MicroMax™ 671 Series

BOARD LEVEL

SINGLE AXIS DRIVER ELECTRONICS

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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 671 Series System Overview

1.1 Introduction

The **MicroMax™ Series 671** servo driver is designed for applications and mirror positioning systems that require high performance and high accuracy.

The 671 servo driver is used with Cambridge Technology's line of galvanometer type servomotors, 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 671 servo driver becomes a board level, single-axis mirror positioning system. The compact size and integrated design of the 671 servo driver simplify the installation process and reduce downtime should the need for replacement arise.

This manual contains the information necessary to install, wire, start up, operate, and tune the MicroMax™ Series 671 servo driver. Please read this manual to fully 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.

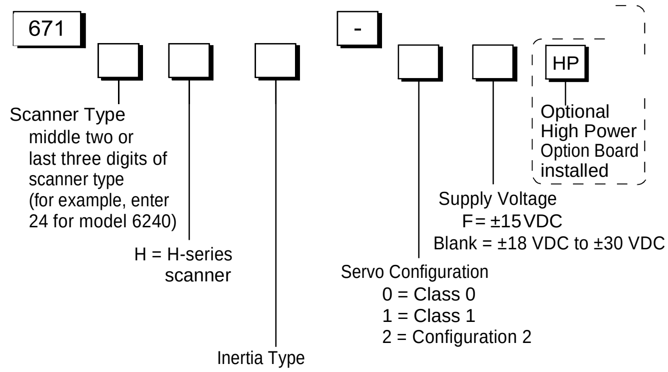
CAUTION

ESD HAZARD!

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

1.3 Part Number Description

The 671 servo board is available in a variety of configurations, as detailed below:



HJ = High Inertia Tuning
for heavier than standard loads for a particular motor type
LJ = Low Inertia Tuning
for lighter than standard loads for a particular motor type
Blank = Standard Tuning
for standard loads for a particular motor type
XX = Tuning for this size load in mm (for non-standard loads)

Example #1: Part # 67123-0

- 6230 Scanner
- Standard Inertia Tuning
- Class 0
- ± 18 VDC to ± 30 VDC Power Supply
- without High Power Option board

Example #2: Part # 67188HJ-1FHP

- Servo driver 671
- Scanner 6880
- High Inertia Tuning
- Class 1
- ±15VDC Power Supply
- with High Power Option board.

Example #3: Part # 671215HHJ-1FHP

- Servo driver 671
- Scanner 6215H
- High Inertia Tuning
- Class 1
- ±15VDC Power Supply
- with High Power Option board.

Example #4: Part # 67122H10-2

- Servo driver 671
- Scanner 6220H
- Tuning for 10mm loads
- Configuration 2
- ± 18 VDC to ± 30 VDC Power Supply
- without High Power Option board

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: 671 Board Specifications

Parameter	Conditions and Limits	Value	Units
Command Input Impedance	Differential	200	Kohm
Command Input Impedance	Single Ended	100	Kohm
Position Output Impedance	Typ	1	Kohm
Analog Input Range	Max	± 10	Volts
Digital Input Range	Max	16	Bits
Digital Input Nonlinearity Error	Max	± 0.0015	%
Position Offset Trimpot Range	Typ	± 10	% of FSR
Position Output Scale Factor	Std	0.500	Volts/° mech.
Fault Outputs	Typ	1kohm to open collector pulled down to -15V	-
Temperature Stability	0-50°C Ambient temp	20	ppm/°C
Absolute Maximum Supply Voltage Note #1	± 18 to ± 30V Range	30	VDC
	± 15V Range	15	VDC
Minimum Operating Voltage Note #1	± 18 to ± 30V Range	18	VDC
	± 15V Range	15	VDC
Undervoltage Trip Point	± 18 to ± 30V Range	17	VDC
	± 15V Range	12	VDC
Output RMS Current	Typical Note #2	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 + 2	Deg
Over-Temperature/ Over current Protection	Scanner RMS	1-3	Sec
Ambient Temperature Range	Max limits	0-50	°C
Size		4.0 x 2.63 x 1.25 10.2 x 6.7 x 3.2	inch cm
Size with HPO		4.0 x 2.64 x 2.49 10.2 x 6.7 x 6.3	inch cm
Weight	With Notch Filter	3.5 99	oz grams
Weight with HPO	With Notch Filter	5.9 167	oz grams

Note #1: Switching the board's input supply voltages from ± 18 to ± 30VDC mode to the ± 15VDC mode or back again requires the change/soldering of resistors and changes in jumper settings for proper operation of the board.

Note #2: Typical and guaranteed peak currents are limited by the 671 board's power output op-amp. Input voltage, power supply capabilities, application waveform, scanner impedance, system step response, etc. all affect the maximum current, voltage, and power the 671 board can deliver.

When driving large loads that demand high peak current, high RMS current, or cause higher temperatures than the 671 servo board can dissipate, there is an optional add-on module (the 671 HPO) that will essentially double the maximum peak current and quadruple the amount of on-board power dissipation.

1.5 Optional Modules

The Series 671 servo driver was designed to accept several optional modules, noted below. Please consult your applications specialist with questions.

Table 2: Optional Modules

Module Name	Module ID	Function
Notch Filter (normally supplied, if necessary it can be added after installation)	6745	Rejects scanner's resonant frequency.
Digital to Analog Converter	6755 or 6756	Allows the system to accept digital command signals.
High Power Option Board	671HPO	Increases the output current and RMS power, as required for larger mirrors.

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 671 Servo Driver Outline Dwg (D04244) sheets 1, 2, and 3 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 heat sink, 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 heat sinking 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 #6 holes at the left and right ends of the black heatsink bracket, and two #6 holes near the middle of the bracket. The board is normally mounted by its heat sink.

   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.

1. Ground either the heatsink or one of the two #4 screw holes located on the left two corners of the board (see drawing D04244) 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.

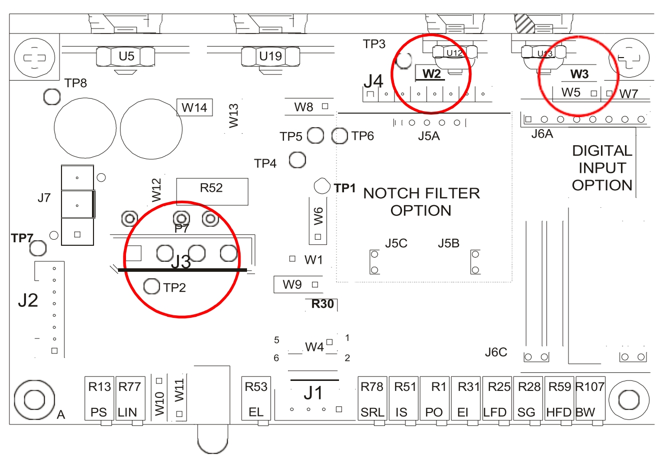
3. Check that the power jumper settings (W2 and W3) and resistors on the board exactly match the requirements for your supply voltage:

Table 3: Power Supply Jumper/Wire Settings

Power Supply Voltage	Jumpers W2 & W3	Resistors R94 & R96
±18 VDC to ±30 VDC	Open	13.3 Kohms
±15 VDC	Closed	7.78Kohms

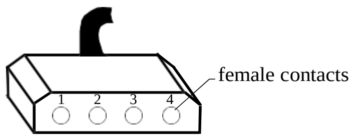
⚠ **CAUTION** ⚠

ELECTRICAL HAZARD.
Improper jumper settings will result in serious damage to the 671 servo board electronics.
Improper resistor settings will cause an incorrect fault trip point level for under voltage protection.
You must change jumpers and resistors to change supply voltage.



4. Check the voltages on the pins of the power supply cable. See *"Section 7.0: Appendix A: Electrical Details" on page 52* for cable construction.

Table 4: Power supply cable pinouts



Pin #	Signal Name	Voltage Range
1	+Supply Voltage	+15VDC or +18VDC to +30VDC
2	+Supply Voltage Return	GND (Common)
3	-Supply Voltage Return	GND (Common)
4	-Supply Voltage	-15VDC 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. In dual-board systems, it is necessary to connect a ground wire between the two boards to reduce crosstalk. See *"Section 7.2: Dual Axis System Wiring" on page 52.*

7. Check/set the jumpers on W4 to match your system's requirements:

Table 5: W4 Signal In Configuration

Input Configuration	Jumper W4 Pin Strapping	Scanner Motion
Analog Differential (Preferred)	1+3	Scanner rotates CW for J1-3 higher than J1-1 [If there is no other ground path to the signal source, J1-2 must be connected to signal source ground.]
Analog Non Inverting	1+3, 4+6	Input amplifier is non-inverting. Scanner rotates CW for J1-3 higher than GND.
Analog Inverting	3+4	Input amplifier is inverting. Scanner rotates CCW for J1-1 higher than GND
Digital Non Inverting	3+5, 4+6	Input amplifier is non-inverting. Scanner rotates CW for VDAC higher than GND
Digital Inverting	5+6, 3+4	Input amplifier is inverting. Scanner rotates CCW for VDAC higher than GND

8. Check the Command Input Connector wiring [*"Section 7.3: Command Input Wiring" on page 52*] and insert the wired female connector into **J1** on the **671** 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: Optional: 6755 / 6756 Digital Input Module Installation

If the optional DAC module is not already installed in the 671 board, use the following procedure to install the module and to configure the 671 board to accept signals from the module instead of an analog command signal.

1. Check that all power to the system has been turned off.

2. Carefully align the 8-pin row of pins at the back of the input module with connector **J6** on the servo card. Check that all eight pins in the back and the four pins in the front of the module line up correctly, then firmly press the module until it is fully seated. See drawing D04244.

3. Connect the 30-pin control cable to connector J1.

4. Check that the jumpers for W4 are installed properly. (See Table 5 on page 8.)

Step 4: 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 17* to tune the board before proceeding to Step 6.

Warning: 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 5: Connect the scanner to the board

1. Plug the extension cable, if there is one, into the scanner, and plug the small 8-pin connector into connector **J2** and plug the 3-pin connector into connector **J7** on the **671** board.

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 55.*]
   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 input to 0V analog or 32768 digital.

4. Turn the power on and observe the scanner shaft. If the system is unstable after the startup sequence, or it makes whistling, buzzing, or squealing noises, turn the power off immediately, and check everything once more. If the problem persists please call Cambridge Technology for help. During a normal startup operation the **671** 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.
   - The **LED** status indicator glows red.

After 1 second:

- The servo driver **Output** 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 2 additional seconds (3 seconds from turn-on):

- The **Command Input** signal is enabled.
- The **Fault Output** signal de-activates and the LED turns green.
- The scanner will begin to follow the **Command Input** signal which is 0°.

5. Hook up an oscilloscope or voltage meter to the Position Output signal at **TP1.** (For TPx locations see drawing **D04244**). At this time the voltage should read very nearly 0.0 volts. Use **TP2** for the ground reference.

6. Input a 30 Hz square wave that spans about 0.1° mechanical or about 50 mV on the Position Out signal. For analog inputs, apply a square wave of about 50 m Vp-p at about 30 Hz to the position input pins on J1. 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.

9. 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 it is necessary to change the bumpers in the field, the overposition limits must also be changed. They are set by resistor, R24. Refer to the Over-Position Chart below to determine the correct value.

10. If the 671 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 6: Over-Position/Standard Resitor Values

Nominal Field Size Mechanical Degrees	Over-Position Angle Mechanical Degrees	Over-Position Voltage	R24
< 18 (+/-9)	< ± 10	See Note 3	See Note 3
18 (± 9)	± 10	5	Open
19 (± 9.5)	± 10.5	5.25	200k
20 (± 10)	± 11	5.5	100k
21 (± 10.5)	± 11.5	5.75	66.5k
22 (± 11)	± 12	6	49.9k
23 (± 11.5)	± 12.5	6.25	40.2k
24 (±12)	± 13	6.5	33.2k
25 (± 12.5)	± 13.5	6.75	28.7k
26 (± 13)	± 14	7	24.9k
27 (± 13.5)	± 14.5	7.25	22.1k
28 (± 14)	± 15	7.5	20k
29 (± 14.5)	± 15.5	7.75	18.2k
30 (± 15)	± 16	8	16.9k
31 (± 15.5)	± 16.5	8.25	15.0k
32 (± 16)	± 17	8.5	14.3k
33 (± 16.5)	± 17.5	8.75	13.3k
34 (± 17)	± 18	9	12.1k
35 (± 17.5)	± 18.5	9.25	11.5k
36 (± 18)	± 19	9.5	11k
37 (± 18.5	± 19.5	9.75	10.5k
38 (± 19)	± 20	10	10k
39 (± 19.5)	± 20.5	10.25	9.31k
40 (± 20)	± 21	10.5	9.09k
40 (± 20)	± 22	11	8.25k

Table 7: Current to Voltage and Coil Temperature Calculator Table

	Conversion Ratio	Multiply Volts Across 0.1∧ by	Maximum RMS Current	RMS Volts at Current Monitor CTC Limit
6200	1V/A	10	1.6A	1.6V
6200H	1V/A	10	2.3A	2.3V
6210	2V/A	20	1.6A	3.2V
6210H	2V/A	10	2.4A	2.4V
6215H	1V/A	10	4.1A	4.1V
6220	1V/A	10	2.6A	2.6V
6220H	1V/A	10	3.9A	3.9V
6230	0.5V/A	5	5.4A	2.7V
6230H	0.5V/A	(V across 0.05∧) 10	7.0A	3.5V
6231C	0.5V/A	5	5.4A	2.7V
6231HC	0.5V/A	5	5.8A	2.9V
6240	0.5V/A	5	7A	3.5V
6240H	0.5V/A	(V across 0.05∧) 10	8.2A	4.1A
6800	2V/A	20	1.6A	3.2V
6810	1V/A	10	2.6A	2.6V
6850	0.5V/A	5	4.6A	2.3V
6860	0.5V/A	5	4.6A	2.3V
6870	0.5V/A	5	5.5A	2.75V
6880[1]	0.5V/A	(V across 0.05∧) 10	7.7A	3.65V
6350	2V/A	20	1.1A	2.2V
6450	2V/A	20	1.77A	3.54V
6650	1V/A	10	2.83A	2.83V
6900	0.5V/A	5	5A	2.5V
6400[2]	0.5V/A	(V across 0.02∧) 25	10A	5V

Notes:
1. The 67123H, 67124H, and 67188 boards use a 0.05ohm current sensing resistor.
2. All 6400 boards are special cases. Please check with Cambridge Technology.
3. Systems can be configured by CTI with over-position limits under +/-10 degrees by request.

Special Note: A small number of the scanners with star (*) numbers have nonstandard coil impedances. The maximum current for these scanners will be different. Please check with Cambridge Technology.

3.0 671 System Test and Alignment

This section is a condensed version of the normal factory procedure for testing and aligning a new 671 board with a scanner, modified for field use. It is followed by much longer and more detailed versions 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, Class 1, or Configuration 2. Changing the servo type 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 will be damaged by 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.

Step 1: Board Preparation

Note: Board is viewed from the connector side with the heatsink to the rear. See *"Section 3.1: Outline Drawings" on page 15*.

1. Check all jumpers:

Table 8: Jumper Locations/Settings

Jumper	Purpose		Settings	Notes
W1	Class 0		1+2	High speed system
	Class 1		2+3	High accuracy system
	Configuration 2		1+2	High speed and accuracy
W2	External Positive Supply Voltage		+18-30V	Off
			+15V	On (Solder in a jumper)
W2	External Negative Supply Voltage		-18-30V	Off
			-15V	On (Solder in a jumper)
W4	Signal In	Analog Non-inverting	1+3 4+6	Input amplifier is non-inverting Scanner rotates CW for J1-3 higher than GND.
		Analog Inverting	3+4	Input amplifier is inverting. Scanner rotates CCW for J1-1 higher than GND.
		Digital Non-inverting	5+3 4+6	Input amplifier is non-inverting. Scanner rotates CW for Vdac higher than GND.
		Digital Inverting	5+6 3+4	Input amplifier is inverting. Scanner rotates CCW for Vdac higher than GND.
		Differential	1+3	Scanner rotates CW for J1-3 higher than J1-1. [If there is no other ground path to the signal source, J1-2 must be connected to signal source ground.]
W5	Normal		2+3	[Pin 1 is at the right end.]
	Mirror Alignment		1+2	
W6	Class 0		1+2	[Pin 1 is at the near end.]
	Class 1		2+3	
	Configuration 2		2+3	
W7			none	Not a jumper block
W8	NFM Present		1+2	[Pin 1 is at the right end.]
	No NFM		2+3	
	Adjusting NFM		none	
W9	Class 0		2+3	[Pin 1 is on the right end.]
	Class 1		1+2	
	Configuration 2		2+3	
W10 and W11	Slew Rate Limit On		1+2	[W10 Pin 1 is at the rear. W11 Pin 1 is at the front.]
	Slew Rate Limit Off		2+3	
W12	Single-ended output		On	[Soldered jumper wire]
	Differential output		Off	(Normal)
W13	No Booster Amp		On	[Soldered jumper wire]
	Booster Amp		Off	
W14	No Booster Amp		On	(differential output) [Soldered jumper wire]
	Booster Amp		Off	(differential or single-ended output)
	Single-ended output		Off	(with or without booster)
R63	Differential output		Installed	(Normal) zero ohms
	Single-ended output		Remove	
R94, R96	± 18-30V Supply		13.3Kohms	
	± 15V Supply		7.87Kohms	

2. Select and solder in R30 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.

3. Detune by setting the following fully CCW:
- R25/LFD
- R28/SG
- R31/EI
- R53/EL
- R59/HFD
- R78/SRL
- R107/BW

Leave these pots 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.

4. Inspect for obvious faults.

Step 2: Installing the High Power Option Board

This option is normally installed at the factory. If you have a field installation kit, see *"Section 9.0: Appendix C: Installing the 671HPO Kit" on page 56*. Contact Cambridge Technology with any questions.

Step 3: Power Test

1. Connect to an external DC supply, and turn the supply on.

2. Check that the Fault Detector LED turns red, and check the following voltages on the board:

Voltage	Min	Max	Test Points
External ±18-30VDC	±18	±30	W2-1 & W3-2
External ±15VDC	±14.55	±15.45	W2-1 & W3-2
±15VDC	±14.55	±15.45	W2-2 & W3-1
+5VDCref	+4.95	+5.05	W7-1
-5VDCref	-4.90	-5.10	W7-3
+5VDClogic	+4.75	+5.25	U14-1

Step 4: Board Alignment - Gross Function

Required Equipment: Scanner with load (specified mirror), scanner cable, scanner clamp, 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 heatsink to the rear. The external heatsink is optional at this point, but will be needed later. Do not leave the board running indefinitely without the heatsink. It will get hot, and the amplifier and regulators may turn off.
   b). Connect the scanner to the board at J2 and J7, using the cable ordered with the board.
   c). Connect the DVM [VDC] to Vagc [TP7] and GND.
   d). Check that there is no shunt on W8.
   e). Plug the power cable into J3.

2. Turn on the power.

3. Measure Vagc. It should be between 7.0VDC and 10.4VDC. [A very few systems, mostly with 6900 scanners or certain special systems configured for +/-15V supplies, have ~5V for AGC.]

4. Connect the DVM to Vpos (TP1 or J4.2). Gently 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 Fault Detector LED should turn red and the output amplifier should be disabled at the over-position limit. This is set at the factory, and may be set to any angle from 10 to 22 degrees. The scaling is 0.5V/degree. Move the shaft slowly by hand while watching the LED and the DVM.

Step 5: Linearity and Position Scale

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

See *"Section 4.1: Position Scale Factor and Linearity Adjustment" on page 18*.

Step 6: Continuation of System Test

1. Install the specified mirror, and tighten the mounting screws evenly and thoroughly.
   See *"Section 8.0: Appendix B: Mirror Handling and Mounting" on page 55*.
2. Clamp the scanner firmly.
3. Attach the heatsink to the onboard heatsink using #6 screws, and lay the board down with the heatsink to the rear.

Step 7: Notch Filter Selection - 6745 Dual NFMs

[It is not necessary to detune the 671 board to readjust the notch filter.]

The board is normally supplied with the correct NFM for the scanner and load. The first torsional resonance can range from less than 1kHz to 30KHz, depending on the load and scanner. Please call Cambridge Technology if a different one is needed.

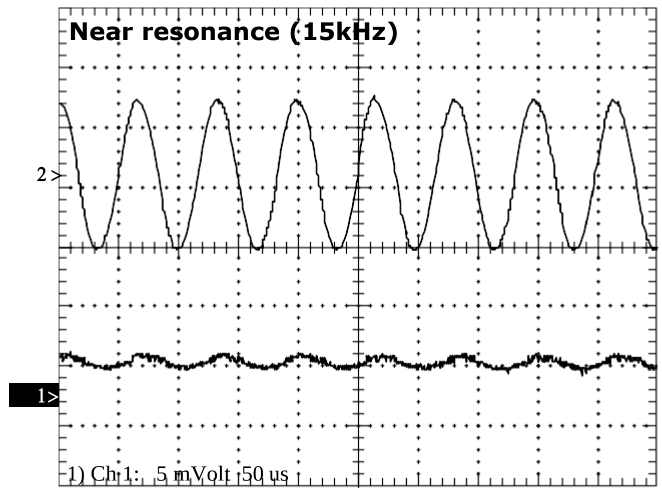
1. Check that the 6745 NFM is not in the J5 socket.
   Check the jumpers on the 6745. The unused notch, NF1or NF2, can be disabled for scanners without a significant second torsional resonance. See *"Section 3.1: Outline Drawings" on page 15*.

W1	
NF1 enabled	2+3
NF1 disabled	1+2
W2	
NF2 enabled	2+3
NF2 disabled	1+2

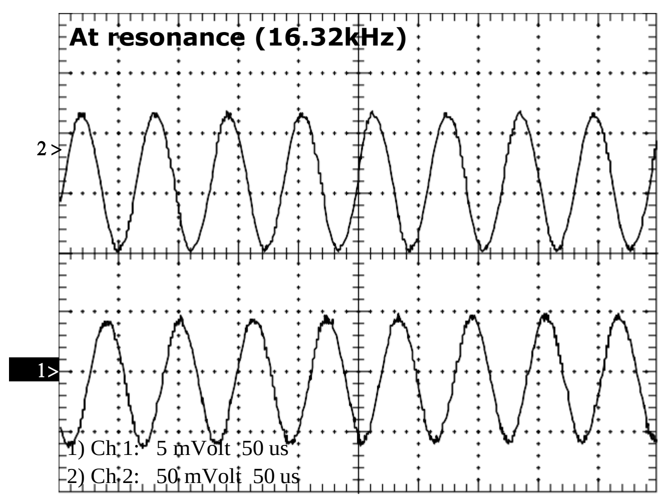
2. Check that there is no shunt on W8.
   Connect the signal generator (1kHz sine, output ~50mVpp) to TP6, and monitor Vpos (TP1) and Current (TP3) with the scope.
3. Use the generator offset to roughly center the mirror (the scanner should not be at either stop), and set the output for ~200mVpp on the current trace.
4. 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.



2) Ch 2: 50 mVolt 50 us



5. Select the notch filter module (6745-xx) with the range where the resonant frequencies are nearest to the middle of the notches.
6. Turn off the power, insert the module in J5, and ground the Mute line (TP4) to disable the output stage.
7. Connect the generator to TP5 and monitor TP6 with the scope.
8. Turn the power on, set the generator frequency to exactly the first torsional resonance, and bring the generator output back up to ~2Vpp at J5-1.

9. Adjust R8/NF1 (Frequency) and R9 (Depth) on the filter for the best rejection. The signal at TP6 should be less than 1/100th the signal at J5-1, or <20mVpp for 2Vpp in. In other words, more than 40db down.

10. Set the generator to exactly the second torsional resonance and adjust R18/NF2 for the best rejection.

11. Disconnect the generator from TP5 and remove the ground on TP4.

12. Put the shunt on W8 1+2. Pin 1 is on the right.

Step 8: Small Step Response Adjustment

First check whether the board is Class 0, Class 1, or Configuration 2. Class 1 and Configuration 2 boards use one more pot than Class 0, and the pots react differently. See *"Section 4.0: Detailed Tuning and Alignment Procedures" on page 17* for detailed tuning procedures.

1. Scope:

Channel 1	Vpos [TP1]	20mV/div
Channel 2	Current Monitor (TP3)	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 about 3 turns CW and HFD/R59 about 2 turns CW.

Class 0

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

3. Turn SG/R28 CW until the mirror starts locking in the center position, and Vpos starts showing a square wave.

4. Continue to turn SG/R28 CW until the square wave shows several cycles of ringing. (Adjust HFD/R59 for stability if needed.)

5. Adjust LFD/R25 CW to reduce the ringing.

6. Adjust HFD/R59 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 pots run out of range, then make fine adjustments. Change the current and voltage ranges and the timebase as the errors get smaller. BW/R107 interacts with HFD/R59 in the later stages of tuning, and moves the dips and bumps sideways. Start adjusting it as soon as it has a noticeable effect. The object 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 doesn't count 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 4.3: Measuring the Step Response Time" on page 21*.

Class 1

[If the board is Configuration 2, skip ahead to Step 3 under Configuration 2.]

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

4. Turn EI/R31 CW cautiously until the mirror moves and Vpos starts showing a square wave.

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

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

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

8. Adjust HFD/R59 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 pots run out of range, then make fine adjustments. Change the current and voltage ranges and the timebase as the errors get smaller. BW/R107 interacts with HFD/R59 in the later stages of tuning, and moves the dips and bumps sideways. Start adjusting it as soon as it has a noticeable effect. The object 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 4.3: Measuring the Step Response Time" on page 21*.

Configuration 2

3. LFD/R25 five turns CW, and HFD/R59 four turns CW to get the correct initial damping.

4. Turn SG/R28 CW until the mirror starts locking in the center position, and Vpos starts showing a square wave.

5. Continue to turn SG/R28 CW until the top of the step is as straight as possible, without any overshoot.

6. Turn EI/R31 CW slowly. The step will get larger. Continue to turn EI CW until the top of the step is a straight as possible, without any overshoot.

7. Turn SG/R28 CW until there is a moderate amount of ringing.

8. Turn EI/R31 CW until the top of the step is as straight as possible. Do not go beyond this point.

9. Adjust LFD/R25 CW to reduce the ringing. Stop when the straight part of the step is the longest.

10. Turn SG/R28 CW until there is a moderate amount of ringing. The peak current should be close the final value for the specified step time.

11. Turn EI/R31 CW until the top of the step is as straight as

possible. Do not go beyond this point.

12. Turn LFD/R25 CW until the first peak is level with the top

of the step.

13. Turn HFD/R59 CW to reduce the ringing to a single spike.

14. Turn BW/R107 CW to straighten out the kink to the right of the spike.

15. EI/R31 CW. Turn EI/R31 CW until the top of the step is as straight as possible. The next stage is the fine tuning.

16. Turn LFD/R25 CW to reduce the leading spike. Stop when it is the same heaight as the start of the exponential curve.

17. Turn HFD/R59 CW until there is a smooth exponential curve. Readjust BW/R107 at this point if needed.

18. Turn EI/R31 CCW to flatten the top of the step.

19. Repeat steps 16, 17, and 18 to fine tune the step response. SG/R28 can be adjusted to help flatten the initial overshoot of the step. BW/R107 can be readjusted as needed. The object 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°. For detailed tuning

    procedure with scope images, see *"Section 4.3: Measuring the Step Response Time" on page 21*.

Step 9: Offset Adjustment PO/R1

1. Short the input to ground and connect the DVM to Vpos (TP1).

2. Adjust PO/R1 for 0V ±1mV

Step 10: Slew Rate Limiting Adjustment SRL/R78

(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, and to prevent instability and poor settling. See *"Section 4.4: Slew Rate Limiter Adjustment" on page 35*.

1. Set up
   Generator: 20Hz ~50mVpp square wave.
   Scope:
     Ch 1 5V [Vpos - TP1]
     Ch 2 5V [Vout - TP8]

2. Turn SRL/R78 CW until the voltage spikes on TP8 are clean.

3. Increase the input slowly to 20Vpp or full scale while adjusting SRL/R78 to keep the spikes clean. In Class 1 set the spikes 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 11: Error Limiting Adjustment EL/R53

The Error Limiter is enabled only in some Class 0 systems, never in Class 1 systems. In most cases the Slew Rate Limiter works better. The adjustment is similar to the Slew Rate Limiter adjustment. See *"Section 4.4: Slew Rate Limiter Adjustment" on page 35*.

Step 12: Set System Scale IS /R51

using the 5VDC reference as the input.

1. Disconnect the generator and connect the +5VDC reference (W7-1) to the input.

2. Measure and make a note of the voltage at the input.

3. Adjust IS/R51 for the calculated output at Vpos (TP1).

Step 13: Step Response

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

Step 14: 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 15: Mirror Alignment Jumper

[The jumper should normally be changed with the power off.] See *"Section 4.5: Aligning the Mirror" on page 41*.

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

2. Move the jumper from W5 2+3 to W5 1+2. The mirror should move under light pressure and still center itself. Restore the jumper to W5 2+3. The mirror should stiffen and center without substantial oscillation.

Step 16: Remote Shutdown, Muting, and Power Fault Detection

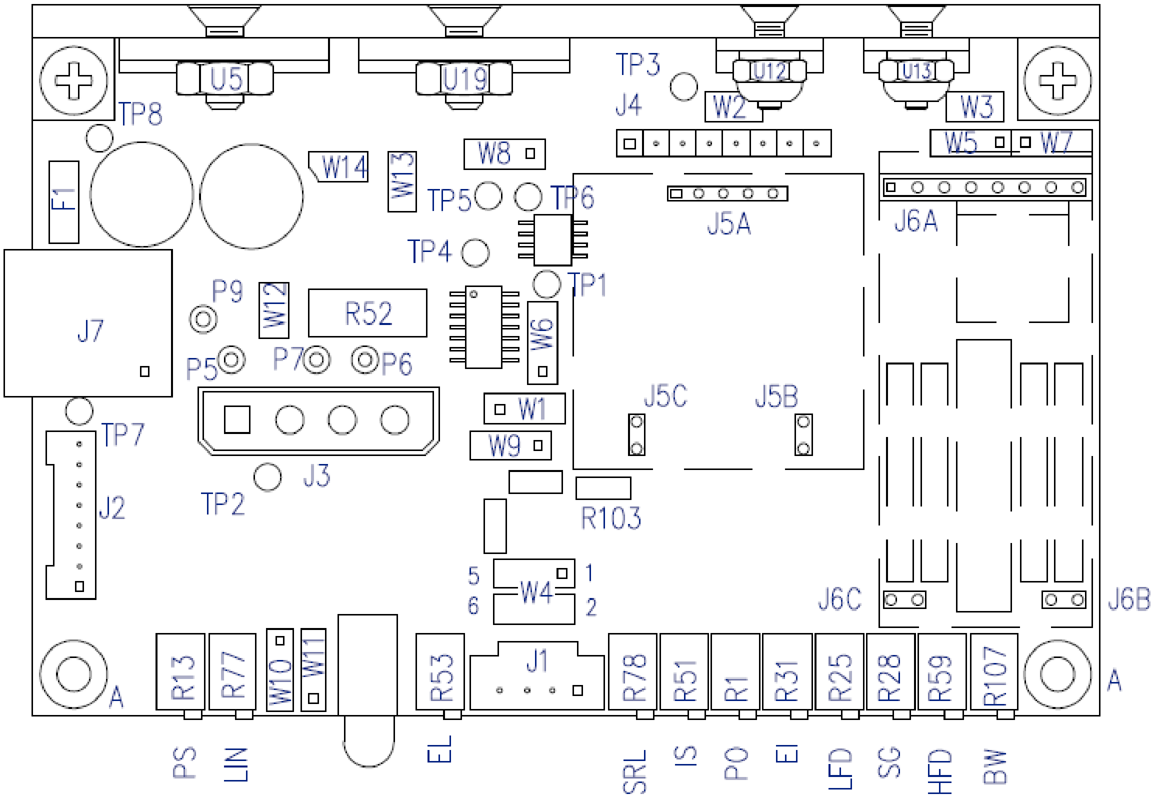
1. Check Remote Shutdown by grounding J4-8 with a jumper. The LED should turn orange, and the output amp should be disabled, and the system should restart when the jumper is removed.

2. Check that the Fault Detector LED turns red without chattering when power is turned off, and that the LED turns from red to green about three seconds after power is turned on.

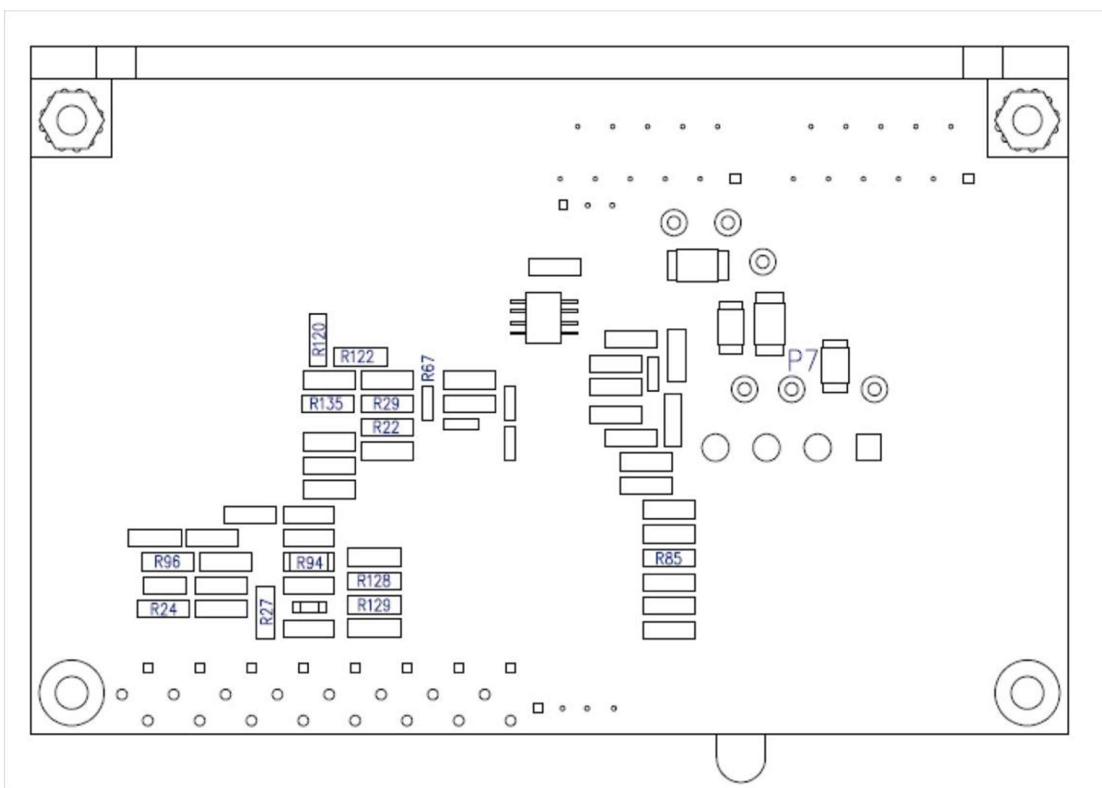
System gain, from the input to Vpos, is normally Field Size/40.
That is for a 40° system it is 1, for a 30° system 0.75, and so on.
Calculate the gain and output from the Field Size at this point,

3.1 Outline Drawings

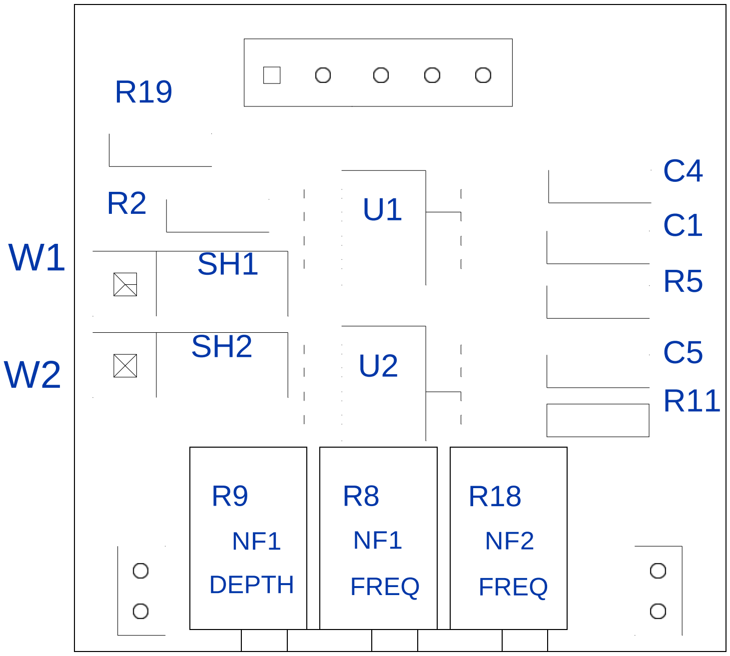
General Outline: 671 Top View



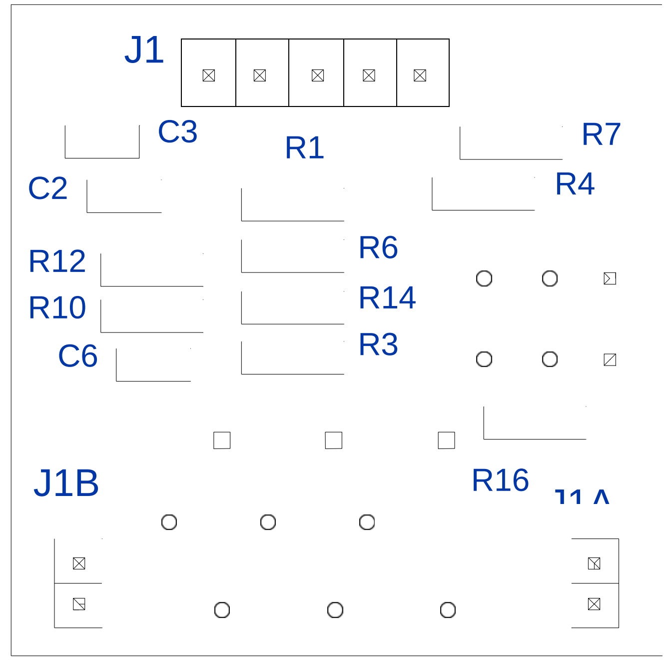
General Outline: 671 Bottom View



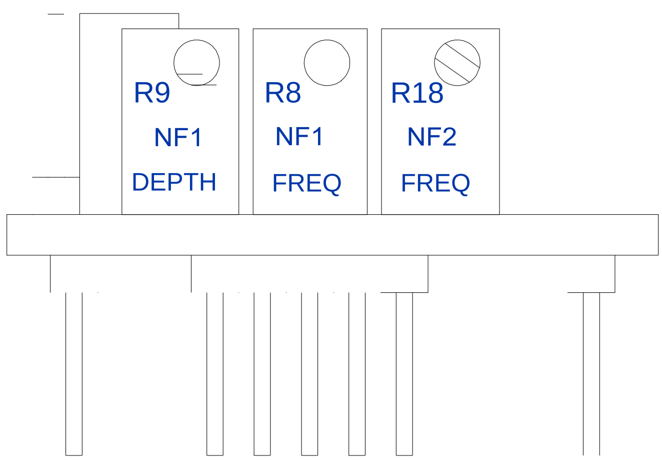
Notch Filter



Top View



Bottom View



Side View

4.0 Detailed Tuning and Alignment Procedures

The following procedures are provided to aid new or infrequent users with the detailed steps necessary to properly tune a system.

Please also see *“Section 3.0: 671 System Test and Alignment” on page 10*.

For most users, the factory settings on the 671 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 9: Potentiometers

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

Refer to the **671 SERVO DRIVE OUTLINE** drawing **D04244** 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.

! 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 trim pots 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 - needs to have a sine and square wave output.
- Digital voltmeter and frequency counter.
- Hand tools - jeweler's screwdriver flat-tip
- Clip lead with "micro grabber" ends.

Order of adjustments

4.1 Position Scale Factor and Linearity Adjustment

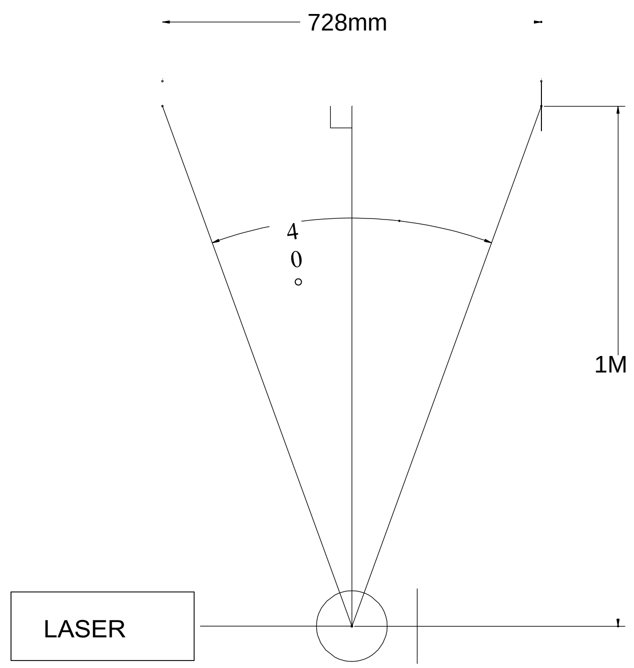
When the 671 board is supplied in a matched set with a scanner, the Position Scale Factor and Linearity of the set are adjusted at the factory, and should never need readjustment as long as the original board and scanner are used together.

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.

4.1.1 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.



4.1.2 Closed Loop Method

Use this method if the system is already tuned and stable.

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, or set the DAC output to zero volts. Check that Position on TP1 is 0V, and adjust the offset with PO/R1 if necessary.
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 on its axis 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 TP7 (AGC) and set it to 10mV/div 10ms/div AC coupled
3. Measure the AC voltage at TP1 (Position), and set the generator for 3.535Vac at TP1.
4. Check that there is no DC offset in the generator signal. (Connect the generator 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 again.

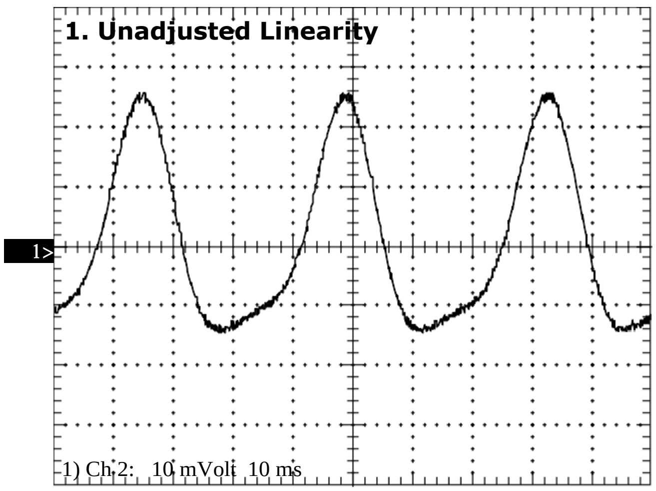
Step 3: Adjust Position Scale and Linearity

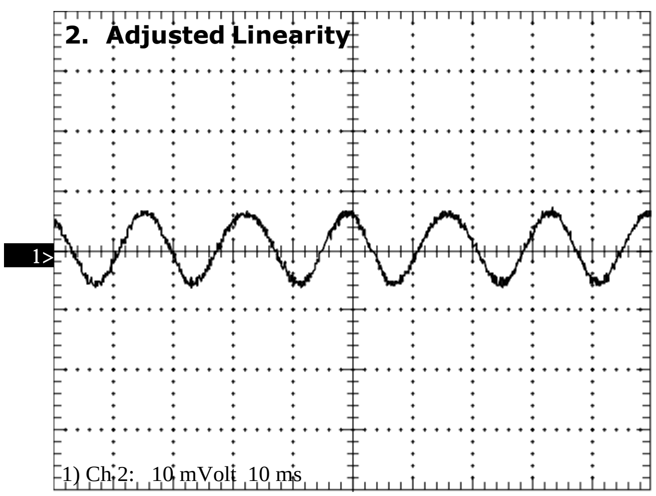
The laser should now be scanning a line on the wall directly on top of the test scale, and roughly centered horizontally. If the laser line is above or below the test scale, or at an angle to it, go back and recheck the positioning of the laser and scanner.

1. Adjust PS/R13 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 R77/LIN 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 if necessary, and then R77/LIN. These adjustments may interact, and take several cycles.

Step 4: Check the AGC Voltage

1. Connect the DVM to AGC (TP7) and ground (TP2).
2. Measure the DC voltage. If it is greater than 11V, please check with Cambridge Technology for technical assistance.





4.1.3 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.

Needed: 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 4.1.1: Set Up" on page 18*.)
2. Disable the output amplifier on the 671 board by grounding the Mute pin (TP4) or the Remote Shutdown line (J4-8), or by disconnecting the scanner cable from J7.
3. Connect the DVM to ground (TP2) and Position (TP1).
4. Turn on the power.

Step 2: Zero the Linearity Pot

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

Step 3: Set the 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*) until the DVM reads +5.0VDC.
4. Adjust PS/R13 until laser beam hits the mark at the end of the line.
5. Repeat steps 2, 3, and 4 until the measurements as accurate as practical.
6. Rotate the mirror until the DVM reads -5.0VDC
7. Check that the laser beam is reasonably close to the other end of the test scale.

Step 4: Check the AGC Voltage

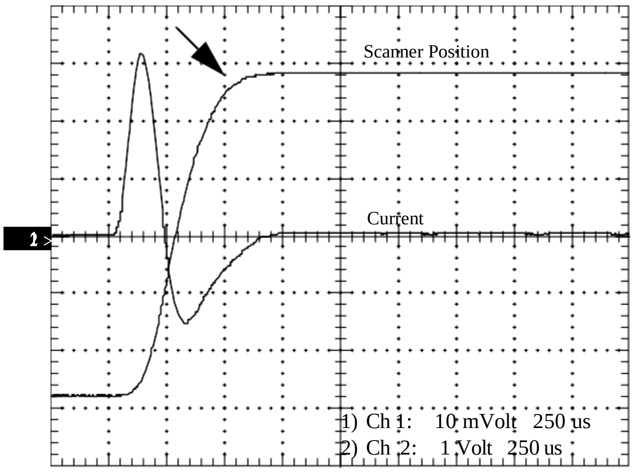
1. Connect the DVM to AGC (TP7) and ground (TP2).
2. Measure the DC voltage. If it is greater than 11V, please check with Cambridge Technology for technical assistance.
3. After tuning the system, readjust scale and linearity using the closed-loop method. See *"Section 4.1.2: Closed Loop Method" on page 18*.

4.2 Small Angle Step Response Tuning

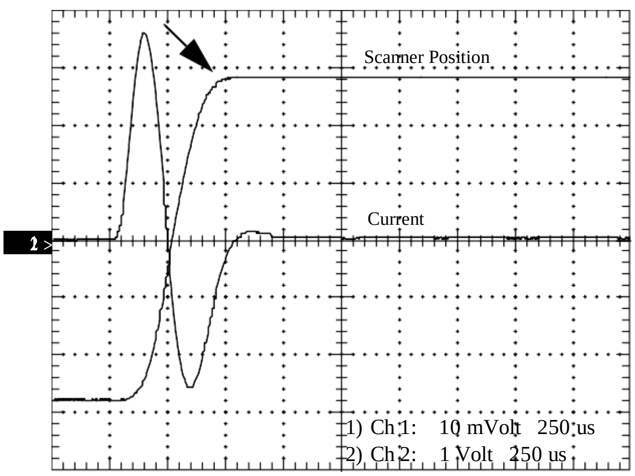
This procedure details the steps necessary to tune a system (adjust trim pots) to achieve the fastest controlled response to a command input signal. This properly tuned response is called "critically damped." Complete this procedure after scale and linearity have been adjusted, and the notch filter is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

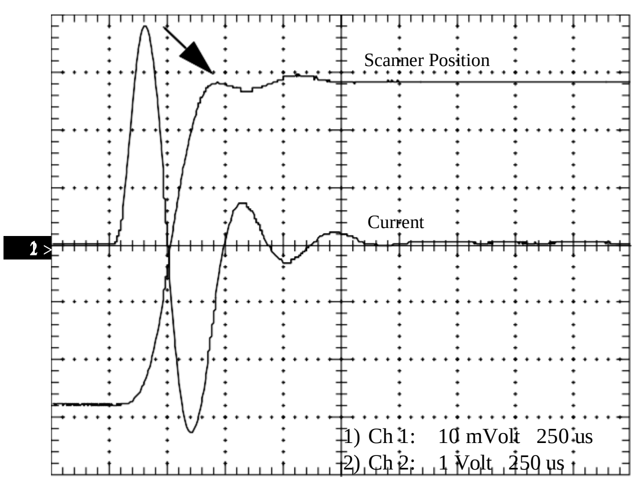
Over-Damped Response



Critically-Damped Response



Under-Damped Response



4.3 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 step responses are defined as settling to within 99% of the final level, and are measured from the start of the input step.

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 50µs.
5. Set the level of the waveform on Position (TP1) accurately. This is the step size specified for the test, and may vary from 0.1 degree to 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 is 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.

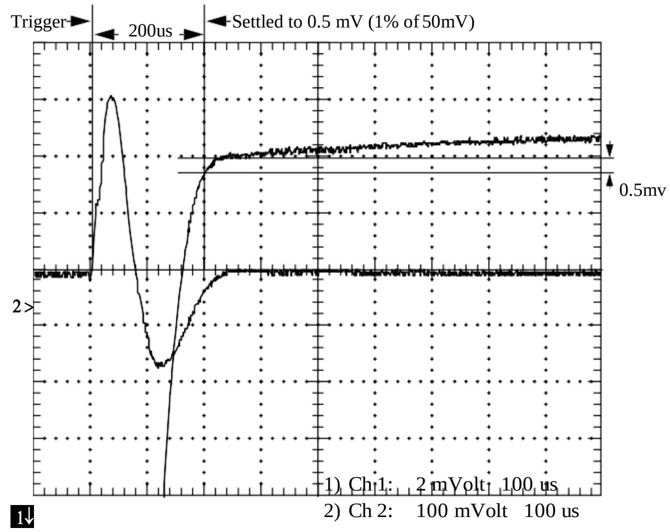
   Use the offset on the generator output, or the position knob on the scope, to bring the top of the waveform into view. Check that the generator or the scope input doesn't overload and limit the signal. (Compare the current waveform with the sample plot.)
7. Check that the waveform is clean, and a reasonable match for the sample plot.
8. 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

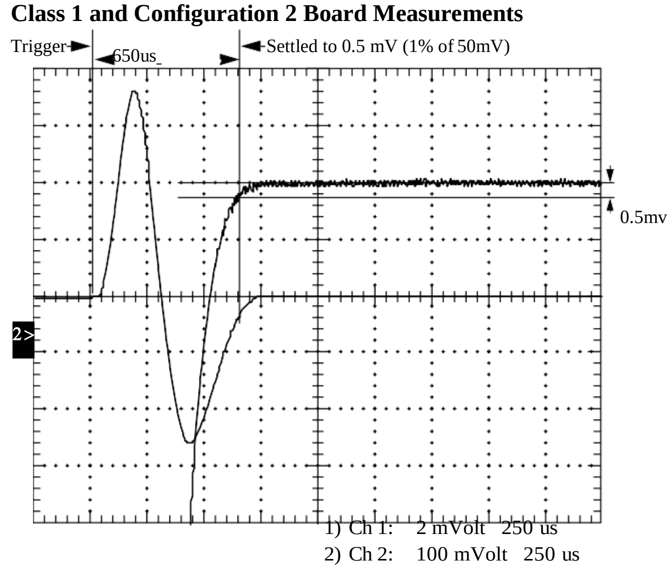
   -Class 1 system: this is 1% below the point the waveform crosses the right edge of the screen.
9. Measure the time from the trigger point to the settling point. When using the cursors on the scope to measure the time, move them to precisely the trigger point and the settling point, then read the time. ***The cursors are dangerously 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 and Configuration 2 Board Measurements



4.3.1 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 that the system never comes close to saturation. If the system clips or saturates, it will be much more difficult to tune, and if the tuning does compensate for the saturation, the step response will be inaccurate at all other angles, and the system may be unstable. Typically the 671 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 671 systems ranges from 100us to more than 40ms, depending on the scanner, load, and application. Do not tune the system faster than needed 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 by experiment. See *“Section 4.3: Measuring the Step Response Time” on page 21* and *“Section 6.2: Speed” on page 48*.

2. Check that the Notch Filters have been adjusted. See *Step 7: Notch Filter Selection - 6745 Dual NFMs on page 12*.

3. Determine your board type by the W1 jumper settings shown below and follow the appropriate procedure. Class 1 and Configuration 2 boards use one more trim pot than Class 0 and pots react differently on each board type.

   Table 10:Board Class Type and Jumper Settings

Type	W1 Jumper Settings	W6 Settings
Class 0 Servo	1+2	1+2
Class 1 Servo	2+3	2+3
Configuration 2 Servo	1+2	2+3

4. Setting up the Oscilloscope and Signal Generator:
   - Channel 1 is always the Position signal (**TP1**). 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 (**TP3**). Set the vertical sensitivity to 100mV/division, change it as needed.
   - Set the timebase to 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 50-100mVpp, and adjust it to the specified angle on the Position signal later.

4.3.2 General Notes

- The tuning of all Class 0 systems is essentially the same as the tuning of all other Class 0 systems, and the tuning of all Class 1 or Configuration 2 systems is essentially the same as all other Class 1 or Configuration 2 systems, respectively. The scaling changes; the algorithms and waveforms do not.
- These tuning procedures assume that the loads used 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 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 pot. 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.

If this is a Class 0 system, go to *“Section 4.3.3: Class 0 Tuning” on page 23*.

If this is a Class 1 system, go to *“Section 4.3.4: Class 1 Tuning” on page 27*.

If this is a Configuration 2 system, go to *“Section 4.3.5: Configuration 2 Tuning” on page 32*.

4.3.3 Class 0 Tuning

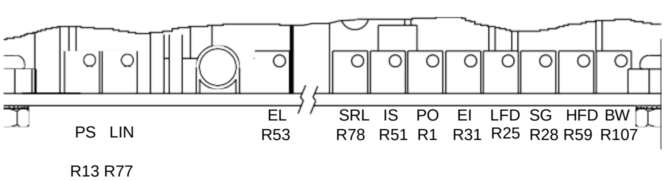
Trimpots

Table 11:Trimpots, Class 0 Board Turning

Trimpot	Name	Purpose
SG/R28	Servo Gain	This pot controls the basic gain of the system. Turn it CW to increase the speed of the step.
LFD/R25	Low Frequency Damping	This pot damps the overshoot on the leading edge of the step waveform. Turn it CW to reduce the overshoot
HFD/R59	High Frequency Damping	This pot damps the ringing not controlled by the **LFD** pot, 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	Bandwidth	This pot adjusts the center frequency of the **HFD** pot. 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** pot 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
   EL/R53
   EI/R31
   SG/R28
   LFD/R25
   HFD/R59
   BW/R107
   This should take a maximum of 12 turns.



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.

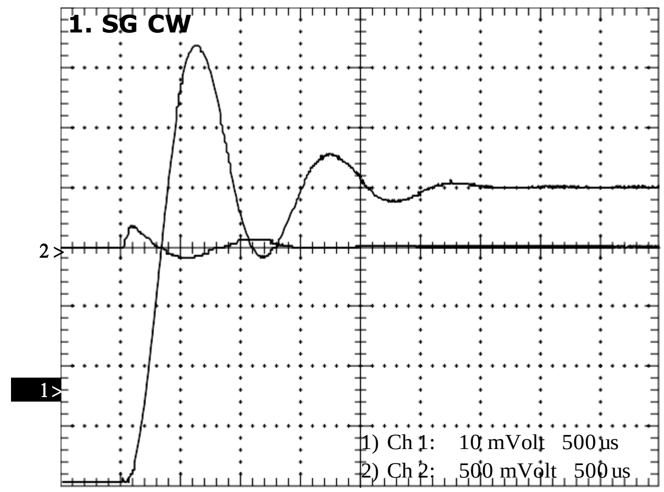
3. Turn **LFD** three turns **CW** and **HFD** two turns **CW**.

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

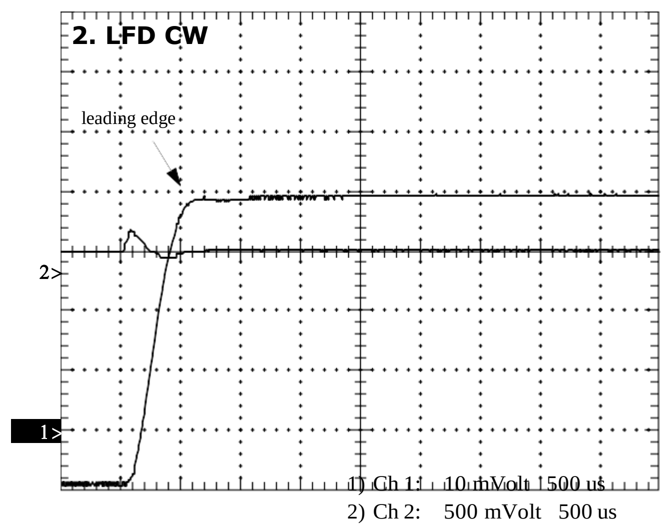
Step 2: Tune the Class 0 Board

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** pot 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.

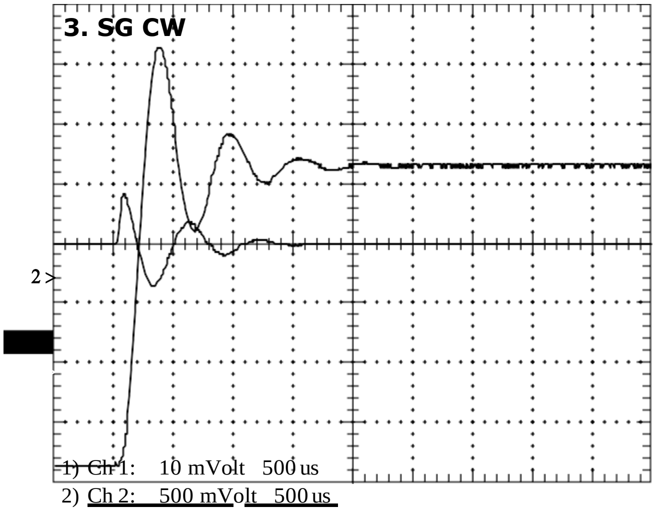
1. Turn **SG CW** until the scanner starts to center and several cycles of ringing appear.



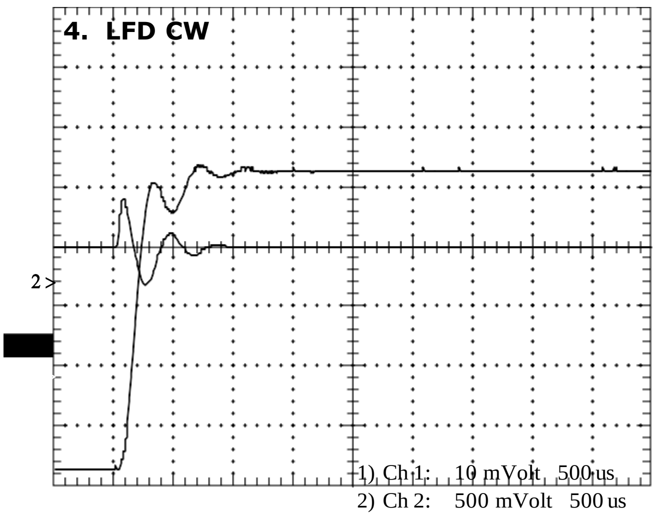
2. Turn **LFD CW** until the leading edge is level with the rest of the waveform. Ignore the slight dip.



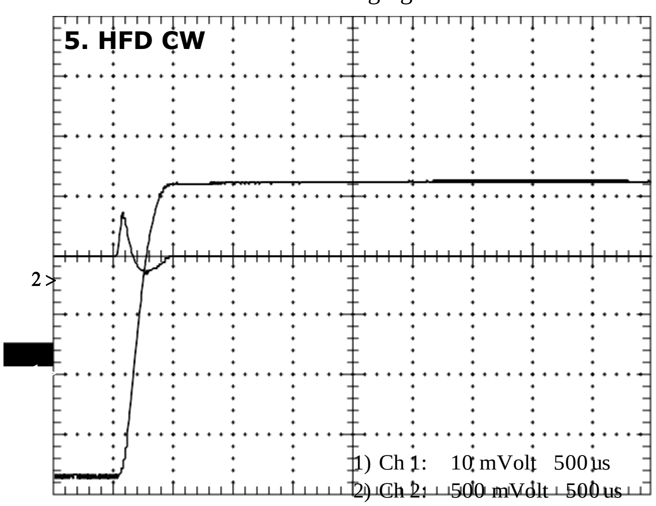
3. Increase the signal gain again (turn **SG CW)** until several cycles of ringing appear.



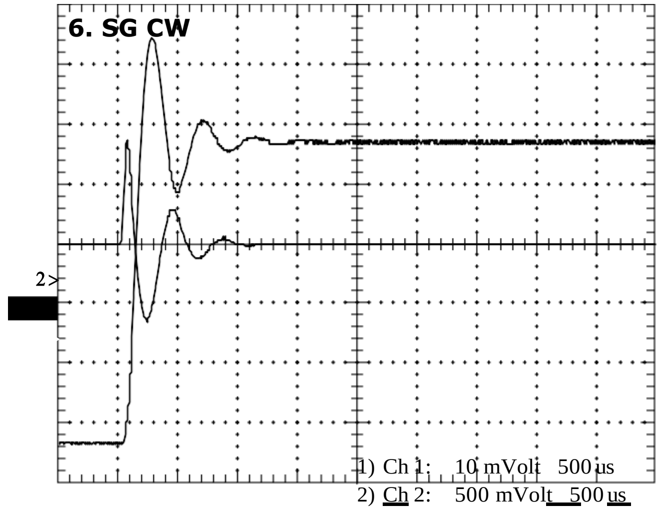
4. Turn **LFD CW** until the leading edge is level with the rest of the waveform.



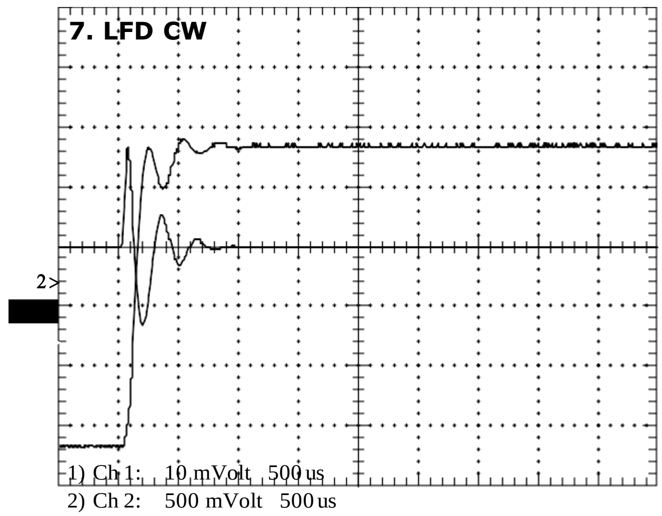
5. Turn **HFD CW** to minimize ringing.



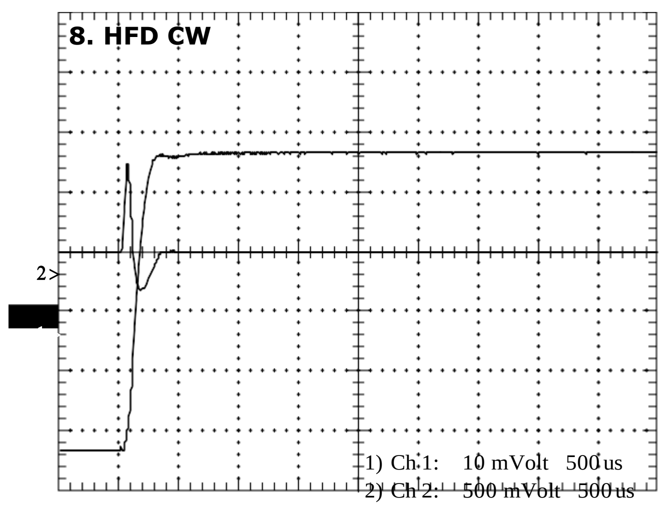
6. Increase the signal gain again (turn **SG CW**) until several cycles of ringing appear.



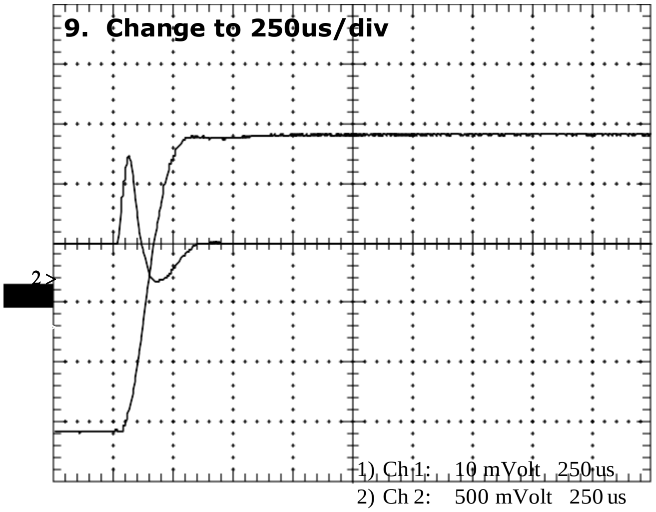
7. Turn **LFD CW** until the leading edge is level with the rest of the waveform.



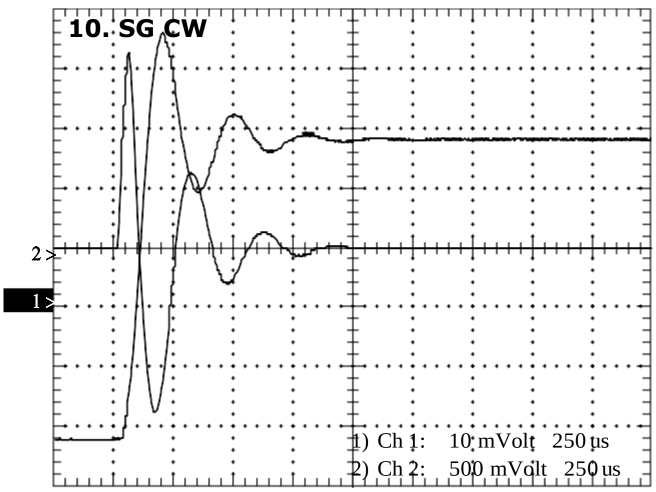
8. Turn **HFD CW** to minimize ringing.



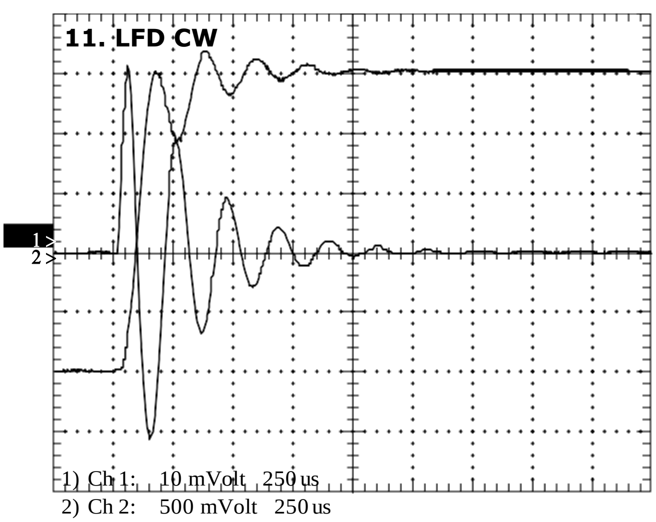
9. Change the time base to 250 us/division (zoom in).



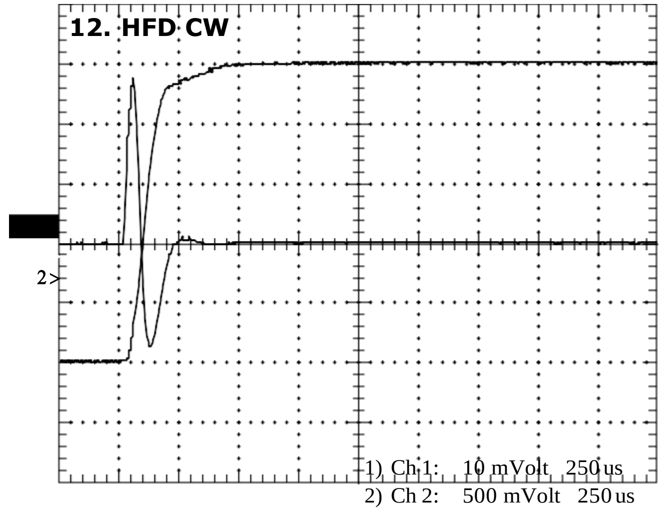
10. Increase the signal gain again (turn **SG CW**) until several cycles of ringing appear.



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



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

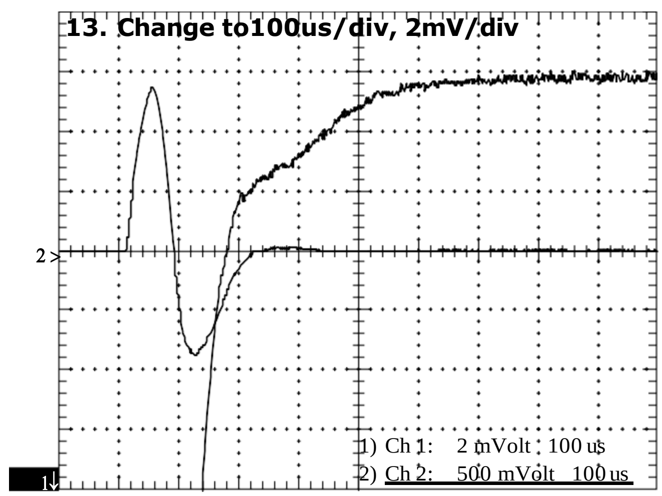


Fine Tune the Class 0 Board

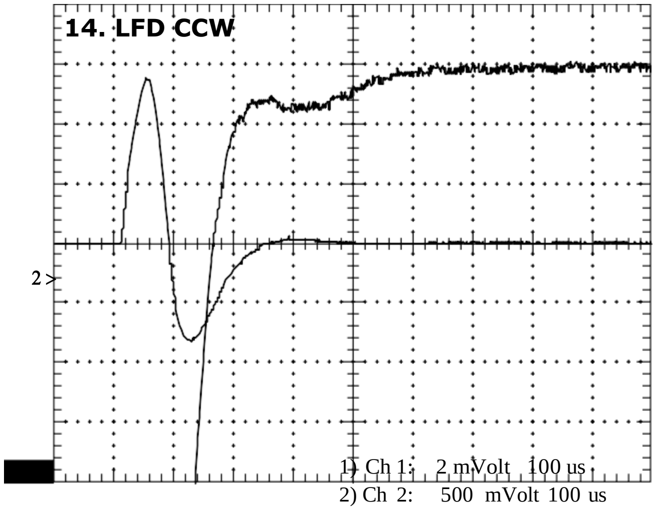
At this point the step response is close to 200us, and it's time to start the fine tuning. It's important to change scale here, to see that the signal settles to within 1%, and to measure the time accurately.

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

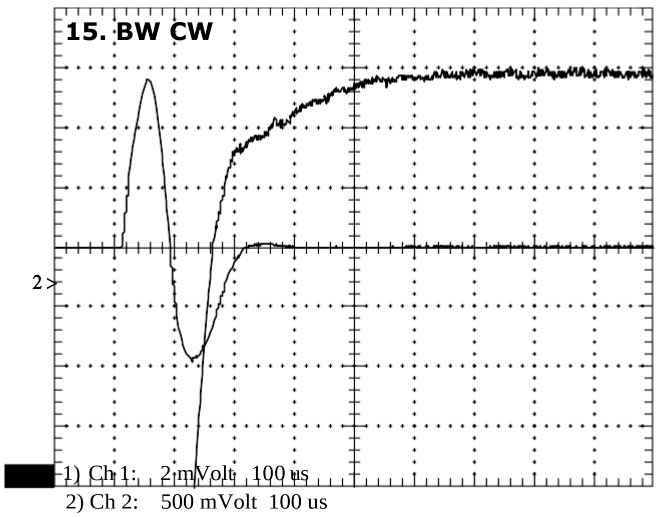
13. Change the time base to 100us/div and the Ch 1 scale to 2 mV/div (zoom in).



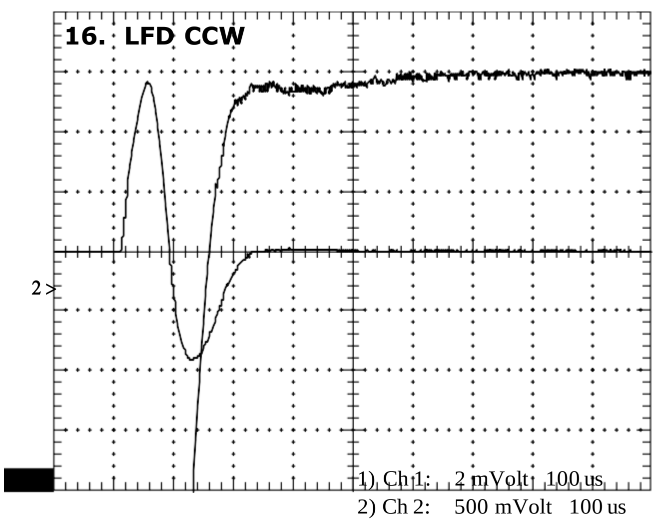
14. Turn **LFD CCW** to bring up the leading edge.



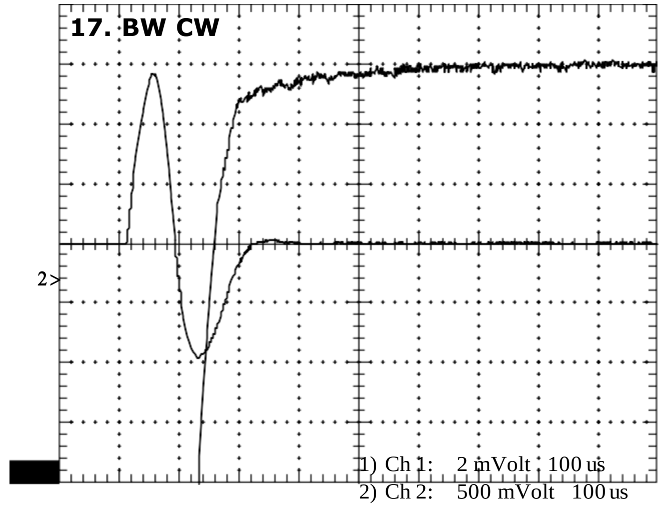
15. Turn **BW CW** to flatten out the dip.



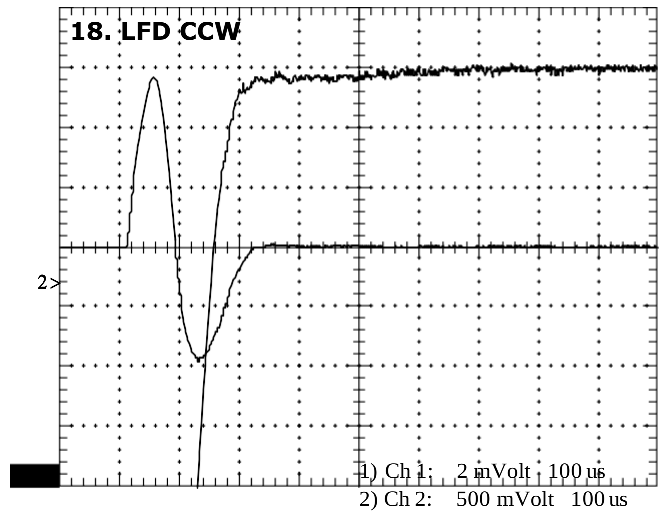
16. Turn **LFD CCW** again to bring up the leading edge.



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.

4.3.4 Class 1 Tuning

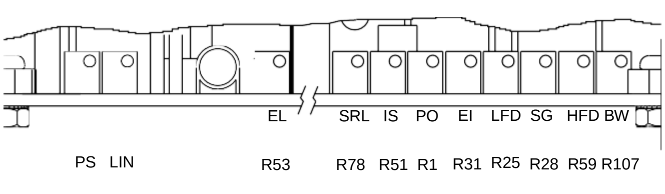
Trimpots

Table 12:Trimpots, Class 1 Board Turning

Trimpot	Name	Purpose
EI/R31	Error Integrator	This pot 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	Servo Gain	This pot 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	Low Frequency Damping	This pot 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	High Frequency Damping	This pot reduces the bump remaining from the **LFD** pot. 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	Bandwidth	This pot adjusts the center frequency of the **HFD** pot. 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** pot alone until the end.]

Step 1: Prepare the Class 1 Board

1. Detune the board:
   Detune the board by setting:
   SRL/R78
   EL/R53
   EI/R31
   SG/R28
   LFD/R25
   HFD/R59
   BW/R107
   fully **CCW**. This should take a maximum of 12 turns.



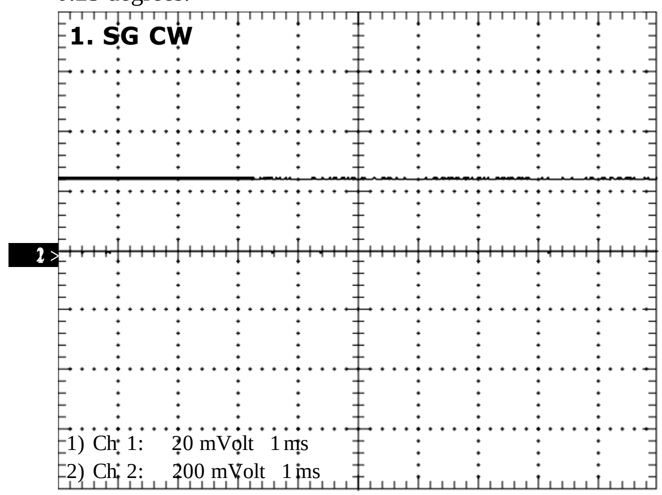
2. Turn on the power. Follow the instructions above each example plot that follows to change the traces in the previous plot to the current one.

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

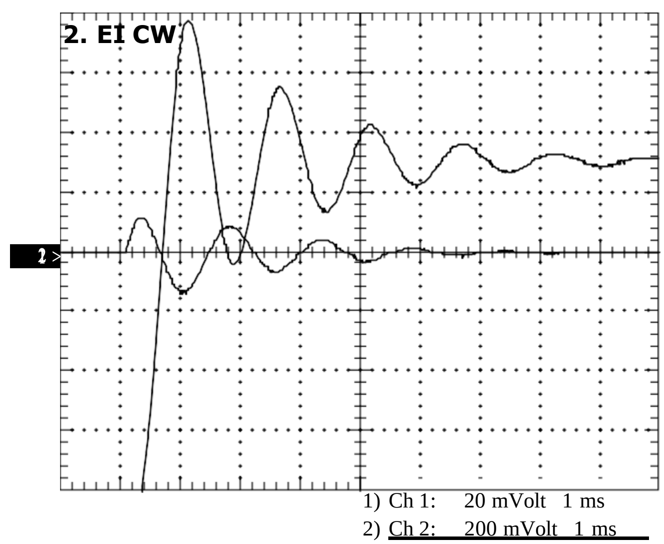
   This generally provides the correct initial damping for the system, but experiment may show that another adjustment is better.

Step 2: Tune the Class 1 Board

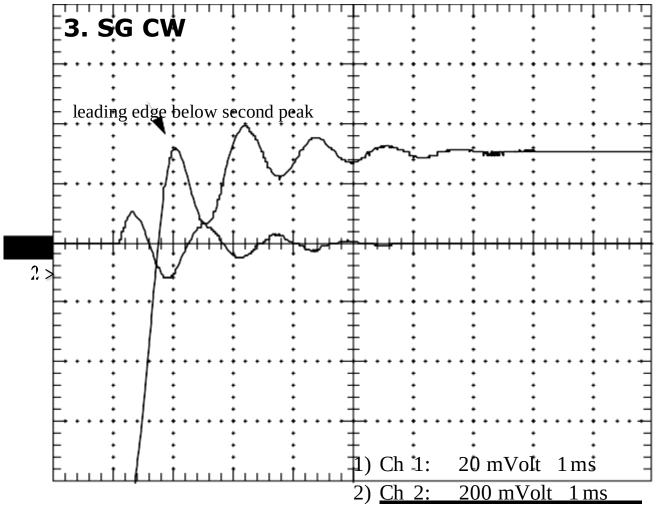
1. Turn **SG CW** until the scanner starts to center and the trace approaches 0 volts. Note: Adjust the Position signal on channel 1 to keep it on the screen. Use either the vertical position on the scope, or the offset on the signal generator. These adjustments are not mentioned in the procedure. The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



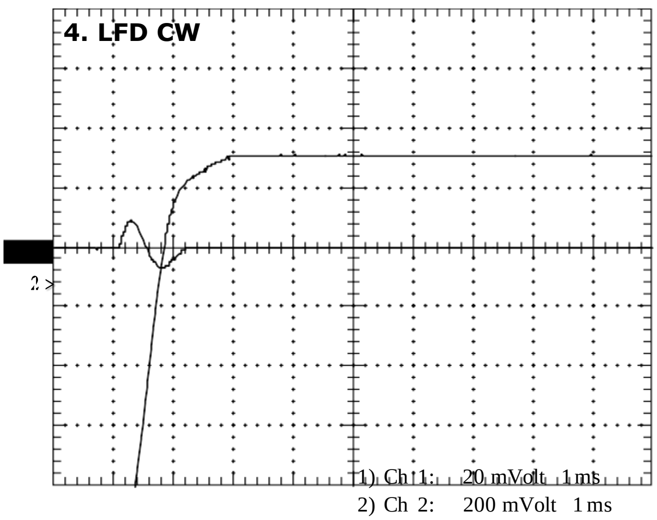
2. Turn **EI CW** until a step with a moderate amount of ringing appears.



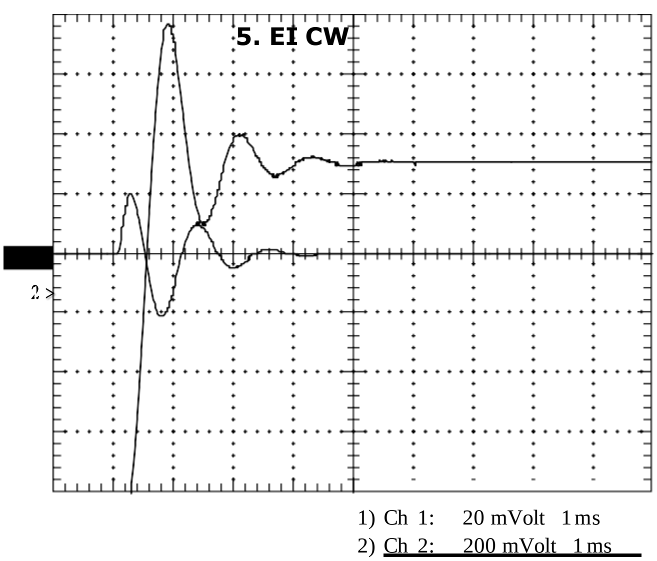
3. Turn **SG CW** until the leading edge is below the second peak.



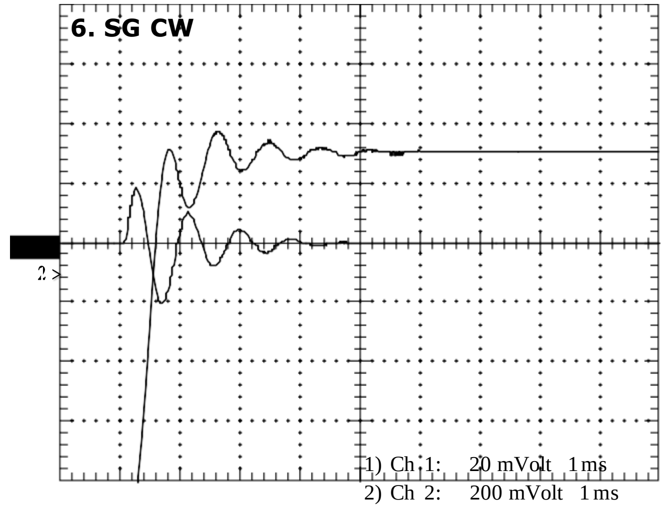
4. Turn **LFD CW** until there is a single bump. The bump may sink to the level of the top of the waveform, if there was sufficient HFD at the start.



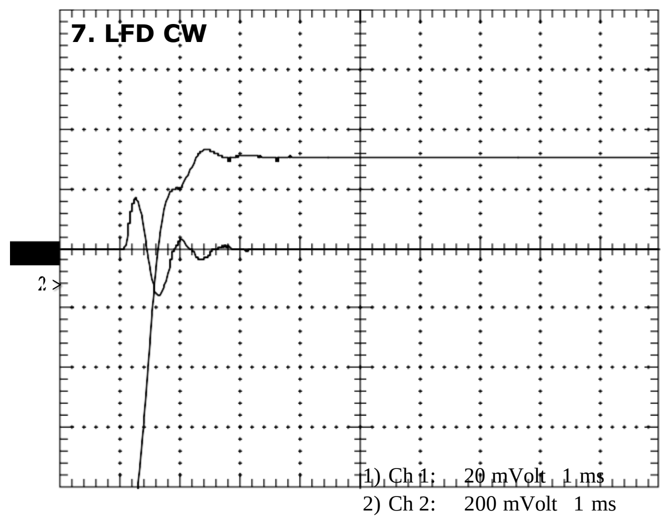
5. Turn **EI CW** until a step with a moderate amount of ringing appears.



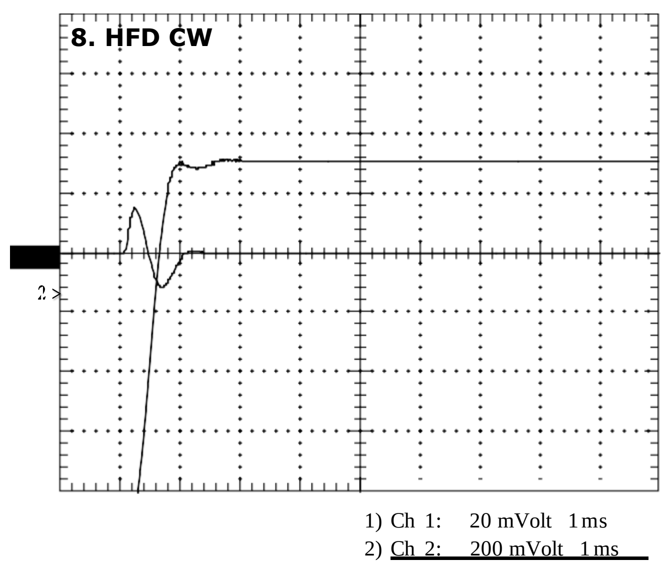
6. Turn **SG CW** until the leading edge is below the second peak.



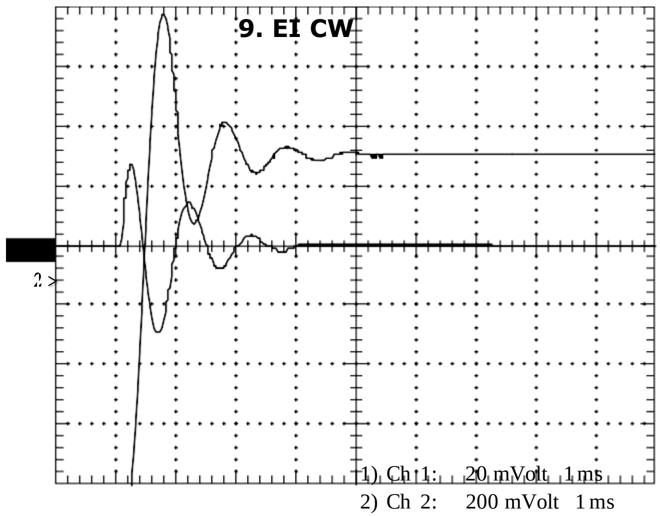
7. Turn **LFD CW** until there is a single bump.



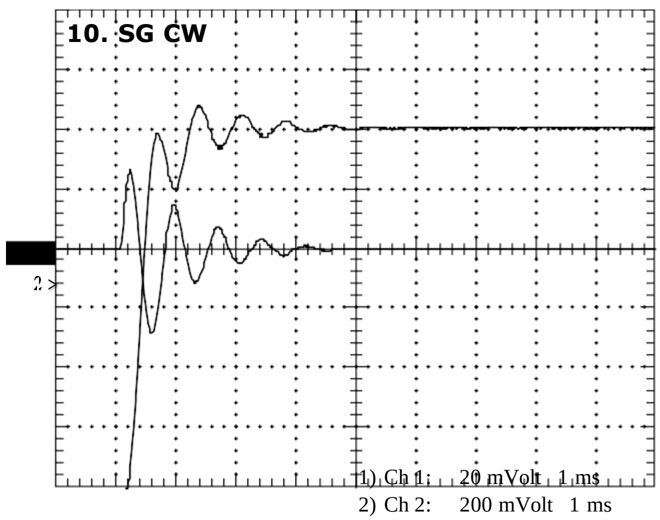
8. Turn **HFD CW** until the bump and dip are centered on the top of the step.



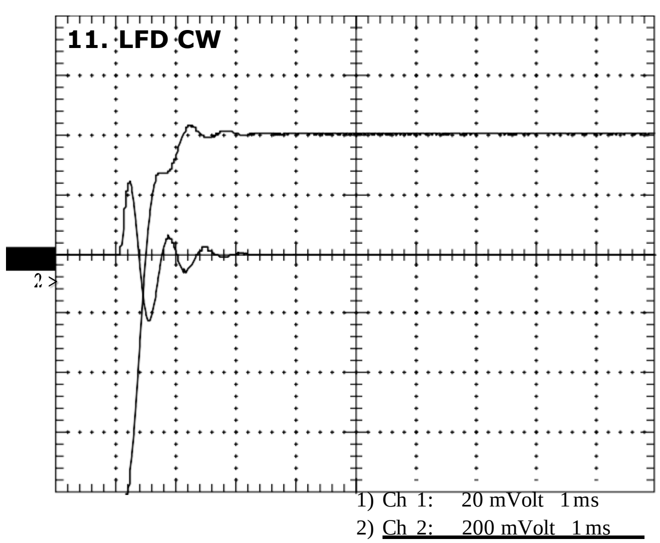
9. Turn **EI CW** until a step with a moderate amount of ringing appears.



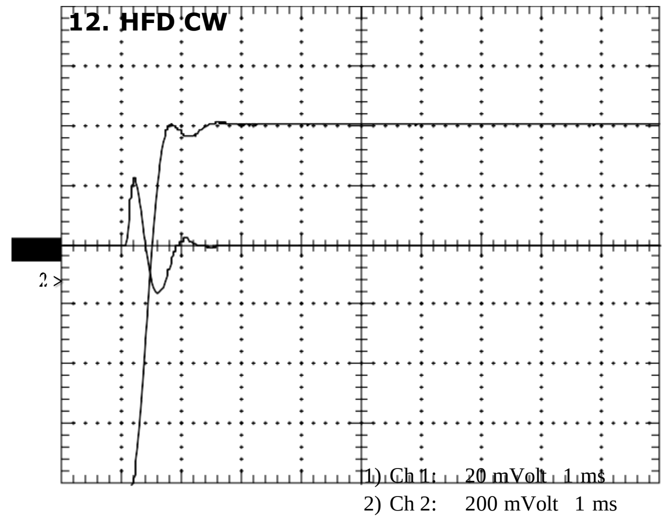
10. Turn **SG CW** until the leading edge is below the second peak.



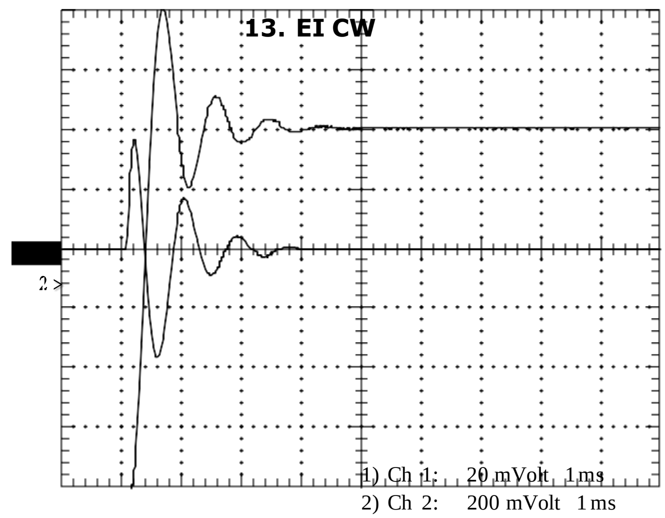
11. Turn **LFD CW** until there is one bump remaining.



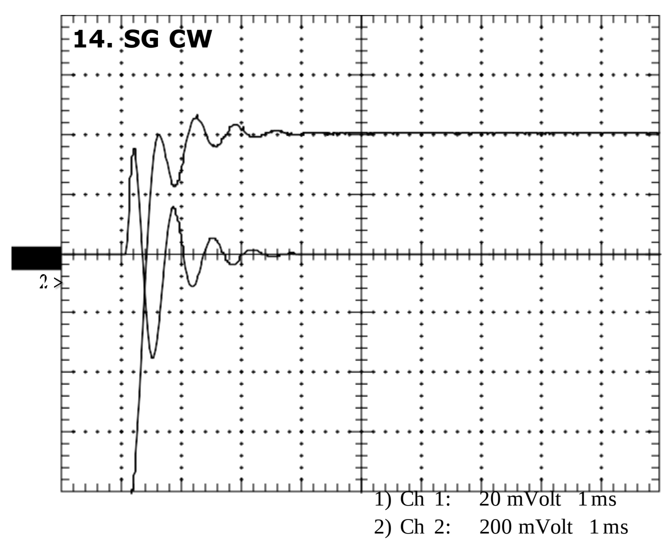
12. Turn **HFD CW** until the bump and dip are centered on the top of the step.



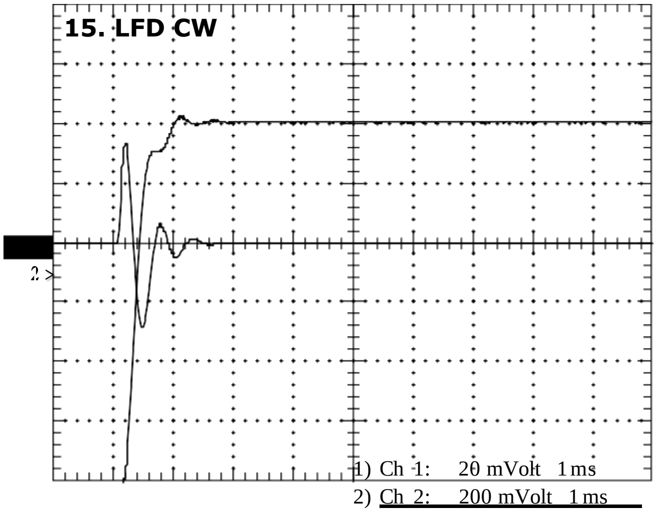
13. Turn **EI CW** until a step with a moderate amount of ringing appears.



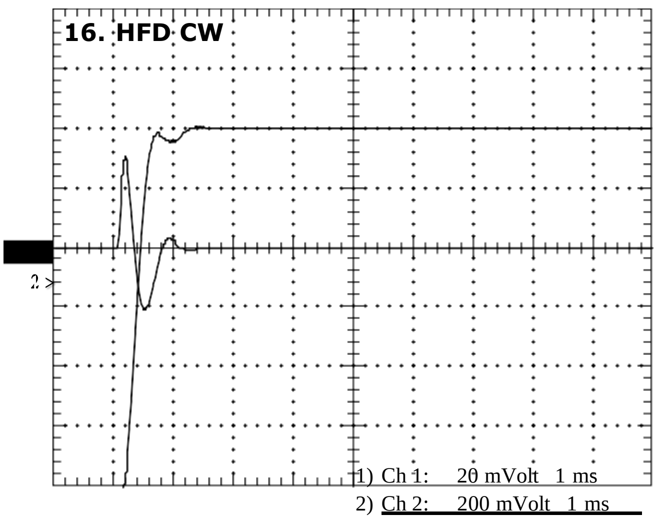
14. Turn **SG CW** until the leading edge is below the second peak.



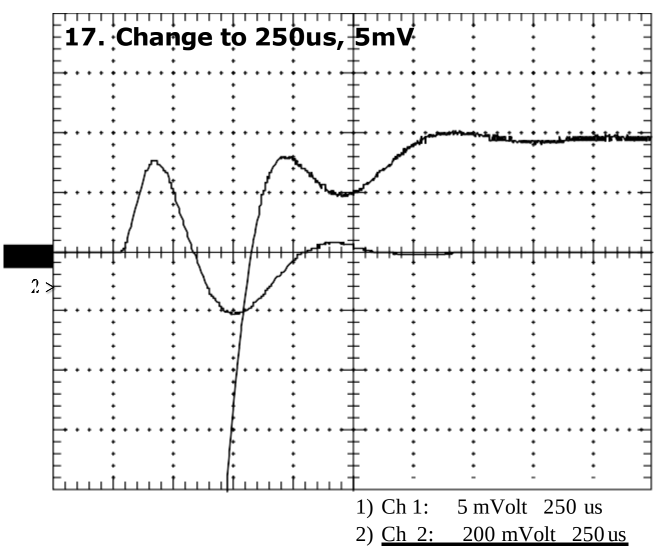
15. Turn **LFD CW** until there is one bump remaining.



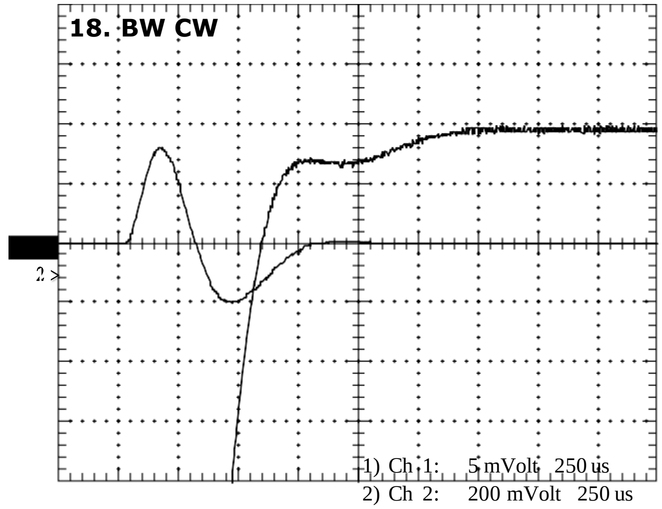
16. Turn **HFD CW** until the bump and dip are centered on the top of the step.



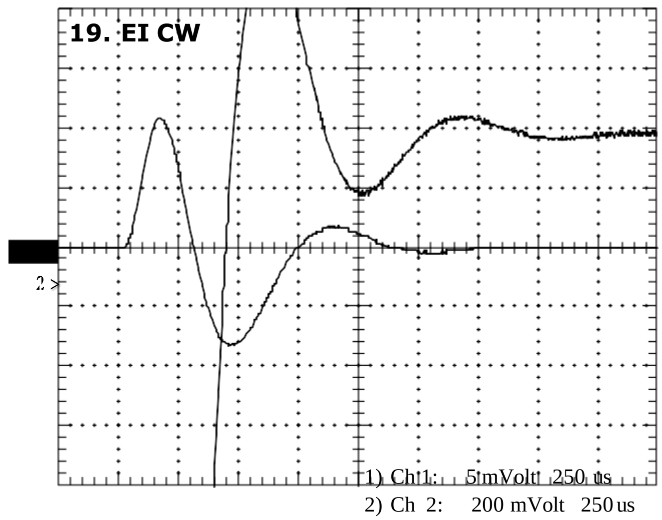
17. Change the Channel 1 scale to 5mV and the timebase to 250us.



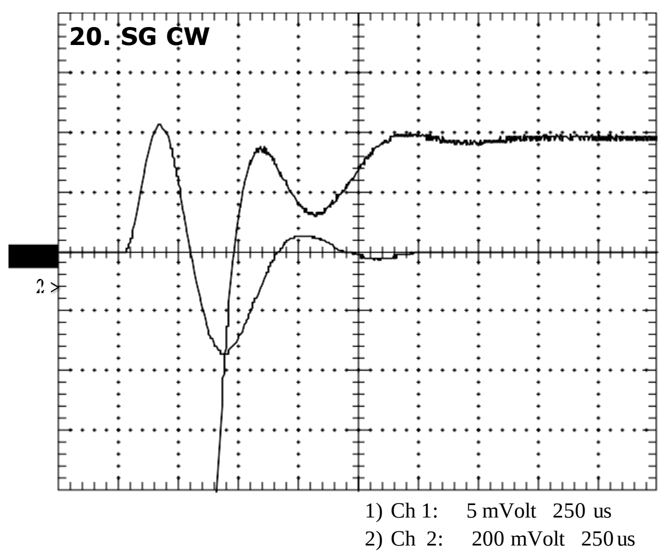
18. Turn **BW CW** to partly fill in the dip. **BW** moves the bumps left by the **HFD** and **LFD** sideways.



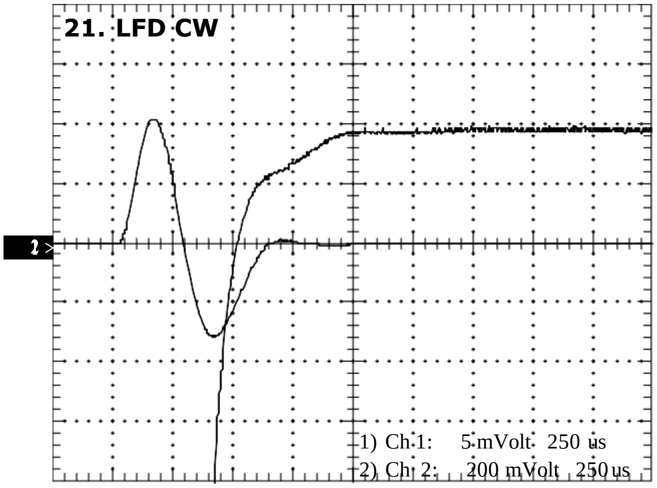
19. Turn **EI CW** until a step with a moderate amount of ringing appears.



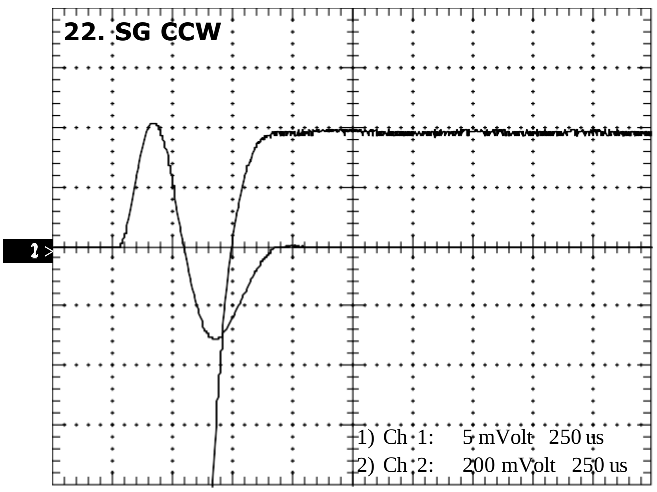
20. Turn **SG CW** to bring the leading edge down to the top of the step.



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.



4.3.5 Configuration 2 Tuning

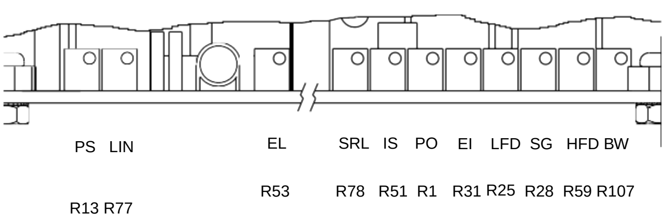
Trimpots

Table 13:Trimpots, Class 1 Board Turning

Trimpot	Name	Purpose
EI/R31	Error Integrator	This pot controls the level of integrated error in the system. This is apparent as a slow ramp at the top of the step. Turn it CW to increase the level of integrated error.
SG/R28	Servo Gain	This pot controls the basic gain of the system. Turn it CW to increase the speed of the step. This pot is used to set the speed of the system, and all other pots are adjusted relative to it to acheive proper system reponse. **SG** provides enough gain to center the scanner at the start of tuning (see Step 2 below). In general get the scanner within 50-100mV of center. Too much gain at this point will cause stability problems later.
LFD/R25	Low Frequency Damping	This pot 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	High Frequency Damping	This pot reduces the bump remaining from the **LFD** pot. 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	Bandwidth	This pot adjusts the center frequency of the **HFD** pot. 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** pot alone until the end.]

Step 1: Prepare the Configuration 2 Board

1. Detune the board:
   Detune the board by setting:
   SRL/R78
   EL/R53
   EI/R31
   SG/R28
   LFD/R25
   HFD/R59
   BW/R107
   fully **CCW**. This should take a maximum of 12 turns.



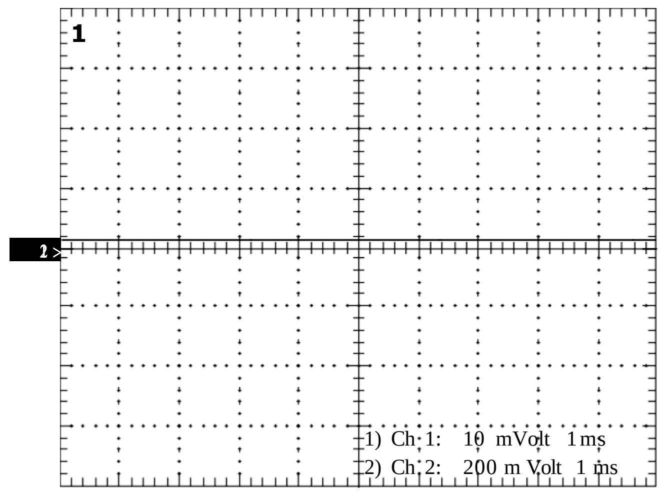
2. Turn on the power. Follow the instructions above each example plot that follows to change the traces in the previous plot to the current one.

3. Turn **LFD** five turns **CW** and **HFD** four turns **CW**.

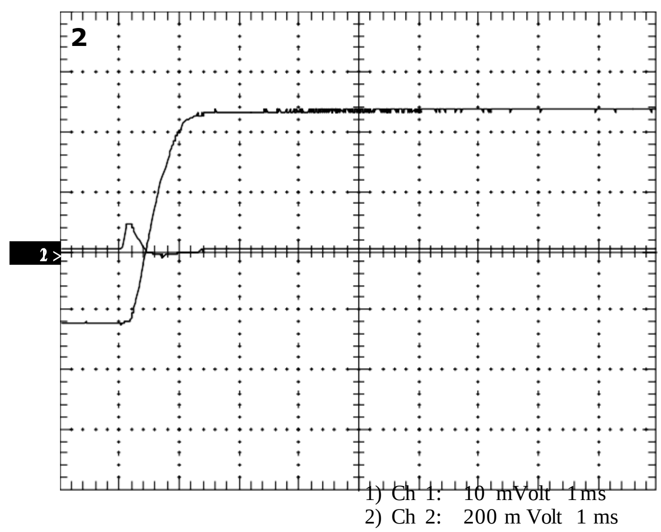
   This generally provides the correct initial damping for the system, but experiment may show that another adjustment is better.

Step 2: Tune the Configuration 2 Board

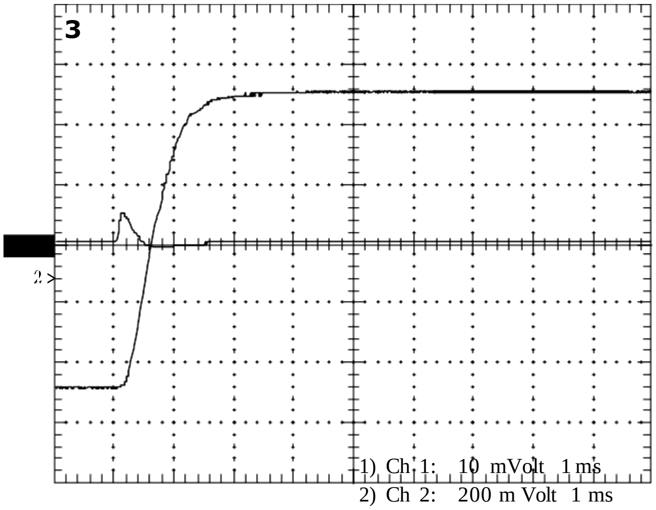
1. Turn SG/R28 CW until the mirror starts locking in the center position, and Vpos starts showing a square wave. Note: Adjust the Position signal on channel 1 to keep it on the screen. Use either the vertical position on the scope, or the offset on the signal generator. These adjustments are not mentioned in the procedure. The final tuning for the system in this example is 600us at 0.1 degree.



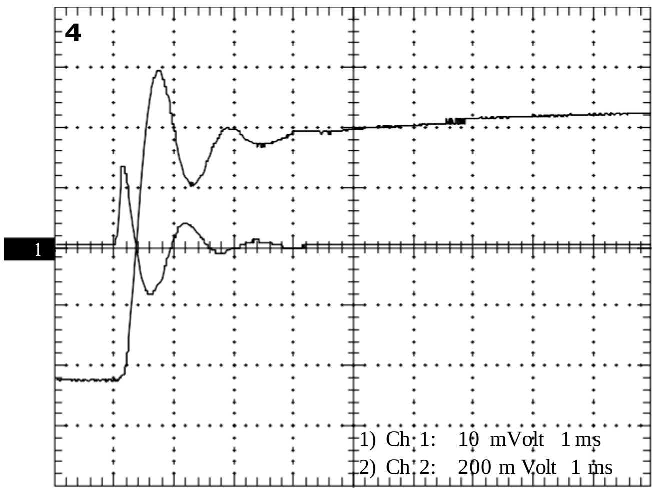
2. Turn SG/R28 CW until Vpos starts showing a square wave.



3. Turn **EI CW** until the top of the step is a straight as possible, without any overshoot.

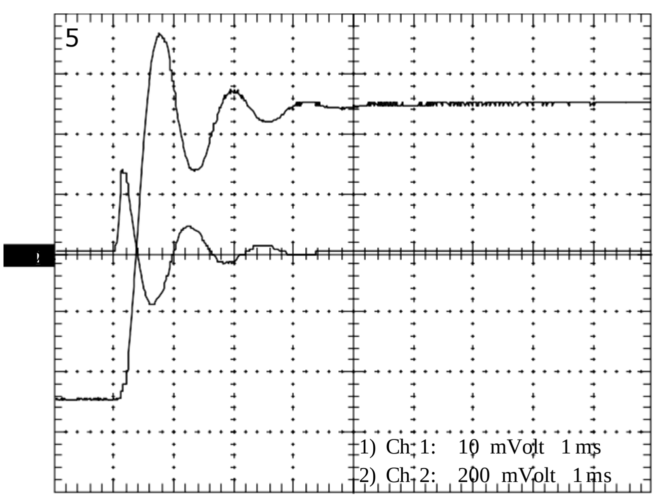


4. Turn **SG CW** until there is a moderate amount of ringing.

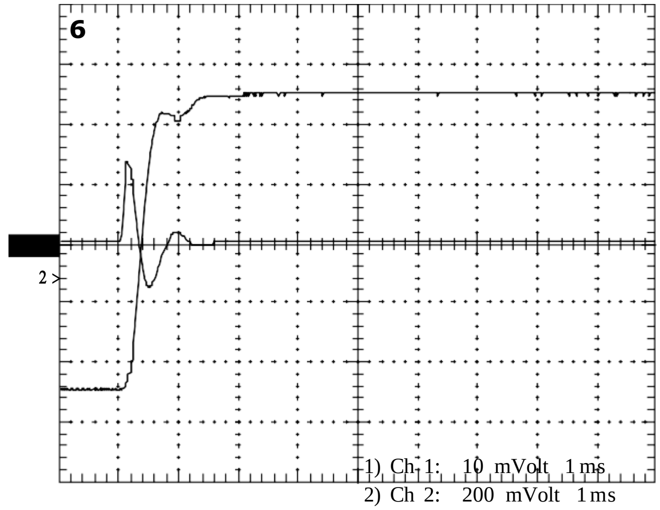


5. Turn **EI CW** until the top of the step is as straight as

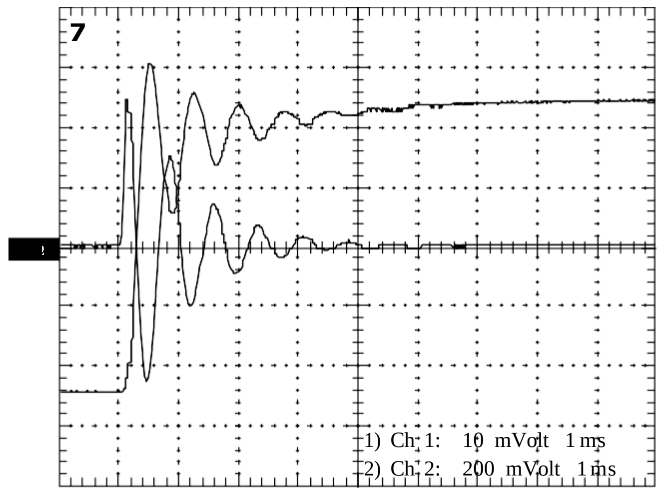
possible. Do not go beyond this point.



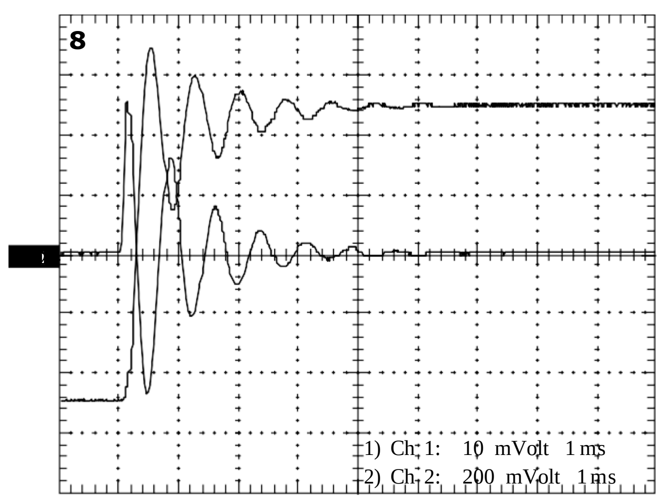
6. Turn **LFD CW** to damp the ringing. Stop when the straight part of the step is the longest.



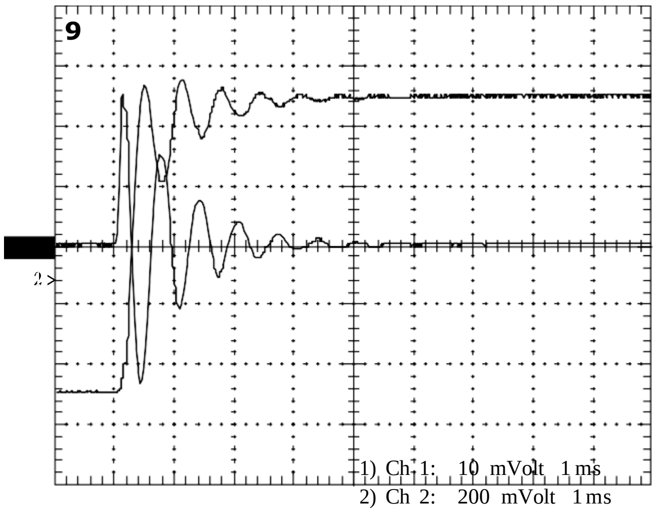
7. Turn **SG CW** until there is a moderate amount of ringing. The peak current is close the final value for the specified step time.



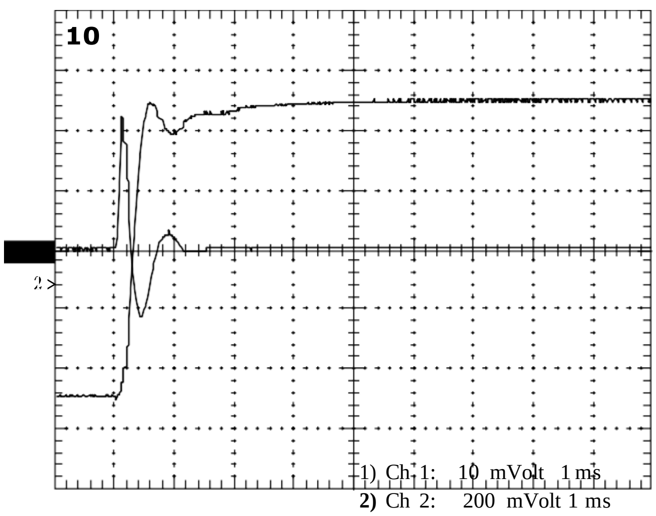
8. Turn **EI CW** until the top of the step is as straight as possible. Do not go beyond this point.



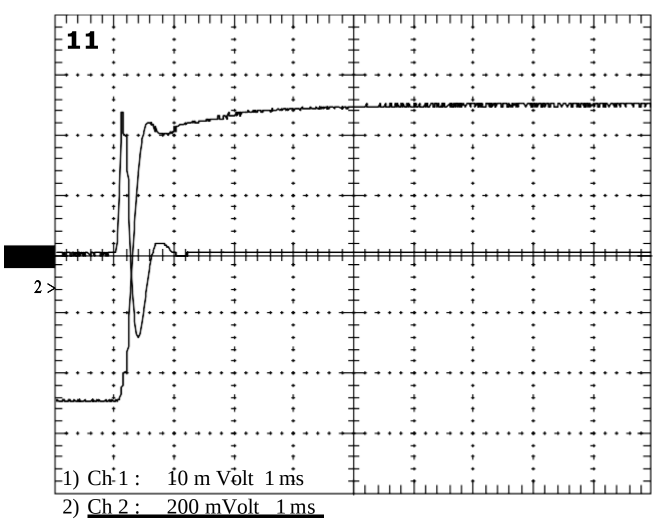
9. Turn **LFD CW** until the first peak is level with the top of the step.



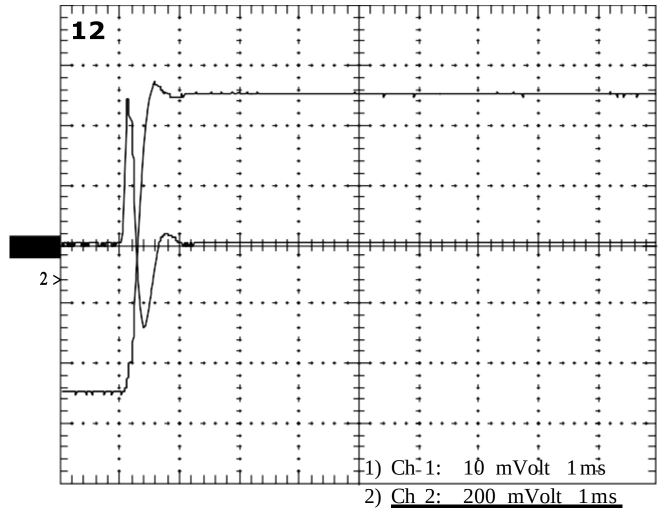
10. Turn **HFD CW** to reduce the ringing to a single spike.



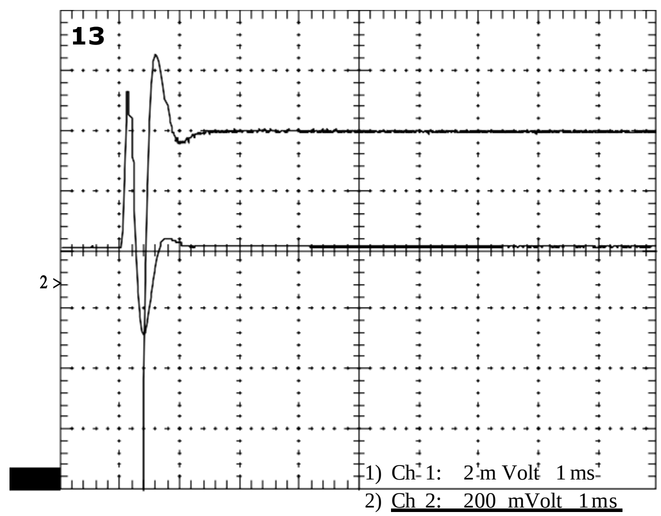
11. Turn **BW CW** to straighten out the kink to the right of the spike.



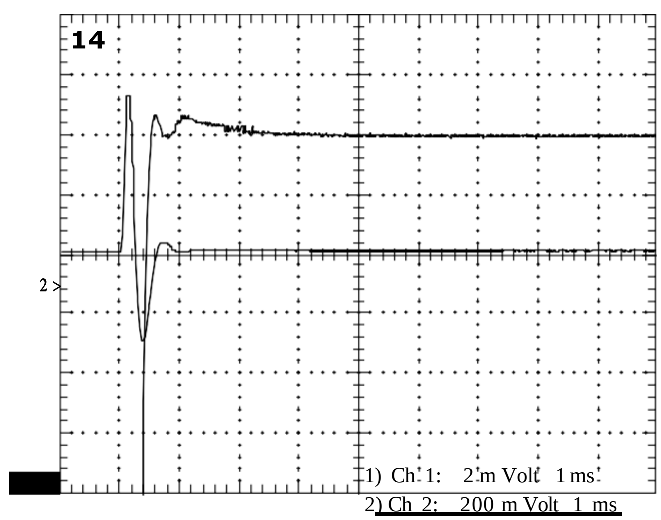
12. Turn **EI CW** until the top of the step is as straight as possible. The next stage is the fine tuning.



13. Change the vertical scale to 2mV/division.

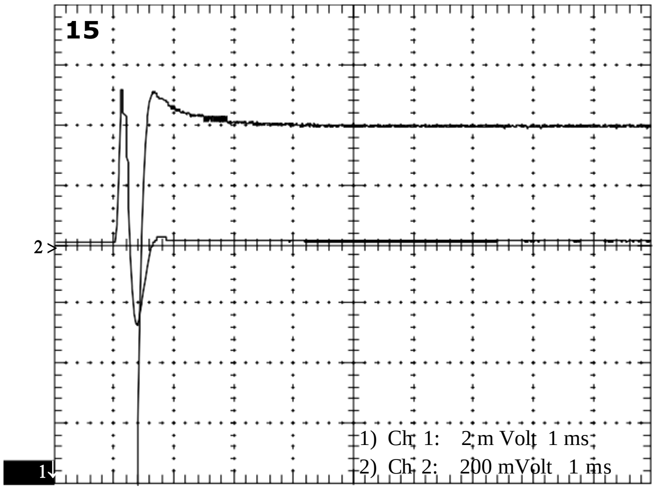


14. Turn **LFD CW** to reduce the leading spike. Stop when it is the same heaight as the start of the exponential curve.

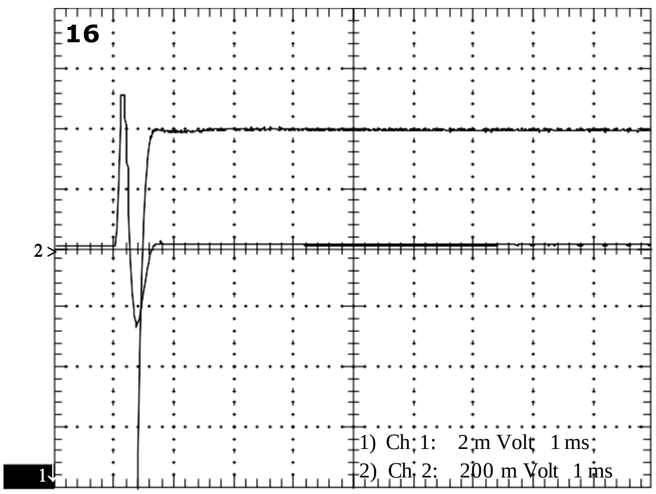


15. Turn **HFD CW** until there is a smooth exponential curve.

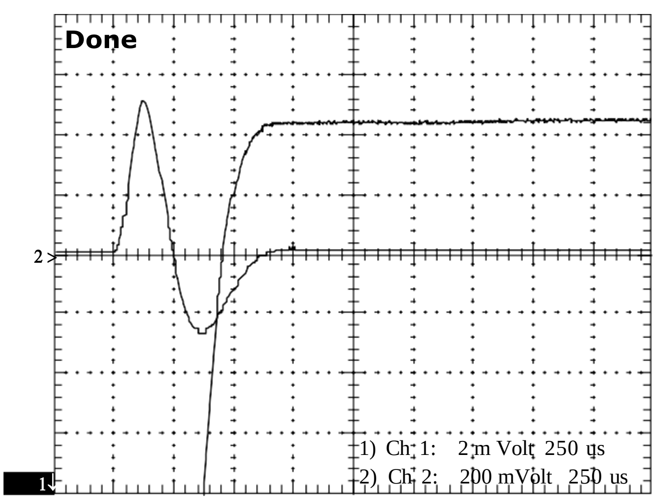
Readjust BW at this point if needed.



16. Turn **EI CCW** to flatten the top of the step. The settling is now within spec.



17. Change the timebase to check that the step time is correct. It is now settling to 1% of the final value in 600us, which is what was specified. Repeat steps 7 through 14 to adjust the speed of the step until the system is critically damped and tuned to the correct speed as illustrated below.



4.4 Slew Rate Limiter Adjustment

After the small angle step response is set (*"Section 4.2: Small Angle Step Response Tuning" on page 20*, 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.

Configuration 2 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, but it may be desirable to keep the output stage from saturating for critically damped performance.

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.

4.4.1 Adjusting the Slew Rate Limit - Class 0

Step 1: System Setup

1. Check that the Slew Rate Limiter is enabled.
   W10 1+2
   W11 1+2

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	TP1 (Position)	10mV/div
Channel 2	TP8 (Power Amp Out)	10V/div
Timebase	1ms/ div nominal	
Trigger	External (from the generator sync)	

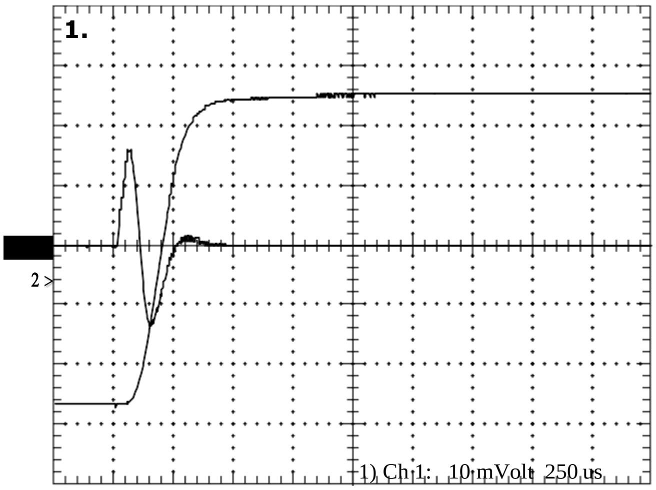
Generator	
Square wave	
Frequency	30Hz nominal
Amplitude	50mVpp, measured at TP1
Offset	0V

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.

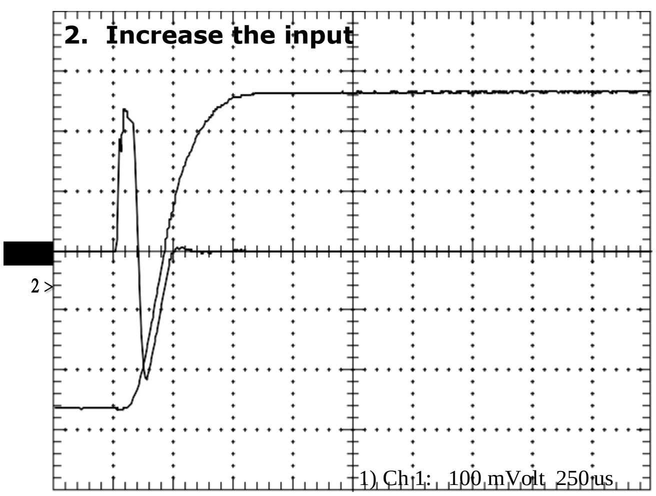
Step 2: Adjusting the Class 0 Board

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.



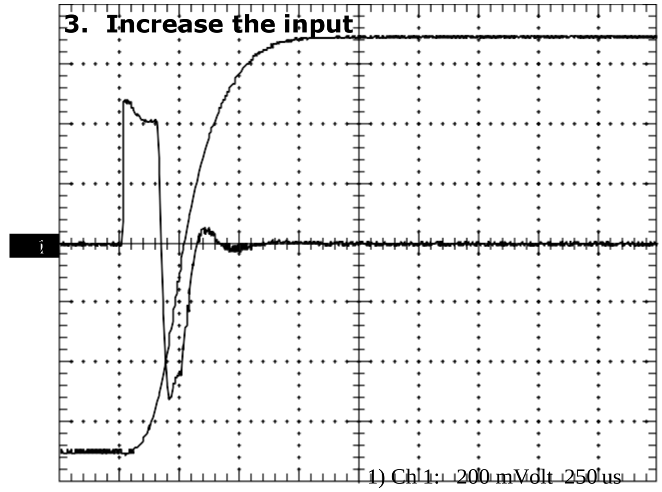
1) Ch 1: 10 mVolt 250 us
2) Ch 2: 2 Volt 250 us

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



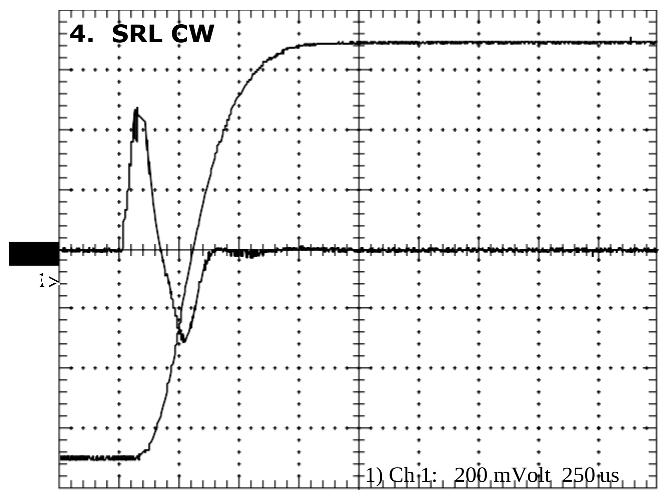
1) Ch 1: 100 mVolt 250 us
2) Ch 2: 10 Volt 250 us

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



1) Ch 1: 200 mVolt 250 us
2) Ch 2: 10 Volt 250 us

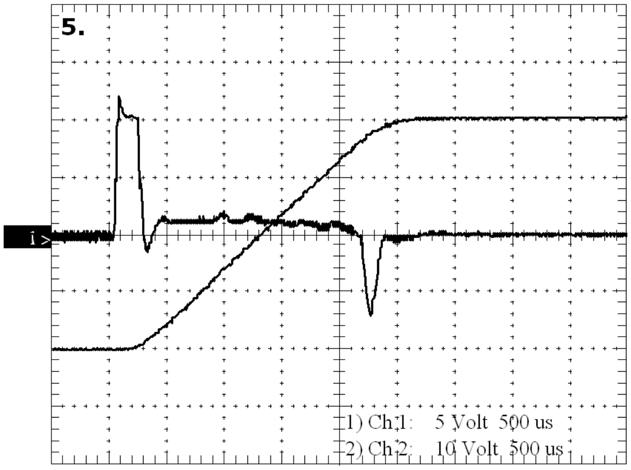
4. Turn SRL/R78 CW until the second spike doesn't clip, and the first spike clips moderately.



1) Ch 1: 200 mVolt 250 us
2) Ch 2: 10 Volt 250 us

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.



4.4.2 Adjusting the Slew Rate Limit - Class 1 and Configuration 2

Step 1: System Setup

1. Check that the Slew Rate Limiter is enabled.
   W10 1+2
   W11 1+2

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	TP1 (Position)	10mV/div
Channel 2	TP8 (Power Amp Out)	10V/div
Timebase	1ms/ div nominal	
Trigger	External (from the generator sync)	

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.

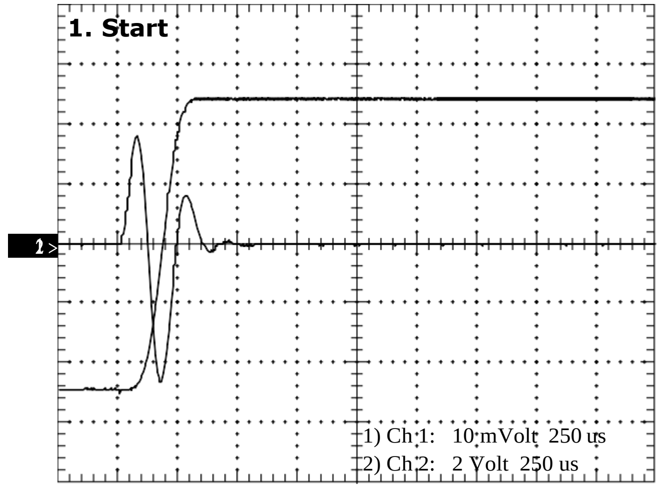
If the supply voltage sags under load, or the system reaches its maximum output current before the maximum output voltage, another formula will work better.

Vpeak=0.85 Vclip

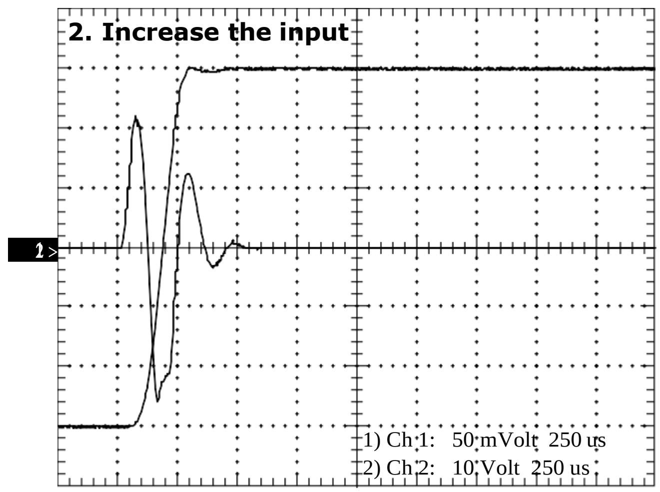
That is, measure the drive voltage when it just clips (**Vclip**), and then set it to 15% below that.

Step 2: Adjusting the Class 1 or Configuration 2 Board

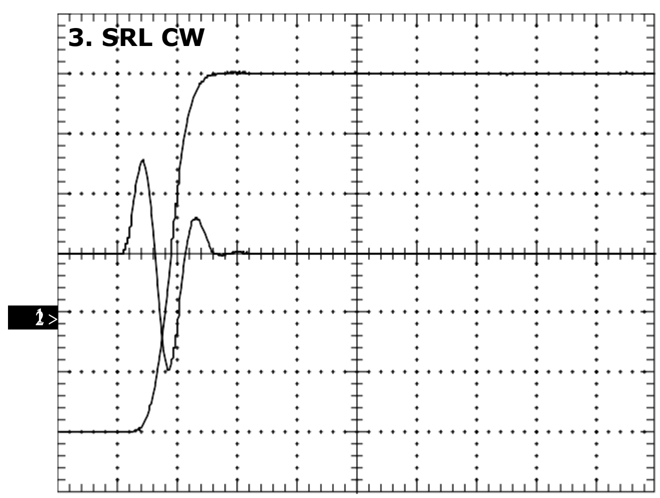
1. Start with a carefully tuned small-angle step. Channel 2 is the output drive voltage of the power amplifier. When it clips (when the peak squares off or becomes ragged), the amplifier has reached the maximum drive voltage or current possible with the supply and load.



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.

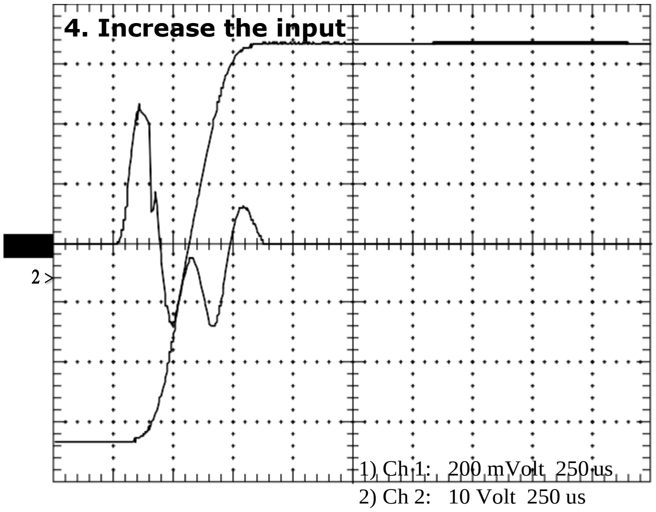


3. Turn SRL/R78 CW until both peaks are clean. The step now settles without the dip.

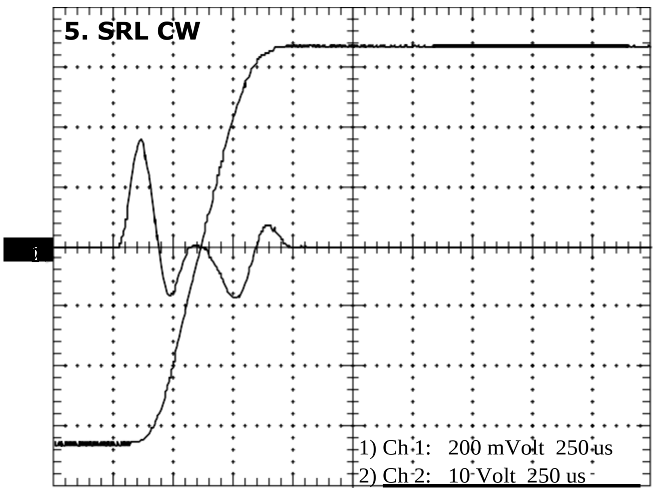


1) Ch 1: 50 mVolt 250 us
2) Ch 2: 10 Volt 250 us

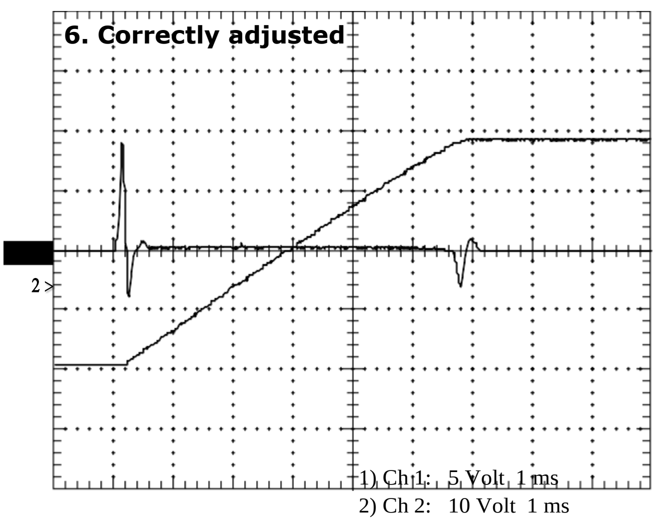
4. Increase the input level until the drive voltage signal starts clipping. The positive peak is clipping.



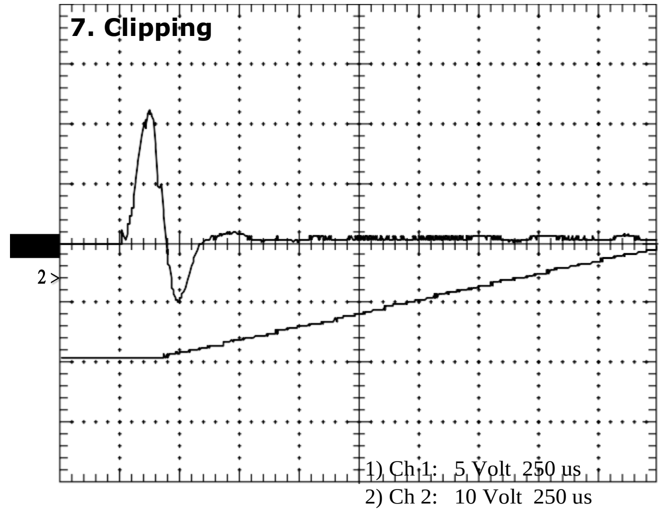
5. Turn SRL/R78 CW until the positive peak is clean.



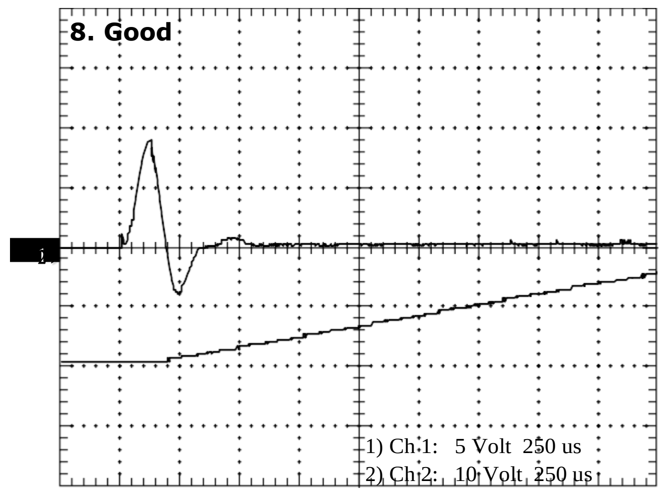
6. Increase the input and adjust SRL/R78 until the maximum angle for the system is reached, which is 40 degrees in this example, and the peak voltage is set to the calculated limit.



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



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



4.4.3 The Error Limiter - EL/R53

The error limiter is enabled on some Class 0 boards (never on Class 1 or Configuration 2 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 fully CCW unless it is used.

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 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	TP1 (Position)	10mV/div
Channel 2	TP8 (Power Amp Out)	10V/div
Timebase	1ms/div nominal	
Trigger	External (from the generator sync)	

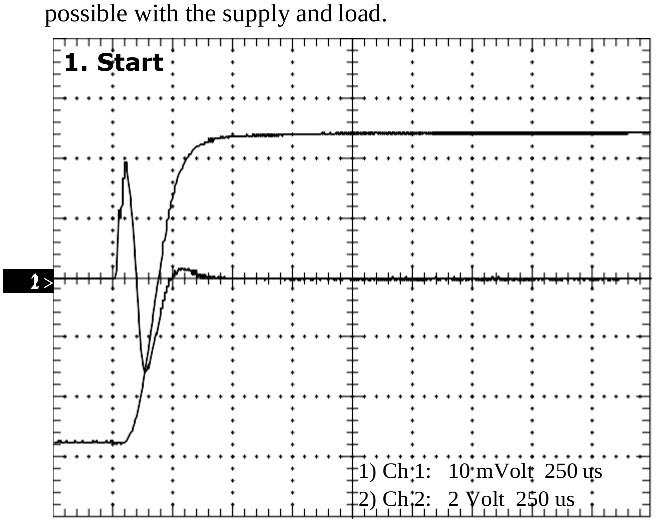
Generator	
Square wave	
Frequency	30Hz nominal
Amplitude	50mVpp, measured at TP1
Offset	0V

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

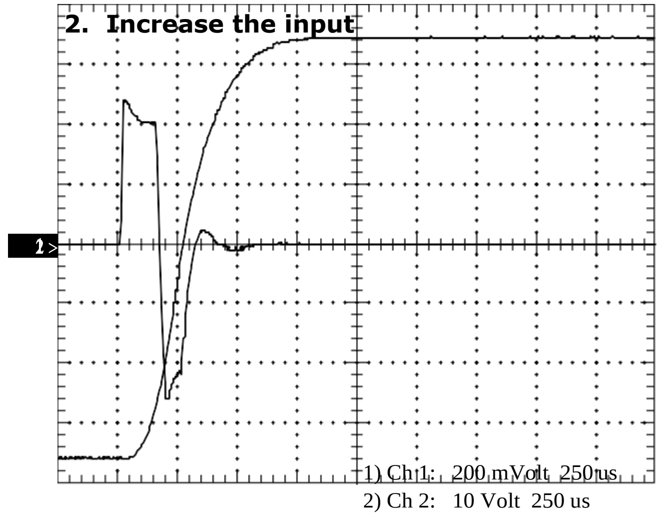
Lower the frequency of the square wave with high-inertia loads, to reduce the average power.

Step 2: Adjust the Class 0 Board

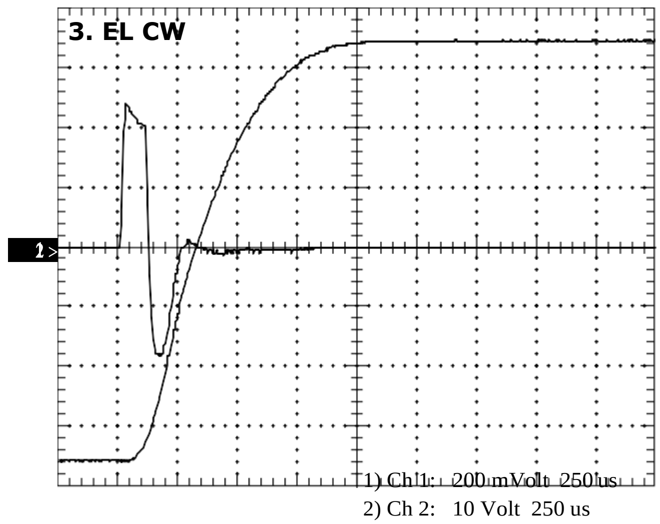
1. Start with a carefully tuned small-angle step. Channel 2 is the output drive voltage of the power amplifier. When it clips (when the peak squares off or becomes ragged), the amplifier has reached the maximum drive voltage or current possible with the supply and load.



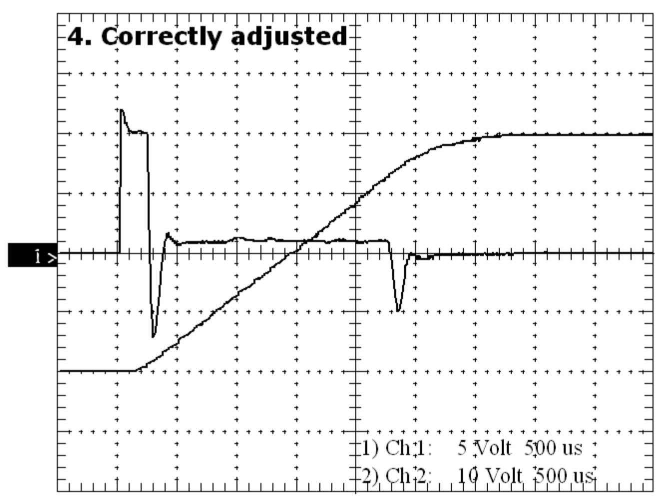
2. Increase the input until the drive voltage starts clipping. Note that it is clipping on both the positive and negative peaks.



3. Turn EL/R53 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 as needed.



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

The 671 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 trim pot 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 the pot 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.

4.5 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.

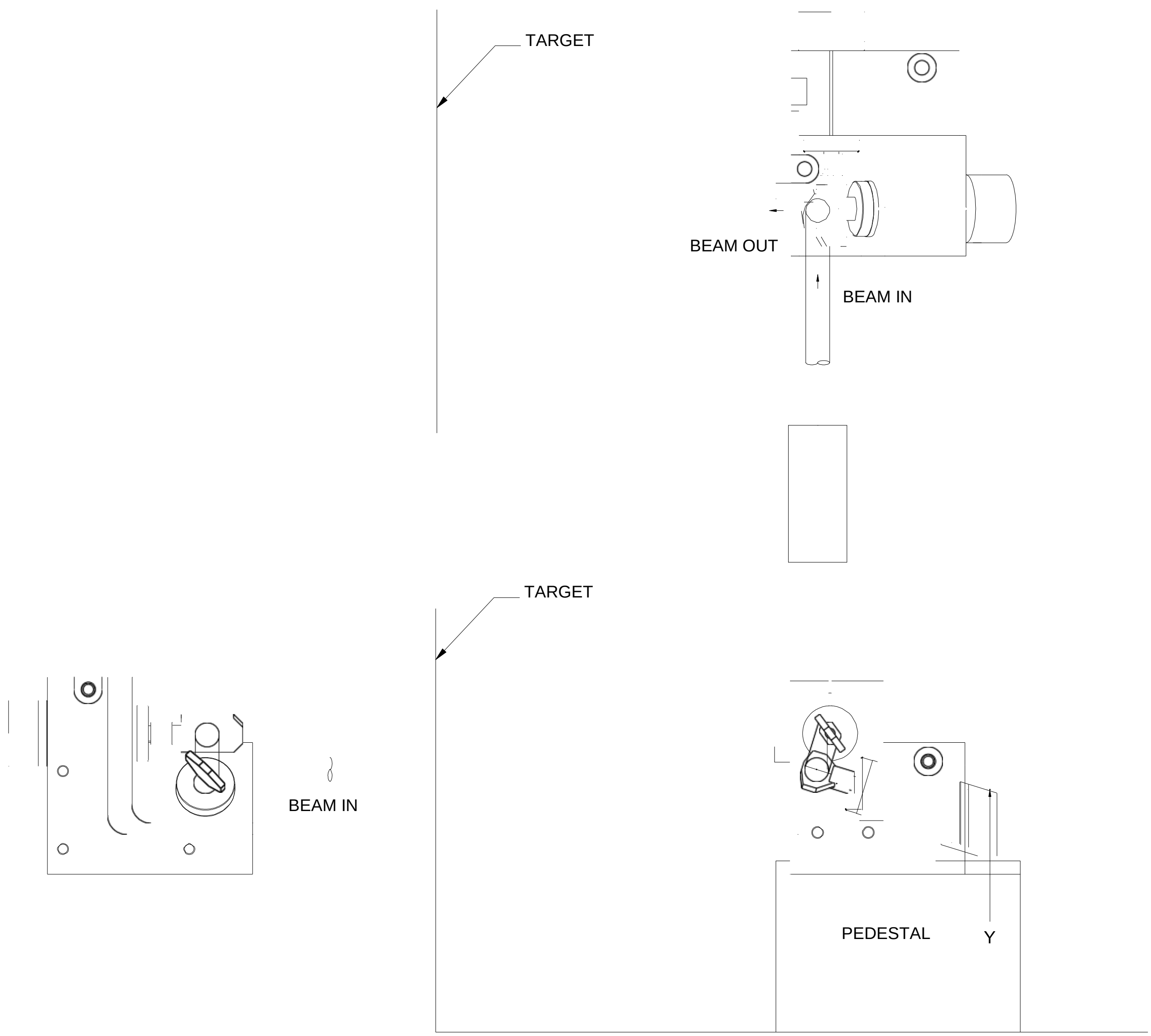
Mirror Alignment Mode reduces the loop gain of the system so the mirror can be loosened on the shaft, aligned, and retightened, without the system going unstable. The scanner will center itself, and will feel soft when the shaft is rotated by hand. In Class 1 the input signal is disconnected, and in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

4.5.1 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 in the XY mount 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.

4.5.2 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 W5 to W5 1+2. See *“Section 3.1: Outline Drawings” on page 15*.
4. If the system is in analog mode, ground the input. If the system is in digital mode center the output of the DAC (digital 32768).
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 W5.

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 W5 back on W5 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.

4.5.3 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 W5 to W5 1+2. See *“Section 3.1: Outline Drawings” on page 15*.
4. If the system is in analog mode, ground the input. If the system is in digital mode center the output of the DAC (digital 32768).
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 W5.

Step 2: Alignment

See *“Section 8.0: Appendix B: Mirror Handling and Mounting” on page 55* 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 W5 back on W5 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 to correct it.

4.6 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.

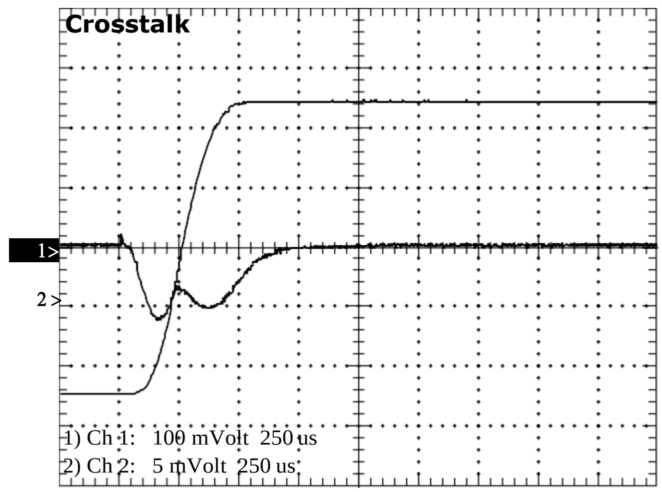
2. Monitor the Position signal (TP1) on both boards and set the scope to reasonable scales for the large and small angle signals. In general 30Hz is a reasonable frequency, but it may be necessary to use a lower frequency with high-inertia loads.

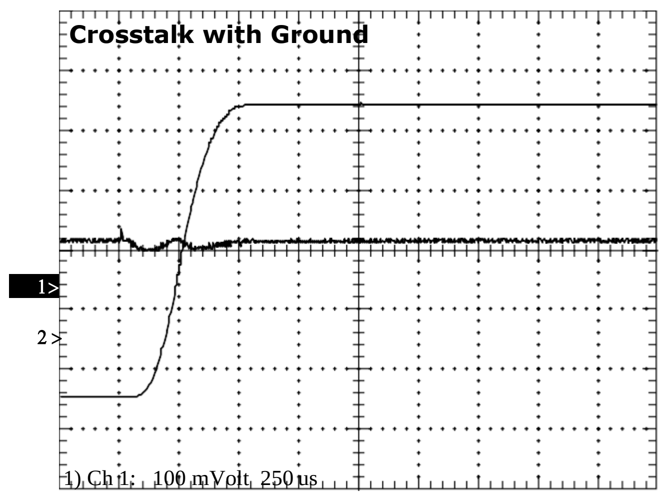
3. Make sure that both scanners are solidly mounted. Any movement of the scanner will make it difficult to tune the system accurately and to get a good match.

Step 2: Checking for Crosstalk

1. Check for crosstalk between the X and Y channels. Disconnect the input from one channel, run the other channel with a small-angle square wave, and look at the position signal on both channels. The signal that appears on the channel without an input is caused by high currents in the ground lines. The simplest way to reduce the crosstalk is to connect the heaviest practical ground directly between the power grounds at the power connectors on the boards.

   Crosstalk between the channels will make it very difficult to get a good XY match.





2) Ch 2: 5 mVolt 250 us

Step 3: Matching

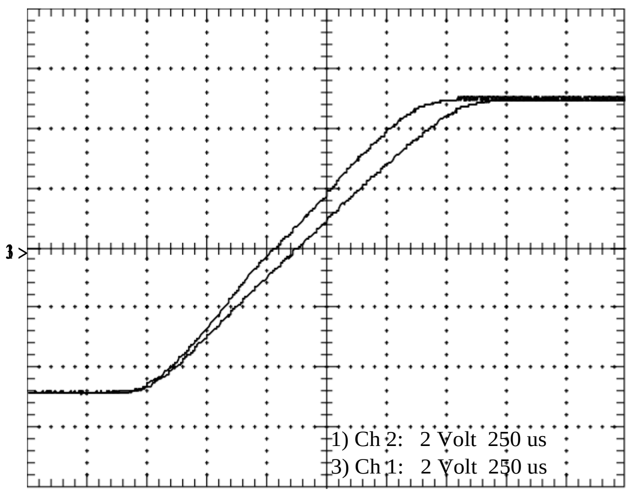
This procedure assumes that the Step Response times were approximately matched when the two systems were tuned.

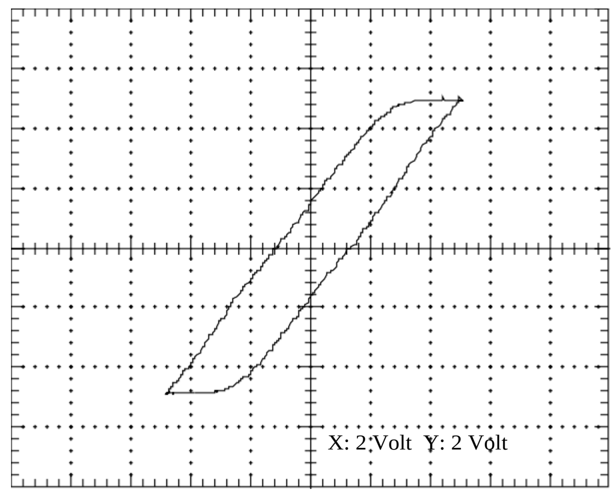
Matching is normally done at two angles: the largest angle at which the system normally operates, and a small angle where the system is bandwidth limited, usually the same angle the system was tuned at. The systems are matched at large angle by adjusting the slew rate limiter. They are matched at small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

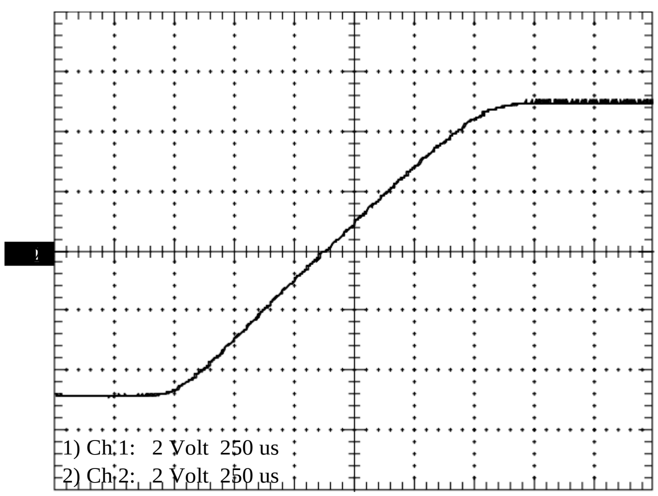
In most XY systems one channel, usually the Y, has higher inertia and a slower step reponse time than the other. **Always tune the slower channel first very carefully, then leave it alone, and do all the matching adjustments on the other channel.** Even if the X and Y mirrors are identical, choose one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

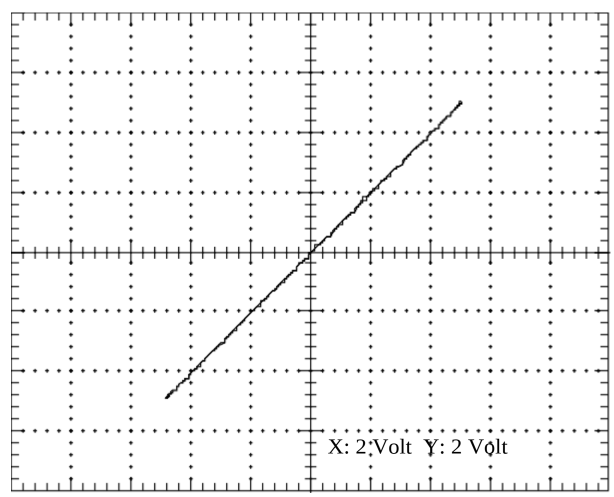
In these plots the small-angle step is 0.25 degrees, but experiments may show that some other small step (in the range the system is bandwidth limited) gives better results. The slow channel, the one that is never readjusted, is called the Y channel in this procedure.

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 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.

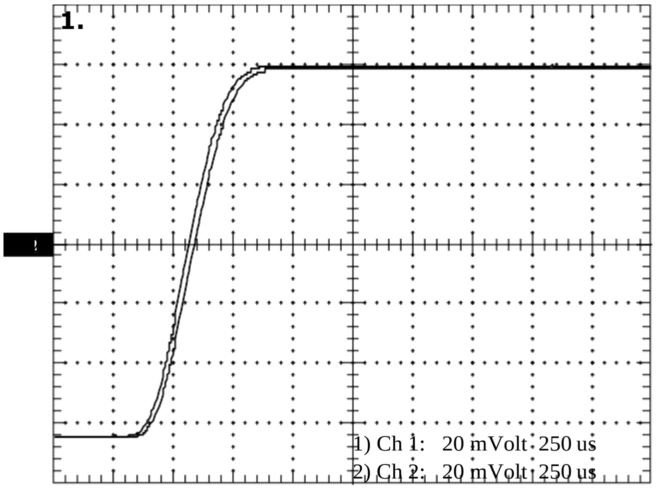


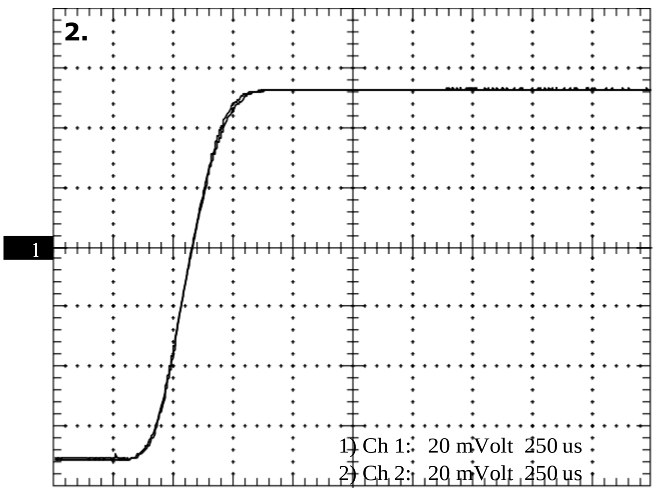


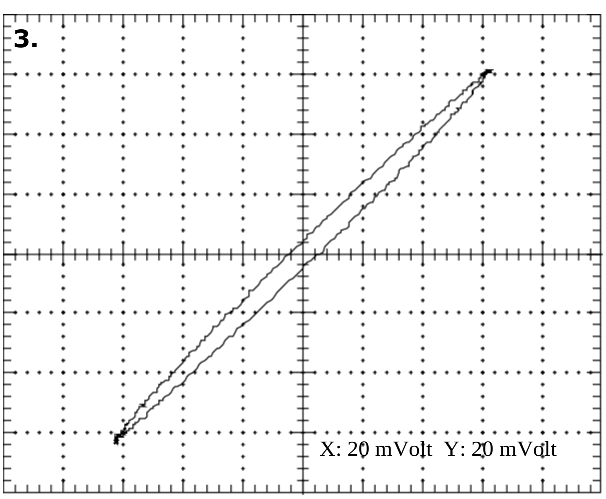


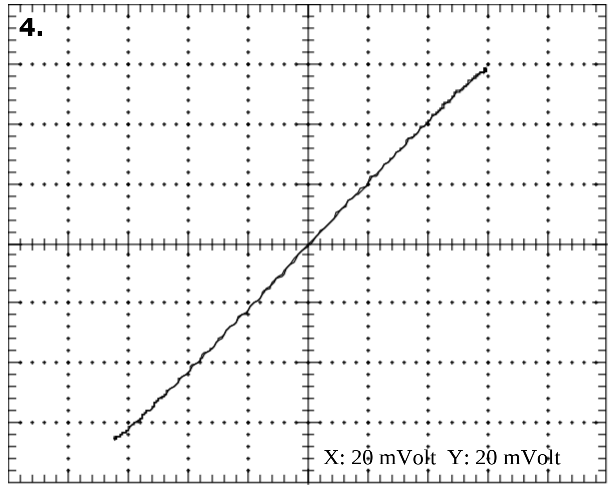


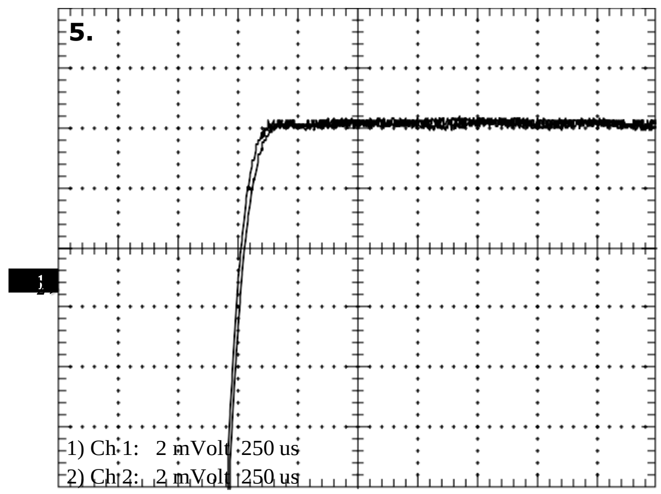
2. Match the Small Angle Steps:
   - Plot 1 One channel is faster than the other.
   - Plot 2 Retune the X channel to match the Y as closely as possible.
   - Plot 3 Mismatched channels in XY format.
   - Plot 4 Matched channels in XY format.
   - Plot 5 When retuning always check that the damping and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









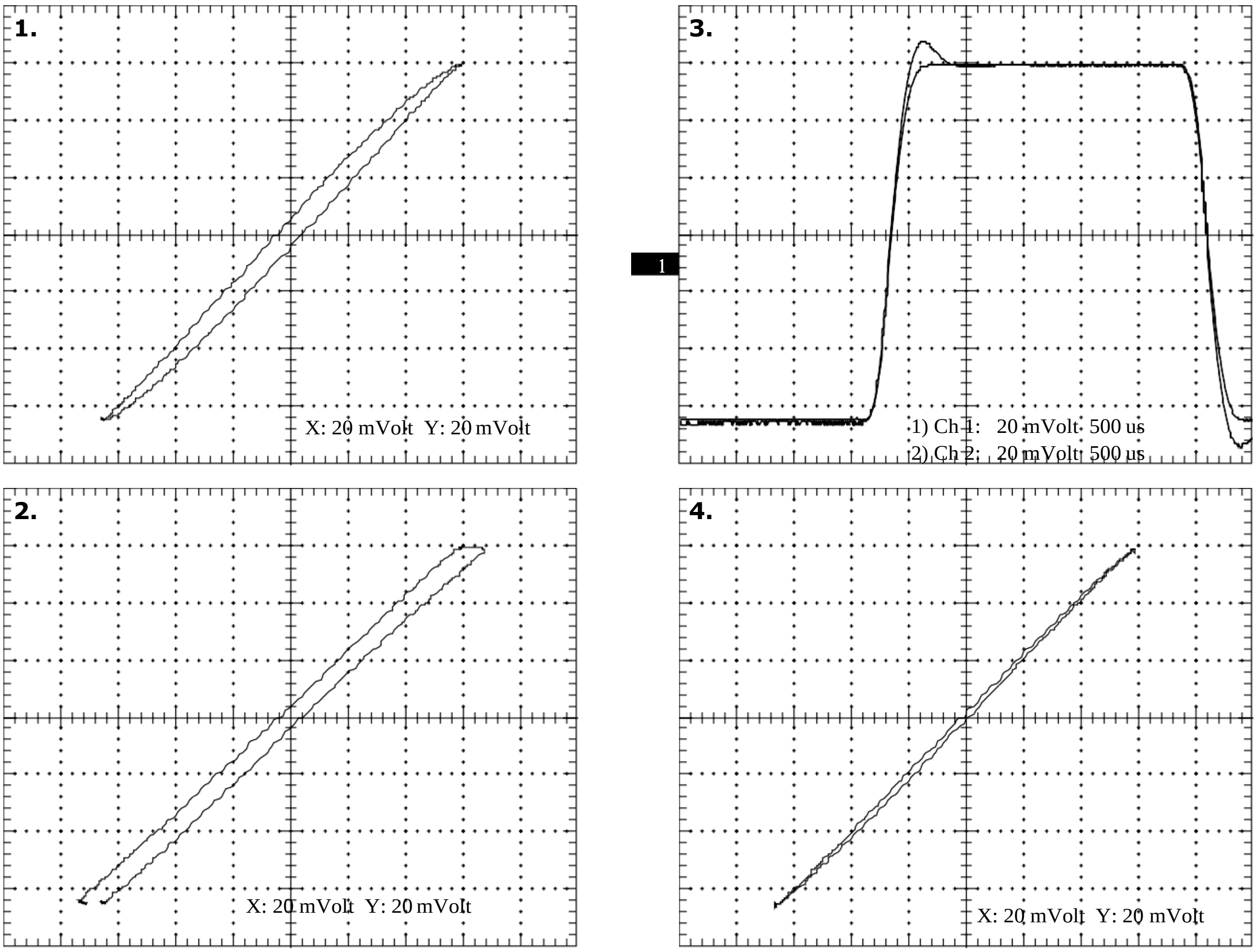


3. Recheck the Large Angle Step Match
The large angle and small angle matches interact, and it is usually necessary repeat both adjustments several times to get an exact match.

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 (class 1 or configuration 2 only) on the X channel board until the two lines come together, then continue turning the pot 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 a few cycles to reach an exact match.



5.0 Fault States

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

Table 14: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 mechanical 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 671 board is accomplished by the I2*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 “Power Flag" Output signal will be activated when within 10% of tripping the fault detector. 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, check that 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.)
90% Power	• When the current reaches 95% of the maximum RMS current (90% of maximum RMS power), J4.6 is pulled low by an open collector to -15V.

6.0 System Integration

6.1 Introduction

This section covers integrating the 671 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.

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, 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 to position 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 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 671 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 an XY system running at full power can be very large, as large as 20A RMS and 50A peak.

6.3.1 Supply Voltage

The 671 boards can be configured for ±15V supplies, or for ±18-30V supplies. In general the larger the supply voltage (up to the ±30V limit), the faster the large-angle step. Large-angle step response speed is often limited by output amplifier saturation. Therefore a higher supply voltage will allow faster large-angle step response before saturation occurs. The small-angle step response time is not substantially affected by the supply voltage.

Supply voltage linearly affects the power dissipation by the output amplifiers on the 671 servo. A +/-30V supply voltage will cause about twice as much power to be dissipated to the 671 heatsink bracket as a 671 board with a +/-15V supply running the same galvos. Therefore heatsink selection and thermal design should be considered when selecting a power supply voltage.

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. If a switching supply is used, care should be taken to reduce or eliminate switching frequency noise as much as possible. A supply that uses fold-back current limiting can cause problems if the peak currents drawn by the system shut the supply down. If a supply with fold-back current limiting is used, the current limit should be high enough that the initial current (due to local electrolytic capacitors and initial mirror centering) when the 671 is first powered on does not trip the power supply current limit. Also, a supply with foldback current limiting should not reset automatically to normal operation. Supplies that fold back for a few seconds and then reset to normal operation can cause an oscillatory condition with the 671 inrush and mirror-centering current on power-up.

In general regulated power supplies are not required, but the supply voltage 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 will shut the board down, and the system will restart. The 470uF capacitors on the supply lines on the 671 board and the HPO module provide a moderate amount of filtering, but when peak currents are extremely large, more capacitance on the power supply output will help. Class 1 boards can fault during operation involving high peak currents if the power supply voltage drops low enough that the output amplifiers saturate.

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 250ma for each 671 board in the system.

Consider a 6880 XY system running on a ±28V supply. The maximum RMS current for the 6880 is 7.7A. The two scanners need 15.4A, and the two boards need another 500ma. The minimum supply to run the system at full power would be 16A at

±28V. The peak current, assuming the 671 has the HPO, would be 50A. 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 scanner 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 TP3 on the 671 board, and then allow something extra for the normal variation in systems and tuning. Use the current to voltage conversion factor from *"Table 7: Current to Voltage and Coil Temperature Calculator Table" on page 9*.

Consider a 6880 XY system used for raster scanning. The measured current at TP3 on the X channel is 3.2A RMS (1.6V RMS at 0.5V/A), and the current on the Y channel is 500mA. Allow another 500mA for the two boards, and the total current is 4.2A. A 5A ±28V supply would be adequate.

6.4 Heatsinking

The heatsink bracket on the 671 board has just enough dissipation for the idling current when the scanner is not plugged in. A working system must be mounted on an adequate external heatsink. See drawing D04244 for the mounting dimensions. Use thermal grease, and use screws in all 4 mounting holes (in all 7 mounting holes, if the board has the HPO).

6.4.1 Choosing a Heatsink for the Board

The first step in choosing a heatsink is calculating the maximum power the 671 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 system with a bridge output and the High Power Option running a 6880 scanner on a ±28V supply. The maximum RMS current for the 6880 is 7.7A. The scanner needs 7.7A, and the board needs another 250ma. The system at full power would use 8A at 56V (in the bridge circuit the current flows through the load from one supply to the other, not to ground) or 448W. Subtract the 90W dissipated in the scanner, and the heatsink must dissipate 358W.

   This system will obviously need a large heatsink, and a fan. The output operational amplifiers set the practical temperature limit for the system. They will dissipate about 60W each when the system is running at full power with the HPO. Their junction to case thermal resistance is 1 °C/W, and the maximum junction temperature is 150°C. With a perfect heatsink they will rise to 85°C junction temperature at 25°C ambient. However the heatsink must dissipate 358W. Allow a maximum rise of 30°C at full power (the op-amp junctions then rise to 115°C). The thermal resistance of the heatsink must be better than 30°C/358W, or 0.084°C/W. Even with a heatsink that meets this rating, it would be wise to use a fan, to allow some margin for the thermal resistance between the 671 bracket and the heatsink, and for high ambient temperatures.

2. A 6210H system with a bridge output running on a ±15V supply. The maximum RMS current for the 6210H is 2.4A. The scanner needs 2.4A, and the board needs another 250ma. The system at full power would use 2.65A at 30V (in the bridge circuit the current flows through the load from one supply to the other, not to ground) or 80W. Subtract the 30W dissipated in the scanner, and the heatsink needs to dissipate 50W.

   In this case the output op-amps dissipate about 21W 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 21°C above the case. The maximum thermal resistance of the heatsink should be 54°C/40W or 1.35°C/W. A 1.2°C/W or better heatsink would be suitable.

3. A 6200 single-ended system running on a ±28V supply. The maximum RMS current for the 6200 is 1.6A. The scanner needs 1.6A, and the board needs another 250ma. The system at full power would use 1.85 A at 28V (in the single-ended circuit the current flows through the load from the supplies to ground) or 52W. Subtract the 8W dissipated in the scanner, and the heatsink needs to dissipate 44W.

   In this case one output op-amp dissipates all the power, about 37W (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 37°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/44W or 0.86°C/W. A 0.75°C/W or better heatsink would be suitable.

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 the High Power Option.

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.

Once a thermal management design is fabricated for the galvo mounts, a simple experiment should be conducted to ensure the scanners are not overheating at the maximum expected operating temperature condition. A thermocouple can be pressed against the galvo case near the longtitudinal midpoint of the galvo to measure temperature. Use a thermally insulating material to press the thermocouple against the galvo body. Run the system at maximum power for the application and at the highest anticipated ambient temperature. The thermocouple temperature should never exceed 50C.

6.5 Configuring the Power Amplifier

The output stage of the 671 board can be configured with or without the High Power Option, and as a bridge or a single-ended amplifier. Each of these four combinations is useful.

6.5.1 High Power Option (HPO)

The HPO is a sub-board, with a larger heatsink bracket, which essentially doubles the maximum current and quadruples the power dissipation of the standard 671 board. It is normally installed at the factory, but a field installation kit is available. See the outline drawing D04244 for dimensions and mounting details.

6.5.2 When to Use the High Power Option

The HPO is standard for the 6400 and 6900 scanners. The HPO is needed to run a number of the other scanners at full power.

Unfortunately there is no simple way to decide if the HPO is needed in a particular system. It depends on the RMS power needed, the peak current needed, the waveforms used, the coil resistance of the scanner, and the supply voltage, among other factors. In marginal cases the higher currents and better heatsinking of the HPO may improve the stability of the system. The following formulas may be useful.
System Current is the RMS current when the system is running at full power. Supply Voltage is the difference between the plus and minus supplies. Scanner Power is the power in watts dissipated in the scanner at full power.

If
System Current * Supply Voltage - Scanner Power >120W
then the HPO is needed.

If
Peak Current >10A
then the HPO is needed.

Experiment to find the optimum system.

6.5.3 Bridge Amplifier - No HPO

This is the standard configuration for almost all 671 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 caused by ground currents.

6.5.4 Bridge Amplifier - with HPO

This is the standard configuration for the 6400 and 6900 scanners. The HPO allows higher peak and RMS currents, and greater power dissipation in the board. It is useful when the peak currents needed for fast steps are greater than the standard 671 can provide, or when the RMS power is too high.

6.5.5 Single-ended - No HPO

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 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. The high ground currents may cause errors and crosstalk in the system.

6.5.6 Single-ended - with HPO

When the scanner drive voltages are low, but the currents needed are high, the single-ended amplifier with the HPO may be the best choice. A large scanner with a heavy load running a sine wave or a raster with a slow retrace is one example. 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. The high ground currents may cause errors and crosstalk in the system.

6.5.7 A Note on Overheating

671 board overheating is characterized by a high frequency duty-cyling of the output amplifiers. This may not even be noticeable becaus ethe servo will quickly fault due to servo instability. 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 four (seven for the HPO) 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.

6.5.8 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 TP8 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 TP8 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

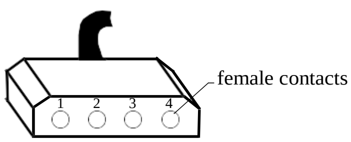
7.1 Single Axis System Wiring

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 671CK connector kit.

Table 15: 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 16:Connector J3, Input Power, Pinouts



Pin #	Signal Name	Voltage Range
1	+Supply Voltage	+15VDC or from +18VDC to +30VDC
2	+Supply Voltage Return	GND (Common)
3	-Supply Voltage Return	GND (Common)
4	-Supply Voltage	-15VDC or from -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 cuase problems which are hard to diagnose. [Note: Never tin the wire before crimping. If necessary, solder the connection after crimping it.]

7.2 Dual Axis System Wiring

When wiring Dual Axis systems, make separate connections to the power supply for each board.

Connect a short, heavy ground wire between the two boards. This reduces crosstalk between the two channels caused by high ground currents. See 671 Power Connections Wiring Diagram D05820.

Use a short piece of 14AWG wire and solder on two of the ground lugs contained in the 671CK connector kit. Use the #0-80 screws and standoffs in the kits to fasten the ground wire to the boards. Use P7 (behind J3, see D04244), and put the standoff and ground wire on the bottom of the board. If the HP is installed, use P8 on the HPO.
The kit also contains a #0-80 screw and standoff that is used to attach the ground lug to the standoff to P7 on each board, or solder the wire directly to P7.

Refer to **D04244 sheet 1** to locate P7. It is easiest to make this connection on the bottom of the board, if space allows. For systems that have the 671HPO installed, use P8 on the optional board as shown on **D04244 sheet 2**.

7.3 Command Input Wiring

Refer to Signal Connections Wiring Diagram D05819 and *"Section 7.8: External Command Offset" on page 54*.

The **671** servo driver can accept either an Analog Command Signal, External Offset signal or Digital Command signal with input configuration selected as detailed in the table below:

Table 17:W4 Signal In Configuration

Input Configuration	Jumper W4 Pin Strapping	Connector J1 Pin #		
		+ Input	- Input	± Input Return (GND)
Analog Differential	1-3	3	1	2
Analog Differential Inverting	1-3	1	3	2
Analog Inverting	3+4	N/A	1	2
Digital Non- Inverting	3+5, 4+6	N/A	N/A	N/A
Digital Inverting	5+6, 3+4	N/A	N/A	N/A
Analog Non- Inverting	1+3, 4+6	3	N/A	2

1. Analog Command and External Offset Input wiring must be wired with individual twisted shielded pairs.

2. Connect selected cable to the mating **J1** female, in accordance with your selecting input configuration from *Table 5, "W4 Signal In Configuration," on page 8*.

Table 18: Signal Wiring Connector Items

Item	Description
Connector	Molex # 50-57-9404
Pins	Molex # 06-02-0103
Crimper	Molex # 11-01-0208
(Pins and connector are included in Connector Kit # 671CK.)	

3. 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.

4. 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 19:Scanner/Voltage Position Movements

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

See *"Section 7.6: User Outputs and Remote Shutdown Input Wiring" on page 53*.

Note: Different Input methods are included for backwards compatibility with older boards. Cambridge Technology recommends using the Analog Differential Input.

There should be a direct ground connection from the signal source to the Pin 2 on the input connector (J1, Pin 2), 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.

7.4 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 from Cambridge Technology.

7.5 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.

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.

7.6 User Outputs and Remote Shutdown Input Wiring

Various observation and control signals are accessible on the **671** servo drive via the **J4** connector:

Table 20: Connector J4 Pinouts (User Outputs and Remote Shutdown Pinouts)

Pin #	Parameter's Name	Function	Description	Characteristic
1	Velocity	Output	Voltage signal is proportional to the velocity of the scanner	1K ohm Output impedance
2	Position	Output	Position Out signal	1K ohm Output impedance
3	Ground	Output	Ground Return for User signals	GND
4	Error	Output	Difference between Command Input and Position Output	1K ohm Output impedance
5	Current	Output	Current monitor	1K ohm Output impedance
6	Power Flag	Output	Pulled down to -15VDC when 90% of the maximum power is detected	1K ohm Output impedance & 10ma sink current
7	Fault	Output	Pulled down to -15VDC when the fault detector trips	1K ohm Output impedance & 10ma sink current
8	Remote Shutdown	Input	Disables the output when connected to ground	10K ohm to +15V

- A 0.100 Flat Flex cable assembly, in length up to 8 inches may be used to facilitate wiring to the J4 connector.
- A shielded cable assembly or individual twisted pairs can be used for connections to the J4 connector more than 8 inches in length. It is the customer's responsibility to select the proper cable or wires for the number of signals used.
- Use pin #3 as the ground return for all User Output and Remote Shutdown Input signals.

7.7 6755/6756 Digital to Analog Converter Operation

The digital input option employs a 16-bit digital-to-analog converter or DAC. This DAC converts the digital signal presented at its input into an analog voltage. This voltage is proportional to the 16-bit “word” sent. This allows the 671 card to position the scanner to 65536 different angles equally spread across the field. This is the fastest and most accurate way for controlling the scanner.

The converter used on the 6755 is the Analog Devices’ AD7846. The converter used for the newer 6756 is Linear Technology’s LTC1597-1ACG. All specifications can be found at each DAC manufacturer’s website: Analog Devices: www.analog.com , Linear Technology: www.linear.com

The 6755 and the newer 6756 are pin-for-pin compatible, so the interface for either does not change.

Each dac converts its 16-bit TTL signal into an analog voltage from +10 volts to -10 volts as shown below: (Note: This is for the “normal” or “non-inverting” configuration.

dac count = 0_{10} VDAC = -10 voltsposition = full CCW angle
dac count = 32768_{16} VDAC = 0 voltsposition = center
dac count = 65535_{16} VDAC = +10 voltsposition = full CW angle

To monitor the voltages at the outputs of the DAC, use the jumper connecting W4 pins 5 – 3. Use TP2 as the ground return.

The 6755 (and 6756) board has pullup/pulldown resistors to center the scanner when the inputs are sent to a "high Z" state or are unconnected. The DAC has true 16-bit monotonicity that is crucial for many high resolution applications. The DAC inputs are fully double buffered and the data can be strobed in by action of the CS, R/W, and LDAC lines. Refer to sheet 3 of D04244 for pin locations of these signals.

Initialize the digital input by setting CLR line low and the R/W high. In this state, no data line changes or changes to the CS or LDAC lines will cause any changes in the DAC’s output. To write to the module, send the digital word to the 16 data lines, bring the CLR line high, and the R/W line low. Then set the CS line low. This will store the digital signal in the first buffer of the DAC.

At this time, the digital signal has still not yet been presented to the DAC output. To do this, bring the LDAC line low. This action stores the digital signal into the second buffer of the DAC.

Both the CS and LDAC lines are level triggered, so the DAC can be made transparent (it follows the input in real time) by just setting both low at the same time and holding them there.

CAUTION

Do not set the R/W line high while the CS line is low. An internal data conflict inside the 6755 will occur. This does not apply to the 6756.

Sometimes it is advantageous to have an X/Y system move both scanners at the same instant. To perform this, the double buffering feature of the DAC is used. Follow the initial procedures as described above except leave both LDAC lines high. Write data into both channels using the CS lines also as described above. The data for both channels is now stored in the DAC input buffers, but not yet sent to the DAC outputs. Then bring both channels’ LDAC lines low at the same time. This allows both DACs to respond simultaneously.

7.8 External Command Offset

There are two ways to add an offset to the Command signal. The first is the Position Offset pot (P0/R1). The nominal range is ±5% of the input range. If the field size is 40°, the adjustment range is ±1°. If the field size is 20°, the adjustment range is ±0.5°.

The second is the External Command Offset, which can be used to sum external correction signals with the Command signal, or for a remote offset control. This is a buffered high-impedance input with a range of ±10V. Connect the External Command Offset to J1.4, and use J1.2 for the ground return.

External Command Offset is normally disabled, unless it is requested by the customer. It is enabled by installing R85. R85 also scales the offset. The nominal range as a percentage of the input range is given by:

Range = 10000/R85

If R85 is 100Kohms, the offset range will be ±10% of the input range, or ±2° when the field size is 40°. If R85 is 1Mohm, the offset range will be ±1% of the input range.

The sum of the Command and External Offset signals should not be greater than ±10V. If it exceeds the Over Position limit for the system, it will force the system into fault mode.

If the External Command Offset is enabled but not used, connect J1.4 to J1.2 to ground the input. If the input is left floating it will pick up noise.

8.0 Appendix B: Mirror Handling and Mounting

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 great 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 21: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. The smaller scanners do not have standard mounting clamps.

9.0 Appendix C: Installing the 671HPO Kit

Tools Needed:

- Medium Phillips screwdriver
- Long-nosed cutters
- Long-nosed pliers
- .050" hex wrench
- 1/4" nut driver or 1/4" wrench
- Heatsink grease
- DVM
- 671HPO Kit

9.1 671HPO Kit

Check the contents of the 671HPO Kit. It should contain:

- Replacement heatsink bracket with 671 HPO board mounted
- 671HPO assembly drawing (D04738)
- Installation instructions (this document)
- 16 #0-80x1/4 socket screws (2 spares)
- 16 #0 split lock washers (2 spares)
- 8 #0-80x3/8 standoffs (1 spare)

9.2 Prepare the 671 Board

1. Cut or remove the jumper wires at W13 and W14.
2. Remove the screw and standoff at P7, if it is there.
3. Fasten the seven standoffs to the 671 board at P1 through P7, using the #0-80 socket screws and the lock washers. Do not tighten them completely.

9.3 Add a Ground Point to the HPO Board

1. If a ground connection is needed on the 671HPO board (for example for XY systems), fasten the standoff that was removed from P7 on the 671 board, or the standoff from the 671CK connector kit, to P8 on the HPO board. Use a #0 lock washer and a #0-80x1/4 socket screw. Put the standoff on the component side of the board.

9.4 Remove the Old 671 Heatsink Bracket [Important - Save all the insulators and hardware.]

1. Remove the two #4 screws and nuts at the rear corners of the board.
2. Remove the two #6 screws and nuts on U5 and U14.
3. Remove the two #4 screws and locknuts and the shoulder washers on U12 and U13.
4. Carefully remove the old heatsink bracket and save the insulators on U12 and U13.

9.5 Mount the 671 Board on the HPO Heatsink Bracket

1. Check that the surface of the heatsink bracket and the backs of U5, U19, U12, and U13 on the 671 board are clean and free from dust.
2. Put a thin layer of heatsink grease on the backs of U5, U19, U12, and U13 on the 671 board. Use the thinnest layer that still leaves the backs of the devices white. A little grease should squeeze out at the edges when the screws are tightened.
3. Place the two insulators on U12 and U13. Line the holes up with the holes on the tabs. Put a little heatsink grease on the insulators.
4. Slide the board into place on the HPO heatsink bracket, with the corners of the board under the tabs.
5. Install the screws, nuts, and shoulder washers. These are the ones from the old heatsink. Do not tighten them completely.

Corners 2 #4x3/8 pan head
2 #4 KEP nuts
U5, U19 2 #6x7/16 flat head
2#6 KEP nuts
U12, Ul3 2 #4x7/16 flat heat
2 #4 shoulder washers
2 #4 lock nuts

6. Line up the holes at P1 through P7 on the HPO board with the standoffs on the 671 board. If necessary, loosen the screws on Q1 through Q4 on the HPO board, and move it slightly.
7. Install the #0-80 screws and lock washers at P1 through P7 on the HPO board. If there was a ground wire at P7 on the 671 board, attach it to the standoff at P8 on the HPO board.
8. Make sure that shoulder washers are properly seated on U12 and U13 and Q1-Q4, and that the insulators are aligned.
9. Tighten all the hardware.

9.6 Safety Checks

! WARNING

This board operates at high currents and dissipates as much as 600 watts. If there are shorts or bad connections the system will be seriously damaged.

1. Check that all the hardware is tight.
2. Measure the resistance between two points on the heatsink, to make sure that the probes are making good contact through the anodization. The resistance should be less than 1 ohm.
3. Measure from the tabs of U12 and U13 to the heatsink. The resistance should be ~20k ohms.
4. Measure with an ohmmeter from the tabs of Q1 through Q4 to the heatsink. The resistance should be greater than 20k ohms.

10.0 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.

Configuration 2
The configuration 2 servo combines the low noise and fast tuning speed of a class 0 servo with the precise settling of a class 1 servo.

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.

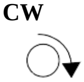
Critically Damped
The state of a system tuned properly so it reaches the steady state in the least possible time, without overshoot.

Crosstalk
Crosstalk is a signal that is transferred from one circuit to another where it shouldn't be, by inductive or capacitive coupling, or by high currents in the power and signal grounds.

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

DAC
The 6755 and 6756 digital to analog convertors plug into the 671 board, and convert a 16-bit parallel input to ±10V analog signal.

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 671 servos because the slew rate limiter gives slightly better performance.

Error Output
The error output provides a voltage proportional to the difference between the command signal and the position signal.

External Offset
An auxiliary input used to add an offset signal to the command signal.

Fault Output
The Fault Output is an open collector output that is pulled down to -15V through a 1k resistor when the system is in fault mode. The Fault Output is low during faults, during the power-on delay, and when the system is in Remote Shutdown.

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.

NFM (see also Notch Filter)
The 6745 dual notch filter module plugs into the 671 board. It has two tunable band-reject filters which can be separately enabled. 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, bandwidth and servo topology 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 (NFM) 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 671 board goes into fault mode and disables the scanner by turning off the power amplifier. This angle can be set from ±10° to ±22°. 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 *"4.2 Small Angle Step Response Tuning" on page 20*.

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 TP1/J4-2. 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 4.3: Measuring the Step Response Time" on page 21*.

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.

Remote Shutdown
When the remote shutdown line is pulled to ground, the system is forced into fault mode (the output amplifier is disabled and the command signal is muted), and the LED turns orange. When the system comes out of remote shutdown, it goes through the normal power-on sequence.

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 going 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.

90% Power
The 90% Power output is an open collector output that is pulled down to -15V through a 1k resistor when the scanner current reaches *95%* of the scanner's rating. It can be used as a warning that the system is close to its power limit.

11.0 Appendix E: Drawings

671 Signal Connections D05819 Rev A

671 Power Connections D05820 Rev B

671 Functional Diagram D05151 Rev A

671 HPO Assembly Drawing D04738 Rev D

671 Outline Drawing D04244 Rev H

- **D04244 Sheet 1**
- **D04244 Sheet 2**
- **D04244 Sheet 3**
- **D04244 Sheet 4**

Refer to www.cambridgetechnology.com for cable drawings.