

This section is a condensed version of the normal factory procedure for testing and aligning a new 673 board with a pair of scanners, modified for field use. It is followed by a much longer and more detailed version of the procedures for tuning the small-angle step response and for setting the Slew rate Limiter and the Error Limiter. The factory procedure for setting Position Scale and Linearity requires special equipment. Section 4.1 includes a moderately accurate field procedure.

When to Use This Procedure

When possible, Cambridge Technology ships systems completely tuned and aligned. Please check the state of the system carefully before retuning it or making any adjustments.

⚠ CAUTION ⚠

Detuning the system unnecessarily or altering the factory settings will make unnecessary work, and may limit the system's performance.

Tuning Notes:

- If the system was shipped with scanners and mirrors, do not make any adjustments until after the initial tests. Some fine tuning may be needed later for particular applications.
- If the system was shipped tuned to a test load, it may be necessary to check the adjustment of the notch filter (Step 7), and to make minor adjustments in the tuning (Step 8).
- If the system was shipped detuned with scanners, complete the entire alignment procedure, except Step 5 (Linearity and Position Scale).
- If the board was shipped without scanners, or it is being matched to a replacement scanner, go through the entire procedure, including Step 5 (Linearity and Position Scale).

Before Starting

Before starting any tests or adjustments, please read the entire procedure to be sure that the necessary equipment is on hand, and that the adjustments are done in the correct order.

- Check whether the board is Class 0 or Class 1. Changing the class of the board requires component changes as well as jumper changes, and is not normally done in the field.
- Check the supply voltage of the board:
  A board configured for ±15V may behave badly if it is tuned at a higher voltage. A board configured for ±18 to ±30V will not work on ±15V.

Please call Cambridge Technology with any questions you might have.

Note: This is a two channel board used in X(Y) systems. Conventionally the first channel is the X channel and the second channel is the Y channel. When components and jumpers are mentioned in pairs such as W3(W23), R13(R213), or TP4(TP204), the first is always the X channel and the second the Y channel, but their functions are identical.

With the connector side of the board up, with the heatsink facing away from you, the X channel is on the right and the Y channel is on the left. See the outline drawing, D05606. See *"Section 10.0: Appendix E: Drawings" on page 49*

⚠ CAUTION ⚠

Please do not attempt to modify or repair the 673 board (except for the Command Input Scale Factor and Over-Position Trip Point resistors) without consulting Cambridge Technology first. The components are very small (most are 0402 size, which means they are 0.040" by 0.020", or 1mm by 0.5mm) and close together. The traces are narrow and the pads are small. It is difficult even for a skilled technician working with a microscope to change components without damaging the board.
The only components normally changed in the field are R30(R230), for the Command Input Scale Factor, and R90(R290) for the Over-Position Trip Point.

⚠ CAUTION ⚠

Be careful when replacing the fuses! Use a small pair of long-nosed pliers to grip the middle of the fuse and pull straight up. Do not try to pry the fuse out of the holder! The holder will break, and it is very difficult to replace.

Step 1: Board Preparation

Note: Board is viewed from the connector side with the heatsink to the rear. See outline drawing D05606.

1. Check all jumpers:

   a). Jumper Locations/Settings

Jumper	Purpose	Settings	Notes
W1/W4	Power Supply Low Limit (Undervoltage Fault)	2+3	±18V - ±30V
		1+2	±15V - ±18V
W3/W23	Differential Signal In	1+2, 3+4	Scanner rotates CW for J4-6(2) higher than J4-5(1)
		1+3, 2+4	Scanner rotates CCW for J4-6(2) higher than J4-5(1)
W2/W22	Notch Filter Bypass	1+2	Notch Filter Enabled
		2+3	Bypass Notch Filter
		NONE	Tuning Notch Filter
W7/W27	Notch Filter Bypass	1+2	Notch Filter Enabled
		2+3	Bypass Notch Filter
		NONE	Checking Resonance
W11/W31	Mirror Alignment	2+3	Normal
		1+2	Mirror Alignment

2. Check the class of servo, either class 0 or class 1. Check the part number for the board on the Sales Order that came with the system. Then refer to the part number legend in *"Section 1.3: Part Number Description" on page 5*. [Note: The board's class is set by a number of 0603 zero ohm resistors. Some configuration changes also involve other component changes. The part number is the most reliable way for the customer to identify the board class.]

3. Select and solder in R30/R230 to set the specified field size. For maximum temperature stability, use a high stability metal film resistor such as: Vishay Series P1206YxxxxDB or KOA Speer Series RN73T2BTxxxxD.
   R30+R119 = R29 (40/x), where x is the field size in degrees. R29 is normally 10k, but may be larger in some cases. R119 is 1k. Gain will be trimmed later, so the resistor may be as much as 7% off the nominal value, if the correct resistor is not available.

4. Detune by setting the following fully CCW:
   - LFD/R25(R225)
   - SG/R28(R228)
   - EI/R31(R231)
   - EL/R1(R201)
   - HFD/R59(R259)
   - SLR/R78(R278)
   - BW/R107(R307)

   Leave these trimpots with all the slots pointing straight up.

   ⚠ WARNING

   Detuning the system unnecessarily will make extra work, and may limit the system's performance. Do not detune the system if it is already tuned and stable. Do not detune the system just to readjust the notch filter.

5. Inspect for obvious faults.

Step 2: Power Test

1. Fasten the board to a heatsink using three #4-5/8 or longer screws. The heatsink is needed for all the tests, and all three screws are needed for good thermal contact.

2. Connect the board to the external DC supply, and turn the supply on.

Table 7: Power Supply Voltage Checks

Voltage	Min	Max	Test Points
External ±18-30VDC	±18	±30	J3
External ±15-18VDC	±14.55	±15.45	J3
±12VDC	±11.60	±15.40	U31-3 U30-3
+5VDCref	+4.95	+5.05	R13-1 R213-1
-5VDCref	-4.90	-5.10	R13-3 R213-3

Step 3: Board Alignment - Gross Function

Required Equipment: Scanners with load (specified mirror), scanner cables, scanner clamps, true RMS DVM, oscilloscope, frequency counter (if the scope doesn't have a reliable frequency readout), signal generator, external DC supply, cables, jumpers, large heatsink.

1. Preparation
   a). Lay the board down with the mounting bracket to the rear.
   b). Connect the scanners to the board at J2 and J22, using the cables ordered with the board.
   c). Connect the DVM [VDC] to Vagc [J4-9/10] and GND [J4-5/6].
   d). Check that there are no shunts on W2/W22
   e). Plug the power cable into J3.

2. Turn on the power.

3. Measure Vagc. It should be between 6.0VDC and 8.0VDC. [A very few systems, mostly with 6900 and 6400 scanners, have ~5V for AGC.]

4. Connect the DVM to Vpos, J4-3 (J4-4). Turn the shaft by hand through the full angle. Vpos should be positive when the shaft is rotated CW, and negative when it is rotated CCW. The output amplifier should be disabled at the over-position limit. This is set at the factory, and may be set to any angle up to +/-16.5 degrees. (Note: +/-16.5 degrees is the maximum for the standard board. Operation up to +/-20deg is possible, but components need to be changed. Please contact Cambridge Technology, Inc. for more information.) The scaling is 0.5V/degree. Move the shaft slowly by hand while watching the DVM.

Step 4: Linearity and Position Scale

These adjustments are factory only, and need special equipment for accurate results. AGC/R13(R213) and LIN/R77(R277) should not be adjusted in the field, unless a scanner or board is replaced in the system.

See *"Section 4.2: Position Scale Factor and Linearity Adjustment" on page 16.*

Step 5: Continuation of System Test

1. Install the specified mirrors, and tighten the mounting screws evenly and thoroughly.
   See *"Section 8.0: Appendix B: Mirror Handling and Mounting" on page 46.*

2. Clamp the scanners firmly.

Step 6: Notch Filter Tuning

[It is not necessary to detune the 673 board to readjust the notch filters.]

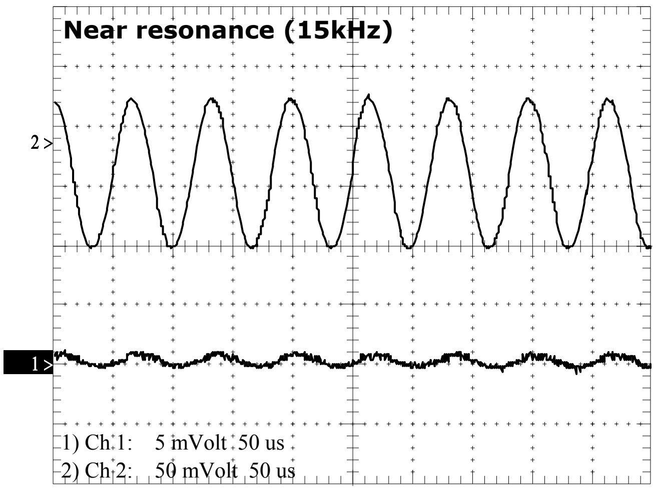
The board normally has two notch filters, RF1 and RF2, in each channel configured for the standard scanner and load. In some cases, when there is only one significant resonance, RF1 or RF2 may be disabled. Torsional resonances can range from less than 1kHz to 32KHz, depending on the load and scanner. Please call Cambridge Technology if the notch filters cannot be adjusted to match the torsional resonances of the scanners.

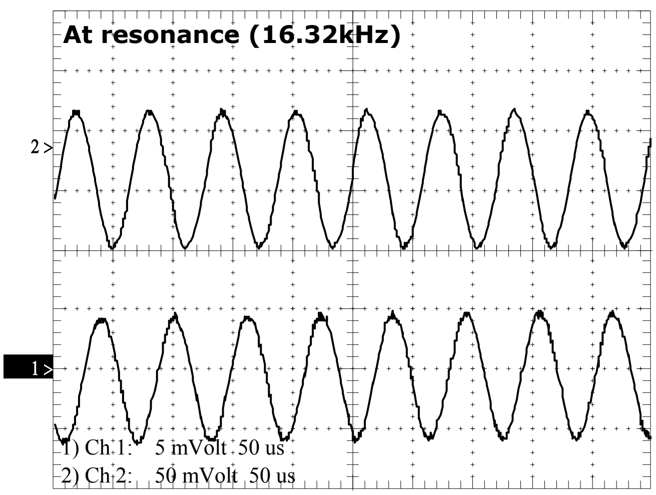
3. Check that the shunts on W2/W22 and W7/W27 have been removed.
   Connect the signal generator (1kHz sine, output ~50mVpp) to TP6(TP206), and monitor Vpos J4-3 (J4-4) and Current J4-7 (J4-8) with the scope.

4. Use the generator offset to roughly center the mirror (the scanner should not be at either stop), and set the output for ~200mVpp on the current trace.

5. Increase the frequency of the generator until it reaches the first torsional resonance. There may be other small increases in the amplitude of the position signal, but the torsional resonances are large and well-defined. See the sample plots.
Watch the amplitude on the scope, and tune carefully for the maximum signal on Vpos. Record the resonant frequency on the test sheet, and then go on to the second torsional resonance and also record it on the test sheet. Turn the generator output all the way down.

⚠ **CAUTION** ⚠
DO NOT leave the system running at a resonance more than five seconds as damage to the scanner bearings can occur.





6. Connect the generator to TP5 (TP205) and monitor TP6 (TP206) with the scope.
7. Put the shunt on W2 (W22) 1+2.
8. Ground the Mute line, J1-3 to disable both channels' output stages.
9. Turn the power on, set the generator frequency to exactly the first torsional resonance, and bring the generator output back up to ~2Vpp at TP5 (TP205).
10. Adjust RF1, R93(R293) for the best rejection.
11. Set the generator to exactly the second torsional resonance and adjust RF2, R100(R300) for the best rejection.
12. Turn the power off, disconnect the generator from TP5 (TP205), and remove the ground from the Mute line, J1-4.
13. Put the shunt on W7 (W27) 1+2.

Step 7: Small Step Response Adjustment

First check whether the board is Class 0 or Class 1, by checking the part number of the board with the part number description in *"Section 1.3: Part Number Description" on page 5*. Class 1 boards use one more trimpot than Class 0, and the trimpots react differently. See *"Section 4.0: Detailed Tuning and Alignment Procedures" on page 14* for detailed tuning procedures.

1. Scope:

Channel 1	Vpos [J4-3/4]	20mV/div
Channel 2	Current Monitor (J4-7/8)	50mV/div
Trigger	Generator Sync Out	EXT
Generator	0.050Vpp (or 0.1°) ~20Hz square wave.	

2. Turn the power on, and turn LFD/R25(R225) about 3 turns CW and HFD/R59(R259) about 2 turns CW.

Class 0

[If the board is Class 1, skip ahead to Step 3 under Class 1.]

3. Turn SG/R28(R228) CW until the mirror starts locking in the center position, and Vpos starts showing a square wave.
4. Continue to turn SG/R28(R228) CW until the square wave shows several cycles of ringing. (Adjust HFD/R59(R259) for stability if needed.)
5. Adjust LFD/R25(R225) CW to reduce the ringing.
6. Adjust HFD/R59(R259) CW to remove the dip.
7. Repeat steps 4, 5, and 6 until the specified response time is reached, or one or more of the trimpots run out of range, then make fine adjustments. Change the current and voltage ranges and the timebase as the errors get smaller. BW interacts with HFD and LFD in the later stages of tuning, and moves the dips and bumps sideways. Start adjusting it as soon as it starts producing a noticeable effect. The objective is a clean square wave without ringing or overshoot with the specified step response time for the scanner and load in use. Step response time is defined as the time from the external trigger from the generator to when the position trace settles to 99% of the final level. Note that in Class 0 there is a long slow rise after the initial settling time. This is normal in Class 0 and is not included when measuring the step response. Check this at 2mV/div. The current trace should also settle cleanly. The final step response spec is usually at 0.1°. See *"Section 4.4: Measuring the Step Response Time" on page 19*.

Class 1

3. Turn SG/R28(R228) CW until the mirror starts locking in the center position, and Vpos approaches 0V.

4. Turn EI/R31(R331) CW slowly until the mirror moves and Vpos starts showing a square wave.

5. Continue to turn EI/R31(R231) CW until the square wave shows several cycles of ringing. (Adjust HFD/R59(R259) for stability if needed.)

6. Adjust SG/R28(R228) CW to reduce and center the ringing.

7. Adjust LFD/R25(R225) CW to flatten the first cycle of the ringing and leave a bump.

8. Adjust HFD/R59(R259) CW to remove the bump.

9. Repeat steps 5, 6, 7, and 8 until the specified response time is reached, or one or more of the trimpots run out of range, then make fine adjustments. Change the current and voltage ranges and the timebase as the errors get smaller. BW interacts with HFD and LFD in the later stages of tuning, and moves the dips and bumps sideways. Start adjusting it as soon as it starts producing a noticeable effect. The objective is a clean square wave without ringing or overshoot with the specified step response time for the scanner and load in use. Step response time is defined as the time from the external trigger from the generator to when the position trace settles to 99% of the final level. Check this at 2mV/div. The current trace should also settle cleanly. The final step response spec is at is usually at 0.1°
   See *"Section 4.4: Measuring the Step Response Time" on page 19*.

Step 8: Offset Adjustment PO/R1(R201)

1. Short both sides of the input to ground and connect the DVM to Vpos, J4-3 (J4-4).

2. Adjust the Position Offset trimpot, PO/R1(R201) for 0V ±1mV

Step 9: Slew Rate Limiting Adjustment SRL R78(R278)

(Note: this adjustment depends on the power supply as well as the board and scanner. The object is to keep the output amplifier from saturating, by controlling the large angle slew rate of the input signal. Improper setting of this adjustement can result in system instability and poor large angle settling See *"Section 4.5: Slew Rate Limiter Adjustment" on page 29*.

1. Set up
   Generator: 20Hz ~50mVpp square wave.
   Scope:
   Ch 1 5V [Vpos - J4-3/4]
   Ch 2 5V [Vout - TP4/TP204]

2. Turn SRL/R78(R278) CW until the voltage spikes on TP8 (TP208) show no sign of saturation.

3. Increase the input slowly to 20Vpp or full scale while adjusting SRL/R78(R278) to keep the signal free of saturation. In Class 1 set the signal peaks to about three volts less than the point at which clipping and oscillation start. In Class 0 some clipping on the first pulse is acceptable.

Step 10: Error Limiting Adjustment EL/R53(R253)

The Error Limiter is enabled only in some Class 0 systems, never in Class 1 systems. In most cases the Slew Rate Limiter provides better performance. The adjustment is similar to the Slew Rate Limiter adjustment. See *"Section 4.5.3: The Error Limiter - EL/R53(R253)" on page 33*.

Step 11: Set System Input Scale Factor IS/R51(R251)

The Input Scale Factor is measured as the amount of input voltage required to move the rotor some amount of angle. For a system with a Fieldsize of 40 deg, this is 0.5V/deg. For a system with a fieldsize of 30 deg, this is 0.667V/deg. Thus, the Input Scale Factor equals (40 deg * 0.5V/deg)/Fieldsize. Set the Input Scale trimpot, R51 (R251) using the equation above, the desired Fieldsize and the std Ouput Scale Factor, 0.5V/deg.

1. Set the generator to ~5VDC. Measure the exact voltage using a DVM.

2. Adjust the Input Scale trimpot, IS/R51 (R251) for the calculated output at Vpos, J4-3 (J4-4).

Step 12: Step Response

Input voltages will vary depending on field size and scale factor. Recheck and readjust the small and large angle steps.

Step 13: Current to Voltage Converter and Coil High Temperature Protection

⚠ **CAUTION** ⚠

HEAT DAMAGE!
DO NOT try to run the system at full power without an adequate heatsink for the scanner. Please see the scanner manual.

Step 14: Mirror Alignment Jumper

[The jumper should normally be changed with the power off.]
See *"Section 4.6: Aligning the Mirror" on page 34*.

1. Verify that there is no input to the device.

2. Move the jumper from W11(W31) 2+3 to W11(W31) 1+2. The mirror should move under light pressure and still center itself. Restore the jumper to W11(W31) 2+3. The mirror should stiffen and center without substantial oscillation.

Step 15: Startup, Shutdown, and Muting

1. Check that the system starts cleanly when the power is turned on and shuts down cleanly when the power is turned off.

2. Check that grounding the Mute line (J1-4) disables both scanners, and that the system restarts when the ground is removed.

4.0 Detailed Tuning and Alignment Procedures

The following procedures are provided to aid new or infrequent users with certain sections of the tuning procedure explained in more detail.

Please also see *"Section 3.0: 673 System Test and Alignment" on page 10*.

For most users, the factory settings on the 673 board will never need adjusting. However, if you want to change the mirror load originally used, the system will need to be tuned.

⚠ CAUTION ⚠

This procedure is aimed at the user who has an electronics background dealing with servo controlled systems. Do not attempt this procedure if any part of it is not clearly understood. This procedure explains all of the adjustments that are performed at Cambridge Technology.

Table 8: Potentiometers

ID	Ref Des	Description of Potentiometer Function
PS	R13(R213)	Position Output Scale Factor adjustment
LIN	R77(R277)	Linearity adjustment
EL	R53(R253)	Error Limiter adjustment
SRL	R78(R278)	Slew Rate Limiter adjustment
IS	R51(R251)	Command Input Scale adjustment
PO	R1(R201)	Command Position Offset adjustment
EI	R31(R231)	Error Integrator adjustment
LFD	R25(R225)	Low Frequency Damping adjustment
SG	R28(R228)	Servo Gain adjustment
HFD	R59(R259)	High Frequency Damping adjustment
BW	R107(R307)	Band Width adjustment for HFD and LFD alignment

Refer to *"Section 10.0: Appendix E: Drawings" on page 49* for the 673 Outline Drawing, D05606 for potentiometer locations.

When to Use These Procedures

When possible, Cambridge Technology ships systems completely tuned and aligned. Please check the state of the system carefully before retuning it or making any adjustments, and see the note at the beginning of Section 3. The procedures below are just detailed explanations of the procedures in *"Section 3.0: 673 System Test and Alignment" on page 10*. Do not perform any of the procedures of this section without completely understanding the context and the order of them as described in the previous section.

⚠ WARNING

Detuning the system unnecessarily or altering the factory settings will make extra work, and may limit the system's performance.

- Read the following procedure completely before attempting to retune the system. Serious damage to the scanner could result if the servo is improperly adjusted!
- Failure to carefully monitor the scanner's position response while adjusting the servo trimpots could result in instability, which could damage the scanner.

⚠ CAUTION ⚠

Turn the power off immediately if the system becomes unstable or makes buzzing, whistling, or squealing noises.
Check to make sure the mirror load is correct for the scanner and is firmly attached. If so, start the tuning procedure over again. This is the only way to ensure the scanner isn't damaged. Contact Cambridge Technology if a resonance condition cannot be resolved.

Required Tools and Materials

- Dual trace oscilloscope.
- Function generator - with sine and square wave output.
- Digital voltmeter and frequency counter.
- Hand tools - jeweler's screwdriver flat-tip
- Clip lead with "micro grabber" ends.
- Observation cable assembly - Available as an option from Cambridge Technology, Inc. Please contact the factory for more information.
- Fully wired power supply cables and input signal cables

4.1 Changing the Input Scale Factor

Cambridge Technology sets up the Input Scale Factor at the factory as ordered from the customer or as appropriate for the type of system shipped. However, it is sometimes appropriate for the customer to want to change the fieldsize of the system to better match the input signal span. This section is written for customers who need to change their Input Scale Factor, and they have a system that allows it.

⚠ CAUTION ⚠

If there are any questions about this procedure or whether the system shipped supports the change in fieldsize proposed, please contact Cambridge Technology, Inc. for technical support. It is possible to damage the scanner if the fieldsize is increased on a system that does not support the change.

The standard input signal range is +/-10V for the maximum full-field. If the system is setup for +/-10deg, then this means the Input Scale Factor is set for 1.00v/degree mechical. If the system is setup for +/-15deg, then the Input Scale Factor is 0.667volts/degree. For small changes in fieldsize, ~+/-10%, use R51(251) as shown in *"Section Step 11:: Set System Input Scale Factor IS/R51(R251)" on page 13*.

But for larger changes, the value of R30 must be changed. After this change, Overposition Limit Resistor, R90(290), needs to be changed correspondingly. See *"Section Table 5:: Over-Position/Standard Resistor Values" on page 9*

Also, the Small Angle Step Response, the Large Angle Step Response, and either the Error Limiter or the Slew Rate Limiter Adjustments should be checked to ensure proper operation of the servo. The Notch Filter adjustments and the Output Scale Factor need not be checked if only the Input Scale Factor has been changed.

⚠ CAUTION ⚠

Never set the Input Scale Factor so low (the Fieldsize so large) that the scanner is driven into the bumpers while still under servo control. This will cause a servo instability which could damage the scanner. Always set the Fieldsize and Overposition Limit so the servo shuts off just before contacting the bumper.

To change the Input Scale Factor and thus the maximum Fieldsize of the system, refer to the table shown below. For maximum temperature stability, use a high quality metal film 1206 SMT resistor such as Vishay Series P1206YxxxxDST, KOA Speer Series RN732BTTDxxxxD10, IRC Series PCFW1206LF12xxxxDPLT, or equivalent. These resistors all have temperature coefficients of 10ppm/deg C or less.

Please note that only the **bolded** resistors in the table are stocked values. All others must be custom ordered with 12 - 16 week lead times. However, because of the Input Scale Adjustment trimpot R51(251) there is much overlap between resistor values.

For example:

For a 30degree p-p mechanical system, the table calls out for a 10.2Kohm resistor. But since there is less than a 10% difference between 10.2Kohm and 10.0Kohm, it can be substituted and it is a stock value.

Also, note that the stocked values were determined at the time this revision was written. More values might have been added since then. Please contact Cambridge Technology, Inc. to see if the resistor needed might have been added to the stocked list.

The last five entries of the table show that +/-15V regulators are required for operation at angles greater than +/-17 degrees mechanical. Please contact Cambridge Technology for operation at these angles.

Table 9: Selection of R30(230) for Fieldsize Changes

Nominal Fieldsize Mechanical Degrees P-P	Value for R30(230) (R119(319) = 1K)	CTI Part Number	Comments
10	**33.2K**	**P0157-0243**	**+/-12V Reg**
11	29.4K	P0157-0238	+/-12V Reg
12	27.4K	P0157-0235	+/-12V Reg
13	24.9K	P0157-0231	+/-12V Reg
14	23.2K	P0157-0228	+/-12V Reg
15	21.5K	P0157-0225	+/-12V Reg
16	**20.0K**	**P0157-0222**	**+/-12V Reg**
17	18.7K	P0157-0219	+/-12V Reg
18	17.8K	P0157-0217	+/-12V Reg
19	**16.9K**	**P0157-0215**	**+/-12V Reg**
20	15.8K	P0157-0212	+/-12V Reg
21	**15.0K**	**P0157-0210**	**+/-12V Reg**
22	14.3K	P0157-0208	+/-12V Reg
23	13.7K	P0157-0206	+/-12V Reg
24	13.0K	P0157-0204	+/-12V Reg
25	**12.4K**	**P0157-0202**	**+/-12V Reg**
26	12.1K	P0157-0201	+/-12V Reg
27	11.5K	P0157-0199	+/-12V Reg
28	**11.0K**	**P0157-0197**	**+/-12V Reg**
29	10.7K	P0157-0196	+/-12V Reg
30	10.2K	P0157-0194	+/-12V Reg
31	**10K**	**P0157-0193**	**+/-12V Reg**
32	9.53K	P0157-0191	+/-12V Reg
33	**9.31K**	**P0157-0190**	**+/-12V Reg**
34	**8.87K**	**P0157-0188**	**+/-12V Reg**
35	8.66K	P0157-0187	+/-12V Reg
36	**8.45K**	**P0157-0186**	**+/-15V Reg Needed**
37	8.25K	P0157-0185	+/-15V Reg Needed
38	7.87K	P0157-0183	+/-15V Reg Needed
39	7.68K	P0157-0182	+/-15V Reg Needed
40	**7.50K**	**P0157-0181**	**+/-15V Reg Needed**

4.2 Position Scale Factor and Linearity Adjustment

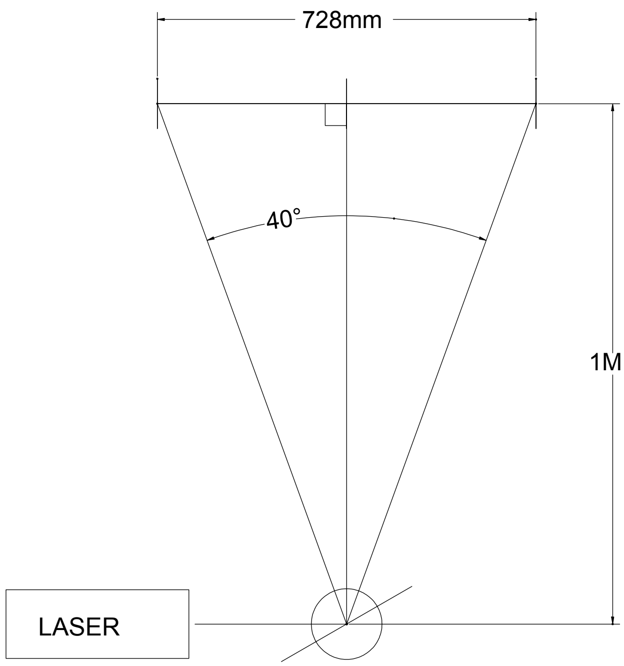
When the 673 board is supplied in a matched set with a scanner, the Position Scale Factor and Linearity are adjusted at the factory, and should never need readjustment as long as the original board and scanner are used together.

If it is necessary to replace a scanner or board in the field, the system can be calibrated with moderate accuracy using the following procedure. The scanner must have a mirror mounted on the shaft.

4.2.1 Set Up

The scale will be set by adjusting the deflection of a laser beam over a known angle using a test scale on the wall. Measure the distance from the center of the mirror to the wall. From this, calculate the length of a line that subtends exactly 40 degrees on the wall. For example, if the mirror is one meter from the wall, the length of the line is 2 x 1 meter x tan 20° which is 728mm. Mark the exact center of the line, and the two ends. See the sketch below.

For this to work, the line on the wall, the laser beam, and the center of the mirror must be in the same plane. The axis of the scanner must be perpendicular to the plane. The laser beam must start parallel to the line on the wall. The center of the mirror must be exactly opposite the center of the line on the wall. The accuracy of this method depends on the accuracy of all these lengths and angles.



4.2.2 Closed Loop Method

Use this method if the system is already tuned and stable. Do this procedure for one channel at a time.

Needed: Oscilloscope, true RMS DVM, signal generator, laser (a laser pointer in a clamp is good enough)

Step 1: Zero the Scanner

1. Ground the Input Signal, J1-5+6 (J1-1+2), or input zero volts. Check for 0.000 volts on the Position Signal, J4-3(J4-4), with a DVM and adjust any servo offset with PO/R1(R201) as necessary. Use J4-5(J4-6) for Ground.
2. Turn on the laser, and aim the beam at the center of the mirror. Make sure the beam is parallel to the test scale on the wall, and in the same plane.
3. Rotate the scanner body (not the shaft yet) until the beam is exactly on the center of the test scale.

Step 2: Set the Signal Level.

1. Connect a sine wave from the signal generator to the input. The frequency should be about 30Hz. It may be necessary to use a lower frequency for systems with very large loads and low bandwidths.
2. Connect the scope to monitor the AGC Signal, J4-9(J4-10). Adjust the scope to 10mV/div 10ms/div AC coupled.
3. Measure the AC voltage on Position Signal J4-3 (J4-4)with the DVM, and set the generator for 3.535VAC†as viewed on Position.
4. Check that there is no DC offset in the input signal. (Disconnect the generator from the Input Signal and connect it directly to the DVM, measure VDC, and adjust the generator offset for 0V± 10mV. The DVM may reject the AC signal better if the generator is set to the local power line frequency [50Hz or 60Hz].)
5. Connect the generator to the Input Signal again.

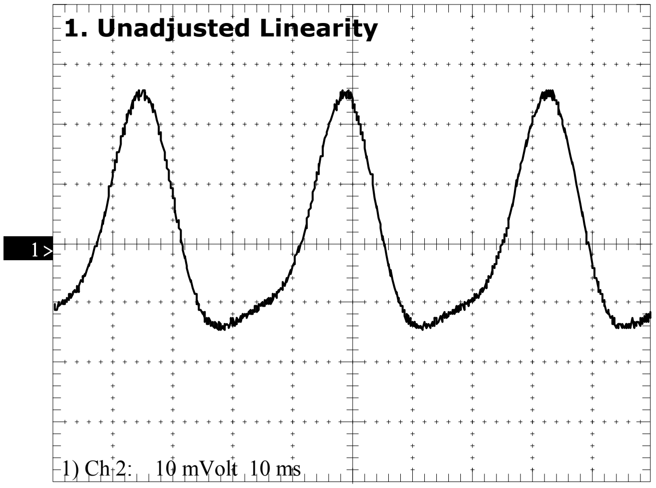
Step 3: Adjust Position Output Scale and Linearity

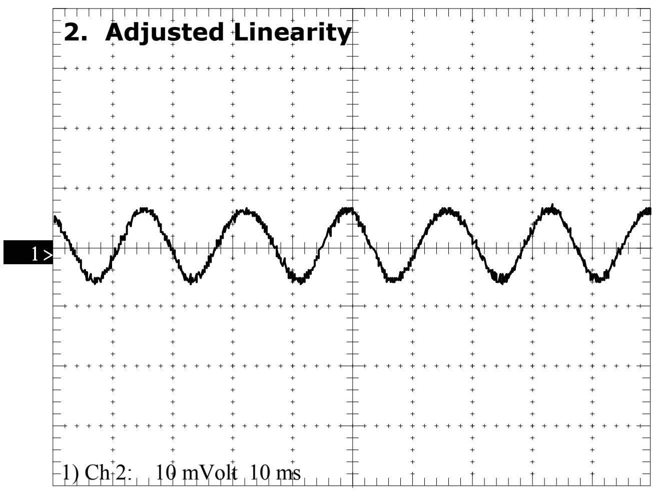
The laser should now be scanning a line on the wall directly on the test scale, and roughly centered horizontally. If the laser line is above or below the test scale, or at an angle to it, go back and recheck the positioning of the laser and scanner.

1. Adjust PS/R13(R213) until the laser line on the wall is exactly as long as the 40 degree test scale on the wall. It may not be perfectly centered.
2. Watch the scope, and adjust LIN/R77(R277) for the minimum peak-to-peak AC signal. This method does not measure linearity, but it should get the adjustment fairly close to the optimum.
3. Readjust PS/R13(213) if necessary, and then LIN/R77(R277). These adjustments may interact, and take several iterations.

Step 4: Check the AGC Voltage

1. Connect the DVM to the AGC Signal, J4-9(J4-10) and Ground at J4-5(J4-6).
2. Measure the DC voltage. If it is greater than 8.0V, please check with Cambridge Technology for technical assistance.





4.2.3 Open Loop Method

If the system has not been tuned or there is some doubt about the state of the tuning, this method can be used to adjust Position Scale well enough to tune the system.

Equipment required: DVM, laser (a laser pointer in a clamp is good enough)

Step 1: Set Up

1. Set up the scanner, laser, and the test scale on the wall. (See *"Section 4.2.1: Set Up" on page 16*.)
2. Disable the output amplifier on the 673 board by grounding the Mute Signal on J1-4. Connect J1-3 for the Mute Return.

Note: The Mute Signal disables both channels at the same time.

3. Connect the DVM to Monitor the Position Signal J4-3(J4-4). Use J4-5(J4-6) for Ground.
4. Turn on the power.

Step 2: Zero the Linearity TrimPot

1. Turn LIN/R77(R277) fully CCW
2. Turn LIN/R77(R277) 6 turns CW. This should put it at the center of its range.

Step 3: Set the Input Scale

1. Turn on the laser, and aim the beam at the center of the mirror. Make sure the beam is parallel to the line on the wall, and in the same plane.
2. Rotate the mirror until the DVM reads 0VDC as nearly as possible, and then rotate the scanner until the laser beam is as close as possible to the center of the test scale on the wall. The DVM should read 0VDC when the laser beam is on the center of the test scale.
3. Rotate the mirror (*not the scanner body*) clockwise, CW, until the beam hits the mark at the end of the line.
4. Adjust PS/R13(R213) until the Position Signal reads +5.0V DC.
5. Repeat steps 2, 3, and 4 until the measurements are as accurate as practical.
6. Rotate the mirror counterclockwise, CCW, until it is at the other end of the line.
7. Check that the Position Signal is reasonably close to -5.0V DC.

Step 4: Check the AGC Voltage

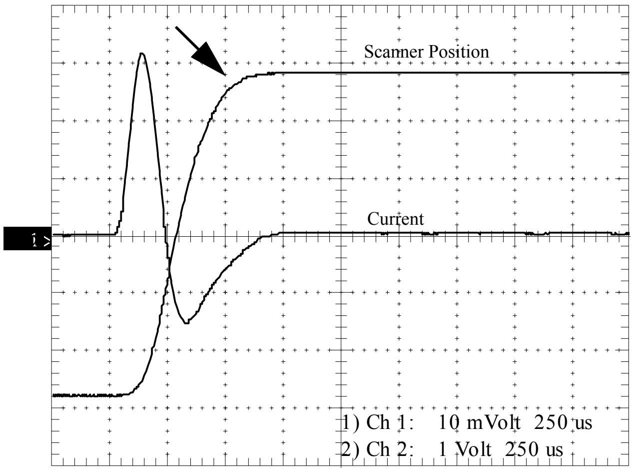
1. Connect the DVM to monitor the AGC Signal, J4-9(J4-10). Use J4-5(J4-6) for Ground.
2. Measure the DC voltage. If it is greater than 8.0V, please check with Cambridge Technology for technical assistance.
3. After tuning the system, readjust Input Scale and Linearity using the Closed-Loop Method for a more accuracate system. See *"Section 4.2.2: Closed Loop Method" on page 16*.

4.3 Small Angle Step Response Tuning

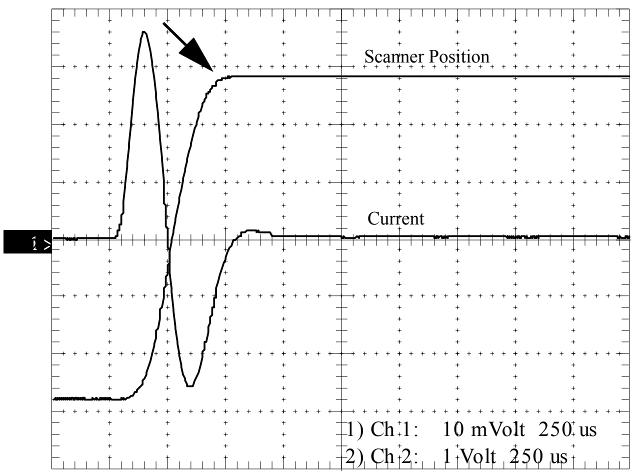
This procedure details the steps necessary to tune a system (adjust trimpots) to achieve the fastest controlled response to a command input signal. This properly tuned response is called "critically damped." Complete this procedure after scale and linearity have been adjusted, and the notch filter is tuned.

In contrast to a critically damped system (see figures below), an over-damped or under-damped system will take too long to settle to the correct position and may overshoot and ring.

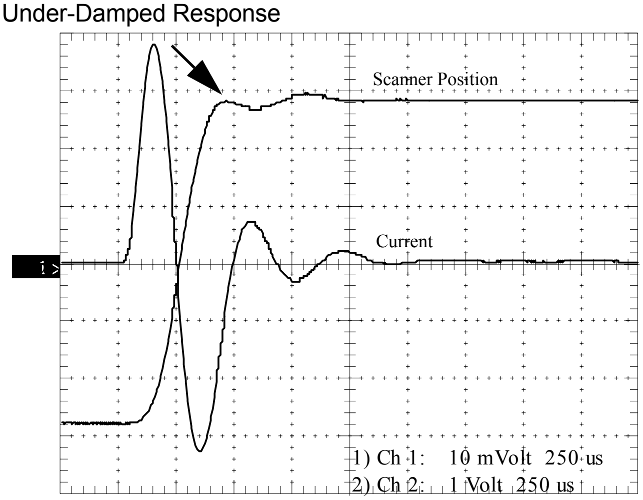
Over-Damped Response



Critically-Damped Response



Under-Damped Response



4.4 Measuring the Step Response Time

The step response time is an important specification of the scanner system, and measuring it accurately is vital. If it is unknown or measured incorrectly, other settings and specifications will be wrong, and it will be difficult to set up the system.

Cambridge Technology defines step response time from the start of the input step to the point where the Position waveform is settled to within 99% of its final level.

If possible, compare the waveforms with a sample plot from a correctly tuned system

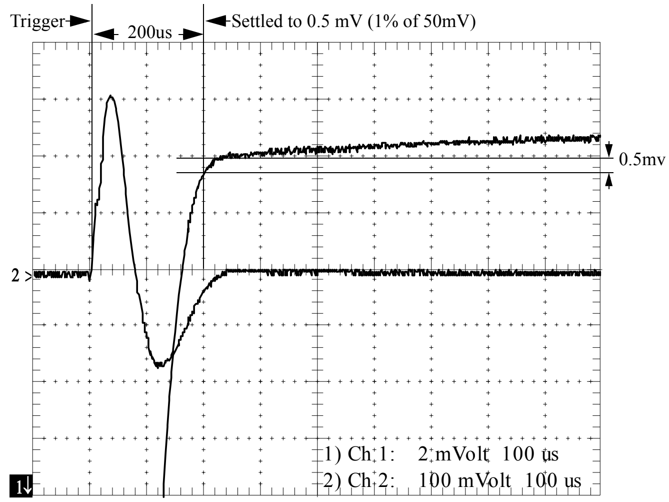
1. Disconnect any external filters.
2. If possible, use a digital scope, and use the signal averaging to get a clearer waveform.
3. Always trigger from the sync output of the generator, and set the trigger point on the display accurately. One major division from the left is convenient.
4. Set the time scale so that the specified response time will cover at least two major divisions on the display. That is, if the spec is 200us, set the timebase to 100us, or 50us.
5. Set the size of the step of the test waveform accurately. Observe this on the Position Signal, J4-3 (J4-4). This is the step size specified for the test, and is usually 0.1 degree p-p but can be as large as 40 degrees.
6. Expand the vertical scale so that 1% of the step is at least one minor division on the display. That is, if the spec calls for a 0.1 degree (50mV on Position) step, change to the 2mV scale. 1% of 50mV is 0.5mV, which is 1.25 minor divisions.
7. Use the offset on the generator output, or the position knob on the scope, to bring the top of the waveform into view. Check that the generator or the scope input doesn't overload and limit the signal. (Compare the current waveform with the sample plot.)
8. Check that the waveform is clean, and a reasonable match for the sample plot.
9. Find the 99% point on the waveform:
   - Class 0 system: this is 1% below the point at which the signal reaches an approximately constant slope
   - Class 1 system: this is 1% below the point the waveform crosses the right edge of the screen.
10. Measure the time from the trigger point to the settling point. When using the cursors on the scope to measure the time, move them to precisely the trigger point and the settling point, then read the time.

⚠ **CAUTION** ⚠

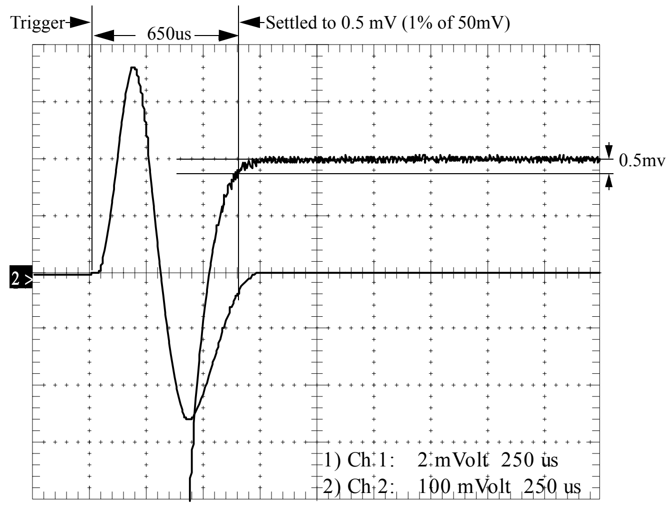
The cursors can be very inaccurate when they are used at the wrong scale, or used backwards (setting the cursors to the specified time, then looking at the position of the cursor).

See plots for measurement examples.

Class 0 Board Measurements



Class 1 Board Measurements



4.4.1 Small Step Response Tuning Preparation

1. Choose the tuning parameters:
   The first step is to choose the tuning angle and the step response time for the system. The tuning angle should always be small enough the system never comes close to saturation. If the system clips or saturates, it will be much more difficult to tune. Even if the system can be tuned with saturation, all other step sizes will be under- or overdamped which could lead to an instability. Typically the 673 systems are tuned at 0.1 degrees, but a larger angle may sometimes be better, especially for systems that are tuned slow.
   The small-angle step response of 673 systems ranges from 100us to more than 40ms, depending on the scanner, load, and application. Do not tune the system faster than required for the application. The extra speed will increase noise and jitter, and may reduce the margin of stability. The best way to find the optimum speed is through experimentation. See *“Section 4.4: Measuring the Step Response Time” on page 19* and *“Section 6.2: Speed” on page 41*.

2. Check that the Notch Filters have been adjusted. See *Step 6: Notch Filter Tuning on page 11*. The best way to determine your servo class is by the paperwork included with your order. Use the part number written on the paperwork included with you system and see *“Section 1.3: Part Number Description” on page 5* to determine whether the servo board is set for class 1 or class 0.

   Note: There are several jumpers on the 673 board that set the servo configuration. But these resistors are small and hard to locate. Please refer to the 673 Dual Axis Outline Drawing in *“Section 10.0: Appendix E: Drawings” on page 49*.” If their is any question as to which servo class board you have, please contact Cambridge Technology, Inc. before attempting to retune your servo. Class 1 boards use one more trimpot than Class 0 and the trimpots react differently on each board type.

3. Setting up the Oscilloscope and Signal Generator:
   - Channel 1 is always the Position Signal, J4-3 (J4-4). Set the vertical sensitivity so the small-angle step will take roughly 5 major divisions. That is, for 0.1 degrees (50mV) set it to 10mV/division.
   - Channel 2 is always the Current Monitor Signal, J4-7(J4-8). Set the vertical sensitivity to 100mV/division, change it as needed.
   - Set the scope’s timebase two to five times the final step response time. That is, for 200us set it to 500us or 1ms/division, and for 1ms set it to 2ms or 5ms/division.
   - Set the trigger point one major division from the left edge of the scope screen, and use the TTL-level sync output of the generator for a trigger. Otherwise trigger from the input.
   - Set the output of the signal generator to a 20Hz square wave, about 50-100mVp-p, and adjust it to the specified angle on the Position Signal later.

4.4.2 General Notes

- The tuning of any particular Class 0 system is essentially the same as the tuning of any other Class 0 systems, and the tuning of any particular Class 1 system is essentially the same as any other Class 1 systems. The scaling changes; the algorithms and waveforms do not.
- These tuning procedures assume that the loads are well matched to the boards and scanners. If the inertia is very high or very low, tuning will be more difficult, and in extreme cases impossible.
- The plots in these examples are from complete step-by-step records of the tuning of particular boards and scanners. They are useful as an indication of what to do to get from one step to the next, but don't expect any system to be an exact match.
- When tuning, don't spend time trying to get a completely clean step at each stage. Save the fine tuning for the end.
- Do not try to completely correct an error with one adjustment of one trimpot. It doesn't work. The usual result is a badly overdamped system.
- Keep an eye on the current waveform. It can be a strong indication of overdamping or ringing.
- If the tuning seems wrong by comparison with the examples and it can't be easily corrected, turn off the power, detune the board, and start again. There are times when there is no direct path from a mistuned system to a tuned system.
- Do not rush. Do not expect to tune the system completely in exactly twenty steps. Take small steps and make small adjustments. Rapid, accurate tuning is a skill which is acquired only by practice.
- If the system starts oscillating or making buzzing, whistling, or squealing noises, turn off the power, detune the board, and start again. If the problems persist, please call Cambridge Technology for help.
- When starting with a completely detuned board, only tune one channel of the board at a time.

If this is a Class 0 system, go to *“Section 4.4.3: Class 0 Tuning” on page 21*.

If this is a Class 1 system, go to *“Section 4.4.4: Class 1 Tuning” on page 25*.

4.4.3 Class 0 Tuning

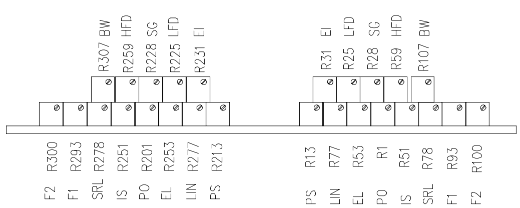
Trimpots

Table 10:Trimpots, Class 0 Board Turning

Trimpot	Name	Purpose
SG/R28 (R228)	Servo Gain	This trimpot controls the basic gain of the system. Turn it CW to increase the speed of the step.
LFD/R25 (R225)	Low Frequency Damping	This trimpot damps the overshoot on the leading edge of the step waveform. Turn it CW to reduce the overshoot
HFD/R59 (R259)	High Frequency Damping	This trimpot damps the ringing not controlled by the **LFD** trimpot, and acts to the right of the leading edge of the step. Turn it CW to reduce the ringing and bring down the waveform just after the leading edge.
BW/R107 (307)	Bandwidth	This trimpot adjusts the center frequency of the **HFD** trimpot. It has very little effect until the last stages of tuning. Turning it CW moves bumps and dips to the left. It interacts with **HFD** and **LFD**, and all three will need fine adjustments in the last stage of tuning. If there are problems with the fine tuning, it's useful to turn **LFD** and **HFD** half a turn CCW, and then readjust **BW**. [Note: As the speed of the step increases, the correct adjustment goes CCW. This is why it's a good idea to leave the **BW** trimpot alone until the end.]

Step 1: Prepare the Class 0 Board

1. Detune the board:
   Detune the board by setting each of the following fully counter-clockwise (CCW):
   SRL/R78(R278)
   EL/R53(R253)
   EI/R31(R231)
   SG/R28(R228)
   LFD/R25(R225)
   HFD/R59(R259)
   BW/R107(R307)
   This should take a maximum of 12 turns, and the trimpots usually click at the end of their range.



2. Turn on the power. Follow the instructions above each example plot that follows to change the traces in the previous plot to the current one.

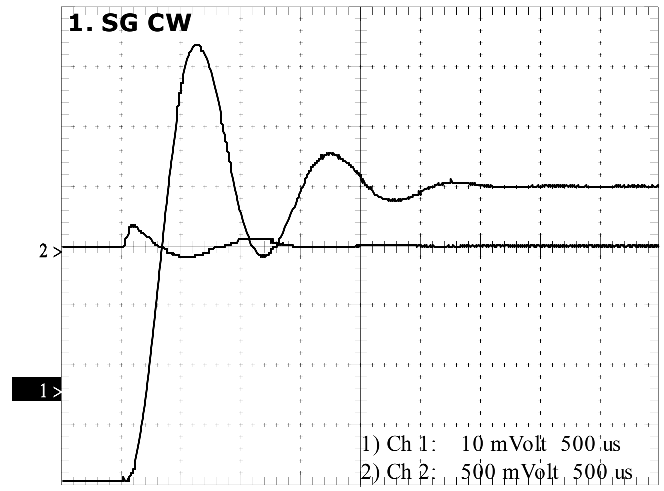
3. Turn **LFD** three turns **CW** and **HFD** two turns **CW**.

   This generally provides the correct initial damping for the system, but experimentation may show that another adjustment is better.

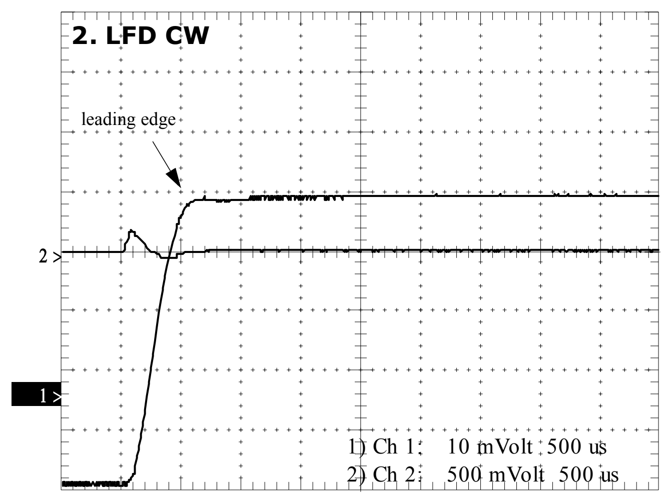
Step 2: Tune the Class 0 Board

In this stage bring up the gain and damping step by step until the system is close to the specified step time. The normal cycle is **SG**, to bring up the gain, **LFD**, to damp the overshoot on the leading edge, and **HFD**, to reduce the ringing. The **BW** trimpot is not normally needed until fine tuning.
Note: Adjust the Position signal on channel 1 to keep it on the screen. Use either the vertical position on the scope, or the offset on the signal generator. These adjustments are not mentioned in the procedure. The final tuning for the system in this example is 200us at 0.1 degrees.

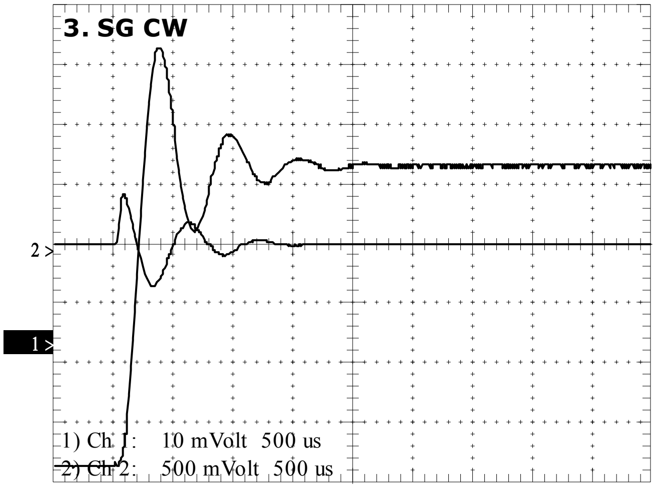
1. Turn **SG CW** until the scanner starts to center and several cycles of ringing appear.



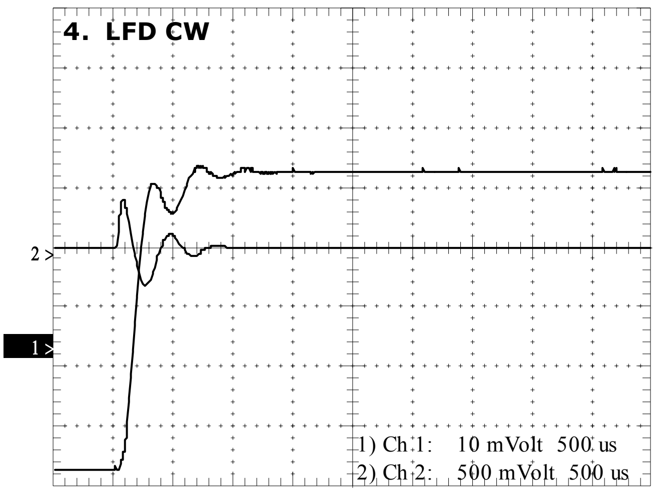
2. Turn **LFD CW** until the leading edge is level with the rest of the waveform. Ignore the slight dip.



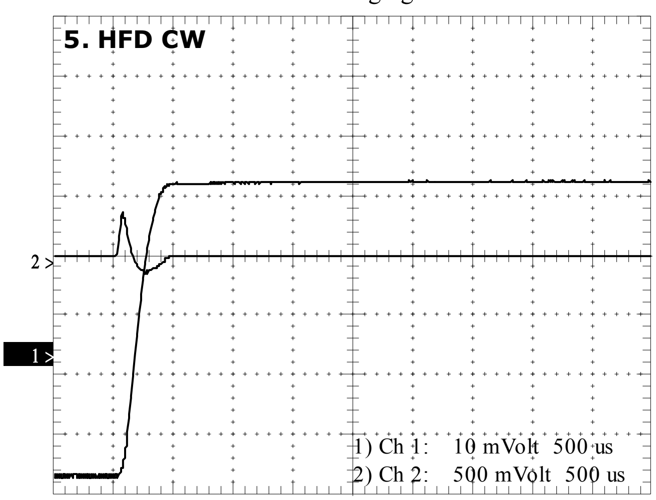
3. Increase the signal gain again (turn **SG CW)** until several cycles of ringing appear.



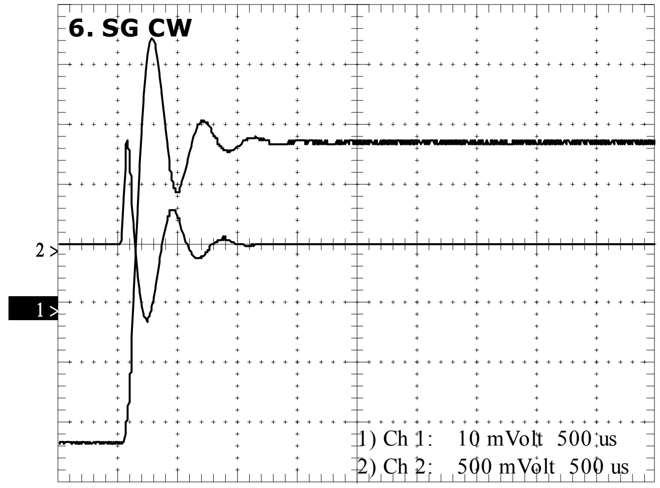
4. Turn **LFD CW** until the leading edge is level with the rest of the waveform.



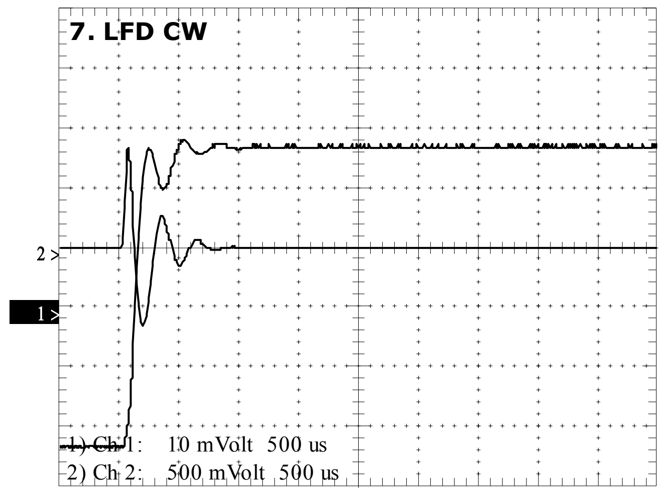
5. Turn **HFD CW** to minimize ringing.



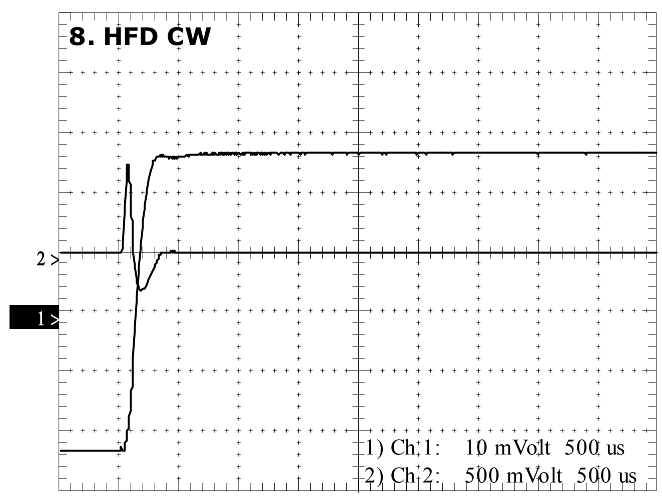
6. Increase the signal gain again (turn **SG CW**) until several cycles of ringing appear.



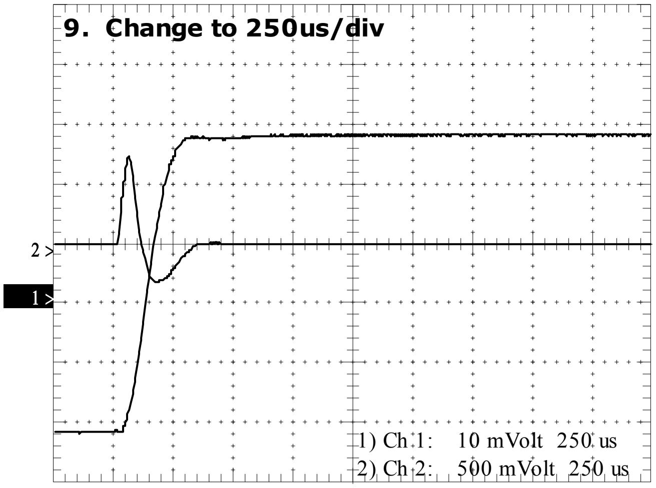
7. Turn **LFD CW** until the leading edge is level with the rest of the waveform.



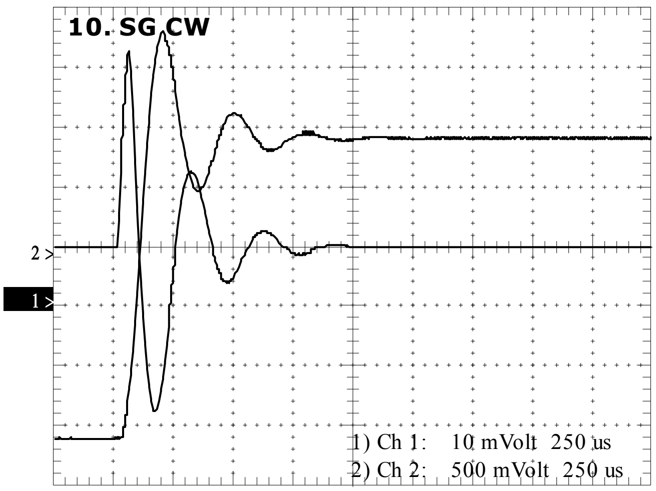
8. Turn **HFD CW** to minimize ringing.



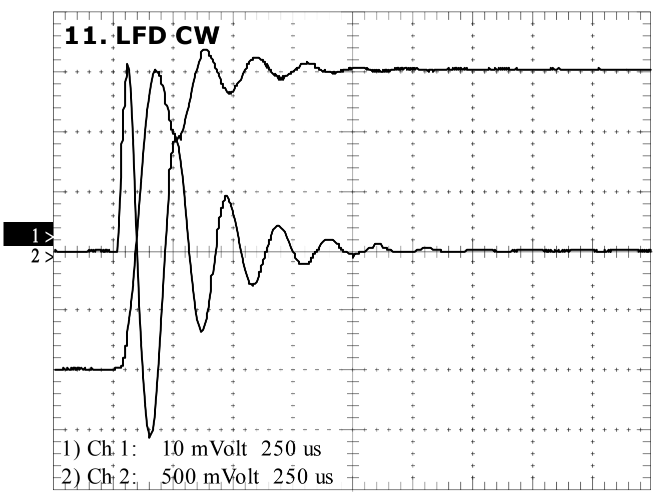
9. Change the time base to 250 us/division (zoom in).



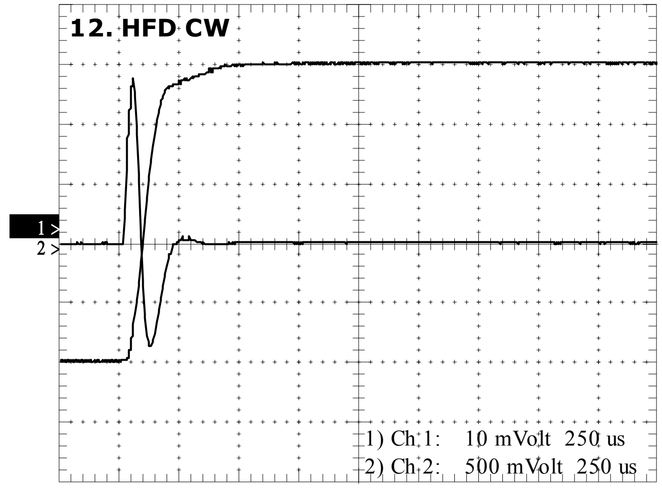
10. Increase the signal gain again (turn **SG CW**) until several cycles of ringing appear.



11. Turn **LFD CW** until the leading edge is level with the rest of the waveform.



12. Turn **HFD CW** to minimize ringing.

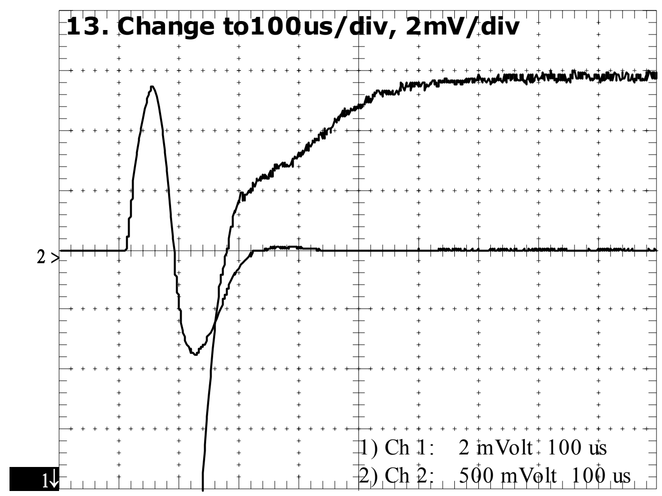


Fine Tune the Class 0 Board

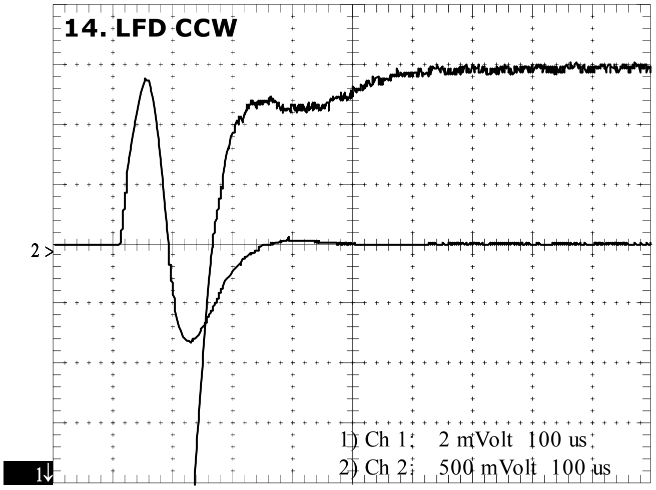
At this point the step response is close to 200us, and it's time to start the fine tuning. It's important to change scale here, to see that the signal settles to within 1%, and to measure the time accurately.

This is where the BW trimpot becomes useful. It adjusts the center frequency of the HFD trimpot and moves the bumps and dips in the step sideways.

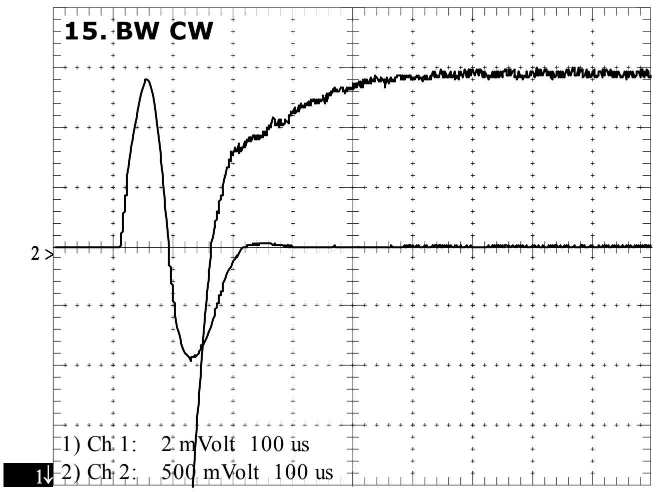
13. Change the time base to 100us/div and the Ch 1 scale to 2 mV/div (zoom in).



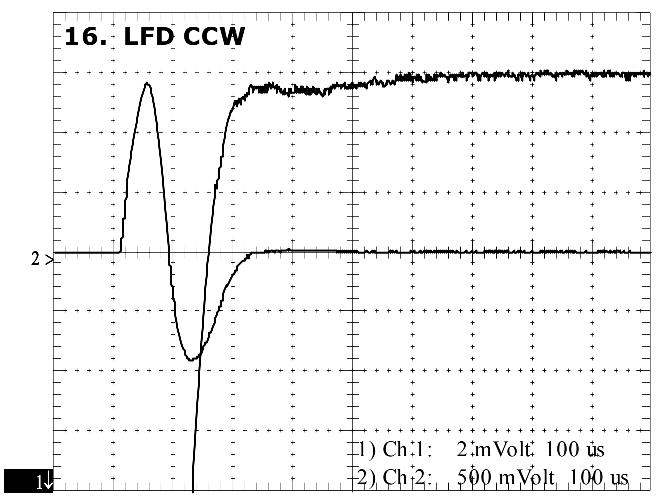
14. Turn **LFD CCW** to bring up the leading edge.



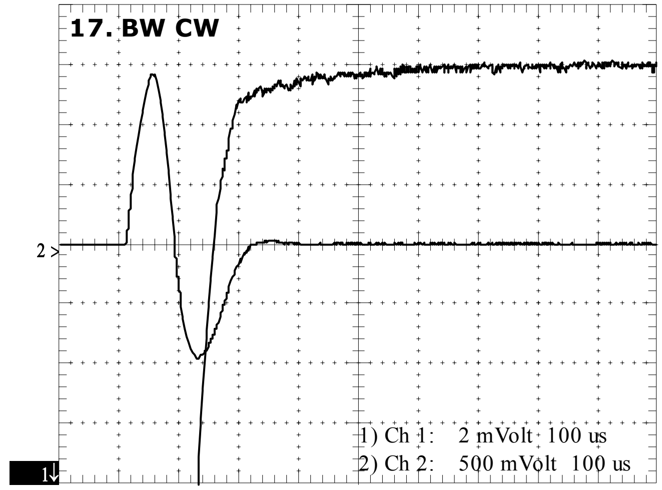
15. Turn **BW CW** to flatten out the dip.



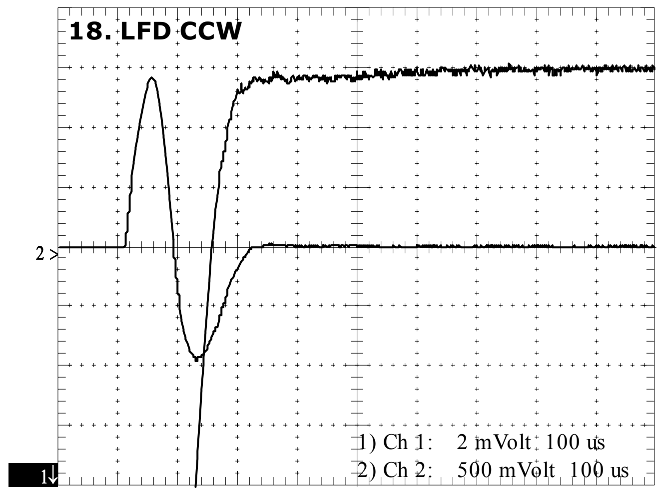
16. Turn **LFD CCW** again to bring up the leading edge.



17. Turn **BW CW** again to flatten out the dip.



18. Turn **LFD CCW** again to bring up the leading edge.



Tuning is now finished. This could be improved slightly by careful fine tuning, but it is within specification.

4.4.4 Class 1 Tuning

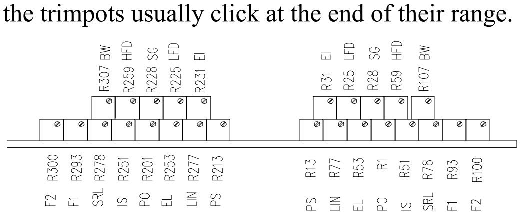
Trimpots

Table 11:Trimpots, Class 1 Board Turning

Trimpot	Name	Purpose
EI/R31 (R231)	Error Integrator	This trimpot controls the basic gain of the system. Turn it CW to increase the speed of the step. The step will then overshoot and ring.
SG/R28 (R228)	Servo Gain	This trimpot starts damping the ringing on the leading edge of the step waveform. Turn it CW to reduce the ringing. As a rule turn it just far enough CW to bring the top of the first cycle of ringing even with, or just below, the top of the second cycle. **SG** provides enough gain to center the scanner at the start of tuning (see Step 2 below), but the signal will not appear. In general get the scanner within 50-100mV of center. Too much gain at this point will cause stability problems later.
LFD/R25 (R225)	Low Frequency Damping	This trimpot reduces the ringing further. As a rule turn it CW until leading edge of the waveform is even with or somewhat lower than the settled part of the waveform, and there is one main bump remaining. The leading edge should still be visible.
HFD/R59 (R259)	High Frequency Damping	This trimpot reduces the bump remaining from the **LFD** trimpot. Make small adjustments, and center the bump and dip on the settled part of the waveform. It will not completely remove the bump and dip until **BW** is correctly adjusted.
BW/R107 (R307)	Bandwidth	This trimpot adjusts the center frequency of the **HFD** trimpot. It has very little effect until the last stages of tuning. Turning it CW moves bumps and dips to the left. It interacts with **HFD** and **LFD**, and all three will need fine adjustments in the last stage of tuning. If there are problems with the fine tuning, it's useful to turn **SG**, **LFD**, and **HFD** half a turn CCW, and then readjust **BW**. [Note: As the speed of the step increases, the correct adjustment goes CCW. This is why it's a good idea to leave the **BW** trimpot alone until the end.]

Step 1: Prepare the Class 1 Board

1. Detune the board:
   Detune the board by setting:
   SRL/R78(R278)
   EL/R53(R253)
   EI/R31(R231)
   SG/R28(R228)
   LFD/R25(R225)
   HFD/R59(R259)
   BW/R107(R307)
   fully **CCW**. This should take a maximum of 12 turns, and the trimpots usually click at the end of their range.



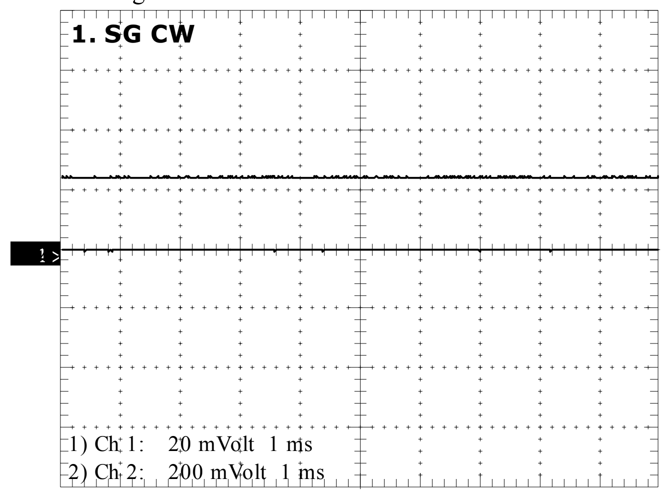
2. Turn on the power. Follow the instructions above each example plot that follows to change the traces in the previous plot to the current one.

3. Turn **LFD** three turns **CW** and **HFD** two turns **CW**.

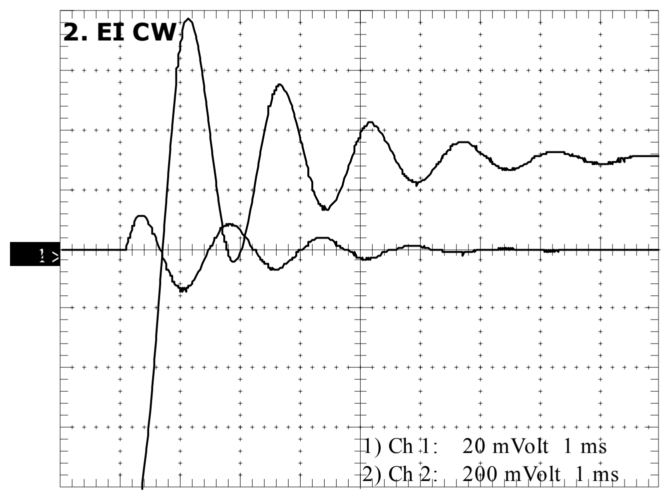
   This generally provides the correct initial damping for the system, but experiment may show that another adjustment is better.

Step 2: Tune the Class 1 Board

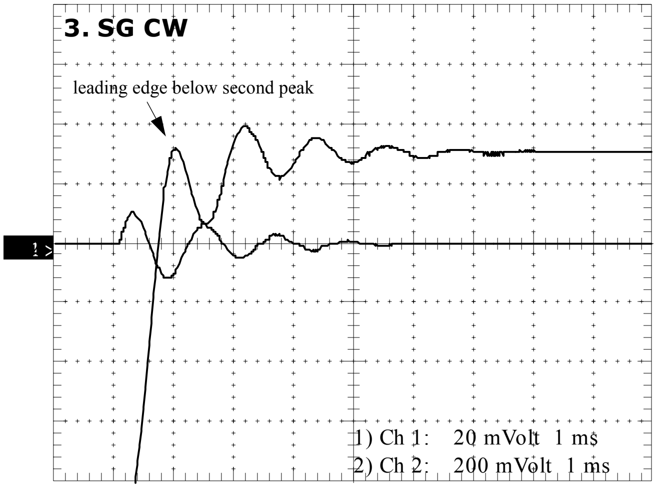
1. Turn **SG CW** until the scanner starts to center and the trace approaches 0 volts. Note: Adjust the Position signal on channel 1 to keep it on the screen. Use either the vertical position on the scope, or the offset on the signal generator. These adjustments are not mentioned in the procedure. The final tuning for the system in this example is 550-600us at 0.25 degrees.



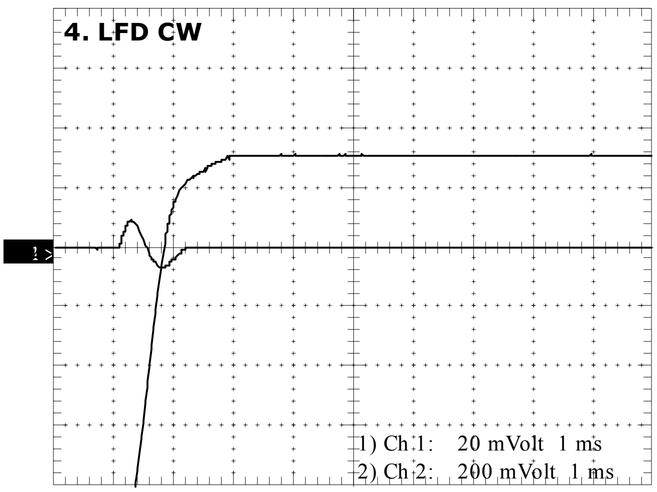
2. Turn **EI CW** until a step with a moderate amount of ringing appears.



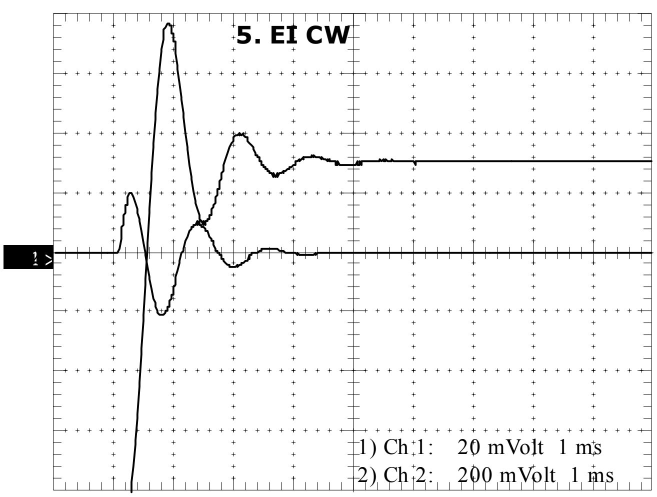
3. Turn **SG CW** until the leading edge is below the second peak.



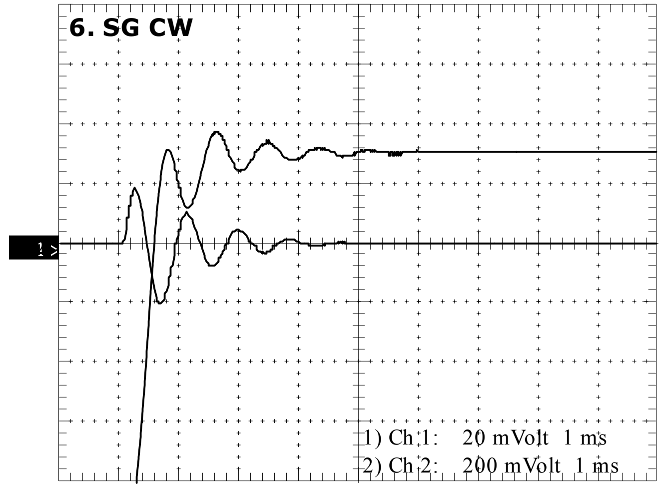
4. Turn **LFD CW** until there is a single bump. The bump may sink to the level of the top of the waveform, if there was sufficient HFD at the start.



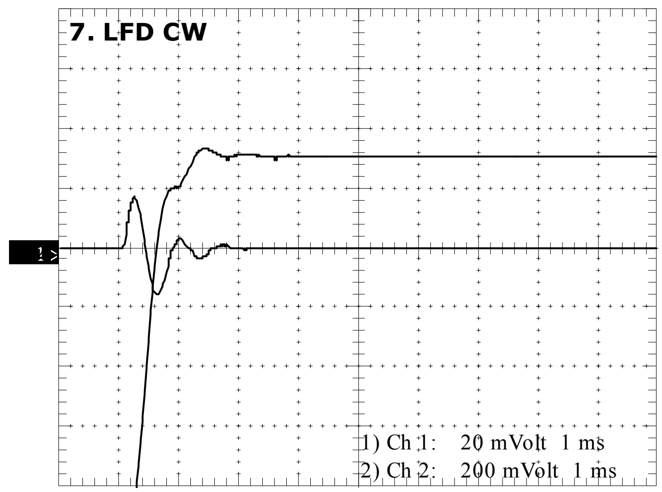
5. Turn **EI CW** until a step with a moderate amount of ringing appears.



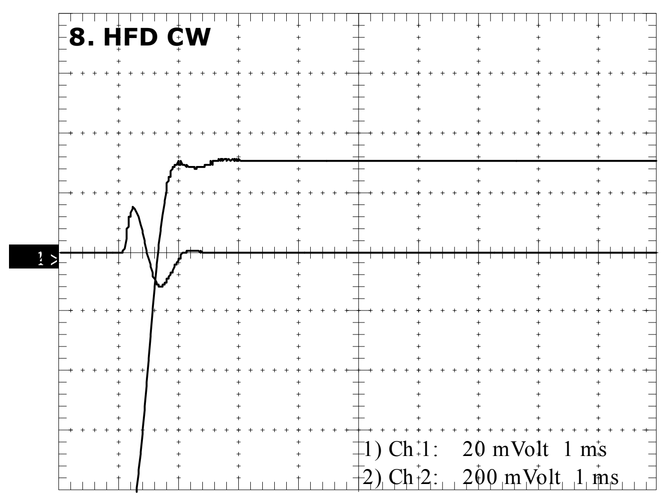
6. Turn **SG CW** until the leading edge is below the second peak.



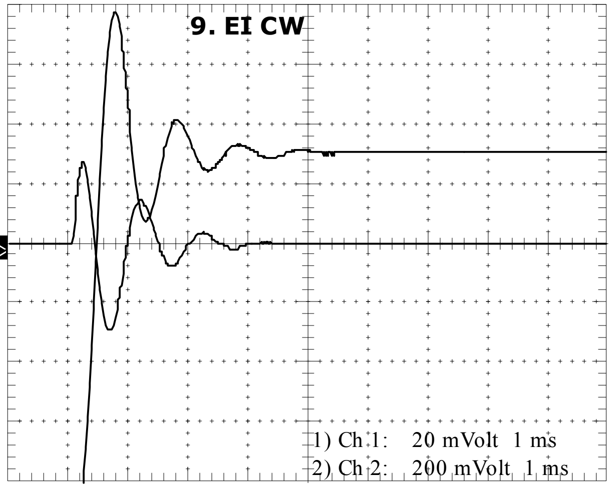
7. Turn **LFD CW** until there is a single bump.



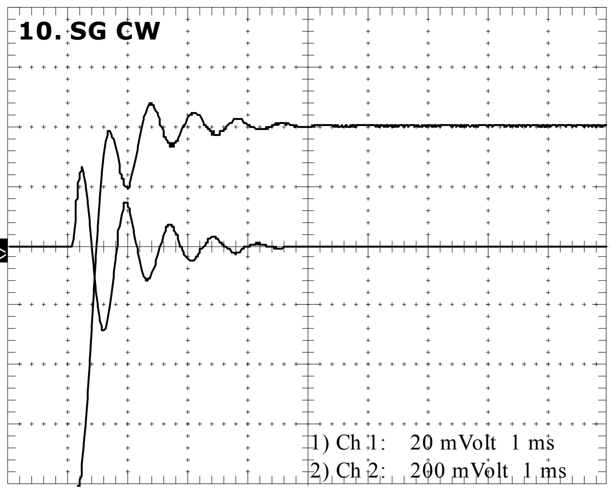
8. Turn **HFD CW** until the bump and dip are centered on the top of the step.



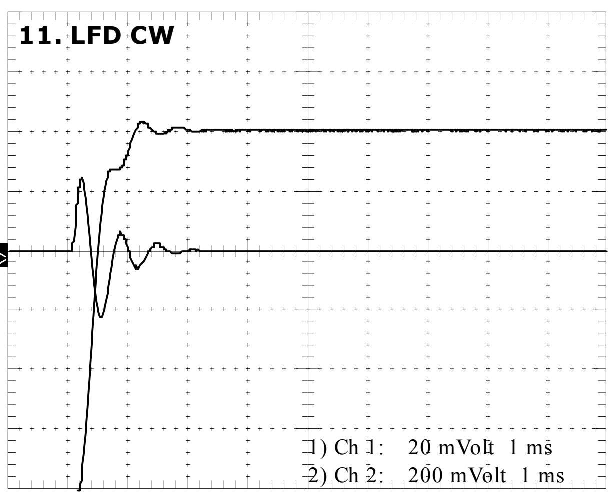
9. Turn **EI CW** until a step with a moderate amount of ringing appears.



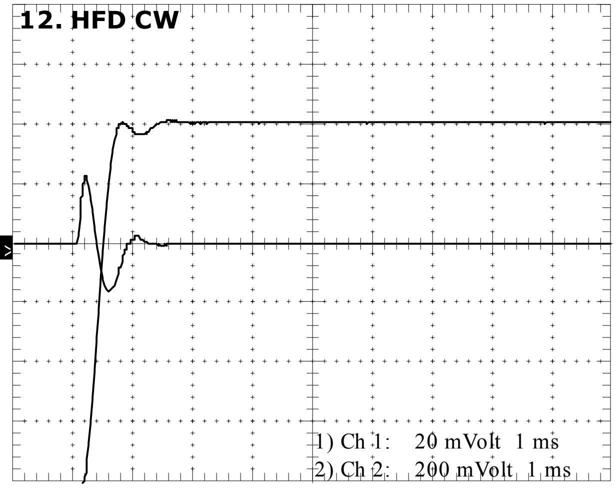
10. Turn **SG CW** until the leading edge is below the second peak.



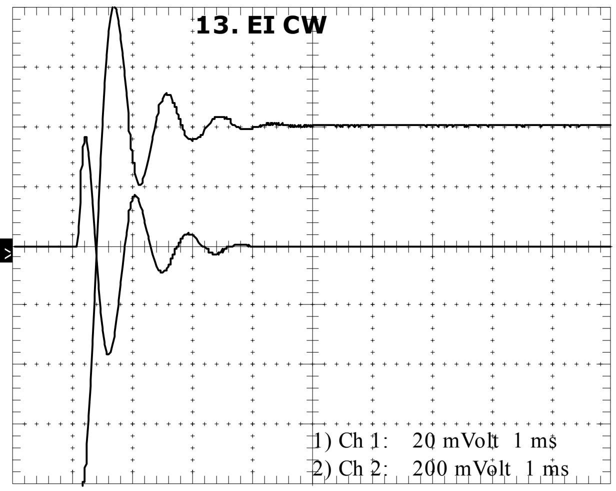
11. Turn **LFD CW** until there is one bump remaining.



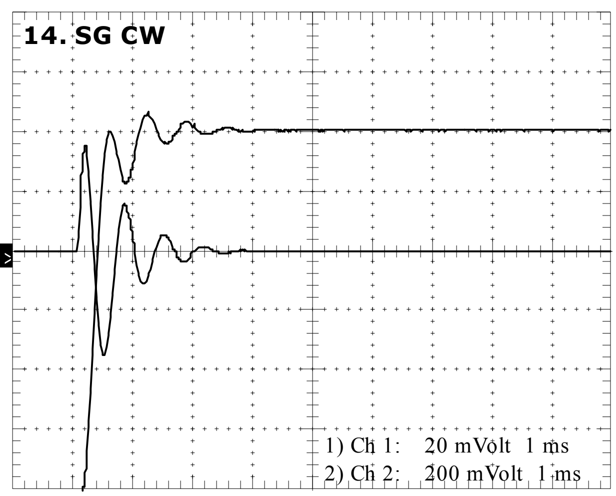
12. Turn **HFD CW** until the bump and dip are centered on the top of the step.



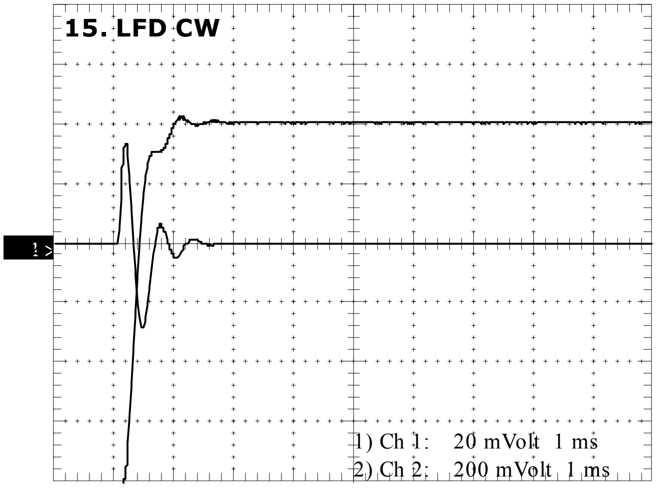
13. Turn **EI CW** until a step with a moderate amount of ringing appears.



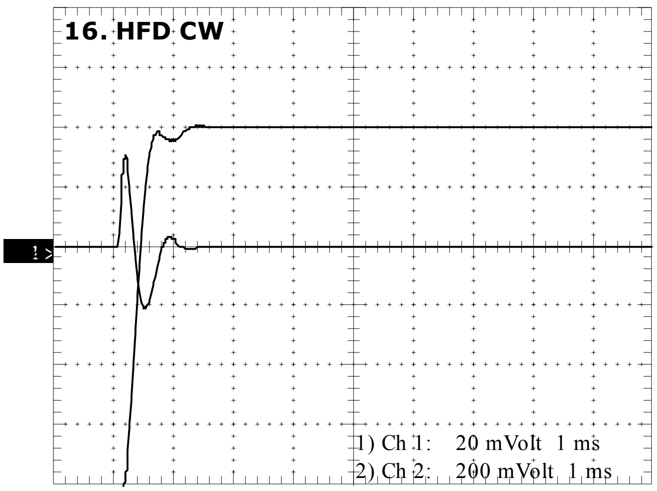
14. Turn **SG CW** until the leading edge is below the second peak.



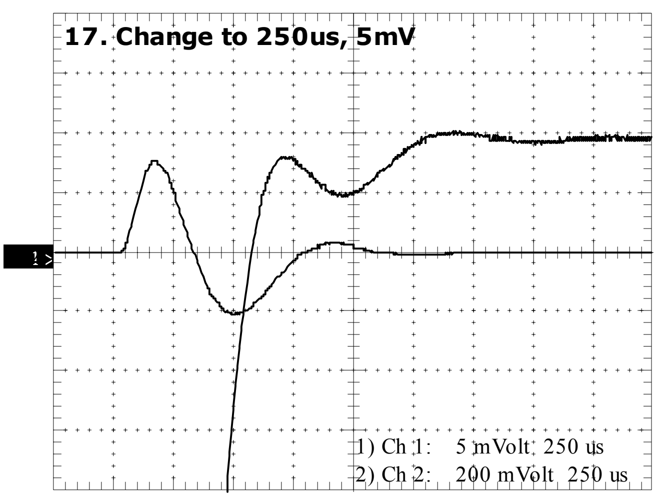
15. Turn **LFD CW** until there is one bump remaining.



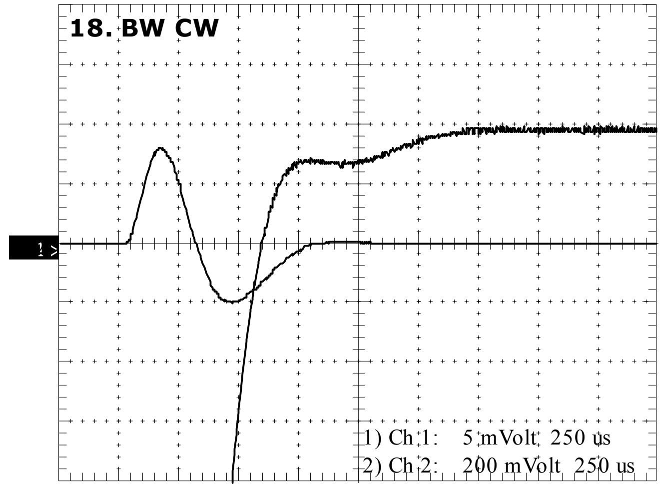
16. Turn **HFD CW** until the bump and dip are centered on the top of the step.



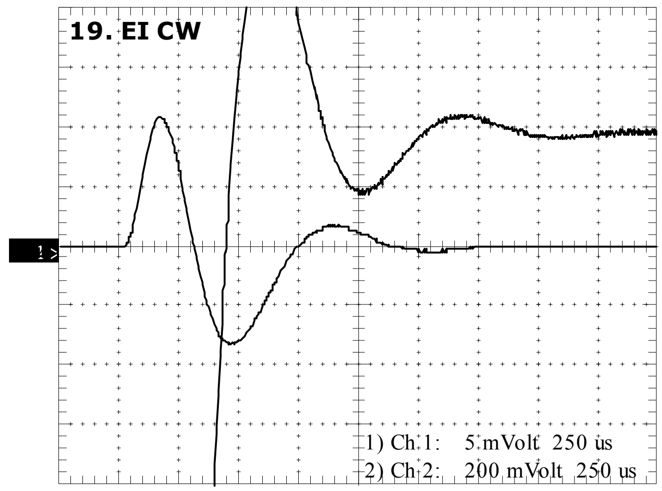
17. Change the Channel 1 scale to 5mV and the timebase to 250us.



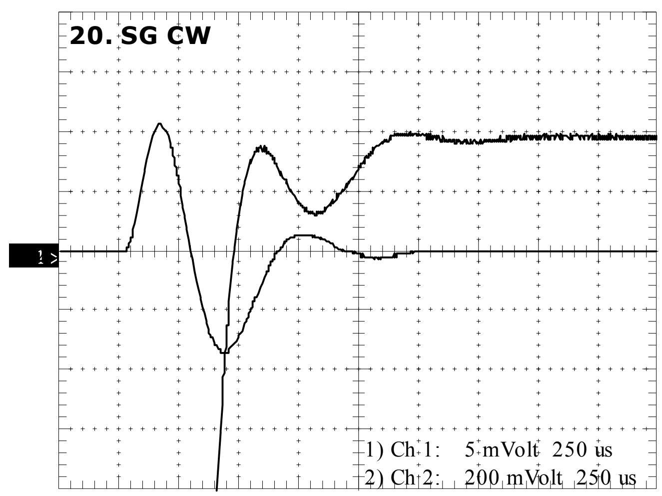
18. Turn **BW CW** to partly fill in the dip. **BW** moves to the left the bumps left behind by the **HFD** and **LFD**.



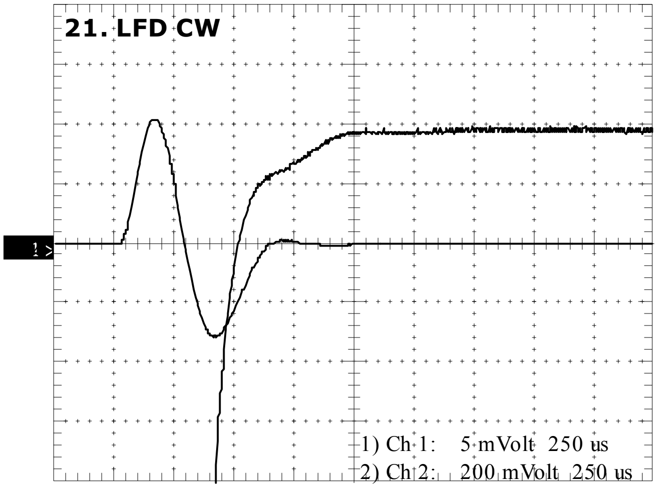
19. Turn **EI CW** until a step with a moderate amount of ringing appears.



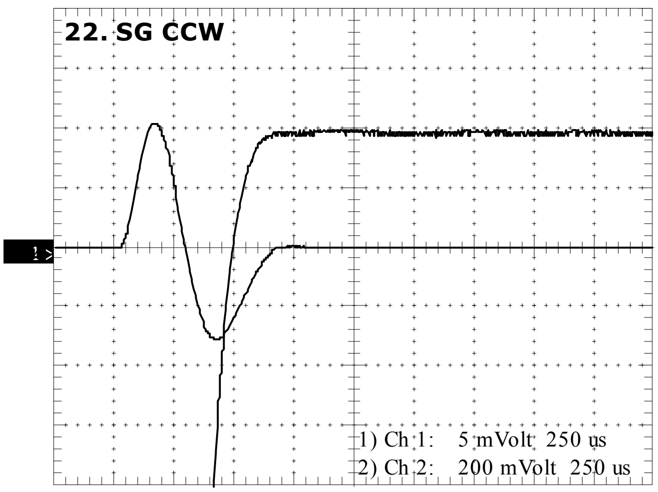
20. Turn **SG CW** to bring the leading edge down to the top of the step.



21. Turn **LFD CW** until the bump is level with the top of the step.



22. Turn **SG CCW** until the leading edge is level with the top of the step. This is now within spec, but it could be improved for better results when matching channels.



4.5 Slew Rate Limiter Adjustment

After the small angle step response is set (*"Section 4.3: Small Angle Step Response Tuning" on page 18*, the Slew Rate Limiter adjustment can be set to control the large angle response.

Purpose

Class 0 Board: to keep the Position signal critically damped, for any possible move to be performed in the application. The output stage of the servo can saturate.

Class 1 Board: to keep the output stage of the servo from saturating to achieve the largest and fastest possible move to be performed in the application. This is usually a full-field square wave.

All of the Command Input signals, whether analog, digital, or offset, normally pass through the slew rate limiter. The slew rate limiter is used to limit the maximum rate of change of the input signal, to prevent overdriving the output amplifier. When the output amplifier saturates and it can no longer follow the input signal, the feedback loop is broken, and the system becomes potentially unstable. At best it will recover from overloads relatively slowly, and at worst repeated instability may cause damage.

For some applications, fast large-angle positioning is not needed. For those applications, the slew rate limiter can be used to reduce the maximum angular speed for large moves, thus reducing the amount of wobble and jitter.

It is possible to design the input waveforms so that they never overdrive the system ('structured waveforms'). This is typically done to make the fastest possible large-angle moves, or to reduce the peak currents needed to make a move, for example in the flyback of a raster scan. In this case the slew rate limiter can be disabled, to avoid distorting the structured waveforms.

4.5.1 Adjusting the Slew Rate Limit - Class 0

Step 1: System Setup

1. Check that the scanner has an adequate heatsink. See the scanner manual.

2. Set up the system per the table below:

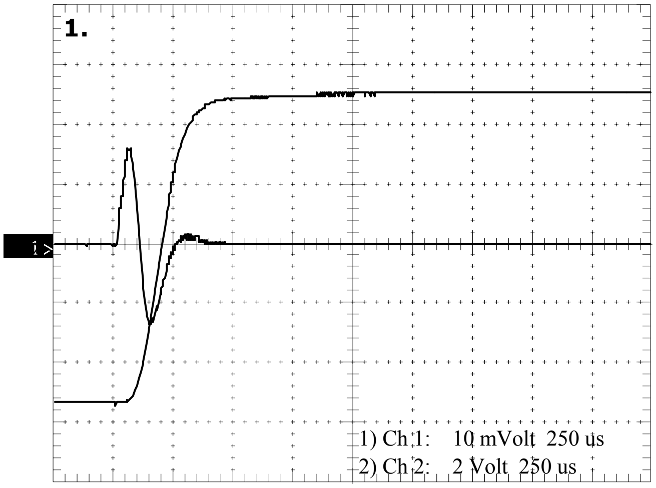
Scope		
Channel 1	J4-3(J4-4) Position Signal	10mV/div
Channel 2	TP4(TP204) Power Amp Out	10V/div
Timebase	1ms/div nominal	
Trigger	External (from the generator sync)	
Signal Generator		
Waveform	Square wave	
Frequency	30Hz nominal	
Amplitude	50mVpp, measured at TP1	
Offset	0V	

Vary the timebase to get a useful display, according to the step response time of the system.

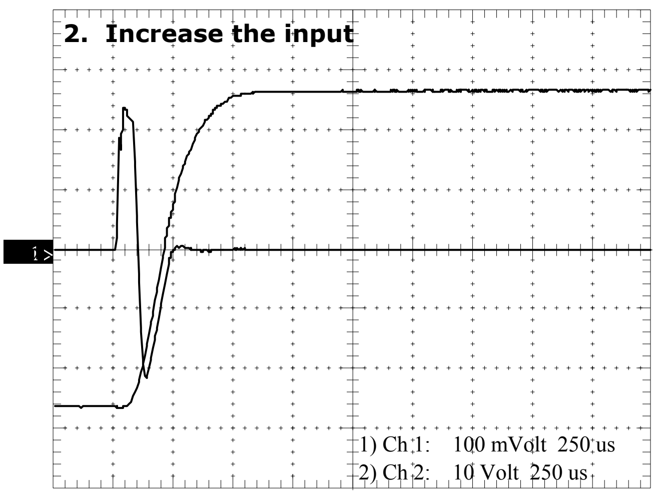
Lower the frequency of the square wave with high-inertia loads, to reduce the average power.

Step 2: Adjusting the Class 0 Board

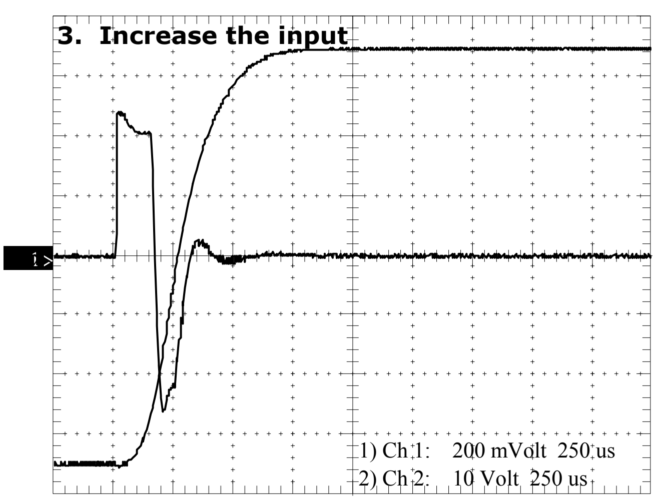
1. Start with a carefully tuned small-angle step. Channel 2 is the output drive voltage of the power amplifier. When it clips (when the peak squares off or becomes ragged), the amplifier has reached the maximum drive voltage or current possible with the supply and load.



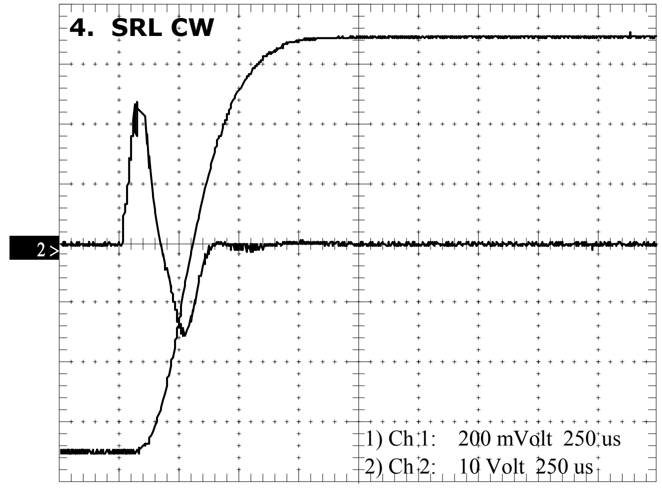
2. Increase the input until the first spike of the drive voltage starts clipping. Note that it is clipping at about 24V.



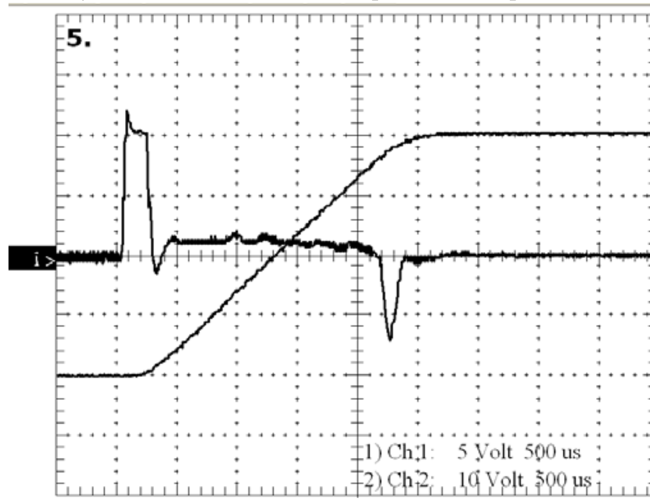
3. Continue to increase the input until the second spike also clips.



4. Turn SRL/R78(R278) CW until the second spike doesn't clip, and the first spike clips moderately.



5. Increase the input slowly to full scale, 40 degrees in this case, and check that the step does not ring or overshoot at any level, and that the second spike never clips.



4.5.2 Adjusting the Slew Rate Limit - Class 1

Step 1: System Setup

1. Check that the scanner has an adequate heatsink. See the scanner manual.

2. Set up the system per the table below:

Scope		
Channel 1	J4-3(J4-4) Position Signal	10mV/div
Channel 2	TP4(TP204) +Motor Signal	10V/div
Timebase	1ms/div nominal	
Trigger	External (from the generator sync)	
Signal Generator		
Square wave		
Frequency	30Hz nominal	
Amplitude	50mVpp, measured at TP1	
Offset	0V	

Vary the timebase to get a useful display, according to the step response time of the system.

Lower the frequency of the square wave with high-inertia loads, to reduce the average power.

Note: Before starting, decide how much margin to leave between the point at which the drive voltage clips and the final adjustment. This is necessary to keep the output amplifier from saturating when the scanner reaches its maximum operating temperature. As the coil gets hotter the coil resistance increases, and the drive voltage must also increase for the same current in the coil.

The formula

$$V_{peak} = \frac{\text{Positive Supply Voltage - 2V}}{1.3}$$

gives a useful approximation. **Vpeak** is the maximum drive voltage. If the positive supply voltage is 28V, it works out to 20V.

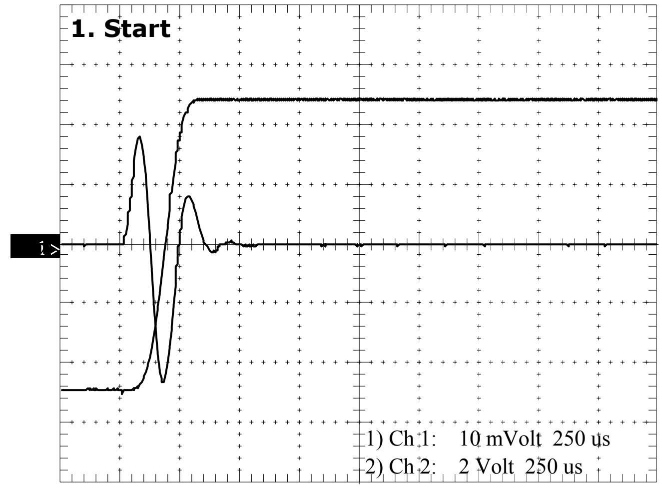
If the supply voltage sags under load, or the system reaches its maximum output current before the maximum output voltage, another formula will work better.

Vpeak=0.85 Vclip

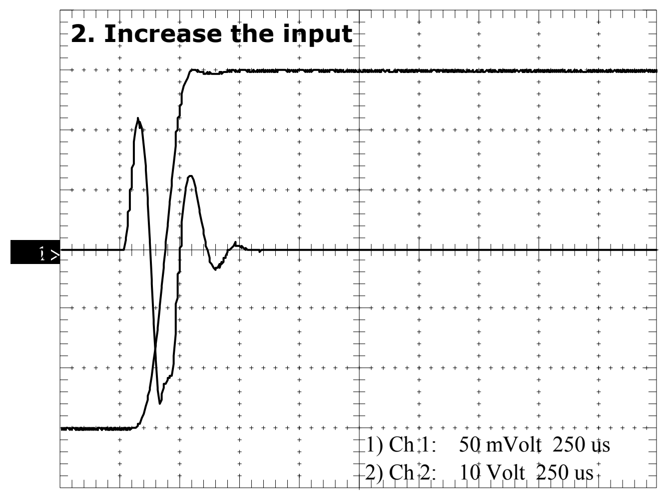
That is, measure the drive voltage when it just clips (**Vclip**), and then set it to 15% below that.

Step 2: Adjusting the Class 1 Board

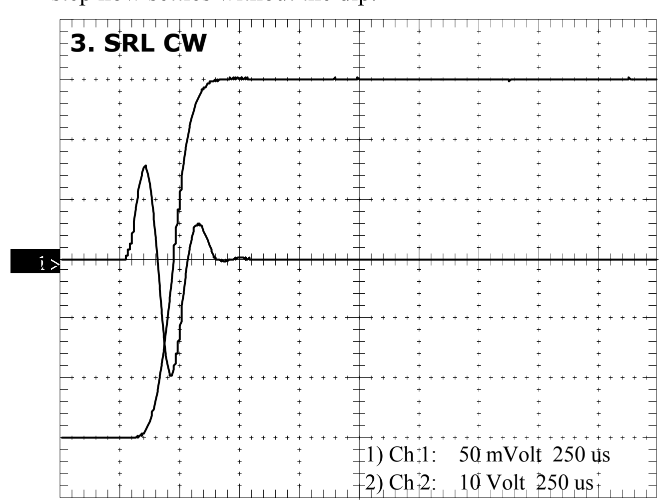
1. Start with a carefully tuned small-angle step. Channel 2 is the output drive voltage of the power amplifier. When it clips (when the peak squares off or becomes ragged), the amplifier has reached the maximum drive voltage or current possible with the supply and load.



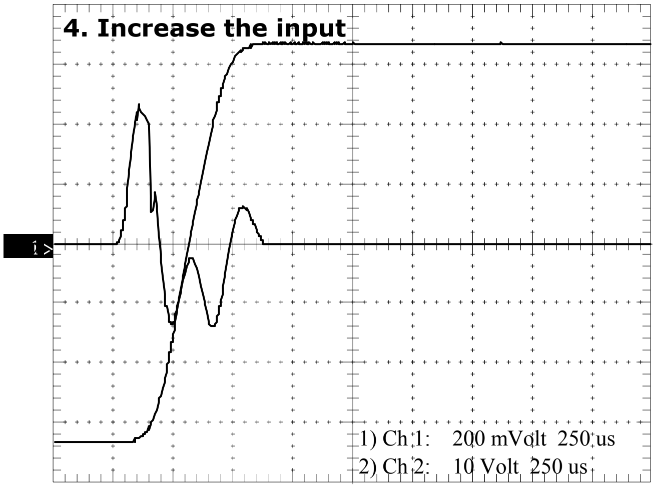
2. Increase the input level until the drive voltage signal starts clipping. Both the positive and negative peaks are clipping, and the step is not settling cleanly.



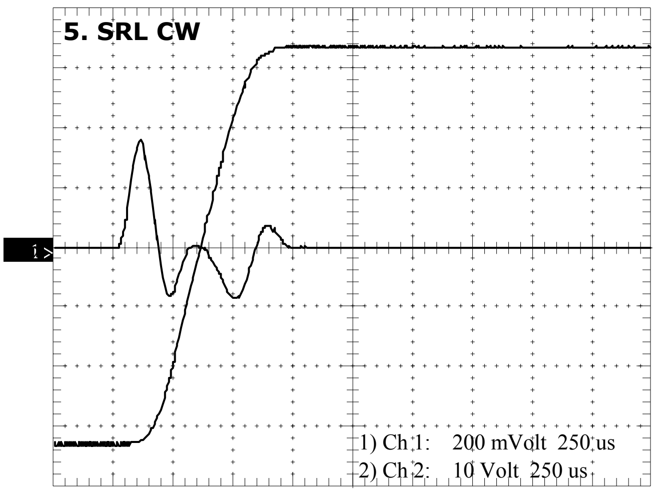
3. Turn SRL/R78(R278) CW until both peaks are clean. The step now settles without the dip.



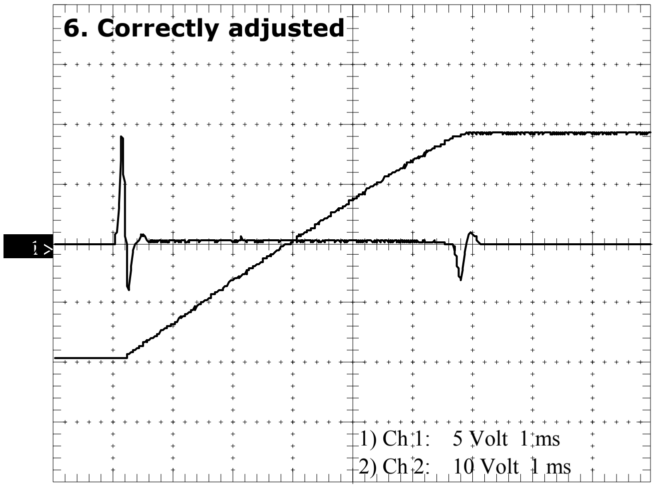
4. Increase the input level until the drive voltage signal starts clipping. The positive peak is clipping.



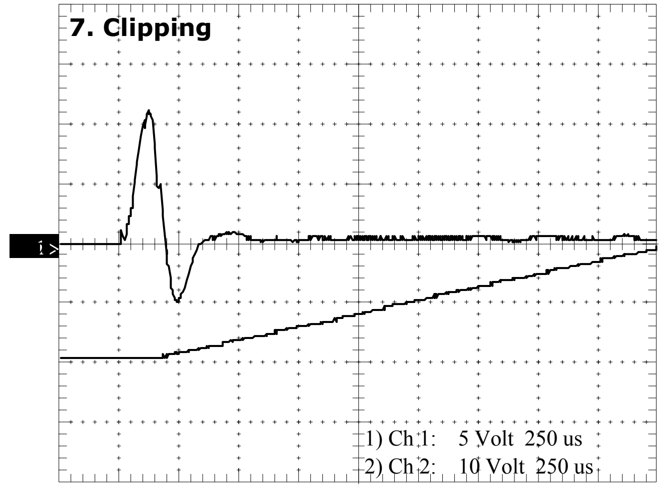
5. Turn SRL/R78(R278) CW until the positive peak is clean.



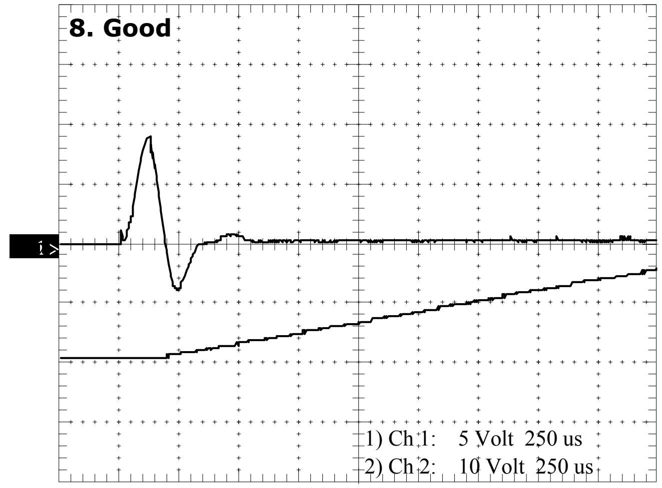
6. Increase the input and adjust SRL/R78(R278) until the maximum angle for the system is reached, which is 40 degrees in this example, and the peak voltage is set to the calculated limit.



7. At 40 degrees, the drive voltage is clipping slightly at 22V. The drive signal is disturbed during the ramp.



8. When SRL/R78(R278) is adjusted for 18V, the drive signal is cleaner during the ramp.



4.5.3 The Error Limiter - EL/R53(R253)

The error limiter is enabled on some Class 0 boards (never on Class 1 boards). It is provided for backwards compatibility with older Class 0 systems, and may be preferred in some cases. In general the slew rate limiter gives a slightly faster small-angle step, and a slightly cleaner large-angle step. Leave EL/R53(R253) fully CCW unless it is required.

The error limiter is adjusted in essentially the same way as the Class 0 slew rate limiter.

Step 1: Adjusting the Error Limiter - Class 0, Setup

1. Check that SRL/R78(R278) is fully CCW.

2. Check that the scanner has an adequate heatsink. See the scanner manual.

3. Set up the system per the table below:

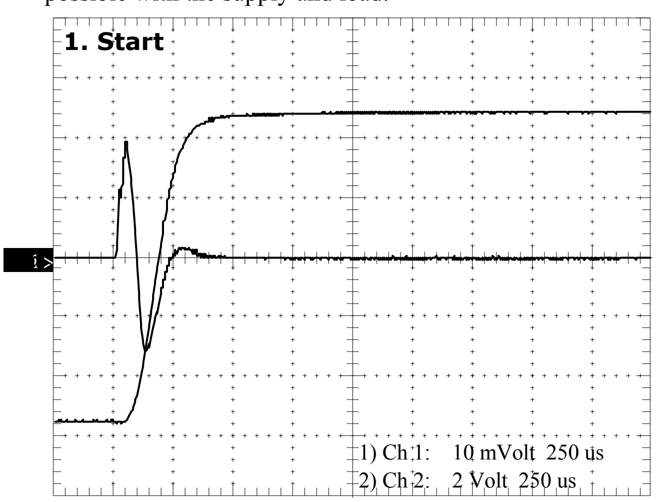
Scope		
Channel 1	J4-3(J4-4) Position Signal	10mV/div
Channel 2	TP4(TP204) +Motor Signal	10V/div
Timebase	1ms/div nominal	
Trigger	External (from the generator sync)	
Signal Generator		
Square wave		
Frequency	30Hz nominal	
Amplitude	50mVpp, measured at TP1	
Offset	0V	

Vary the timebase to get a useful display, according to the step response time of the system.

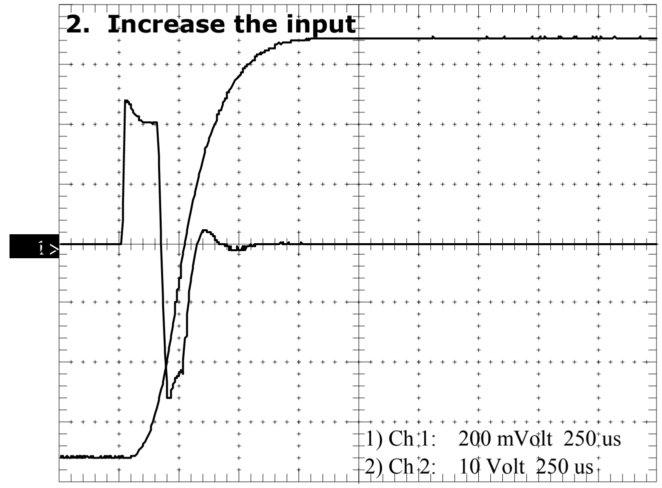
Lower the frequency of the square wave with high-inertia loads, to reduce the average power.

Step 2: Adjust the Class 0 Board

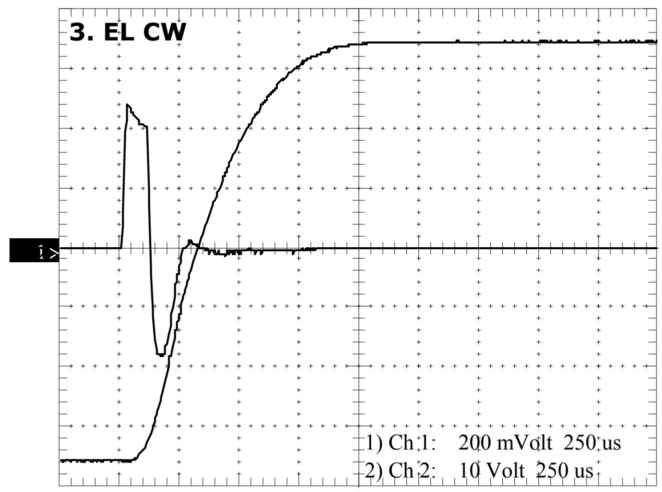
1. Start with a carefully tuned small-angle step. Channel 2 is the output drive voltage of the power amplifier. When it clips (when the peak squares off or becomes ragged), the amplifier has reached the maximum drive voltage or current possible with the supply and load.



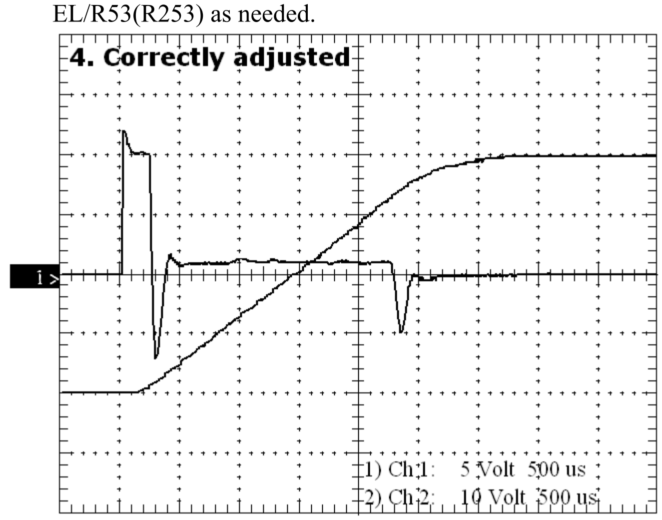
2. Increase the input until the drive voltage starts clipping. Note that it is clipping on both the positive and negative peaks.



3. Turn EL/R53(R253) CW until the second spike doesn't clip, and the first spike clips moderately.



4. Increase the input slowly to full scale, 40 degrees in this case, and check that the step does not ring or overshoot at any level, and that the second spike never clips. Adjust EL/R53(R253) as needed.



4.5.4 Notes on the Class 0 Slew Rate Limiter and Error Limiter Adjustment Algorithms

The 673 boards are used with a very wide range of scanners and loads, and the adjustment procedures given here may not always be optimum. These notes are intended as a guide for adapting the procedures to special requirements.

In some cases with low impedance scanners and large loads, the drive voltage will not be as clean as the illustrations. It may clip badly on the negative spike, and even have a double peak. It will take a very large adjustment of the trimpot to get a satisfactory waveform.

If the large-angle step response of the system is unacceptably slow when it is adjusted this way, it is possible to use another, more difficult, algorithm, which may work better. Do not try this without understanding the process completely.

Bring the input level up slowly, as in the normal procedure, and adjust at each step, but instead of adjusting for clean drive voltage, adjust for accurate settling. Watch the position signal on a scale that will clearly show settling to within 1% of the final value, and make sure that there is no overshoot or ringing at any level from 0.1 degrees to full scale. The worst case is somewhere between 0.5 and 5 degrees in most systems, not at full scale.

4.6 Aligning the Mirror

This procedure describes how to align the mirror while the servo is running, using the Miror Alignment Mode. In most cases the mirror must be aligned when the system is on and the scanner is centered, but the system usually goes unstable when the mirror is handled or loosened on the shaft.

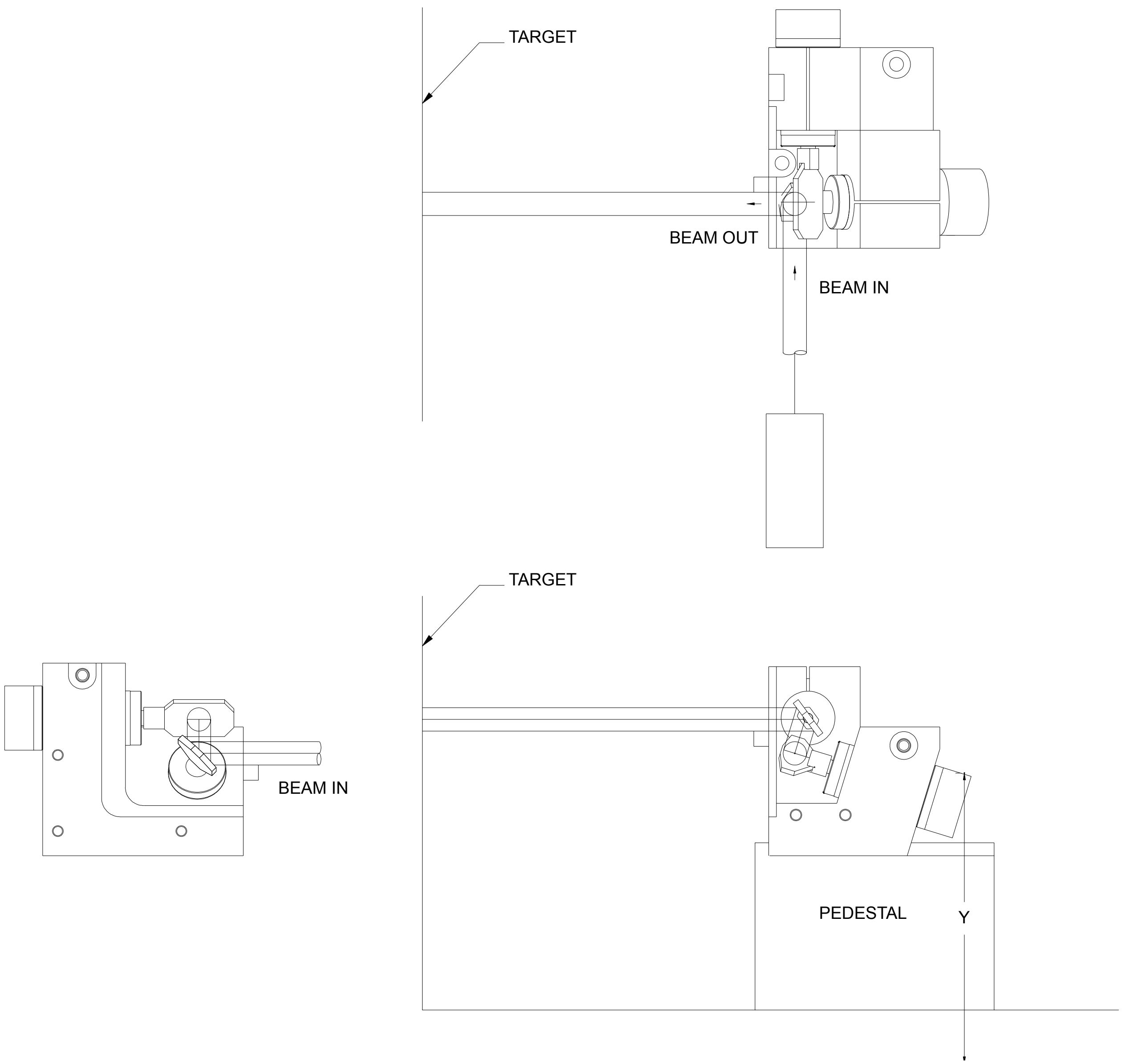
Mirror Alignment Mode reduces the loop gain of the system so the mirror can be loosened on the shaft, aligned, and retightened, without the system going unstable. The scanner will center itself, and will feel soft when the shaft is rotated by hand. In Class 1 the input signal is disconnected, and in Class 0 it is greatly reduced.

Note: This procedure can only be used to align the mirror to the center ('0 degrees') of the system's range, because the scanner is always centered in Mirror Alignment Mode.

4.6.1 Set Up

Needed: Mounted scanners, laser (a laser pointer in a clamp will do), alignment target, digital voltmeter.

A typical case is a pair of scanners in an XY mount. (See the illustration below.



Assume that the scanners are centered, at their zero positions. The laser beam comes in from the right, is reflected by the X mirror up to the Y mirror, and then by the Y mirror to the target. Usually the beam enters (at the entrance pupil) parallel to the base of the mount and perpendicular to the axis of the X scanner, and leaves (at the exit pupil) parallel to the base of the mount and perpendicular to the axis of the Y scanner. That is, the beam changes direction by 90 degrees, and height by the distance between the centers of the X and Y mirrors.

After the scanners have been installed in the XY mount, set up the laser so the beam is parallel to the base of the mount and perpendicular to the axis of the X scanner, then set up an alignment target. Measure carefully and make a mark on the wall at the correct height above the base of the mount (the height of the exit pupil). This height can be found on the XY mount interface drawing.
Make sure that the line from the target to the center of the Y mirror is perpendicular to the axis of the Y scanner. This can be checked by putting a mirror or a retroreflector (corner cube) on the center of the target. When the reflected beam comes back to the center of the Y mirror, the line is perpendicular to the target.

4.6.2 Alignment - Simple Method for Round Scanners

If the scanner is round, there is no need to touch the mirror. The scanner mount can be loosened and the scanner rotated to the correct position. It is still best to put the system in Mirror Alignment Mode to keep it from going unstable if the mirrors are touched accidentally.

Step 1: Set Up

1. Check that the scanner mount, laser, and target are correctly aligned.
2. Check that the system power is off.
3. Move the shunt on W11(W31) to short pins 1+2. See *"Section 10.0: Appendix E: Drawings" on page 49*.
4. Ground the Input Signal.
5. Turn on the power. The system should turn on normally, and the scanner should center. Touch the edge of the mirror very gently. If the system is in Mirror Alignment Mode it will move slightly under light pressure. If it feels very stiff recheck the position of the shunt on W11(W31).

Step 2: Alignment

1. Loosen the scanner mount and rotate the scanner until the beam is on the target, then retighten the mount. In an XY system it may be necessary to realign the two scanners several times.
2. Turn off the power, and put the shunt on W11(W31) back on pins 2+3. This puts the system in normal mode.
3. Turn on the power, and check that beam is still on the target.
4. There may be a small offset in position between Mirror Alignment Mode and Normal Mode. This is caused by the reduced loop gain and the friction or spring in the scanner.

   Either put the system back in Mirror Alignment Mode and offset the scanner to compensate for the error, or, if the error is acceptably small, offset the input signal to correct it.

4.6.3 Alignment - For Scanners that Can't Be Rotated

Step 1: Set Up

1. Check that the scanner mount, laser, and target are correctly aligned.
2. Check that the system power is off.
3. Move the shunt on W11(W31) to short pins 1+2. See *"Section 10.0: Appendix E: Drawings" on page 49*.
4. Ground the Input Signal.
5. Turn on the power. The system should turn on normally, and the scanner should center. Touch the edge of the mirror very gently. If the system is in Mirror Alignment Mode it will move slightly under light pressure. If it feels very stiff recheck the position of the shunt on W11(W31).

Step 2: Alignment

See *"Section 8.0: Appendix B: Mirror Handling and Mounting" on page 46* for critical mirror handling and mounting cautions and instructions.

1. Loosen the screws on the mirror mount and rotate the mirror on the shaft until the beam is on the target, then retighten the screws. Make sure the mirror is pushed all the way down on the shaft. Tighten the mounting screws evenly and firmly. If they are loose or the mirror mount is not properly seated the system will become unstable.

   In an XY system it may be necessary to align the two scanners more than once.
2. Turn off the power, and put the shunt on W11(W31) back on pins 2+3. This puts the system in normal mode.
3. Turn on the power, and check that beam is still on the target.

   There may be a small offset in position between Mirror Alignment Mode and Normal Mode. This is caused by the reduced loop gain and the friction or spring in the scanner.

   Either put the system back in Mirror Alignment Mode and offset the mirror to compensate for the error, or, if the error is acceptably small, offset the input signal using the Position Offset trimpot, PO/R1(R201) to correct it.

4.7 Matching Two Servo (X and Y) Channels

Purpose
To match the X and Y channels of a scanner system as closely as practical using the XY display of an oscilloscope. This procedure assumes that the system is drawing vectors. If the two channels are not closely matched, the system will not draw straight lines when both scanners are moving, and it will not retrace a pattern when it moves in the opposite direction.

The XY Mode on Oscilloscopes
Almost all scopes have an XY mode. It displays the signal on Channel 1 as a function of Channel 2. That is, the signal on one channel controls the vertical scale and the signal on the other channel becomes the horizontal sweep. If the two signals are identical, the display will be a diagonal line, and any differences between the X and Y channels will show as loops or bends in the line.

When the scope is in XY mode it is displaying a vector, and this display can be used to fine tune the system

There are important differences in the way XY mode works in various scopes. Some need to have the time base set to display a full cycle of the waveform. Some digital scopes can't use signal averaging in XY mode. With these scopes it may help to average a full cycle of the waveform in normal (YT) mode, freeze the display, and change to XY mode.

Step 1: Set Up

Needed: X and Y systems completely tuned and tested, oscilloscope with XY mode, signal generator.

1. Connect the same signal to both inputs. If the systems have digital inputs, make sure that both CS lines go low simultaneously. If there is any delay between the inputs to the two channels, this procedure won't work.
2. Monitor the Position signal (J4-3(J4-4)) on both boards and set the scope to reasonable scales for the large and small angle signals. In general 30Hz is a reasonable frequency, but it may be necessary to use a lower frequency with high-inertia loads.
3. Make sure that both scanners are solidly mounted. Any movement of the scanner will make it difficult to tune the system accurately and to get a good match.

Step 2: Matching

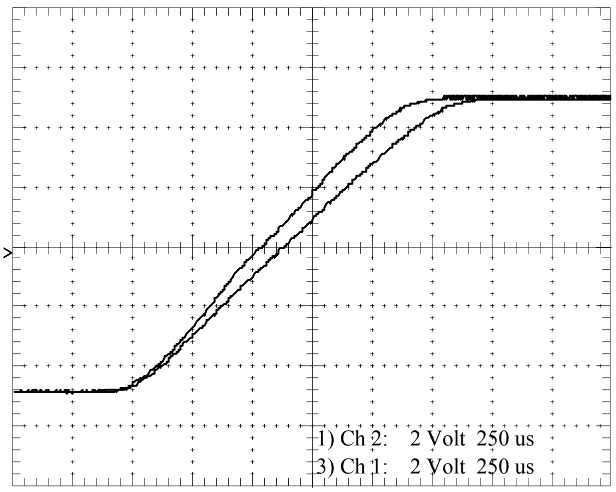
This procedure assumes that the Step Response times were approximately matched when the two systems were tuned.

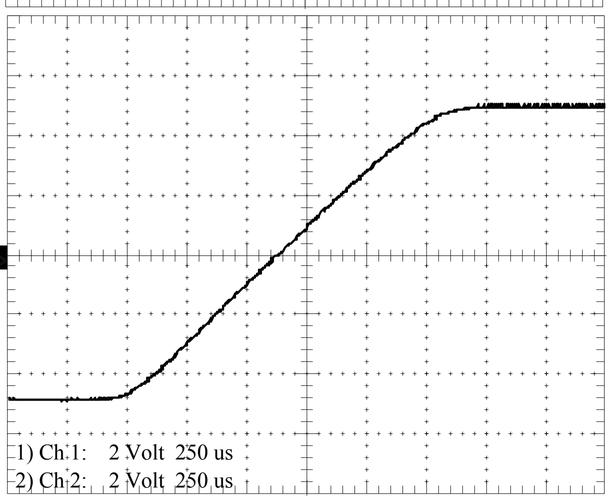
Matching is normally done at two angles: the largest angle at which the system normally operates, and a small angle where the system is bandwidth limited, usually the same angle the system was tuned at. The systems are matched at large angle by adjusting the slew rate limiter. They are matched at small angle by adjusting the tuning.

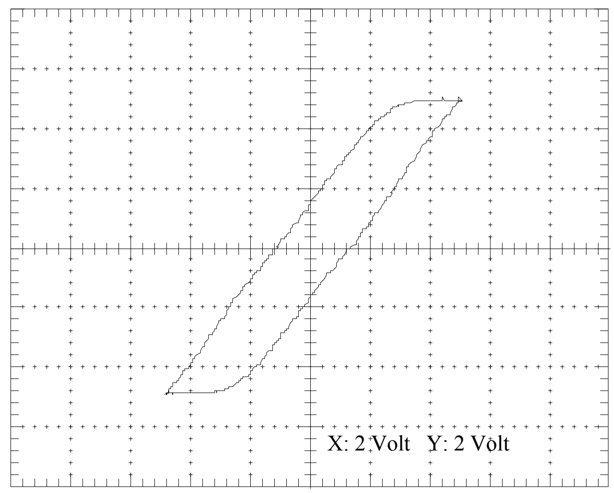
In most XY systems one channel, usually the Y, has higher inertia and a slower step reponse time than the other. **Always tune the slower channel first very carefully, then leave it alone, and do all the matching adjustments on the other channel.** Even if the X and Y mirrors are identical, choose one channel as the 'slow' channel. This is important - repeated fine adjustments on both channels can push the system far out of spec.

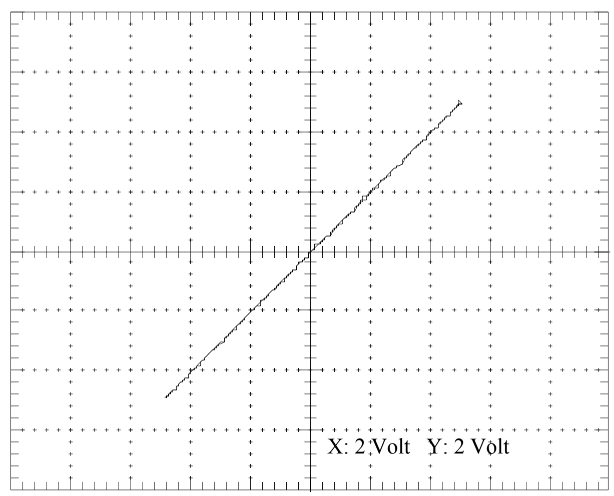
In these plots the small-angle step is 0.25 degrees, but experimentation may show that some other small step (in the range the system is bandwidth limited) gives better results. The slow channel, the one that is never readjusted, is called the Y channel in this procedure.

1. Match the Large Angle Steps:
   The first plot shows that the X channel is faster than the Y channel at large angle. Turn SRL/R78(R278) on the X board CW to reduce the speed and match the Y channel. The second pair of plots shows the same adjustment in XY mode.

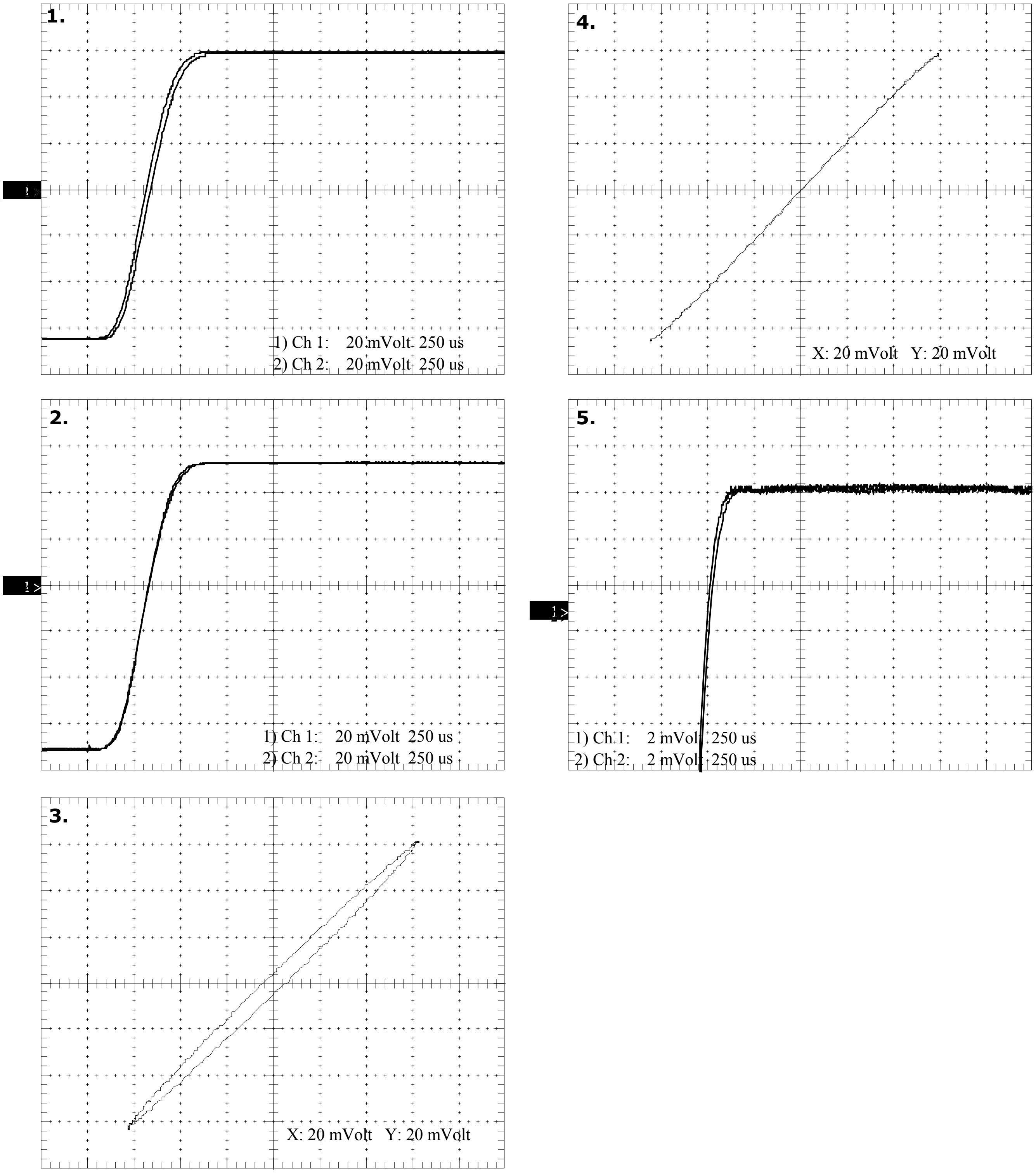








2. Match the Small Angle Steps:
   - Plot 1 One channel is faster than the other.
   - Plot 2 Retune the X channel to match the Y as closely as possible.
   - Plot 3 Mismatched channels in XY format.
   - Plot 4 Matched channels in XY format.
   - Plot 5 When retuning always check that the damping and settling of the two channels match as exactly as possible. Small mismatches will show up as hooks and loops in the XY plot.

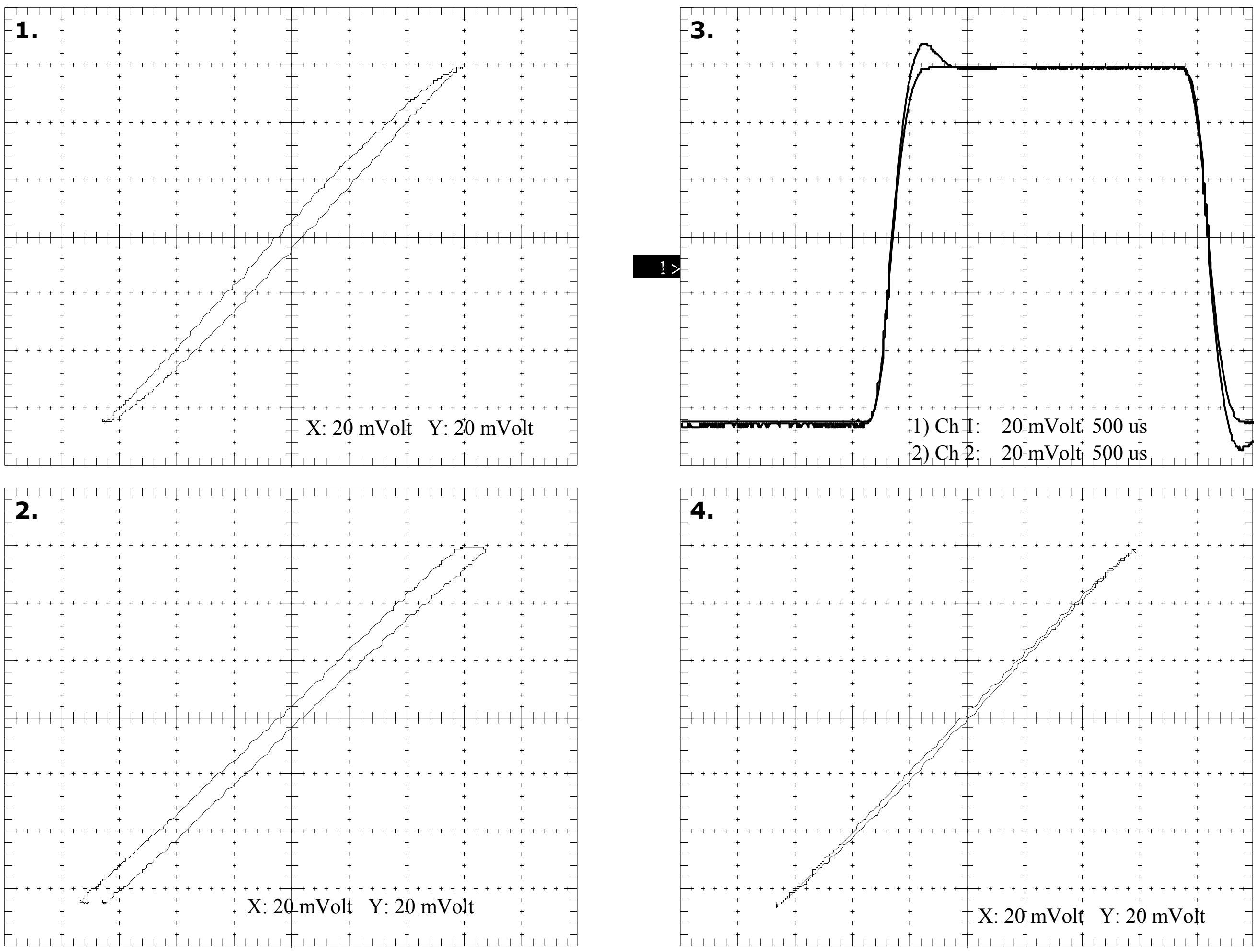


3. Recheck the Large Angle Step Match
   The large angle and small angle matches interact, and it is usually necessary repeat both adjustments several times to get an exact match.

A Note on Matching in XY Mode

When the small-angle XY plot shows a mismatch, there is a simple algorithm for adjusting the step response of one channel to the other fairly rapidly.

- Plot 1. There is a moderate mismatch between the channels.
- Plot 2. Adjust EI/R31(R231) on the X channel until the two lines come together, then continue turning the trimpot in the same direction as before until they separate again.
- Plot 3. The X channel is now under damped. Adjust the damping carefully. When the damping changes, the step time also changes slightly, and the match changes.
- Plot 4. The match is not perfect, but it is better than it would be if the two lines had been set together in step 2. It should take fewer cycles to reach an exact match.



5.0 Fault States

The protection circuitry detects and guards against several fault states, as detailed below:

Table 12:Error States

Error	Causes
Position detector signal lost	• Cable is not plugged into the scanner or the servo. • A loss of position detector signal for any reason.
Position Signal Voltage exceeded the overposition limit (maximum angle)	• Scanner has exceeded the maximum recommended mechanical/electrical range. (There are internal mechanical stops within the scanner that prevent it from spinning a full 360°, however during a fault state, the current must be shut off before the rotor reaches these internal stops.) ⚠ **CAUTION** ⚠ Do not let the system stay in this over-position indefinitely. The scanner might be damaged.
Maximum RMS Current Limit	⚠ **CAUTION** ⚠ Overtemperature Hazard. A properly sized heat sink is required for operation. • RMS current has reached its maximum safe operating limit. (Monitoring on the 673 board is accomplished by an I^2*R calculation to determine the power dissipated in the coil. Then, knowing its thermal time constant and thermal conductivity to the case, the temperature can be calculated. The fault detector will trip and the "Fault" Output signal will activate whenever the coil temperature reaches its maximum safe operating limit.) **Note:** Only valid when the case of the scanner is below 50°C.
Low Supply Voltage	• Input Power Voltage has dropped below a preset minimum (see Specifications). (To ensure protection during "brown-outs", the servo will shut the system down if the Input Power Voltages drop below a preset minimum. During system integration, ensure the power supplies and the power supply connections can meet the demands of the scanner operated at the performance levels expected for the application. If not, the input voltage will dip, and fault circuitry will activate. This can cause a fault "cycling" to occur. Do not operate the system under these conditions or damage to the scanner may occur.)

6.0 System Integration

6.1 Introduction

This section covers integrating the 673 servo board in a complete scanner control system. It covers setting the speed of the system, selecting the power supply and the heatsink, configuring the power amplifier, and wiring the whole system. All of these are interrelated, and must be considered together to design a stable, efficient system.
Note that some of the configuration must be done at the factory; this section is a guide to specifiying the correct version of the board.

6.2 Speed

The speed of a scanner system is usually specified as the small-angle step response time. This is the time, measured from the start of the command signal, it takes for the scanner to settle within 1% of its final position. The angle is generally 0.1°.

In an application, speed may be defined in other ways. It may be the settling time to a very small error at a large angle, or the maximum raster rate over a given angle with a specified error, or vectors in radians per second. In some cases speed is a secondary factor, and the primary one is repeatability or jitter. In all cases the first step is to tune the system to a specified small-angle step response time.

Many times the fastest step does not give the best system performance. Do not tune a system faster than needed. The extra speed will increase noise and jitter, and may reduce stability.

On request Cambridge Technology can provide tuning information for standard combinations, and can assist in configuring systems with unusual loads and special requirements.

6.2.1 Estimating the Step Response Time

If the inertia of a load is reasonably well-matched to the scanner, and it does not have unusually large torsional resonances, it is possible to estimate the shortest step response time from the frequency of the first torsional resonance. This formula should be used to set a target for a load that has never been tuned before. Develop a complete specification once the system has been tuned and configured properly.

The fastest small-angle step is given by

$$\text{Step Time} = S\left(\frac{1}{\text{Torsional Resonance}}\right)$$

The torsional resonance is in Hertz. S is a scale factor which is 10 for systems that do not use a notch filter, and is between 3 and 4 for systems that do use a notch filter.

Thus a system with a first torsional resonance of 10kHz should tune to 300-400us, with a notch filter. A system with a torsional resonance of 2kHz should tune to 5ms, without a notch filter.

6.3 Power Supply Selection

It is important to select the right power supply for a 673 system. The supply must provide the current and voltage needed to run the entire system, even under the worst case for the application. The RMS and peak currents needed for a system running at full power can be as large as 10A RMS and 20A peak.

6.3.1 Supply Voltage

The 673 boards can be configured for ±15-18V supplies, or for ±18-30V supplies. In general the larger the supply voltage (up to the ±30V limit), the faster the large-angle step. The small-angle step response time is not substantially affected by the supply voltage. When the jumper is changed from ±18-30V to ±15V, the absolute maximum supply voltage does not change, but the Undervoltage Shutdown point does change. This undervoltage shutdown function is employed every time the power is shut down so the they servo turns off properly. A system that was originally set for a higher supply voltage may become unstable while the power is turning off and the jumpers are set inappropriately for ±15-18V.

Cambridge Technology tests systems at ±28V, unless the customer requests otherwise. If the system is used at another voltage, it may be necessary to reconfigure or retune it.

6.3.2 Supply Type

Low-noise regulated linear supplies are usually more satisfactory than switching supplies. The noise from a switching supply may reduce the accuracy of the scanner system. A supply that uses fold-back current limiting can cause problems if the peak currents drawn by the system shut the supply down.

The regulation must be accurate enough to keep the supplies within the specified voltage range. If the supply voltage drops under load and goes below the undervoltage trip point, the undervoltage protection circuitry will shut the board down temporarily, then restart. The 470uF capacitors on the supply lines on the 673 board provide a moderate amount of filtering, but when peak currents are large, more capacitance on the power supply output will help. If it is necessary and the power supply allows it, use electrolytic capacitors having several thousand or even tens of thousands of microfarads to help stabilize the voltage.

6.3.3 Supply Size

There are two ways to select the size of the power supply. The first is a worst-case analysis of the system; the second is to measure the maximum current used by a running system. Use the worst-case analysis to choose a supply for a prototype system, then measure the actual current drawn to choose the supply for the production systems.

The worst case is quite simple. Take the maximum rated RMS current for the scanner, from the scanner manual, and add about 200ma for the 673 board.

Consider a 6240 XY system running on a ±28V supply. The maximum RMS current for the 6240 is 7.7A, but the board limit is 5A per channel. The two scanners need 10A, and the board needs another 200ma. The minimum supply to run the system at full power would be 11A at ±28V. The peak current would be about 22A. It might be necessary to add extra filter capacitance on the output of a standard supply.

It is unlikely that a system would run at its full rated power in most applications. To measure the actual current needed, run the scanners in the application that take the highest sustained power. Either measure the current at the supplies with a true-RMS meter (the meters on most power supplies are not adequate), or use a true-RMS DVM to monitor the current at J4-7(J4-8) on the 673 board, and then allow something extra for the normal variation in systems and tuning. Use the current to voltage conversion factor from *"Table 6: Current to Voltage and Coil Temperature Calculator Table" on page 9*.

Consider a 6240 XY system used for raster scanning. The measured current at J4-7 on the X channel is 3.2A RMS (1.6V RMS at 0.5V/A), and the current on theY channel is 500mA. Allow another 200mA for the board, and the total current is 3.9A. A 5A ±28V supply would be adequate.

6.4 Heatsinking

The heatsink bracket on the 673 board has just enough dissipation for the idling current on a ±15V supply when the scanner is not plugged in. A working system must be mounted on an adequate external heatsink. See drawing D05606 sheet 1 for the mounting dimensions. Use thermal grease, and use screws in all 3 mounting holes.

6.4.1 Choosing a Heatsink for the Board

The first step in choosing a heatsink is calculating the maximum power the 673 board must dissipate. The process is similar to calculating the size of the power supply needed, but the power dissipated in the scanner should be subtracted from the total. Several examples follow.

1. A 6210H system with a bridge output running on a ±15V supply. The maximum RMS current for the 6210H is 2.4A. Each scanner needs 2.4A, and the board needs another 200ma. The system at full power would use 5A at 30V (in the bridge circuit the current flows through the load from one supply to the other, not to ground) or 150W. Subtract the 60W dissipated in the scanners, and the heatsink needs to dissipate 90W.

   In this case the output op-amps dissipate about 23W each at full power. Their junction to case thermal resistance is 1°C/W, and the maximum junction temperature is 150°C. Assume the ambient is 25°C, and set the maximum junction temperature to 100°C. The junctions rise 23°C above the case. The maximum thermal resistance of the heatsink should be 52°C/90W or 0.58°C/W. A 0.5°C/W or better heatsink would be suitable, and a fan would be useful.

2. A 6200 single-ended system running on a ±28V supply. The maximum RMS current for the 6200 is 1.6A. The scanners need 3.2A, and the board needs another 200ma. The system at full power would use 3.4A at 28V (in the single-ended circuit the current flows through the load from the supplies to ground) or 95W. Subtract the 16W dissipated in the scanner, and the heatsink needs to dissipate 79W.

   In this case one output op-amp in each channel dissipates all the power, about 40W (the other is disabled). The junction to case thermal resistance is 1 °C/W, and the maximum junction temperature is 150°C. The junction rises 40°C above the case. Assume the ambient is 25°C, and set the maximum junction temperature to 100°C. The maximum thermal resistance of the heatsink should be 38°C/79W or 0.48°C/W. A 0.4°C/W or better heatsink would be suitable, and a fan would be useful.

6.4.2 Notes on High Power Testing

The board is protected against damage from high currents and high temperatures by the power op-amps' internal protection circuits, and by a fuse in the motor connection. The scanner is protected by the Coil Temperature Calculator, which allows very high peak currents, but shuts the system down if the average power exceeds the scanner's rating. The scanner must be in a heatsink that keeps the scanner surface at less than 50°C for the protection to work.

Do not force the system into shutdown unnecessarily. Repeated faults may cause instability or damage the scanner.

Some combinations of high current, voltage, and temperature can trip the internal protection circuits of the output op-amps. This may happen before the Coil Temperature Calculator trips. The scanner may make unexpected clicking or rasping noises at high power, or the system may shut down entirely. The fix is either a better heatsink, or changing to a 671 system with the High Power Option.

Wakefield Engineering, www.wakefield.com and Aavid/Thermalloy, www.thermalloy.com are two companies that make extrusions useful for constructing heatsinks..

6.4.3 Scanner Heatsinks

⚠ WARNING

The scanner will be permanently damaged if it is overheated. The maximum safe case (or mounting surface, for the square scanners) temperature for all Cambridge Technology scanners is 50°C. The heatsink must be carefully designed. Please see the scanner manuals for more information.

Note: The standard CTI XY mounts must be mounted on a larger heatsink to run the scanners safely, and even with a heatsink they may not be adequate for continuous duty at full power. Please consult the factory.

6.5 Configuring the Power Amplifier

The output stage of the 673 board can be configured (at the factory) and as a bridge or a single-ended amplifier. Each of these is useful..

6.5.1 Bridge Amplifier

This is the standard configuration for almost all 673 boards. With a ±28V supply the bridge (differential) amplifier can put ~44V across the load, with peak currents up to 10 A. The high voltage across the inductance of the motor allows higher peak currents on fast steps, and a faster step response for the system. The bridge amplifier also greatly reduces ground currents (the drive current flows through the coil from one supply to the other, and not to ground), and greatly reduces the errors and crosstalk in the rest of the system caused by ground currents.

6.5.2 Single-ended

With a ±28V supply the single-ended amplifier can put ~22V across the load, with peak currents up to 10A. (This is the same configuration as the older Cambridge Technology, Inc. Model 670 and 678 boards.) In most cases the small angle step response will be slower than with the bridge amplifier. Because currents flow from the supplies through the load to ground, the power dissipated in the board will be less than half that in the bridge amplifier. But these high ground currents may cause errors and crosstalk in the rest of the system so more attention needs to be paid to the system setup to minimize ground loops.

6.5.3 A Note on Overheating

If the board overheats or shuts down intermittently there are a number of things to check.

Is the heatsink adequate for the system?

Is the board fastened to the heatsink with all three screws?

Are the screws tight?

Is there enough thermal compound on the heatsink? Use the thinnest layer possible that is a uniform white, without the metal showing through, on one surface. Check that some squeezes out at the edges when the screws are tightened.

6.5.4 Reducing the Power Dissipated in the Board

If the current in the scanner is high, and the drive voltage across the scanner is low, a board configured as a bridge amplifier will run very hot. It may be possible to use it as a single-ended amplifier and reduce the power dissipated in the board by more than 50%.

Measure the peak drive voltage at TP4/TP204 with an oscilloscope. The total voltage across the scanner is twice this number. If the total voltage across the scanner is at least 8V less than half the total supply, it should be possible to run the system single-ended.

For example, if the peak voltage at TP4/TP204 is 9V, the voltage across the scanner is 18V. If the supply is ±28V, half the total supply is 28V, and the voltage across the scanner is 10V less than the supply. It should be possible to run this system single-ended.

7.0 Appendix A: Electrical Details

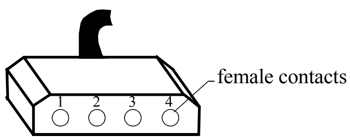
7.1 System Wiring

Power comes into the board through the 4-pin male Molex connector at J3. Parts for the mating connector are listed below, with the recommended hand crimping tool. The pins and housing are normally shipped with the board as part of the 673CK connector kit.

Table 13: Power Wiring Items

Item	Description
Connector	Molex # 15-24-4048
Pins	Molex # 02-08-1202
Crimper	Molex # 11-01-0206
(Pins and connector are included in Connector Kit # 671CK.)	

Table 14: Connector J3, Input Power, Pinouts



Pin #	Signal Name	Voltage Range
1	+Supply Voltage	+15VDC to +18VDC or +18VDC to +30VDC
2	+Supply Voltage Return	GND (Common)
3	-Supply Voltage Return	GND (Common)
4	-Supply Voltage	-15VDC to -18VDC or -18VDC to -30VDC

Use the heaviest wire practical for the power cables (the pins take 14-20 AWG wire), and keep the cables as short as possible. Good crimps are important. The contact resistance in the crimp caused by dirty or oxidized pins or wire, or by a worn or improperly used tool, or by excessive stress on the wire, can cause problems that are hard to diagnose. [Note: Never tin the wire before crimping. If necessary, solder the connection after crimping it.]

7.2 Command Input Wiring

The 673 servo driver can accept a differential Analog Command Signal as detailed in the table below:

Table 15:W4 Signal In Configuration

Input Configuration	W3/W23	Connector J1 Pin #		
		+ Input	- Input	± Input Return (GND)
Differential Non Inverting	1+2 3+4	6 (4)	3 (1)	J3.2
Differential Inverting	1+3 2+4	6 (4)	3 (1)	J3.2
Mute Line		5		2

1. Analog Command must be wired with individual twisted shielded pairs.

2. The Mute line uses Pin 2 as a return.

3. Connect the selected cable to the mating **J1** connector.

Table 16: Signal Wiring Connector Items

Item	Description
Connector	Amp 794617-6
Pins	Amp 794611-3
Crimper	Amp 91501-2
(Pins and connector are included in Connector Kit # 673CK.)	

4. Provide separate wiring channels for wiring high power signals and wiring command signals. Do not mix power and command signal wiring in the same conduit, duct, or wire tray.

5. Use the input voltage range ± 10 VDC for full angular excursion unless the system is specifically configured for a different voltage. The scanner will move as shown below**:**

Table 17:Scanner/Voltage Position Movements

Input Voltage	Position
-10 VDC	Full CCW Angle
0	Center
+10 VDC	Full CW Angle

6.
There should be a direct ground connection from the signal source to the Pin32 on the input connector (J1, Pin 3), which can be either the shield of the wire or a separate wire. If shielded wire is not available, use a third wire then twist all wires to provide some level of shielding

7.3 Motor Wiring

Special care should be taken to ensure that the motor is not damaged due to improper wiring and installation. Proper extension cables are available in 20”, 40”, 80” and 120” lengths.

7.4 Scanner Cables

The assembly drawings for the standard scanner cables are available on the Cambridge Technology website:

www.cambridgetechnology.com

Cambridge Technology can supply all these cables in standard and custom lengths. Extension cables are available, and the connectors can be panel mounted.

⚠ **CAUTION** ⚠

Notes on Cable Modification/Custom Cables:
The cables must be properly shielded and grounded. The details in the drawings are vital. The position detectors in Cambridge Technology scanners have differential output currents measured in microamps, and the motors run on currents as high as 25A peak. Any crosstalk between the motor leads and the position detector leads will cause errors and instability. Excessively long unshielded leads, poor quality cable, or bad or missing grounds can all cause problems.

If a cable is cut in half to provide a panel mount connection, or shortened, be sure the new connectors follow all the details in the drawings. Any non-standard connector must keep the position and motor signals separate and shielded.

Do not tie the motor and position connectors together for neatness on an extension cable or in a panel. The extra coupling between signals can cause instability.

7.5 User Output Wiring

Various observation and control signals are accessible on the **673** servo drive via the **J4** connector:

Table 18:Connector J4 Pinouts (User Outputs and Remote Shutdown Pinouts)

Pin #	Parameter's Name	Function	Description	Characteristic
1	X Velocity	Output	Voltage signal is proportional to the velocity of the scanner	2K ohm Output impedance
2	Y Velocity	Output	Voltage signal is proportional to the velocity of the scanner	2K ohm Output impedance
3	X Position	Output	Position Out signal	2K ohm Output impedance
4	Y Position	Output	Position Out signal	2K ohm Output impedance
5	Ground	Output	Ground Return for User signals	GND
6	Ground	Output	Ground Return for User signals	GND
7	X Current	Output	Current monitor	2K ohm Output impedance
8	Y Current	Output	Current monitor	2K ohm Output impedance
9	X AGC	Output	X AGC Voltage	4.75K ohm Output impedance
10	Y AGC	Output	Y AGC Voltage	4.75K ohm Output impedance
11	X Fault	Output	Pulled down to ground when the fault detector trips	4.75K ohm Output impedance to 12V CMOS logic
12	Y Fault	Output	Pulled down to ground when the fault detector trips	4.75K ohm Output impedance to 12V CMOS logic

- The 12-pin 2mm housing (Molex 0875681273) in the 673CK can be used to make a cable for J4. Robbin cable with 1mm pitch, such as 3M 3625/12, is required to make a calb with this connector.
- Use pins #5 and #6 as the ground return for all User Output signals.

8.0 Appendix B: Mirror Handling and Mounting

⚠ **CAUTION** ⚠

The precision optics used on scanners are easily damaged. The coatings are thin; the surfaces are highly polished and optically flat; the materials may be extremely brittle. There are a few simple rules to follow when handling optics.

- Wear new finger cots or disposable gloves. Gloves and finger cots should be lint and powder free.
- Never touch the optical surface.
- Always handle the optic by the edge or the mount.
- Leave the optic in its wrapping until it is used
- Before cleaning any optic, know the correct technique and have the right tools Optical materials and surfaces vary, and the wrong solvent or cleaning technique can cause permanent damage.

8.1 Mirror Mounting

[This note does not discuss mirror mount design or the techniques for gluing mirrors to mounts or directly to scanner shafts. Cambridge Technology has a complete line of standard mounts for its scanners, and can mount virtually any optic on request. Please call Cambridge Technology for more information.]

There are several important points in fastening a mounted mirror on the scanner shaft.

Choose the angle of the optic to the body of the scanner, if necessary. Most Cambridge Technology scanners are round and can be rotated in the mount, but the direction the cable comes out and clearance for connector may be important.

Check that the correct mirror is mounted on the scanner. If the system was tuned with a mirror, and the mirror was not shipped mounted on the scanner, the system serial number will be on the mirror package. Make sure that this number matches the number on the board and scanner. Check that the X and Y mirrors go on the correct scanners in XY systems.

Make sure that the mount is pushed all the way on the scanner shaft, until the shaft reaches the bottom of the hole in the mount. All Cambridge Technolgy mounts are designed to go all the way on the shaft without hitting the scanner. If the mount is not all the way on, the torsional resonance will change, and the system may be unstable.

If a mount is designed so it hits the face of the scanner when it is all the way on the shaft, use a thin shim while the screws are tightened to hold it a precise distance from the scanner.

Do not move the mount in and out on the shaft to adjust the axial position of the mirror. This changes the torsional resonance, and may also cause optical alignment problems.

Use a good hex wrench or screwdriver. Never use ball-end hex wrenches for tightening or loosening mirror mount screws. Ball-end wrenches and worn or undersized tools will damage the heads of the screws.

Tighten both sides of the clamp evenly, in small steps. The gap between the clamp and the body of the mount should be the same on both sides.

Tighten both screws thoroughly. If possible, use a calibrated torque screwdriver, and use the torques in the following table. Otherwise make sure the screws are completely tightened. If the clamp is not tight enough, the system may be unstable at the torsional resonance.

Table 19:Mirror Mounting Guidelines

Scanner	Screw Size	Hex Key Size	Recommended Torque in Inch-pounds	Recommended Torque in Newton-meters
6220(H)	#00-90	0.035”	0.8	0.09
6230(H), 6231C(H)	#0-80	0.050”	2.0	0.23
6240(H)	#1-72	1/16”	3.8	0.43
6240(H) High Inertia	#2-56	5/64”	6.3	0.73
6350	#00-90	0.035”	0.8	0.09
6450	#0-80	0.050”	2.0	0.23
6650	#1-72	1/16”	3.8	0.43
6650 High Inertia	#2-56	5/64”	6.3	0.73
6810	#00-90	0.035”	0.8	0.09
6850	#0-80	0.050”	2.0	0.23
6860	#0-80	0.050”	2.0	0.23
6870	#0-80	0.050”	2.0	0.23
6880	#1-72	1/16”	3.8	0.43
6880 High Inertia	#2-56	5/64”	6.3	0.73
6900	#4-40	3/32”	13.2	1.49
6900 High Inertia	#6-32	7/64”	23.2	2.63
6400	#6-32	7/64”	23.2	2.63
6400 High Inertia	#8-32	9/64”	45.0	5.09

Notes:

1. The torque is determined by the size of the screw. Check the screw size on nonstandard mounts.

2. Scanners smaller than those listed above do not have standard mounting clamps.

9.0 Appendix D: Glossary

AGC
The AGC or Automatic Gain Control voltage is the power supply for the position detector in the scanner. It is adjusted to calibrate the Position Scale Factor. The AGC voltage varies with time and temperature to keep the Position Scale Factor of the system constant.

Bumpers
Mechanical stops on the scanner to constrain the rotation angle to prevent the mirrors from hitting.

Class 0
A Class 0 servo has no error integrator in the feedback loop. The friction or spring in the scanner causes non-repeatability. It will settle near to the commanded position somewhat more rapidly than a Class 1 servo, but there will be a residual error. A Class 0 servo is also more stable than a Class 1 servo.

Class 1
A Class 1 servo has one error integrator in the feedback loop. It has very good positioning repeatability, and settles very accurately.

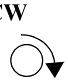
Coil Temperature Calculator
The circuit which monitors the power in the scanner coil. It protects the scanner by putting the board in fault mode and turning off the power amplifier when the RMS power is too great for the scanner, but it does allow short-term peaks, up to the maximum power of the board. The scanner must have an adequate heatsink for the Coil Temperature Calculator to protect it. See the scanner manual. The limit is not field settable.

Critically Damped
The state of a system tuned properly so it reaches the steady state in the least possible time, without overshoot.

Current Monitor
The current monitor provides a voltage proportional to the current in the scanner coil. It is scaled at 0.5V/A, lV/A, or 2V/A, depending on the scanner's characteristics.

Current Integrator (High Frequency Damping)
A circuit that analyzes the current flowing through the rotor to determine velocity information which it then uses as a contributor to system damping.

CW



CCW

Degrees, Optical
The angle which a beam of light moves through when it is reflected by a rotating mirror is measured in optical degrees. The angle in optical degrees is always twice the angle in mechanical degrees, because the angle of incidence equals the angle of reflection.

Degrees, Mechanical
The angle which the shaft of the scanner moves through when it rotates is measured in mechanical degrees. The angle in mechanical degrees is always half the angle in optical degrees, because the angle of incidence equals the angle of reflection.

Dither
See Noise.

Error Integrator
A circuit that compares the actual position to the commanded postion and integrates (adds) the difference over time to eliminate any error: drives the system to a steady-state error of 0.

Error Limiter
The error limiter improves the large-signal settling in a Class 0 servo by limiting the error feedback. It is usually disabled on the 673 servos because the slew rate limiter gives slightly better performance.

Fault Output
The Fault Output is signal that is pulled to ground when the servo is in "fault" mode. This signal has a normal HCF-type CMOS output with an additional 4.75K resistor in series. The normal high state voltage for this gate is +12V. The Fault Output is low during faults, during the power-on delay, and when the system is in Mute.

Field Size
The field size of the system is the total mechanical angle the scanner moves for an input of ±10V (20Vpp). If the scanner rotates ±10° mechanical for an input of ±l0V, the field size is 20°.

High Frequency Damping
See Current Integrator.

Input Offset
A trimpot adjustment, usually providing an offset ~±10% of the input range.

Input Scale Factor
The voltage input per degree of mechanical rotation of the scanner.

Jitter
A motion of the mirror/scanner load that is in the same direction as the rotation of the scanner. It is usually caused by an improperly tuned notch filter, or a system tuned too fast.

Large-Angle Step
A step large enough that the speed of the system is limited by the output current or drive voltage available, not by the small-signal bandwidth.

Linearity
The specified linearity of the scanner system is defined by a least-squares fit of the output of the position detector to the actual position of the scanner shaft, over a specified angle. The scanner and board are adjusted together as a matched set. See the scanner manuals for linearity specifications.

Load
The load is whatever the scanner moves. It is usually a mirror, or some other optical device, but it can also be mechanical. Its important characteristics are its rotational inertia, its stiffness, and its balance.

Low Frequency Damping
See Position Differentiator

Mirror
The typical load controlled/turned by a scanner. Its primary purpose is to redirect an optical beam, allowing the scanner to do useful work.

Mute
When the Mute line is pulled to ground, the system is forced into fault mode (the output amplifier is disabled and the command signal is muted). When the system comes out of mute, it goes through the normal power-on sequence.

NF Section (see also Notch Filter)
The 673 employs an integral dual notch filter. Each servo channel has two tunable band-reject filters which can be separately tuned. They are used to reject drive signals that would excite the scanner's torsional resonances and cause instability.

Noise
A working servo moves randomly around the true position. These moves are very small, and are normal and necessary for the servo to function. This random movement, or dither, is essentially white noise. The amplitude of the noise depends on the gain and bandwidth of the system. As a result the scanner will hiss when it is running, and the hiss may be audible if the mirror is large.

Notch Filter
A notch filter is tuned to remove the (natural system) torsional resonant (instability/oscillation) frequency from the signal driving the output amplifier. The notch filter "eliminates" this frequency to keep the scanner from being excited at its resonant frequency. If the torsional resonance is not excited, the closed-loop bandwidth of the system can be higher, and the step response time faster.

Over Position Limit
The angle at which the 673 board goes into fault mode and disables the scanner by turning off the power amplifier. This angle can be set over a wide range of angles. It is normally set one degree beyond the maximum angle used, and less than the maximum safe angle of rotation for the scanner and mirror. Over Position would be set to ±16° for a system with a field size of 30° (±15°).

Overshoot
Overshoot occurs when the system is mistuned and the position goes beyond the final settling point. See *"4.3 Small Angle Step Response Tuning" on page 18.*

Position Detector
The position detector in the scanner produces a differential current proportional to the shaft angle. It is. always active, as long as the scanner is connected to the board and the power is on, whether or not the board is tuned.

Position Demodulator
The position demodulator on the board converts the differential current output of the scanner to a voltage directly proportional to the angle of the scanner shaft. The scale and linearity are calibrated at the factory. The position demodulator is always active, as long as the scanner is plugged in and the power is on.

Position Differentiator (Low Frequency Damping)
A circuit that analyzes the position signal to yield angular velocity which it then uses as a contributor to system damping.

Position Scale
The position signal is normally calibrated to 0.5V per degree of rotation of the shaft. The voltage becomes more positive as the shaft rotates clockwise, and more negative as the shaft rotates counterclockwise.

Position Scale Factor
The Position Scale Factor is the voltage per degree of mechanical rotation of the rotor measured at J4-3(J4-4). It is usually set to 0.500 volts/degree.

Reduced Angle
A scanner whose angle has been reduced by the use of bumpers.

Saturation
A situation or condition where an operational amplifier is commanded to output more than it is capable of producing.

Settling Time
The time it takes for the scanner to settle within 1% of the final position, measured from the start of the Command signal. (1% is measured on the size of the move. On a 1° move the scanner must settle to within 0.01° degree of the final position.) See *"Section 4.4: Measuring the Step Response Time" on page 19*.

Slew Rate Limiter
A circuit used to limit the maximum angular speed that the system can move. By imposing slight limits on speed, wobble and jitter are reduced to provide accurate positioning. This is especially useful in systems where large-angle motion is needed.

Small-Angle Step
A step small enough that the settling time of the system is limited only by its bandwidth, not by the output current or drive voltage available.

Structured Move
An input signal which is shaped to guide the motion of a scanner to minimize the settling time by not exciting any resonances.

Tuning
The process of adjusting the servo parameters to obtain a critically damped system.

Velocity Output
The velocity output provides a voltage proportional to the velocity of the scanner. The scaling is arbitrary, and is set to give a useful range with the particular scanner. It is used when fine tuning a system for constant velocity.

Wobble
A motion of the mirror/scanner load that is perpendicular to the scanner's rotation. It is always produced by an unbalanced load and it is exacerbated by rotating too fast.

XY Mode
An XY system is used for scanning a beam in two dimensions.

Z-Axis
The third axis of a system. The third axis can control a blanking or beam-dumping mirror, or it can be used for depth information.

10.0 Appendix E: Drawings

1. **673 Functional Diagram Sheet 1 - D06276ASHT1.pdf**
2. **673 Functional Diagram Sheet 2 - D06276ASHT2.pdf**
3. **673 Functional Diagram Sheet 3 - D06276ASHT3.pdf**
4. **673 Dual Axis Outline Sheet 1 - D05606L.pdf**
5. **673 Dual Axis Outline Sheet 2 - D05606LSHT2.pdf**