Series 678XX
Single Axis Board Level
Mirror Positioning System

INSTRUCTION MANUAL

Revision 2, March 12, 2001

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TABLE OF CONTENTS

1.0. Introduction

As the complexity and specification requirements of today's optical systems increase, so does the need for high performance, high accuracy, and compact mirror positioning systems. The Series 678XX system was designed for those applications that require high performance specifications.

The Series 678XX Single-Axis Board-Level Mirror Positioning System consists of a one-channel servo amplifier and a high performance closed-loop scanner. The servo is built on a 2.50" x 3.75" board that employs both through-hole and surface mount technology to achieve its small size but high functionality. The scanner is a compact, closed-loop, limited rotation motor designed for a specific range of inertial loads. This allows mirrors with inertias from less than 0.001 gm-cm^2 to greater than 100,000 gm-cm^2 to be precisely controlled.

This manual describes the 678XX servo board electronics in detail so the user can better integrate this mirror positioning sub-system into the end use application. At the end of the manual is a complete set of tuning procedures, schematics and assembly drawings.

Please read this manual in order 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. Do not attempt to retune the drive electronics until the tune-up procedure in section 6.1 is fully understood. Failure to do so could result in serious damage to both the scanner and electronics.

2.0. Servo/Amplifier Specifications

Analog Input Impedance:
200K ohm, differential, +/-1% min

Analog Position, Velocity, Error Output Impedance:
1000 ohm max

Position Output Scale Factor:
0.500 v/mech degree, standard

Command Input Scale Factor:
0.500 v/mech degree, standard

Input Voltage Requirements:
+/- 15VDC to +/- 28VDC @ 4A Max RMS

Input Power Requirements:
10 watts minimum
200 watts max rms (depends on type of scanner)

Operating Temperature Range:
0 - 50 degrees C

Board Size:
3.75" (9.53cm) long x 2.50" (6.35cm) wide x 1.00" (2.54cm) high

Board Weight:
81 grams

3.0. Description of Operation

3.1. Overview

An optical scanner is only as good as the servo amplifier which controls it. Ultimate performance will not be realized from a servo system that is not well matched to the load that it is controlling.

The 678XX system's electronics are contained on a compact 2.50" x 3.75" surface mount card and is delivered to the customer ready to use immediately out of the shipping carton. Each has been tuned to the customer's particular mirror inertia so that no adjustments are necessary unless the mirror inertia is changed. For those experienced in servo electronics, there is a tuning section included in section 6.1. Also included is a complete set of schematics and assembly drawings.

****Warning!** Do not attempt to retune the servo until section 6.1. is fully understood. Damage to the scanner could result.

****Note:** If by customer request the system was sent untuned, the user will have to follow the tuning procedures in section 6.1 before the system will be ready for use. Also, if the system was shipped without a mirror or other customer load, the system will always be shipped untuned.

The basic operation of the servo is: Accept an analog input command voltage signal and turn that input into a stable, repeatable, angular position of the scanner's output shaft. The amplifier does this by combining the command input information with the feedback information from the scanner to form an error signal. The servo then strives to force this error signal to zero by rotating the scanner's shaft. It is this "following" of the command input signal that allows it to control the scanner's angular position.

The rest of the electronics on the card are used to provide DC power and to monitor the scanner power dissipation in order to limit the average scanner power.

3.2. Mechanical Layout

Refer to the 678XX Outline Drawing located in section 6.2. for details of the mechanical layout.

The 678XX Servo Amp is constructed on a two layer PC board with four clearance holes for #4 screws located at the four corners of the board. It is recommended to use all four mounting holes. For best noise rejection, always ground one or both of the LHS mounting screw holes to chassis ground of the instrument. For maximum heat-sinking, there are three holes for #6 screws on the black heat-sink bracket. ***Bolting the heat-sink bracket to a large bulkhead or plate and using thermal joint compound will greatly increase the maximum power dissipation of the 678XX board and should be considered mandatory***. If this is not possible, expect no more than minimum power delivered to the scanner, and mount the board so that the fin of the heat-sink bracket is vertical (mount the board on its side) to provide maximum airflow around the bracket.

During integration, ensure that there is sufficient clearance around and under the board to keep the circuits from being shorted out. Ensure there is sufficient clearance around and above the board so that the connectors, adjustment potentiometers, and test points are accessible.

3.3. Input Power

Refer to the 678XX Schematic located in section 6.2. for details on this section.

Input DC power is fed onto the board via the male 10-pin AMP connector, J1. A mating female connector, AMP # 102387-1 with AMP pins # 86016-2 have been included with the system and are contained in the connector kit.

The input voltage is connected directly to the output amplifiers for driving the motor current used to move the scanner. The voltages need not be highly regulated, but for high accuracy applications, it is recommended the voltages be as free from noise as practical. Filter capacitors on the 678XX board help to smooth out the board's current demands from the power supplies allowing for smaller supplies in general.

The input voltage is regulated down to +/-15V for the analog circuitry. If the DC input voltage is in the +/-15V to +/-18V range, the +/-15V regulators should be shorted out via W1 and W2. Then the input voltage will be connected directly to the analog circuitry. For those situations, it is highly recommended that low noise power supplies be used. Refer to the next paragraph for instruction.

The input voltage range allowable for the 678XX board is +/-15V to +/-28V. In general the higher the voltage, up to +/-28V, the shorter the large angle step response time or the better the performance. The systems are factory tested at +/-28V. The input current requirements vary depending on a number of parameters e.g. which type of scanner is being used, how the system is tuned, what type of command waveform is being input. Power supply design should consider the current required to run all of the analog circuitry, +/-100mA, and the current required to run the scanner at the maximum RMS current demands. Proper gauging of wire and power supply sizing should be considered during the design integration of the system.

Shown below is the pinout for J1 input power and signal connector:

J1.1 = (-) Voltage
J1.2 = (-) Voltage return (GND)
J1.3 = Mute (GND activated)
J1.4 = Command input GND (Shield)
J1.5 = Command input (+)
J1.6 = Command input (-)
J1.7 = NC
J1.8 = NC
J1.9 = (+) Voltage return (GND)
J1.10 = (+) Voltage

3.4. Position Demodulator

A differential current signal is obtained from the position detector within each scanner. The amplitude of this signal is modulated by the scanner's output shaft angle or "position". Referring to the 678XX schematic, Ia and Ib are converted to voltages, Va and Vb, by the two transimpedance amplifiers in the position demodulator section. The position output (PO) voltage is then detected as the difference of these two voltages. This signal is then sent on to the tuning section of the amplifier and to the outside world via isolation resistor R12. The position signal is available at J4.1. Use J4.4 for the return. The female mating plug for J4, Molex #50-57-9404 with Molex #16-02-0103 pins are included with the connector kit sent with your system. The position output signal can also be monitored at the test point, TP1. Use TP2 for the ground return. The scale factor for this output is 0.500 volt/mechanical degree, standard.

3.5. AGC Circuit

The output signal of a scanner's position detector is powered by an AGC signal generated on the 678XX board. To monitor this signal, use TP5. Use TP2 for the ground return. The 678XX board's AGC circuit monitors the sum of voltages Va and Vb and forces this sum to be constant at all times. Thus, any drift of the position detector is stabilized to a very high degree. Since the angular excursion of the scanner is inversely proportional to the amplitude of Vagc, this circuit is also used to adjust the position detector scale factor or the Position Output (PO) scale factor. However, this should only be done when retuning the original scanner, or when matching a new scanner to the servo board. The scanner's scale factor should never need readjusting during its lifetime. Changing the PO scale factor in this manner directly affects the system's loop gain. Thus, turning R13 to set a scanner's field size will result in changed dynamic performance. Refer to section 6.1.5 for adjusting the output scale factor in this manner.

*****Caution: Improper adjustment of R13 (position scale adjustment) could result in damage to the scanner. Refer to section 6.1.5 before adjustments are made.**

The apparent linearity of the position detector is affected by component tolerancing of the servo board's position demodulator and by other factors within the scanner. These nonlinearities can be partially eliminated by trim-pot R60 on the 678XX board labeled "LIN" for linearity. This trim causes the AGC signal to change minimally during normal scanning. This signal should not need adjusting during the normal lifetime of the scanner. This adjustment should only be made when retuning the original scanner or when matching a new scanner to the servo board. Refer to section 6.1 for details on this procedure.

3.6. Command Input

3.6.1. Analog Input

The Command Input (CI) signal is differentially connected through J1 pins 5 & 6. Use J1.4 to ground the cable shield. The input voltage range is +/-10V for full angular excursion. Ensure that the jumpers for W3 are connected across pins 1&2, and 3&4 (non-inverting differential), or 1&3, 2&4 (inverting differential). The scanner will move as follows:

CI voltage = -10V	position = full CCW angle
CI voltage = 0V	position = center
CI voltage = +10V	position = full CW angle

The connector kit included with your system has the necessary hardware to build the input connector J1. The connectors are AMP #87631-5 with pins AMP #86016-2.

3.6.2. Command input Scale Factor Calculation

The Command Input (CI) scale factor is defined as the number of volts required at the input of the servo board to cause the scanner's output shaft to rotate one mechanical degree. For some applications, fine control of this scale factor is critical. Also, since the input voltage is limited to +/-10V, this also sets the maximum controllable angle or Input Range of the system. This Input Range is also referred to as the "fieldsize" of the system.

The 678XX Single Axis Mirror Positioning System is normally set up for the maximum allowable scan angle for the application unless otherwise specified by the customer. The maximum fieldsize for all Cambridge Technology scanners is +/-20°. As the CI scale factor increases, the inherent fieldsize of the system decreases. Thus, 0.5V/deg system will yield +/-20deg, 1.0V/deg will yield +/-10deg, 2.0V/deg will yield +/-5deg, etc.

Note: It is possible to set the input scale factor to less than 0.5V/deg, however it will allow the input signal to attempt to drive the scanner further than 20degrees. This will cause the system to sense the overposition and clamp the command signal to just over +/- 10V. Ensure that no matter what the servo's input scale factor is set to, the input signal stays within bounds that keeps the scanner within its normal +/-20 degree range.

The CI scale factor is controlled by the following factors:

1.) Position Output (PO) Scale Factor - always set to 0.5V/mech deg (unless otherwise stated)
2.) Error amplifier summing resistor ratio, R22/(R24+R59+R31) - usually set to ~1:1
3.) CI scale adjustment, R70 - adjustable from ~0.83:1 to 1:1

**Note: R70 allows the user to make small adjustments to the CI scale factor. For gross changes use the equations shown below to determine the value of R31+R24+R59.

**Note: Normally, R70 is used to obtain the most accurate command input scale factor possible. However, minimizing the drift associated with R70 is more important than the exact value of the input scale factor, turn R70 to its maximum CW position, then follow the discussion below to calculate the result.

The following equation describes the interaction of the above factors:

CI Scale Factor = PO Scale Factor x ((R31+R59+R24)/R22) x CI Scale Adjustment

For example: Let

PO Scale Factor = 0.5V/mechanical degree
CI Scale Adjustment = 1:0.9 (R70 set to midpoint)
R22 = 110Kohm
desired CI Scale Factor = 2:1 or 1.0V/mechanical degree.
R24 = R59 = 1Kohm

Thus,

R31 = ((CI Scale Factor * R22) / (PO Scale Factor x CI Scale Adjustment)) – R24 – R59

or

R31 = (1.0V/mech deg * 110Kohm) / (0.5V/mech deg x (1/0.9)) – 2Kohm
R31 = 196K ohm ~ 200Kohm (Use a stable metal film resistor, RN55C, for best thermal drift characteristics.)

The CI Range or "fieldsize" is now determined as the product of the range of the CI voltage and the CI scale factor. For the above example:

CI Range = +/-10V * 1.0V/mechanical degree
CI Range = +/-10 mechanical degree = 20 mechanical degrees p-p

A detailed procedure is included in the appendix 6.1.6 on how to set the CI Scale Adjustment.

3.6.4. Position Offset

The Position Offset is used to add a DC offset to the input signal. An on-board adjustment pot, R69, can add +/- 10v of offset to the command signal.

The output of op-amp U2A.1 is the composite command input signal to the servo and consists of the following terms: **Command out = Command(+) - Command(-) + Voffset**. The *differential* gain error due to the position offset adjustment alone is a function of the offset voltage (0.0125% for a +/- 1V offset, and 1.25% for a +/- 10V offset). However, for single ended command inputs, the gain error is simply the mismatch due to resistor tolerances (+/- 2% gain error)

3.7. Tuning Section

The class of servo is determined by how many error integrators are in the servo loop. The error integrator of a class 1 servo makes the system settle to a very high degree of accuracy. Even as friction or other torque disturbances try to affect repeatability, the integrator will eventually take out all error. This is done at a slight speed penalty.

The 678XX servo amp is a Class 0 type, since it does not employ an error integrator. Class 0 servos are slightly faster and more stable than class 1 servos. However, the tradeoff is that any finite friction causes a window of non-repeatability to form around the commanded position. The error is equal to:

$$\text{Error} = \Gamma_D / K_S$$

where, Error = difference between actual and commanded position in radians

Γ_D = the disturbance torque in dyne-cm

K_S = the servos stiffness in dyne-cm/radian

Many applications do allow for the use of the class 0 configuration, along with its inherent non-repeatability.

3.7.1 Class 0

Our class 0 servo consists of the following circuits: a position differentiator, an error amplifier, a current integrator, and a summing amplifier. The transfer function can be characterized by the following differential equation:

$$V(t) = A1 * \frac{d(Vpos(t))}{dt} + A2 * Error(t) + A3 * \int Im(t)dt$$

where:

V(t) = output of summing amplifier
A1 - A3 = constants that are adjusted with the tuning pots R25, R28, and R42, respectively.

Error(t) = the error signal generated as the difference between the position signal, Vp, and the output of the slew rate limiter (command signal).

Im(t) = the current flowing through the rotor coil.

The position differentiator takes the first derivative of the position signal to yield angular velocity. This velocity signal is one of two sources of damping for the servo. Its -3db bandwidth is set relatively low. This is to prevent high frequency noise, present on any differentiated signal, from entering the summing amplifier. Its contribution to the servo is to provide damping at low frequency and is controlled by R25.

The error amplifier compares the actual position to the commanded position and generates a signal proportional to this error. Since this is not an integrated signal, the bandwidth of this stage is much higher. Thus, the closed-loop bandwidth of the servo is also higher. The sacrifice is that if there is any friction or spring present, there will be some DC error. However, since Cambridge Technology's scanners have very low friction and no torsion bar, this error is quite small. The contribution of this amplifier to the servo response is controlled by R28.

The current integrator produces a signal proportional to the integral of the current flowing through the rotor. Since the current flowing through the rotor is proportional to the torque produced, it is also proportional to the angular acceleration. Thus, the integral of current can be used as another source of velocity information, hence damping. The advantage of this form of damping is its inherent low noise. Its bandwidth can be set high without degrading its signal to noise ratio. The overall bandwidth of the system can be extended much further than with position differentiation alone. The current integrator is considered the high frequency damping source and is adjusted with R42.

The summing amplifier algebraically sums all four of these signals to obtain a composite signal that is sent to the output stage.

3.8. Output Amplifier

The output stage uses a power op-amp to supply the large currents used to create torque in the rotor coil. A current feedback loop is tied around this output amplifier allowing the summing amp to control the current in the scanner directly. Thus, changes in cable length, coil resistance, contact resistance, back EMF voltages, etc. do not affect the summing amplifier's ability to control the torque produced in the scanner. This produces a very stable and repeatable system response.

Current flowing through the rotor coil is detected by a low resistance current shunt, R35 and differentially detected by the current monitor, U3A. The current monitor signal is then used to close the current feedback loop around the output op-amp U6. It is also used for the coil temperature calculator to monitor coil heating and by the current integrator to obtain a velocity signal. The current monitor signal is monitored on TP3. Use TP2 for the ground reference. The scale factor varies depending on which scanner is being driven. Referring to the board schematic and actual component values, the current monitor gain can be obtained by the following formula:

$$I_G = R35 * R39 / R36 \text{ amps/volt}$$

3.8.1 Mute Control, Output Fuse

The output amplifier is capable of being open-circuited by grounding the "mute" control input on J1.3. This can be done by using an open collector transistor switch or a CMOS switch capable of sinking at least 1.5ma (with a 0-15v swing). Note that the mute function will discharge C13 from about -3v to 0v with about a 1ma current source. C13 is 100uf, so it takes about 0.30 seconds to disable the output amplifier.

For maximum protection fuse F1 has been placed in-line with the output op-amp U6. See the motor specifications for the proper fuse size to be used with each servo configuration. To monitor the voltage signal being sent to the scanner, use TP4. Use TP2 for the ground reference.

****Warning!!** During output amp Mute the scanner's position may be anywhere within ~120 degrees optical. If the laser power is not removed or the beam diverted, the laser may point in an inappropriate direction when the scanners are shutdown.

3.9 Motor Protection Circuitry

The 678XX has two forms of motor protection. One is command input clamping, and the other is a motor power limiter circuit. The command input clamping prevents command input signals from exceeding +/- 10v. The motor power limiter senses the average power dissipated in the scanner coil via the formula $P_{coil} = (Rcoil * Im^2)$, were Rcoil and Im are known. This coil power calculation is averaged by an RC filter which mimics the thermal time constant of the coil resistance rise with temperature. This assumes that the scanner is properly heat-sinked so that the coil temperature will not exceed 110°C. If the average coil power dissipation exceeds a preset value for that particular scanner, the command input signal is reduced to limit power.

3.9.1. Startup Sequence

Upon power up, the output stage will be muted for approximately 1 second via the R1-C13 time constant. This is to prevent any scanner motion until the power supply voltages have come up to their normal levels.

3.10. Notch Filter Module Socket

The 678XX board is equipped with a socket, J3, which can accept the CTI 6740-XX Notch Filter Module (NFM). When the NFM is not installed, J3.1 and J3.2 should be shorted together. The NFM is used when it is necessary to attenuate the 1st torsional resonant frequency of the scanner rotor/mirror load combination in order to increase the system speed. For more information on the 6740-XX NFM, see section 6.2.

4.0. Operating Instructions

4.1. Precautions and Warnings

As a standard practice, keep the servo channel, scanner, and mirror together as a matched set. At Cambridge Technology, we have matched all three components and tested them as a system. Mixing and matching systems invalidates all of the calibrations that have been done. If mixing the systems is unavoidable, please follow the entire tuning procedure in section 6.1. to verify proper operation. Failure to do so could degrade the performance of the system or possibly damage the system.

Always make sure the scanner is heatsinked properly before operating it for any length of time. Failure to do so can cause a scanner failure due to overheating. Follow the mounting procedures covered in the scanner's Instruction Manual.

Do not attempt to turn any of the servo adjustment potentiometers on the servo board until the entire tune-up procedure has been read and fully understood! The error protection circuitry may not work if the servo were improperly adjusted, causing damage to the scanner.

The Series 678XX Single-Axis Mirror Positioning System is a high performance servo/scanner system that requires delicate handling. Never drop or mishandle the scanner, or damage may result.

Do not operate a scanner without its mirror, or other appropriate load, attached securely to the output shaft. Always ensure the mirror is pushed all the way onto the scanner shaft before tightening. Never use anything other than medium finger pressure to install a mirror mount onto the shaft. Always tighten the mirror mount screws (on a removable mirror) before tuning or running the scanner. Operating the scanner without a load may cause the system to go unstable, possibly causing damage to the scanner. Never change the mirrors in any CTI system without checking the tuning afterwards. The ultimate performance of the system will be greatly reduced.

When operating the system, do not repeatedly slam the scanner into its overposition limits at +/-20 mechanical degrees. Although the protection circuitry shuts the scanner down effectively, the momentum of the rotor and load will still carry the rotor into the mechanical stop. If done repeatedly, the scanner could be damaged.

If the system is ordered without mirrors, the electronics and scanner are tested with test loads, then the servo is "detuned" as outlined in this procedure. These systems must be retuned by the customer before the system can be operated normally. Please refer to section 6.1. for tuning information.

4.2. First Time Startup

1. Using the connector kit provided with your system, make the connector for J1. Do not attach it to the 678XX board at this time. After constructing the cable, double-check the wiring to ensure that everything is correct. Applying voltages to the wrong inputs could damage the scanner and the servo board which would void the warranty. Check the Input Power section, 3.3.

2. Check that the jumper configuration of W1 and W2 are correct for the voltages provided at the power supply inputs. Check the Input Power section, 3.3.

3. Plug the scanner cable, male end, into the 9-pin D-connector on the servo board and tighten the locking screws securely.

4. Plug the scanner cable, female end, into the connector on the scanner and if applicable tighten the locking screws securely.

Note: Step 5 is for systems that do not already have the mirrors mounted and aligned.

5. Install the mirror on the shaft of the scanner and tighten securely. Ensure that the mirror's angular swing does not allow it to hit any obstruction (e.g. the table the scanner is sitting on). Ensure that power is not being applied to the input connector J1. Attach it to the 678XX board.

6. Ensure that W3 is set appropriately for the type of input. Whichever type input is being used, set the input signal so the scanner centers. For analog inputs this is 0.000 volts. For more information, see the CI section 3.6.

7. Turn the power on and observe the scanner shaft. The scanner shaft should immediately turn to its centered position, then begin moving to its commanded position, which should also be centered for now.

8. Turn the mirror load by the edges very lightly to observe if the servo has "stiffened up". "Stiffening up" occurs when the scanner is under proper servo control. The scanner should resist your light efforts to turn it.

9. Hook up an oscilloscope or other voltage meter to the position out signal at TP1. At this time the voltage should read very nearly 0.0 volts. Use TP2 for the ground reference.

10. Input a square wave of about 1V p-p at about 30Hz. For very large scanner/mirror systems, 30Hz may be too fast. For those systems, set the frequency to ~5Hz.

11. 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.

12. Gradually, increase the amplitude of the command input signal until the CI waveform has almost reached ~ +/-10.7 volts. For systems that have an input and output scale factor = 0.5 volts/mechanical degree, the CI will just go into clamping at this point.

13. Now, gradually turn up the frequency of the input waveform until the desired frequency has been reached or the output waveform begins attenuating, whichever comes first. The maximum coil temperature may be reached before this point. To recover, turn the frequency down and possibly the amplitude of the input signal, in that order.

14. If appropriate, adjust the input offset pot to introduce an offset signal into the CI. The output waveform should now be the algebraic sum of both the CI and Voffset.

That is it! If the 678XX system has performed all of the above functions, it is functioning properly. The scanner can be made to follow any input waveform as long as the maximum amplitude/maximum speed limitations are not exceeded.

5.0. 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.

6.0. Appendices

6.1. Tune-up procedure

6.1.1. Precautions

Read the following procedure completely before attempting to retune the system. Serious damage to the scanner could result if the servo were improperly adjusted!

****Caution!!** Shut the system down immediately if a resonance occurs. A resonating scanner will make a loud noise that sounds like a buzzer or possibly like a high frequency whine. Do not confuse this with the normal sound the scanner makes while operating. If this occurs while tuning up the system, shut it down immediately. 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.

6.1.2 Overview

For most users, the factory settings on the 678XX board will never need adjusting. However, if the user wants to change the mirror load originally used, the system will probably have to be retuned. 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. These include the Position Output Scale Factor, the AGC Linearity, the Input Offset, the Command Input Scale Factor, Closing the Servo Loop, Matching Two Servo Channels and adjusting the Notch Filter (if applicable). Note: If the notch filter is to be tuned at this time, adjust it before attempting to close the servo loop. To close the servo loop before the notch filter has been adjusted will definitely cause a resonance problem.

The following procedure can be used to tune-up the system completely, or to just "touch up" or verify any one of the adjustments. If the tuning adjustments are to be just verified and/or touched up, do not initialize the tuning pots as it states for a complete tune-up. Otherwise the customer will be forced to perform unnecessary steps, which could possibly reduce the performance of the system, depending on the experience of the adjuster. Call Cambridge Technology if any parts of this procedure are not completely understood.

****Caution!!** Failure to carefully monitor the scanner's position response while adjusting the servo trimpots could result in an uncontrolled resonance which could damage the scanner.

*****Note!!** Always "tune the notch filter" before the "closing the servo loop," otherwise the adjustments made to close the loop will be lost.

6.1.3. Required Tools and Materials

1. Dual trace oscilloscope.
2. Function generator - needs to have a sine and square wave output.
3. Digital voltmeter
4. Hand tools - jeweler's screwdriver flat-tip
5. Clip lead with "micrograbber" ends.

6.1.4. Initial setup

Ensure the power is turned off prior to performing the following steps.

1. Refer to the startup procedure in section 4.2. above.

2. To find the location of the test points and the tuning potentiometers or "trimpots", refer to the Outline Drawing, D03435, located in section 6.2.

6.1.5. Adjusting the Position Output Scale Factor and the AGC Linearity

The Position Output (PO) Scale Factor is precisely adjusted at Cambridge Technology and under normal circumstances never needs adjusting by the customer for the life of the servo board or scanner. If however the customer has changed the scanner originally sent with the servo board, (remember they are matched sets) use the following procedure to verify/adjust this signal.

The most important signal generated on the 678XX board is the Position Output (PO) signal. In order for the servo to work correctly, the PO signal must be scaled properly. The PO Scale Factor is controlled by increasing or decreasing the AGC signal voltage sent to the scanner's position detector excitation source. The PO Scale Factor is linearly proportional to this AGC voltage. Thus, changes in the PO Scale Factor causes changes in the amount the scanner will move for a given output response. R13 is used to adjust this AGC signal. This trim-pot allows ~10% adjustment range. If the AGC voltage is changed by more than 1% during this adjustment, the tuning of the system must be verified to be sure that it is still set properly. It is always prudent to check the tuning after any adjustment to the PO Scale Factor or the Linearity Adjustment.

The Linearity Adjustment is used to improve the linearity of the position detector and position demodulator. By varying the amount that Va and Vb sums together to create the AGC voltage, the linearity is improved. The intention of this adjustment is to minimize the amount the AGC voltage varies as a function of the angular position of the scanner. Since the Linearity Adjustment and the PO Scale Factor adjustments affect each other, they must both be set at the same time.

Note: Do not let the AGC signal present at U4D pin 14 (TP5) exceed 11 volts or the AGC circuit may saturate, which would result in improper operation.

**Caution: In all cases, the position out (PO) signal must have the ability to exceed +/-10 volts when the scanner shaft is turned to its internal mechanical stops or scanner damage may occur.

6.1.5.1. Closed Loop Method

If the system is already tuned up and verification or "touching up" of the PO Scale Factor and Linearity Adjustment are desired, use of this method is allowed. Also, if mixing and matching scanners, this method can be used. A mirror must be mounted on the scanner shaft, or some other means of measuring the scanner's angular position must be employed. By reflecting a laser beam from the mirror to a wall, and using some simple trigonometry, the PO Scale Factor can be adjusted with high resolution. The further from the wall, the more accurate this method.

1. Follow steps 1 - 7 in section 4.2. above.

2. Turn on the power.

3. The system should perform its normal turn-on process as described in section 4.2. above.

4. Adjust the CI Offset Adjustment trimpot, R69 to 0.000 volts (measure this at the wiper of R69 on the solder side of the board). Use TP2 as the ground reference. Center the scanner by inputting a signal into the CI so that PO voltage reads 0.000 volts as measured at TP1.

5. Reflect a laser beam onto the mirror of the scanner being adjusted. This laser beam should be parallel to the wall and level to the floor before it strikes the mirror on the scanner. Position the scanner body vertically and so that the beam is striking the wall perpendicularly. The scanned beam should be in the same plane as the beam striking the mirror. This is important so that the optical beam deflection angle to mechanical deflection angle relationship is a constant factor of two. Compound angles result in relationships that are not just a factor of two. Mark this location on the wall and label it P1. Measure the length from the mirror to the wall and call this distance L1.

6. Input a sine wave signal that drives the scanner to half of the full peak-to-peak angular swing. Usually an input amplitude of 3.535 volts rms is appropriate. See section 3.6 above for more information on the input scale factor calculation. Use an input frequency of ~30 Hz for most applications. For systems with low system bandwidth, because of very large loads, drop the frequency to ~5Hz. Ensure the input sine wave signal has no DC component, i.e. that the peak positive and negative excursions are equal.
7. Measure the rms PO voltage on TP1. Call this voltage VP1.

8. Label the endpoints of the scanned line on the wall as P2 and P3. Measure the distance from P2 to P3. Call this distance L2.

9. The PO Scale Factor, POSF, is obtained with the following formula:

POSF = (VP1* 1.414) / ((arctangent(L2 / L1 / 2)) / 2) volts/mechanical degree

10. Use R13 to set the POSF to 0.500 volts/mechanical degree. Setting it to anything else can damage the scanner.

11. Ensure that the AGC voltage on U4D.14 (TP5) does not exceed +11V. If it does, the AGC amplifier may saturate as the scanner ages or changes temperature and lose servo control. The scanner would still operate, but at a profound decrease in positioning stability. If the desired position signal gain cannot be obtained without exceeding +11V, seek technical assistance from Cambridge Technology.

12. Monitor the AGC signal at TP5 on an oscilloscope. AC couple the scope. Set the sensitivity to 10mV/div. Adjust the Linearity Adjustment trimpot, R60, to minimize the peak-to-peak excursions of this signal.

13. Repeat steps 4. - 12. above until the desired PO Scale Factor and Linearity are obtained simultaneously. This is an iterative process and could take a few cycles through the procedure.

14. Again, it is recommended that the tuning procedure be followed to ensure the system's closed loop response is still properly adjusted.

6.1.5.2. Open Loop Method

If the system has not been tuned or there is some doubt as to state of the tuning, use this method to adjust the PO Scale Factor to a coarse level so the system can be tuned. After the system is completely tuned, go back to section 6.1.5.1. and perform the Closed Loop Method for PO Scale Factor and Linearity Adjustment.

1. Follow steps 1 - 7 in section 4.2. Ground mute pin J1.3

2. Turn on the power.

3. The system should perform its normal turn-on process as described in section 4.2. above. The output amplifier will be open-circuited.

4. Adjust the CI Offset Adjustment trimpot, R69 to 0.000 volts as measured on its wiper. Use TP2 as the ground reference.

5. Reflect a laser beam onto the mirror of the scanner being adjusted. This laser beam should be parallel to the wall and level to the floor before it strikes the mirror on the scanner. Turn the scanner's output shaft so that the PO signal as measured on TP1 reads as close to 0.000 volts as possible. Simultaneously, position the scanner body vertically and so that the beam is striking the wall perpendicularly. The scanned beam should be in the same plane as the beam striking the mirror. This is important so that the optical beam deflection angle to mechanical

deflection angle relationship is a constant factor of two. Compound angles will result in relationships that are not just a factor of two. Mark the point the laser strikes the wall and label it P1. Measure the distance from the mirror to the wall and call this L1.

6. Move the scanner shaft by hand so that the voltage at TP1 is about +5 volts. Mark the position on the wall and label it P2. Simultaneously measure the voltage at TP1 and label it VP1.

7. Move the scanner by hand so that the voltage at TP1 is about -5 volts. Mark the position on the wall and label it P3. Measure the voltage at TP1 and label it VP2.

8. Measure the distance from P2 to P3. Call this distance L2.

9. The PO Scale Factor, POSF, is obtained with the following formula:

$$POSF = (VP2 - VP1) / (\text{arctangent}(L2 / L1 / 2))$$

10. Use R13 to set the POSF to 0.500 volts/mechanical degree. Setting it to anything else can damage the scanner.

11. Ensure that the AGC voltage on TP5 does not exceed +11V. If it does, the AGC amplifier may saturate as the scanner ages or changes temperature and lose servo control. The scanner would still operate, but at a profound decrease in positioning stability. If the desired position signal gain cannot be obtained without exceeding +11V, seek technical assistance from Cambridge Technology.

12. Again it is recommended that after this procedure has been performed, perform "Closing the Loop" in section 6.1.7., then return to 6.1.5.1. for a more accurate setting of the PO Scale Factor and Linearity Adjustment.

13. Turn off the power.

14. Disconnect the mute pin J1.3 from ground.

6.1.6. Command Input Scale and Offset Adjustment

A trimpot, R70 allows for fine control of the CI Scale Factor. How this affects the overall CI Scale Factor is described more thoroughly in section 3.6.2. and 3.6.3. above.

1. Setup the system as in section 6.1.5.1. above.

2. Set the input signal to the center of the range or 0.000volts.

3. Adjust R69 to obtain 0.000volts as measured at TP1, the Position Out signal

4. Set the input signal to about 50% of the maximum excursion expected in operation. For a full field system this is ~5.000 volts.

5. While monitoring the Position Out signal at TP1, adjust R70. The value obtained at TP1 depends on the Position Input Scale Factor desired. For a full field system and an input of 5.000volts, adjust R70 for a 5.000volt signal at TP1.

6. Iterate steps 2. – 5. until both figures can be obtained.

6.1.7. Closing the Servo Loop

The following steps will close the servo loop and make all of the servo circuitry active. Again, it is stressed that the following steps be read and understood thoroughly before proceeding!

The purpose of this procedure is to adjust the servo loop trimpots so that the scanner/mirror system yields the fastest critically damped step response to a square wave input. Once this is obtained, the system will yield the best overall performance for any given input waveform. Only tune the system up as fast as is needed for the specific application. Excessive speed or "loop gain" will cause the system to behave poorly.

If it is only desired to verify the system tuning, skip down to section 6.1.7.1.2. or to section 6.1.7.2.2. Do not turn all the pots back to ground or the entire tuning procedure will have to be followed.

6.1.7.1 Class 0

The object of this procedure is to bring the servo gain up slowly while maintaining control of the scanners at all times. Move all the trim-pots in small increments until experience with this system is obtained. If at any time during this procedure the scanners start to move erratically and make a loud buzzing noise, shut off the input power immediately and check the procedure to see if all steps were followed properly.

6.1.7.1.1. Coarse Tuning

1. Perform steps 1 - 7 in section 4.2. above.

2. Initialize all tuning pots. Turn R25, R28, and R42 counter-clockwise, CCW, at least 15 turns or until they begin to click. Ensure W3 is configured properly (differential non-inverting or inverting).

3. Turn R25, R28 and R42 4 full turns CW. This should allow the scanner to center with a slight amount of loop gain once the power is applied. It also allows the input signal to pass through the system, so be careful when turning on power in step 5 below. Ensure the input signal is set to a DC voltage of 0.0volts.
4. Attach a scope probe to the input signal generator to monitor the input signal. Use the rising edge of this signal as the trigger source for the scope. Attach another scope probe to TP1 to monitor the Position Output signal, VP. Use TP2 as the ground reference for both signals. Set the vertical gain to 0.2V/div for both channels on the scope.

5. Apply power to the system. The system should perform its normal turn-on sequence and both scanners should center themselves. Check the voltages at TP1 to ensure that the scanners are somewhat near the center of the field. (Within ~1 volt.) If the scanners have not yet centered, turn R25 and R28 CW a little more while carefully watching the oscilloscope for any erratic

behavior. Ensure that the servo loop is slightly "stiff" by attempting to move the mirror. Touch the mirror only by the edges to avoid fingerprints. The use of finger cots is highly recommended. When the servo is stiff, the mirror will resist slight efforts to move it, and center again when released. Once this is obtained, continue on to the next step.

****Caution!!** If at this time a load buzzing or whining noise is heard from the scanners, shut off the power immediately. Turn R28 CCW one full turn and try applying power again. If the system is still not behaving well, start over at step 1, using less turns for step 3. If the system cannot be made to work, call Cambridge Technology for assistance.

6. Input a square wave input signal at a frequency of 30Hz. Set the amplitude to produce about 2 degrees p-p of scanner shaft motion. The exact amount is not important as long as the motion is small.

7. The scanner should now be responding to the input waveform, but should look very underdamped. Continue to turn R28 CW until the oscillations just die out before the next half cycle of the input signal. See figure 1.

8. Turn R25 CW to minimize the first overshoot and to minimize the oscillations. See figure 2.

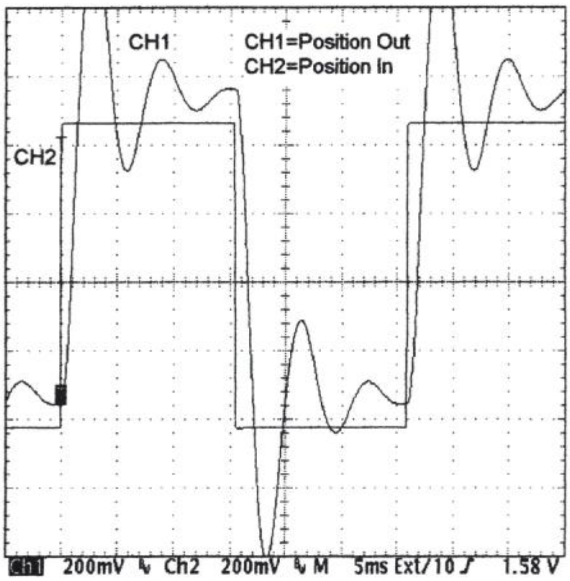


Figure 1.

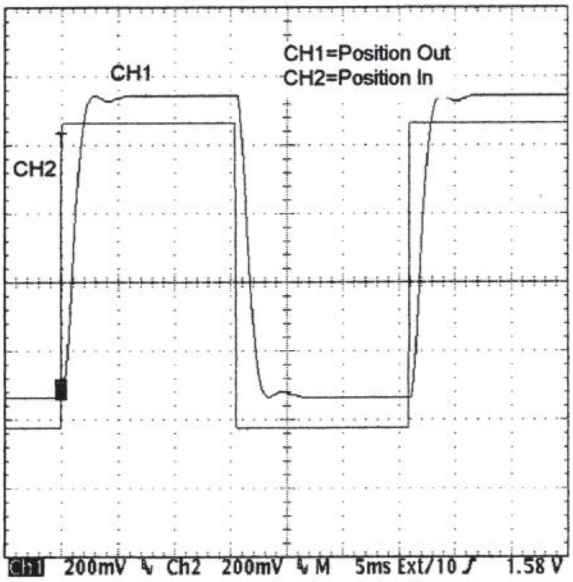


Figure 2.

9. Turn R42 CW until the undershoot is minimized, i.e. at the same amplitude as the settled position. See Figure 3.

10. Turn R25 CW until the first overshoot is minimized, i.e. at the same amplitude as the settled position. See Figure 4.

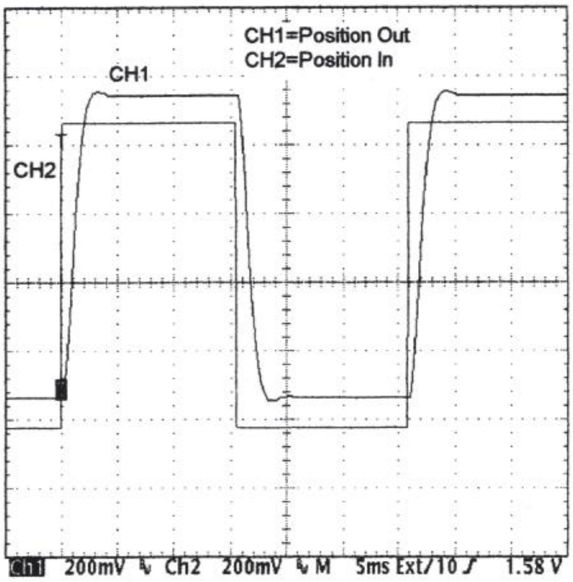


Figure 3.

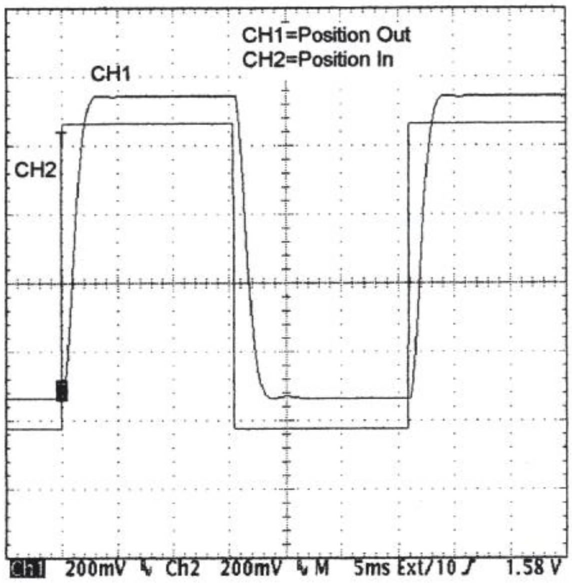


Figure 4.

11. Iterate steps 9 and 10 above until the waveform is critically damped as shown in figure 5.

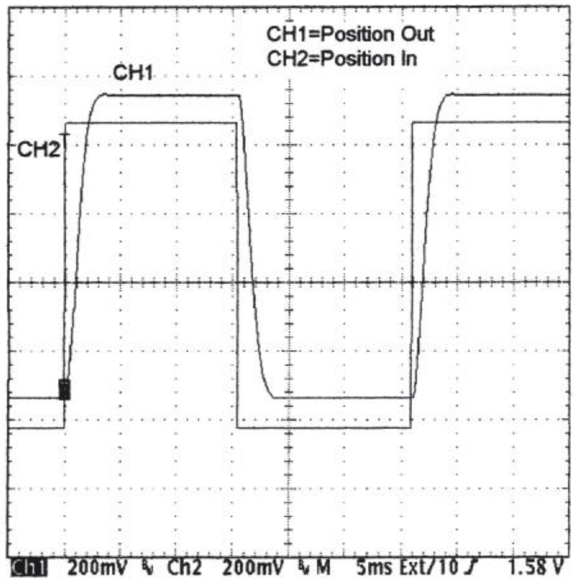


Figure 5.

12. To increase the speed of the system (decrease the step response time) still further, slowly turn R28 CW a few more turns, then re-tweak the other trim-pots as before to make the waveform look critically damped again. This can be done until the desired small-angle step response time is obtained or the system begins to resonate or "ring". If this ringing occurs, immediately turn back the trim-pots starting with R28, then R25 and then R42 until this stops. Turn each trim-pot CCW gradually and evenly, similar to when the loop gain was increased. Do not operate the system with the loop gain turned up so high that the servo rings anywhere in the field. Experience with the system will determine how fast it should be tuned. Call Cambridge Technology Inc. for more information on this subject. Refer to figure 6 for proper tuning after iterating through the above steps.

Note the critical damping in figure 6. There is no appreciable overshoot nor undershoot. The step response for this scanner/servo system is about 1.25msec. The scanner is considered settled when the position signal has settled to within about 1% of the length of the step. The exact step response time will vary from system to system depending on load dynamics and scanner size.

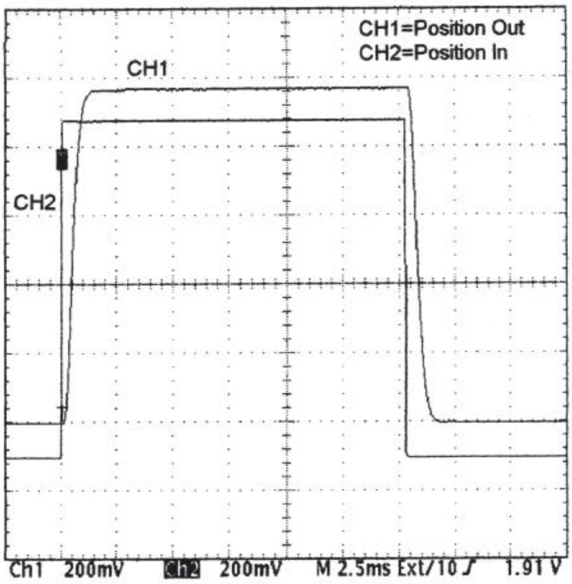


Figure 6.

6.1.7.1.2. Fine Tuning

1. Setup the system by performing steps 1, 4, and 6 from section 6.1.7.1.1. above.

2. Turn on the system power.

3. Adjust the input signal amplitude and offset so that the scanner now steps from -2.0 degrees to 0.0 degrees in a square wave fashion and at the same frequency as before.

4. Adjust the oscilloscope channel monitoring Vp to 10mV/div. The system should now look like Figure 7.

Note: Since only the coarse tuning has been performed thus far, your waveform may look slightly different at this point. However, the same tuning rules still apply.

5. Turn R42 CW to minimize the amplitude of the undershoot as shown in Figure 8.

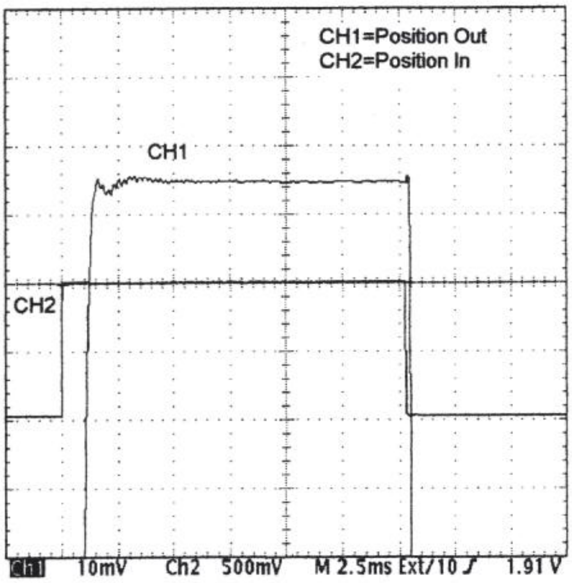


Figure 7.

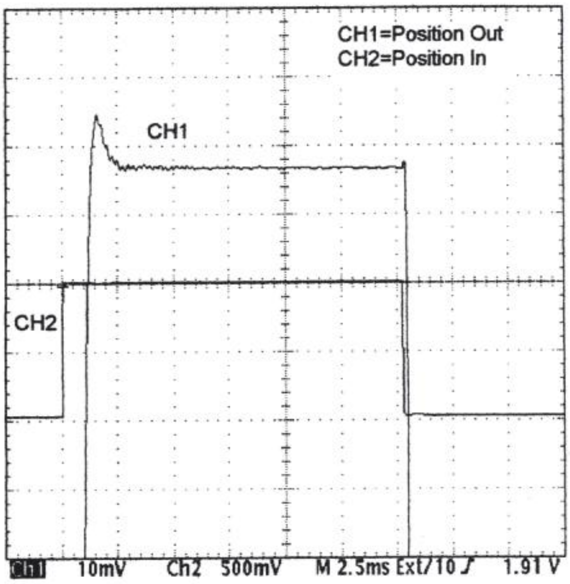


Figure 8.

6. Turn R25 CW to eliminate the overshoot. See Figure 9.
7. Iterate steps 5 and 6 until the system settles as well as possible. See figures 10. and 11.

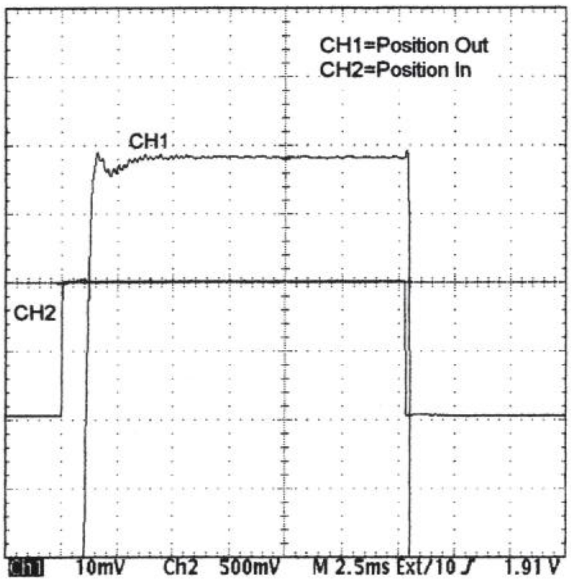


Figure 9.

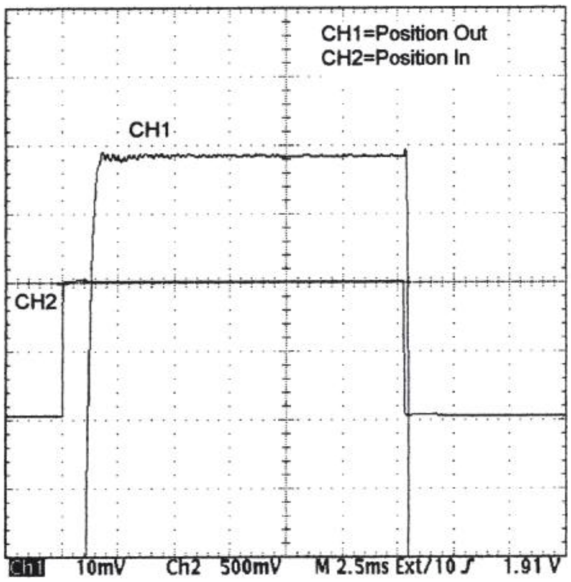


Figure 10.

Note: Whenever the small angle step response is changed, the large angle step response should be checked.

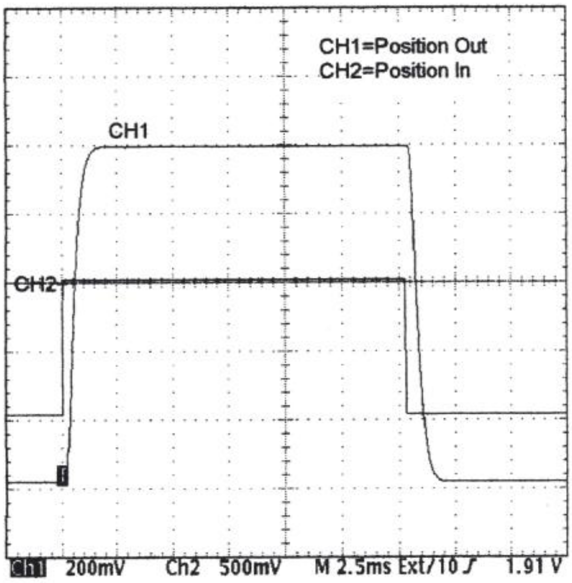


Figure 11.

6.1.7.1.1. Matching the X and Y Channels

The purpose of this section is to match the dynamic performances of two servo channels over all angles and frequencies. If the two channels are not closely matched, the system will not make straight lines when both channels are moved simultaneously. They also will not retrace a pattern when the beam is traveling in the opposite direction. Thus, it is crucial for optimum performance to perform this procedure whenever either servo channel has been retuned. This matching is done standard at Cambridge Technology and should not need to be repeated during the normal operating life of the system.

1. Set up the system by following steps 1 - 7 in section 4.2. The system must have had its Position Input Scale Factor, Position Output Scale Factor, and Closed Loop Response adjusted properly to perform this. Ensure the mirrors are aligned to eliminate the chance of mirror collision or interference.

2. Input a 30 Hz square wave signal such that the scanners move 2 degrees mechanical peak-to-peak. For larger systems a slower square wave can be used. It is very important that the two channels receive the information simultaneously, or this procedure cannot be performed properly. This is easily done by using a BNC "T" connector and hooking up to both inputs simultaneously.

3. Turn on the system power. Monitor both channels' position out signals, Vp on TP1 on an oscilloscope while externally triggering the scope on the input signal at W3. Monitor the channel with the greater inertia first. This is usually the slower system. In most cases this is the Y-channel. Ensure the step response is at the required speed for the application and that

it looks critically damped. Refer to the tuning procedure above in section 6.1. for specific instructions. If it is not tuned as required, retune this channel now.

5. Now monitor both channels' Position Out signals superimposed on one another on the oscilloscope. Increase the vertical gain and sweep speed on the oscilloscope until the speed difference between the two channels is noticeable. See Figures 12 and 13.

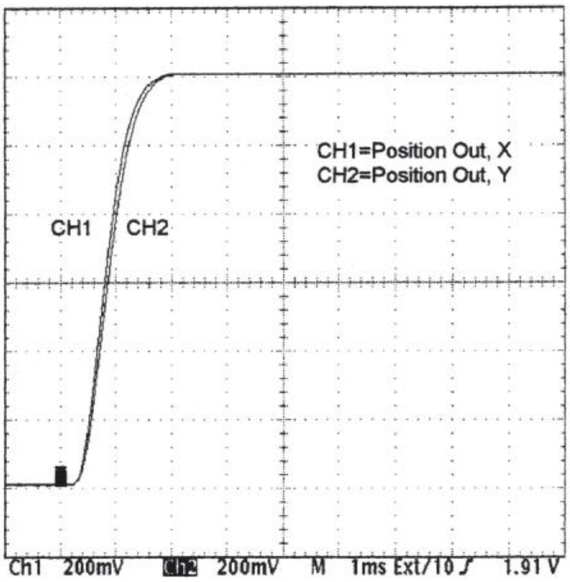


Figure 12.

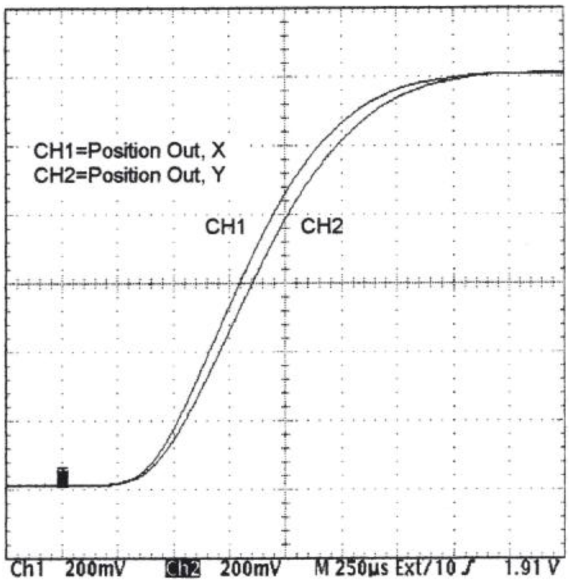


Figure 13.

6. Slow the faster servo channel as necessary by adjusting its servo adjustment trimpots slightly. Refer to section 6.1.7. for proper operation of all the tuning trimpots. Ensure that the channel is still critically damped when done. Be patient. The faster channel should be slowed to track the first almost perfectly. When done, the system should look like Figures 14 and 15.

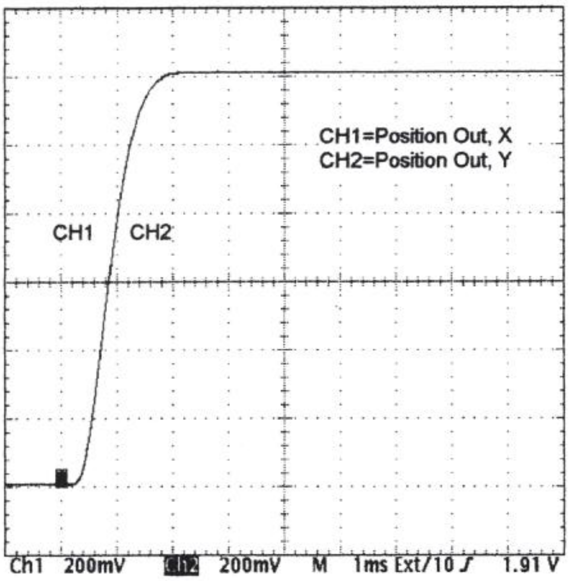


Figure 14.

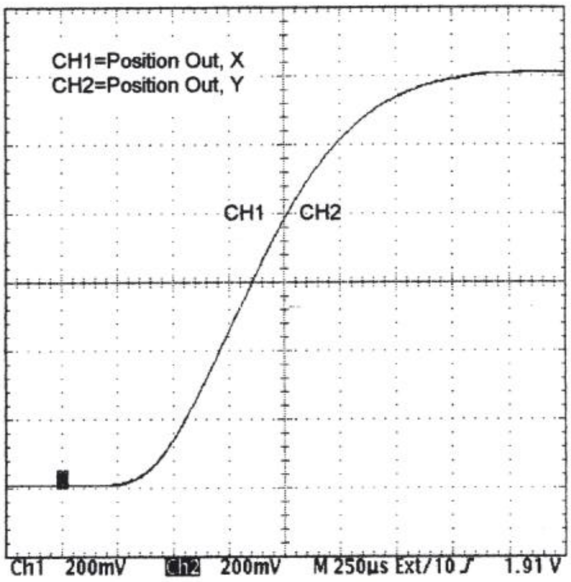


Figure 15.

6.2. Notch Filter Module

6.2.1 Background Theory

All mechanical systems are subject to vibrations via external excitation forces. The degrees of freedom of a vibrating mechanical system are defined by the number of independent coordinates required to identify its displacement during vibration. If we have a Cartesian coordinate system with x, y, and z axis, then for a freely vibrating body, we can have six degrees of freedom. This includes translational and rotational vibration in each of the three axis. Each of these possible vibrations is referred to as a *mode of vibration*. Each mode of vibration has a natural frequency associated with it that is independent of all the other modes.

For our discussion with respect to the scanner, we will concentrate on the rotational axial mode of vibration. The natural frequency F_r of this mode is a function of the mirror load inertia and rotor inertia as well as the torsional spring constant of the rotor shaft which couples the two inertias. The *undamped natural resonant frequency* of this mechanical system is described by the equation below:

$$\omega_R = k^{1/2}[(J_1+J_2)/J_1J_2]^{1/2}, \quad F_r = \omega_R/2\pi$$

where k = rotor torsional spring constant
J_1 = mirror load inertia
J_2 = rotor inertia

Note that in a real mechanical scanner system damping due to bearing friction, air friction on the rotor and mirror load, etc. do indeed exist. However, CTI scanners exhibit very low bearing friction, and the above equation can approximate the resonant frequency quite closely. The damping constant inversely influences the natural resonant frequency slightly. In other words, as the damping constant increases, the natural resonant frequency decreases.

This torsional resonant frequency can exhibit a high Q, which is defined as the sharpness and amplitude of the resonant frequency peak. If this resonance occurs in a closed loop servo system where the gain vs frequency has fallen off enough that the phase shift approaches 180°, and the amplitude peaking at resonance is enough that the position feedback gain rises near unity, servo loop instability and oscillations will result. This is the reason for using a notch filter in the forward path of the servo loop, after the summing amplifier. The notch filter is tuned to remove the frequency component of the error drive signal sent to the scanner control coil which is at the same frequency as the scanner torsional resonance. This keeps the scanner from being excited at its resonant frequency. The rejection of this driving frequency aids the stability of the servo by not exciting this natural resonant mode, and allows the closed loop bandwidth of the system to be higher. Higher closed loop bandwidth allows decreased step response times.

However, this does not mean that the scanner torsional resonance disappears. It does mean the servo amplifier no longer "kicks" the scanner at this frequency.

For very high speed systems, sometimes the first two resonant frequencies have to be notched out. For these systems, a "double notch" filter board has been developed called the 6744. This board is identical to the 6740, except that a second notch has been added to its frequency response. This results in a better response for extremely high speed systems, but also means that both notch filters must be set whenever the system is initially tuned or when the mirror load is changed.

6.2.2 6740-XX Notch Filter Tuning Procedure

The 6740 Notch Filter Module (NFM) is designed to be inserted into J3 of the 678XX servo amp. The selection of the proper NFM is described below, along with tuning information.

Overview

This procedure indicates how to:
1) Determine the **1st** torsional resonant frequency (**Fr**) of a scanner and mirror load combination
2) Select the proper 6740-xx Notch Filter Module (**NFM**)
3) Insert and Tune the NFM to the Fr

This procedure assumes the following:

- A properly heat-sinked, working 678 board is hooked up to a power supply with adequate current capability
- A working scanner *with mirror load* is in an X-Y mount or test clamp similar to that which the end use would provide, and connected to the 678 board
- The proper test equipment for normal system tuning is also set up and ready
- The 678 schematic and outline drawings are in front of you.
- The 6740 Notch Filter Module schematic is in front of you

Equipment Needed:

- Oscilloscope (dual trace, minimum 60Mhz BW)
- Frequency counter

* **678 board GND** connection points: **TP2, J4.4**

6.2.2.1. Determine Fr:

a) Set signal generator to 1khz sine wave, lowest amplitude. Note that we are assuming that Fr will be above 1Khz.

b) Connect a frequency counter to the output of the signal generator with a "T" connector.Without the NFM inserted into J3 (servo loop is broken), connect the signal generator to TP7. Ground can be obtained on TP2 or J4.4.

c) Observe position (TP1) and current (TP3) with scope.

d) Turn on power and signal generator.

e) Adjust the signal generator for about 200mV peak on current. This is an estimated figure. The main concern is that the current through the coil is large enough to view with good S/N ratio, but small enough to avoid excessive coil heating while performing this test. Maintain the position signal near 0 volts by adjusting the DC offset control of the function generator accordingly.

f) Slowly sweep frequency up while observing position and current on scope. Note the frequency where a peaking occurs in the position waveform. This is Fr. You can also hear the scanner become louder at Fr as well. When Fr is identified, keep the signal generator at this frequency and shut it off promptly, as well as board power. Bearing wear will result if the scanner is held at the resonant frequency for too long.

6.2.2.2. Select the proper 6740-XX NFM

The 6740-XX NFM's come in five different frequency ranges:

6740-06	12.5-20 Khz
6740-05	7-14 Khz
6740-04	5-10 Khz
6740-03	3.7-7.5 Khz
6740-02	2.2-4.5 Khz
6740-01	1.6-3.4 Khz

Select the proper one for the Fr measured in step (1.f) above. Choose the one where the measured Fr is closest to the center of the range.

6.2.2.3. Insert and tune the 6740-XX NFM

Make sure that the 678 board is completely de-tuned. This section of the procedure will not work otherwise.

a) Insert the NFM with its solder side facing the 678 heatsink bracket.

b) Connect J1.3 to ground via jumper clip. This open circuits the output amp so that it will not be driving the scanner during NFM adjustment

c) Connect the signal generator to TP6. This is the summing amp input. Connect the scope probe to TP7. This is the NFM output.

d) Turn on the signal generator and observe the NFM output on the scope. The signal generator should still be set at the resonant frequency Fr from the previous measurement. This is very important, since the NFM has a sharp attenuation characteristic. If the frequency that the NFM is being tuned to reject is not exactly at the Fr of the scanner and load combination, ringing may still occur when tuning the scanner. This is especially true for high Q scanner torsional resonances.

e) Adjust the Frequency pot, R8, on the NFM until a minimum is obtained in the NFM output waveform.

f) Now adjust the Depth pot, R9, on the NFM to further minimize the output waveform.

g) Repeat steps (e) and (f) until the NFM output waveform at Fr is minimized as much as possible. At this point, you are done.

6.2.3 6744-XX Dual Notch Filter Tuning Procedure

The 6744 Dual Notch Filter Module (DNFM) is designed to be inserted into J3 of the 678XX servo amp. The selection of the proper NFM is described below, along with tuning information.

Overview

This procedure indicates how to:
1) Determine the **1st** and **2nd** torsional resonant frequencies of a scanner and mirror load combination
2) Select the proper 6744-XX/XX Dual Notch Filter Module (**DNFM**)
3) Insert and Tune the NFM

This procedure assumes the following:

- A properly heat-sinked, working 678 board is hooked up to a power supply with adequate current capability
- A working scanner *with mirror load* is in an X-Y mount or test clamp similar to that which the end use would provide, and connected to the 678 board
- The proper test equipment for normal system tuning is also set up and ready
- The 678 schematic and outline drawings are in front of you.
- The 6740 Notch Filter Module schematic is in front of you

Equipment Needed:

- Oscilloscope (dual trace, minimum 60Mhz BW)
- Frequency counter

* **678 board GND** connection points: **TP2, J4.4**

6.2.3.1. Determine Fr_1 and Fr_2:

a) Set signal generator to 1khz sine wave, lowest amplitude. Note that we are assuming that Fr will be above 1Khz.

b) Connect a frequency counter to the output of the signal generator with a "T" connector. Without the DNFM inserted into J3 (servo loop is broken), connect the signal generator to TP7. Ground can be obtained on TP2 or J4.4.

c) Observe position (TP1) and current (TP3) with scope.

d) Turn on power and signal generator.

e) Adjust the signal generator for about 200mV peak on current. This is an estimated figure. The main concern is that the current through the coil is large enough to view with good S/N ratio, but small enough to avoid excessive coil heating while performing this test. Maintain the position signal near 0 volts by adjusting the DC offset control of the function generator accordingly.

f) Slowly sweep frequency up while observing position and current on scope. Note the **first** frequency where a **major** peaking occurs in the position waveform. This is Fr_1. You can also hear the scanner become louder at this frequency as well. When Fr_1 is identified, sweep up further until you detect the **second** frequency where a **major** peaking occurs in the position waveform. This is Fr_2. Bearing wear will result if the scanner is held at either of these two resonant frequencies for too long.

6.2.3.2. Select the proper 6744-XX/XX DNFM

The 6744-XX/XX DNFM's are defined the same as the single notch filters, except that there are two of them on the board where each can be defined independently. Thus:

-XX	Frequency Range
-06	12.5-20 Khz
-05	7-14 Khz
-04	5-10 Khz
-03	3.7-7.5 Khz
-02	2.2-4.5 Khz
-01	1.6-3.4 Khz

Thus, a 6744-05/06 is a filter whose Fr_1 range is from 7 – 14KHz and whose Fr_2 range is from 12.5 – 20 KHz.

Select the proper one for the frequencies measured in step (1.f) above. Choose the one where the measured frequencies are closest to the center of the range.

6.2.3.3. Insert and tune the 6744-XX DNFM

Make sure that the 678 board is completely de-tuned. This section of the procedure will not work otherwise.

a) Insert the DNFM with its solder side facing the 678 heatsink bracket.

b) Connect J1.3 to ground via jumper clip. This open circuits the output amp so that it will not be driving the scanner during DNFM adjustment.

c) Connect the signal generator to TP6. This is the summing amp input. Connect the scope probe to TP7. This is the DNFM output.

d) Turn on the signal generator and observe the DNFM output on the scope. Set the signal generator to exactly the resonant frequency Fr_1 from the previous measurement. This is very important, since the DNFM has a sharp attenuation characteristic. If the frequency that the DNFM is being tuned to reject is not exactly at Fr_1 of the scanner and load combination, ringing may still occur when tuning the scanner. This is especially true for high Q scanner torsional resonances.

e) Adjust the Frequency pot for Fr_1, R8, on the DNFM until a minimum is obtained in the NFM output waveform.

f) Adjust the Depth pot for Fr_1, R9, on the DNFM to further minimize the output waveform.

g) Turn the signal generator to the second resonant frequency, Fr_2, measured in step 1)f above.

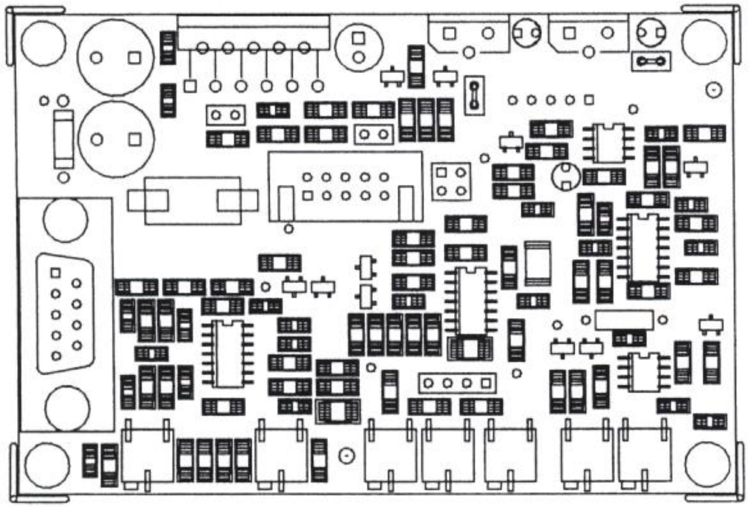
h) Adjust the Frequency pot for Fr_2, R18, on the DNFM until a minimum is obtained in the NFM output waveform. Note: At present there is no depth pot for Fr_2 at the present time.

Repeat steps (d) through (h) until the DNFM output waveform at Fr_1 and Fr_2 is minimized as much as possible. Note: If Fr_1 and Fr_2 are close to each other, they will the frequency adjustment pots will interact strongly. At this point, you are done.

6.3. Schematics and Assembly Drawings

This section contains the following schematic and assembly drawings.

1.) 678XX Schematic	D03277
2.) 678XX Assembly Drawing	D03278
3.) 678XX Silkscreen Drawing	D03285
4.) 678XX Outline Drawing	D03435
5.) 6010-1 Drive Cable Assembly Drawing	D00898
6.) 6010-8 Drive Cable Assembly Drawing	D01978
7.) 6010-8L Drive Cable Assembly Drawing	D03187
8.) 6010-11 Drive Cable Assembly Drawing	D02430
9.) 6010-16 Drive Cable Assembly Drawing	D03188
10.) 6010-17 Drive Cable Assembly Drawing	D03190
11.) 6010-17L Drive Cable Assembly Drawing	D03189
12.) 6010-18 Drive Cable Assembly Drawing	D03365
13.) 6010-19 Drive Cable Assembly Drawing	D04067
14.) 6740 Schematic – Notch Filter Module	D03233
15.) 6740 Assembly Drawing	D03234
16.) 6744 Schematic – Dual Notch Filter Module	D04295
17.) 6744 Assembly Drawing – Front Side	D04305
18.) 6744 Assembly Drawing – Back Side	D04306



AS VIEWED FROM COMPONENT SIDE

NOTES:

1. SQUARE PADS INDICATE THE FOLLOWING:
   A. PIN "1" OF MULTILEAD DEVICES.(DIPS, SIPS, POTS, ETC.)
   B. POLARITY PINS OF DISCRETE COMPONENTS.
      (CATHODE, EMITTER, "+", ETC.)

DRAWN	ZENITH	DATE 5/29/97
CHECKED		DATE
ELECTRICAL ENGINEER		DATE
MECHANICAL ENGINEER		DATE
QUALITY ASSURANCE		DATE
PROJECT ENGINEER		DATE
PROJECT APPROVAL		

UNLESS OTHERWISE SPECIFIED

REMOVE ALL BURRS & BREAK SHARP EDGES .005 MAX.
DIMENSIONS ARE IN INCHES TOLERANCE ON

DECIMALS
.XX +/-.010
.XXX +/-.005
FRACTIONS +/- 1/32
ANGLES +/- 1°

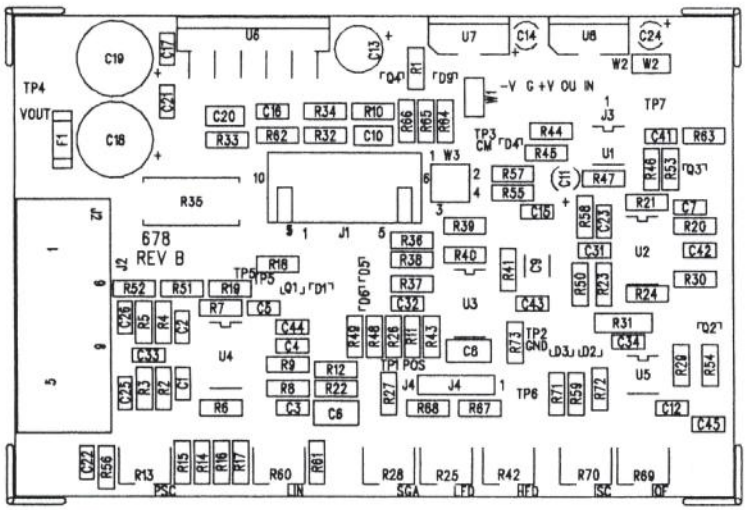
SURFACE ROUGHNESS ✓

DO NOT SCALE PRINT

CAMBRIDGE TECHNOLOGY, INC.

ASSEMBLY DRAWING
678 SMD SERVO AMP.

SIZE	CODE IDENT NO.	TYPE		REV
C			D03278	B
SCALE 2/1			SHEET 1 OF 1	



AS VIEWED FROM COMPONENT SIDE

UNLESS OTHERWISE SPECIFIED	
REMOVE ALL BURRS & BREAK SHARP EDGES .005 MAX. DIMENSIONS ARE IN INCHES TOLERANCE ON	
DECIMALS .XX +/-.010 .XXX +/-.005 FRACTIONS +/- 1/32 ANGLES +/- 1°	SURFACE ROUGHNESS ✓

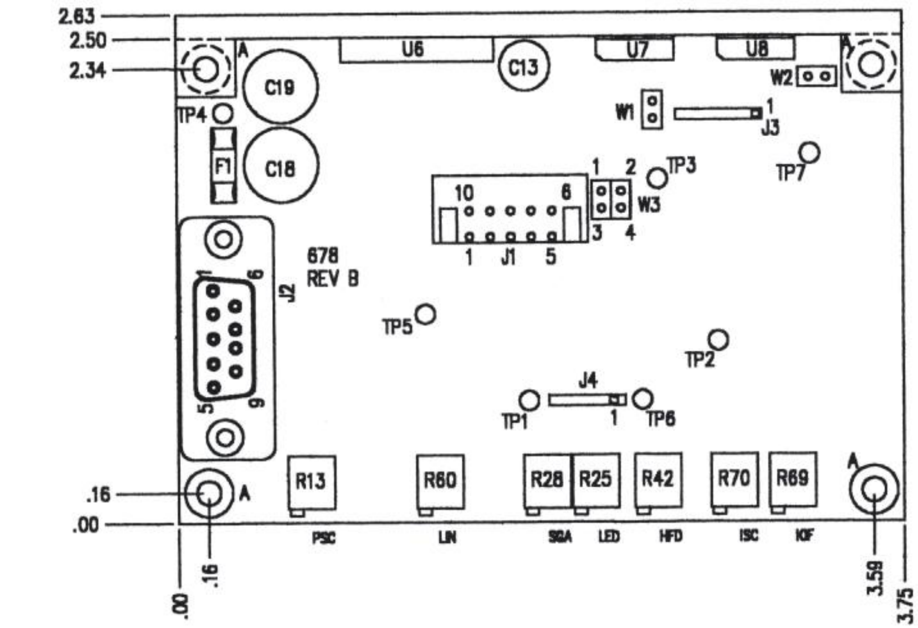
		DATE
DRAWN	ZENITH	5/29/97
CHECKED		
ELECTRICAL ENGINEER		
MECHANICAL ENGINEER		
QUALITY ASSURANCE		
PROJECT ENGINEER		
PROJECT APPROVAL		

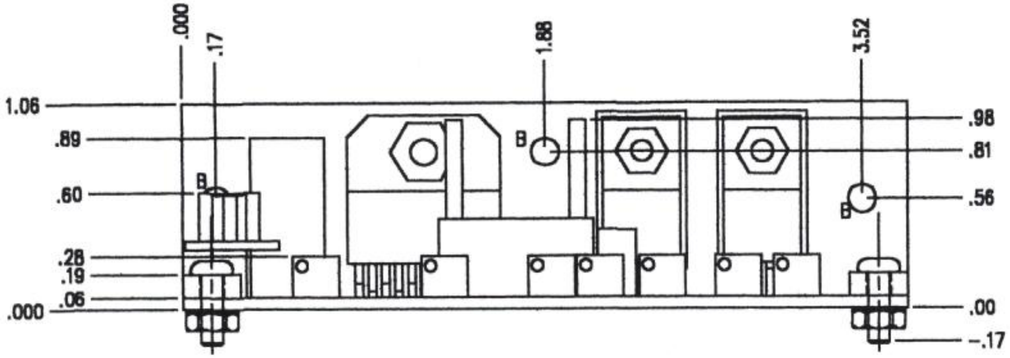
CAMBRIDGE TECHNOLOGY, INC.

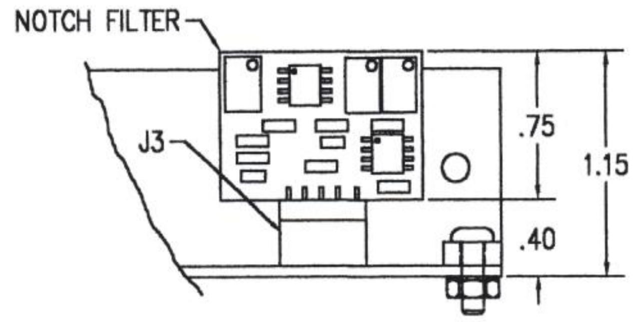
SILKSCREEN DRAWING
678 SMD SERVO AMP.

SIZE	CODE IDENT NO.	TYPE		REV
C			D03285	B

REVISION				
ECO	REV	DESCRIPTION	APPR	DATE







J1 (10 PIN)

PIN #	SIGNAL NAME
1	– DRIVE
2	– DRIVE RET
3	MUTE
4	COMMAND (GND)
5	COMMAND (+)
6	COMMAND (–)
7	N/U
8	N/U
9	+ DRIVE RET
10	+ DRIVE

J2 (9 PIN 'D')

PIN #	SIGNAL NAME
1	+MOTOR
2	MOTOR SHIELD
3	AGC RET
4	DIODE COMMON
5	IA
6	–MOTOR
7	PD SHIELD
8	AGC OUT
9	IB

TRIM	FUNCTION
R60	POS. DET. LINEARITY (LIN)
R13	POS. DET. SCALE FACTOR (PSC)
R25	LOW FREQ. DAMPING (LED)
R28	SERVO GAIN (SGA)
R42	HI FREQ. DAMPING (HFD)
R69	POS. IN. OFFSET (IOF)
R70	POS. IN. SCALE (ISC)

TEST POINTS	FUNCTION
TP1	POSITION SIGNAL, VP
TP2	GROUND
TP3	CURRENT MONITOR
TP4	MOTOR VOLTAGE, +M
TP5	AGC OUT
TP6	SUMMING AMP INPUT
TP7	NOTCH FILTER OUTPUT

J3 (5 PIN)

PIN #	SIGNAL NAME
1	NOTCH FILTER INPUT
2	NOTCH FILTER OUTPUT
3	+ 15V
4	GRD #1
5	– 15V

J4 (4 PIN)

PIN #	SIGNAL NAME
1	POSITION OUT
2	VELOCITY OUT
3	ERROR OUT
4	GND

JUMPER	FUNCTION	JUMPER SETTING	INPUTS, J1 (+)IN	(–)IN	GND
W1,W2	INSTALLED FOR +/-15V OPERATION				
W3	INPUT SELECTOR:				
	NON-INVERTING, DIFFERENTIAL	1-2, 3-4	5	6	4
	INVERTING, DIFFERENTIAL	1-3, 2-4	5	6	4
	NON-INVERTING, SINGLE-ENDED	1-2, 3-4	5		6&4
	INVERTING, SINGLE-ENDED	1-3, 2-4	5		6&4

HOLE	QTY	SIZE
A	4	ø.125 THRU
B	3	ø.145 THRU

UNLESS OTHERWISE SPECIFIED
TOLERANCES
.XX = ±.010
.XXX = ±.005
( ) INDICATES mm
ANGLES± 0°-30'
SURFACE ROUGHNESS 63√
BREAK ALL SHARP EDGES

MATERIAL ________

FINISH ________

USED ON

DRN	JFL	10/97
DES		
CHK		
ENG		
APPR		
PROJECTION		
REVISION	B	

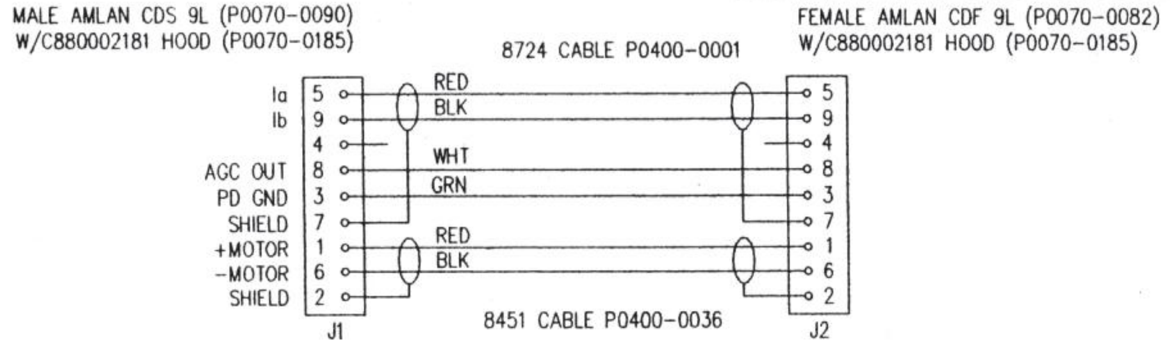
CAMBRIDGE TECHNOLOGY, INC.
109 SMITH PLACE
CAMBRIDGE, MA. 02138 – USA

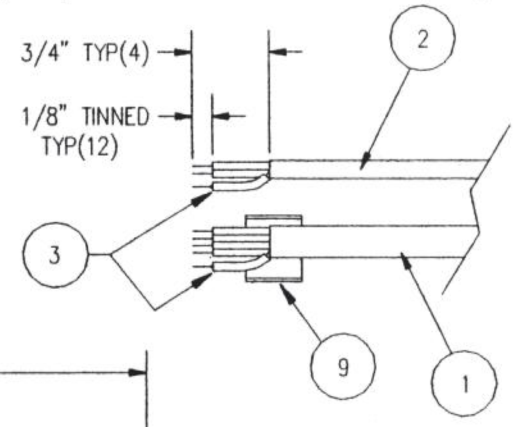
678 SMD SERVO AMP. OUTLINE

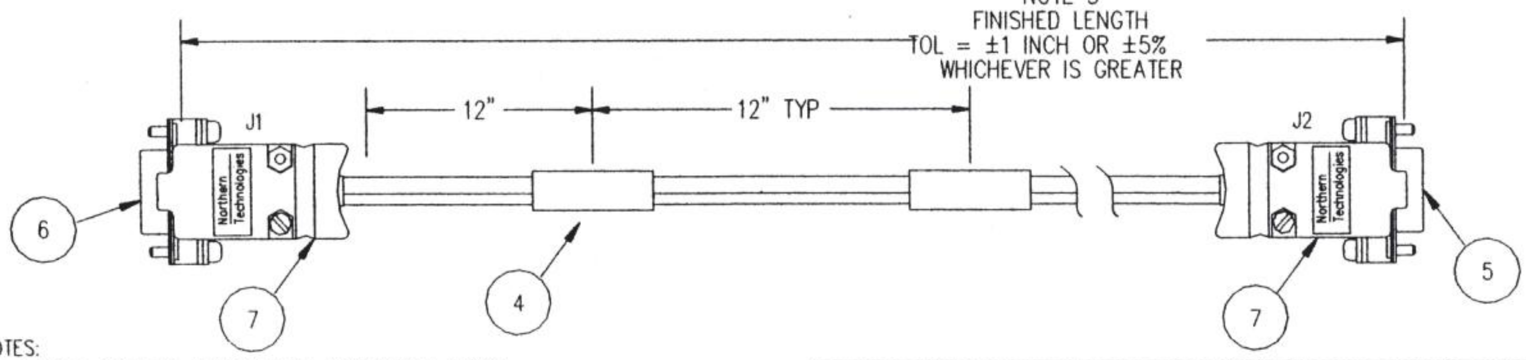
D03435

SCALE 2x | SHEET 1 OF 1

REVISION				
ECO	REV	DESCRIPTION	APPR	DATE
368	A	ASSY VIEW ADDED	PTH	4/91
640	B	NOTES & CBL END PREP VIEW ADDED	PTH	8/94
-	C	LENGTH REDEFINED	PTH	8/96
1069	D	MTL HOOD MFG # CHG'D, STNDOFF REMV'D	PTH	7/97







NOTES:

1. 4 COND CABLE IS BELDEN TYPE 8724(P0400-0001)
2. 2 COND CABLE IS BELDEN TYPE 8451(P0400-0036)
3. 1/16 HEATSHRINK TUBING (P0430-0018)TO BE USED ON SHIELD DRAIN WIRES.
4. +MOTOR IS DEFINED AS CAUSING A CW ROTATION OF THE OUTPUT SHAFT WHEN +MOTOR IS DRIVEN POSITIVE WITH RESPECT TO -MOTOR
5. "FINISHED LENGTH" DEFINED BY -XXX.
   EXAMPLE : D00898-012 FINISHED LENGTH = 12"
6. MEDIAN CUT LENGTH (ON BOM) = FINISHED LENGTH.

UNLESS OTHERWISE SPECIFIED TOLERANCES .XX±.010 .XXX±.005 ( ) INDICATES mm ANGLES± 0'-30'	DRN 10/5/88 B.A. DES CHK ENG APPR	CAMBRIDGE TECHNOLOGY, INC. 23 ELM ST. WATERTOWN, MA. 02172 - USA	
MATERIAL	PROJECTION	6010-1-XXX SCANNER DRIVE CABLE	
FINISH	REVISION D	D00898	
USED ON		SCALE : NONE	SHEET 1 OF 1

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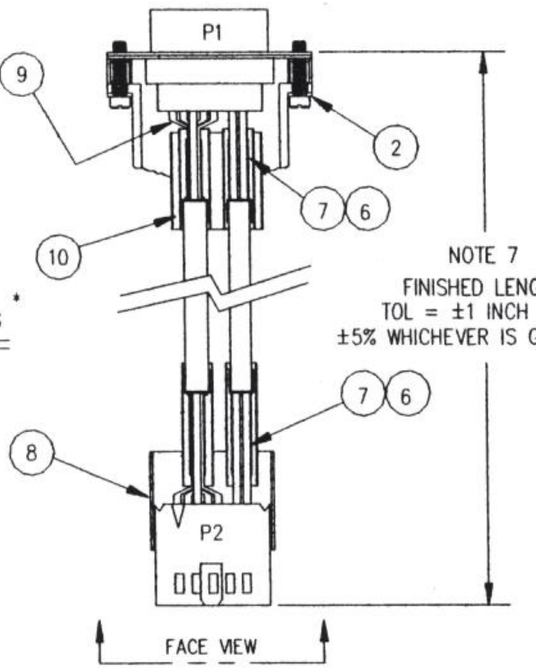
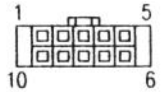
REVISION

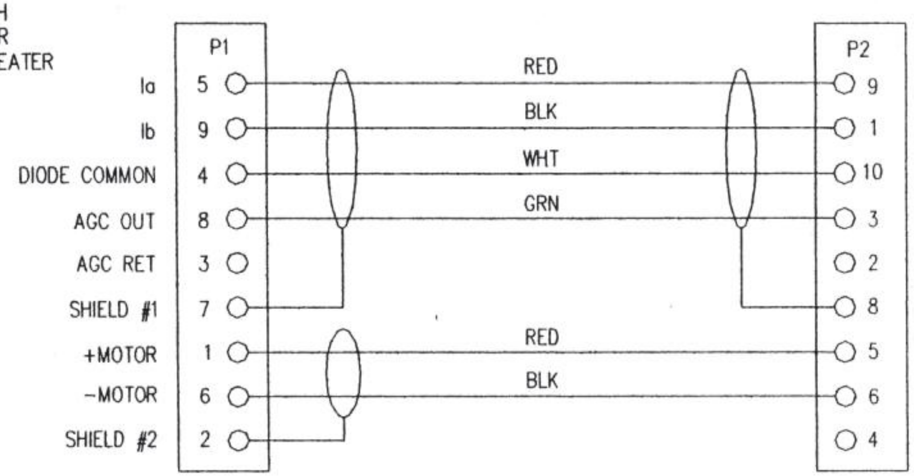
ECO	REV	DESCRIPTION	APPR	DATE
516	B	P2 CONNECTOR CHANGED	PTH	2/93
	C	POLARIZATION NOTE FOR P2 REMOVED	PTH	5/93
642	D	STRIP & TIN NOTE ADDED	PTH	8/94
657	E	ITEM BUBBLES CORRECTED P0430-13 WAS P0430-0014	PTH	9/94
667	F	-13 FM -14 ABOVE RETURNED TO ORIG	PTH	11/94
–	G	DWG# & TITLE UPDATED, LENGTH UPDATED	PTH	7/96
1079	G_1	FINISHED LENGTH NOTES CLARIFIED	PTH	8/97





* FACE VIEW OF PLUG *

AMLAN CDS 9L (P0070-0090)
WITH C88000218 HOOD (P0070-0185)



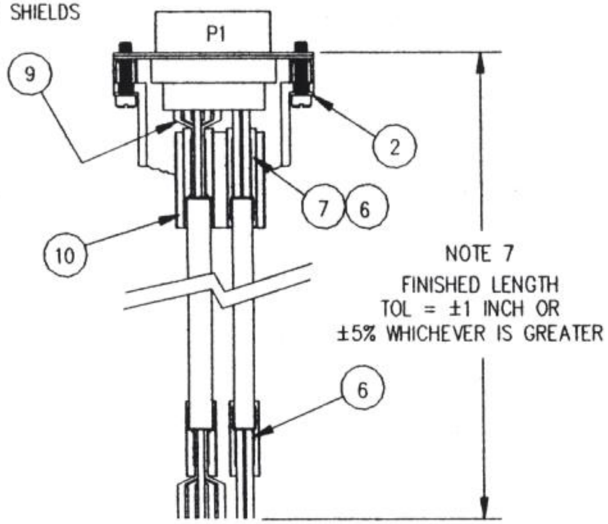
10 PIN AMP #102387-1 (P0070-0173)

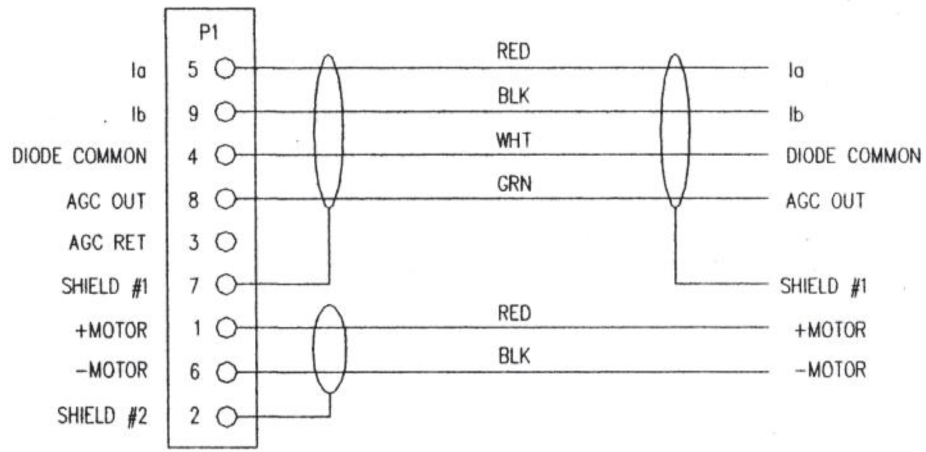
NOTES:

1. 4 CONDUCTOR WIRE - CTI #P0400-0065 (NEEWC#N11-40T-402)
2. 2 CONDUCTOR WIRE - CTI #P0400-0066 (NEEWC#N11-40T-403)
3. STRIP CABLE INSULATION BACK 3/4", STRIP & TIN WIRE INSULATION BACK 1/8" BOTH ENDS.
4. USE HEATSHRINK TUBING #P0430-0014 OVERALL EVERY 12" CAPTURE FIRST PIECE UNDER HOOD (P0070-0091)
5. USE COPPER FOIL - CTI #P0700-0047 ON BOTH ENDS OF EACH CABLE. FOIL MUST CONDUCT TO ITS CABLE'S DRAIN WIRE, AND MUST BE ISOLATED FROM EACH OTHER WITH HEATSHRINK #P0430-0015
6. +MOTOR IS DEFINED AS CAUSING A CW ROTATION OF THE OUTPUT SHAFT WHEN +MOTOR IS DRIVEN POSITIVE WITH RESPECT TO -MOTOR
7. MEDIAN CUT LENGTH (ON BOM) = FINISHED LENGTH.
8. "FINISHED LENGTH" DEFINED BY -XXX. EXAMPLE 6010-8-012 FINISHED LENGTH = 12'

UNLESS OTHERWISE SPECIFIED TOLERANCES +0,-1 INCH ( ) INDICATES mm ANGLES± 0°-30'	DRN	PTH	10/92	CAMBRIDGE TECHNOLOGY, INC. 109 SMITH PLACE CAMBRIDGE, MA. 02138 - USA
	DES	MDT	10/92	
	CHK			6010-8 68XX DRIVE CABLE
	ENG			
	APPR			
MATERIAL N/A	PROJECTION			D01978
FINISH N/A	REVISION G			
USED ON				SCALE NONE / SHEET 1 OF 1

REVISION				
ECO	REV	DESCRIPTION	APPR	DATE
978A	B	NOTE 8 ADDED	PTH	3/97
1069	C	MTL HOOD MFG # CHG'D	PTH	7/97



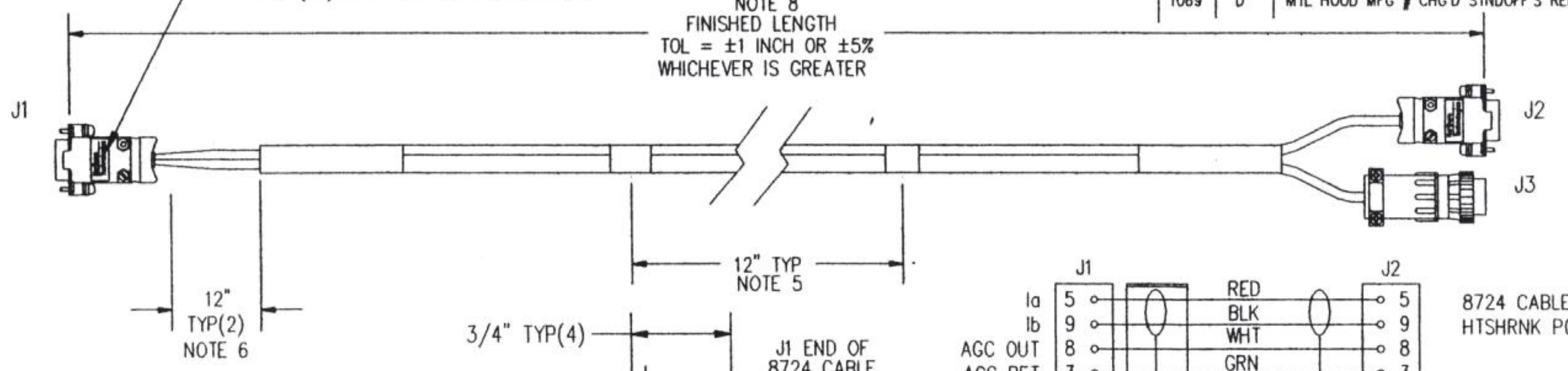


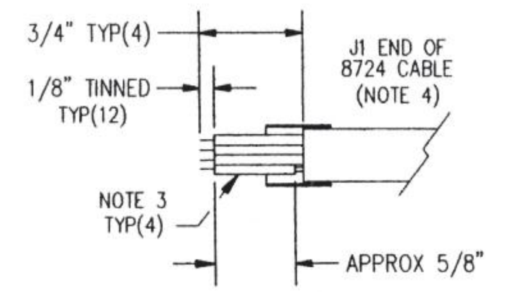
NOTES:

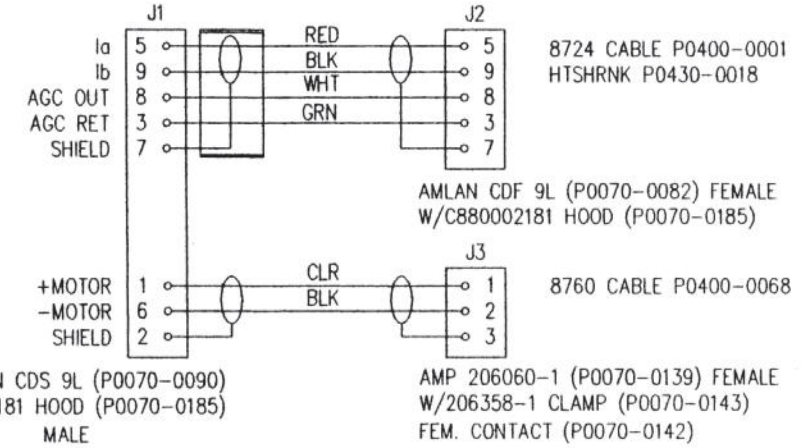
1. 4 CONDUCTOR WIRE - CTI #P0400-0065 (NEEWC#N11-40T-402)
2. 2 CONDUCTOR WIRE - CTI #P0400-0066 (NEEWC#N11-40T-403)
3. STRIP CABLE INSULATION BACK 3/4", STRIP & TIN WIRE INSULATION BACK 1/8" BOTH ENDS.
4. USE HEATSHRINK TUBING #P0430-0014 OVERALL EVERY 12" CAPTURE FIRST PIECE UNDER HOOD (P0070-0091)
5. USE COPPER FOIL - CTI #P0700-0047 ON 9 PIN 'D' END OF EACH CABLE. FOIL MUST CONDUCT TO ITS CABLE'S DRAIN WIRE, AND MUST BE ISOLATED FROM EACH OTHER WITH HEATSHRINK #P0430-0015
6. +MOTOR IS DEFINED AS CAUSING A CW ROTATION OF THE OUTPUT SHAFT WHEN +MOTOR IS DRIVEN POSITIVE WITH RESPECT TO -MOTOR
7. "FINISHED LENGTH" DEFINED BY -XXX. EXAMPLE : 6010-8L-012 FINISHED LENGTH = 12"
8. MEDIAN CUT LENGTH (ON BOM) = FINISHED LENGTH.
9. 1/16" HEATSINK TUBING (P0430-0018) TO BE USED ON SHIELD DRAIN WIRES ON NON-P1 END.

UNLESS OTHERWISE SPECIFIED TOLERANCES +0,-1 INCH ( ) INDICATES mm ANGLES± 0°-30'	DRN 03/04/97 PTH DES CHK ENG APPR	CAMBRIDGE TECHNOLOGY, INC. 23 ELM ST. WATERTOWN, MA. 02172 - USA	
MATERIAL N/A	PROJECTION	6010-8L-XXX 68XX DRIVE CABLE	
FINISH N/A	REVISION C	D03187	
USED ON		SCALE NONE	SHEET 1 OF 1

REVISION				
ECO	REV	DESCRIPTION	APPR	DATE
632	B	SEE ECO	PTH	6/94
-	C	LENGTH REDEFINED	PTH	8/96
1069	D	MTL HOOD MFG # CHG'D STNDOFF'S REMV'D	PTH	7/97





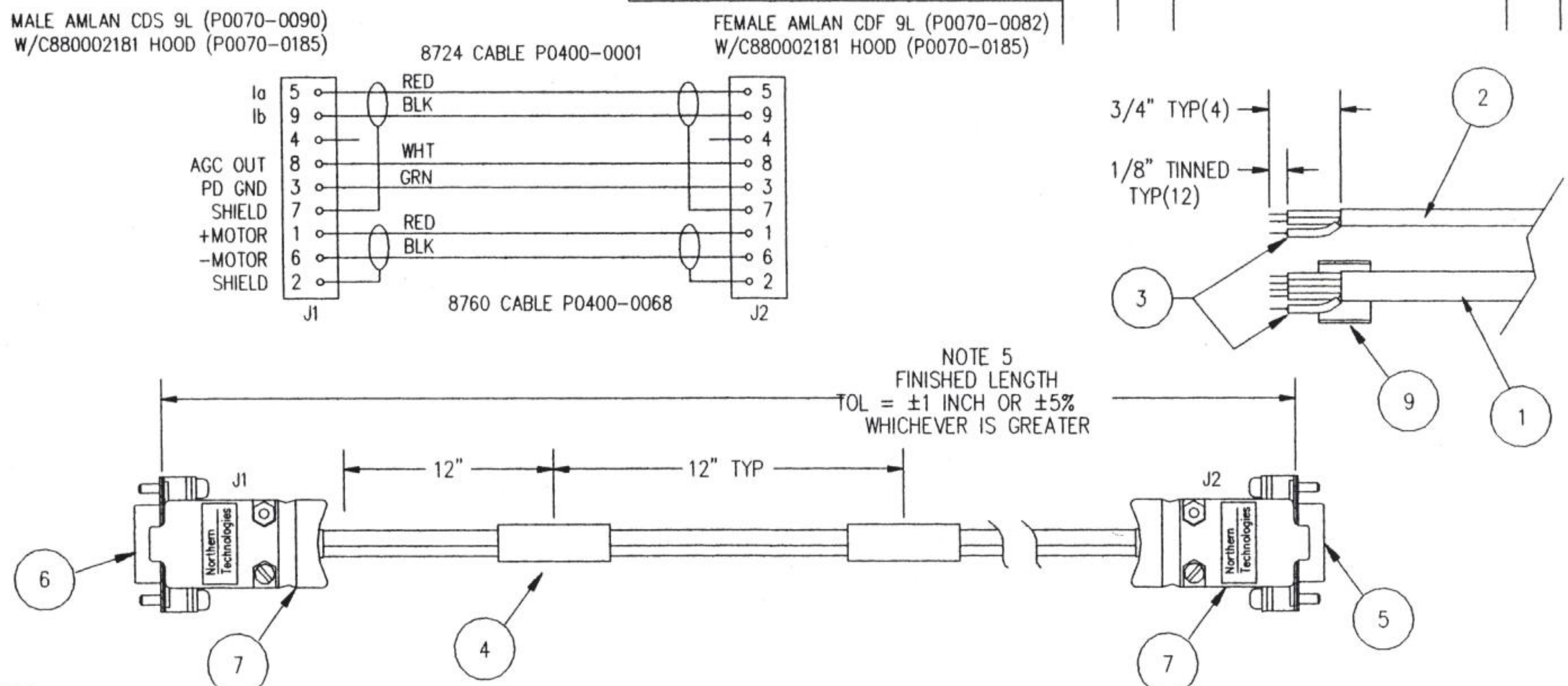


NOTES:

1. 4 COND CABLE IS BELDEN TYPE 8724(P0400-0001)
2. 2 COND CABLE IS BELDEN TYPE 8760(P0400-0068)
3. 1/16 HEATSHRINK TUBING (P0430-0018)TO BE USED ON SHIELD DRAIN WIRES OF 8724 & 8760 CABLES.
4. 3/16 HEATSHRINK TUBING (P0430-0023) TO BE USED ON 8724 CABLE AT J1 END TO COVER EXPOSED FOIL END AS SHOWN.
5. 3/8x1/2 BLK HEATSHRINK TUBING (P0430-0017) TO BE BE USED OVERALL EVERY 12 INCHES.
6. 3/8x2.5 HEATSHRINK TUBING (P0430-0011) TO BE PLACED 12 INCHES FROM EACH END OF THE CABLES AS SHOWN.
7. +MOTOR IS DEFINED AS CAUSING A CW ROTATION OF THE OUTPUT SHAFT WHEN +MOTOR IS DRIVEN POSITIVE WITH RESPECT TO -MOTOR
8. "FINISHED LENGTH" DEFINED BY -XXX. EXAMPLE : D02430-012 FINISHED LENGTH = 12"
9. MEDIAN CUT LENGTH (ON BOM) = FINISHED LENGTH.

	UNLESS OTHERWISE SPECIFIED TOLERANCES .XX±.010 .XXX±.005 ( ) INDICATES mm ANGLES± 0°-30'	DRN 6/2/94	PTH	CAMBRIDGE TECHNOLOGY, INC. 23 ELM ST. WATERTOWN, MA. 02172 - USA
		DES		6509/6900 DRIVE CABLE (6010-11-XXX)
		CHK		
		ENG		
		APPR		
	MATERIAL	PROJECTION		
	FINISH	REVISION D		D02430
USED ON				SCALE — / SHEET 1 OF 1

REVISION				
ECO	REV	DESCRIPTION	APPR	DATE
1069	B	MTL HOOD MFG # CHG'D, STNDOFFS REMV'D	PTH	7/97



NOTES:

1. 4 COND CABLE IS BELDEN TYPE 8724(P0400-0001)
2. 2 COND CABLE IS BELDEN TYPE 8760(P0400-0068)
3. 1/16 HEATSHRINK TUBING (P0430-0018)TO BE USED ON SHIELD DRAIN WIRES.
4. +MOTOR IS DEFINED AS CAUSING A CW ROTATION OF THE OUTPUT SHAFT WHEN +MOTOR IS DRIVEN POSITIVE WITH RESPECT TO -MOTOR
5. "FINISHED LENGTH" DEFINED BY -XXX.
   EXAMPLE : 6010-16-012 FINISHED LENGTH = 12"
6. MEDIAN CUT LENGTH (ON BOM) = FINISHED LENGTH.

USED ON	UNLESS OTHERWISE SPECIFIED TOLERANCES .XX±.010 .XXX±.005 ( ) INDICATES mm ANGLES± 0'-30'	DRN 10/5/88 B.A. DES CHK ENG APPR	CAMBRIDGE TECHNOLOGY, INC. 23 ELM ST. WATERTOWN, MA. 02172 - USA
	MATERIAL	PROJECTION	6010-16-XXX SCANNER DRIVE CABLE
	FINISH	REVISION B	D03188
			SCALE : NONE SHEET 1 OF 1

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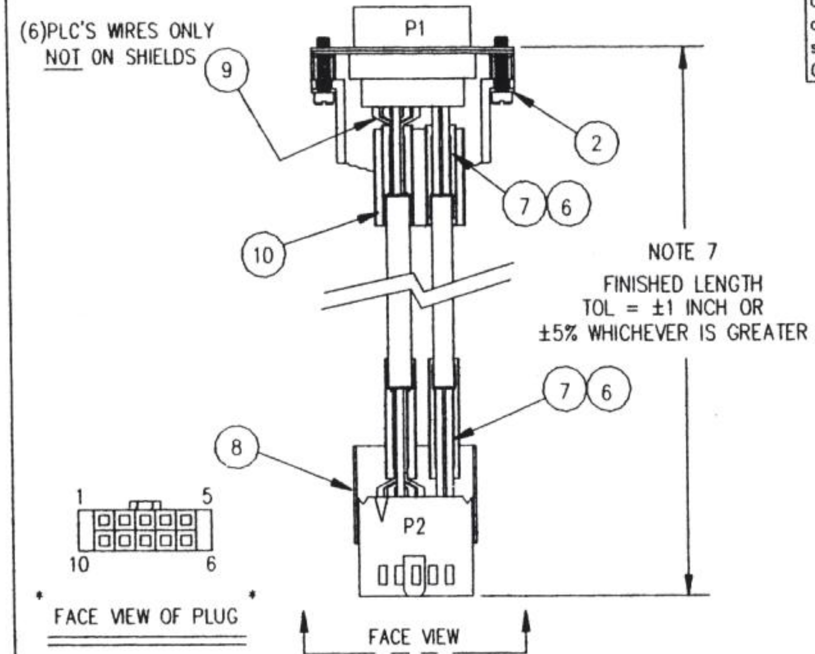
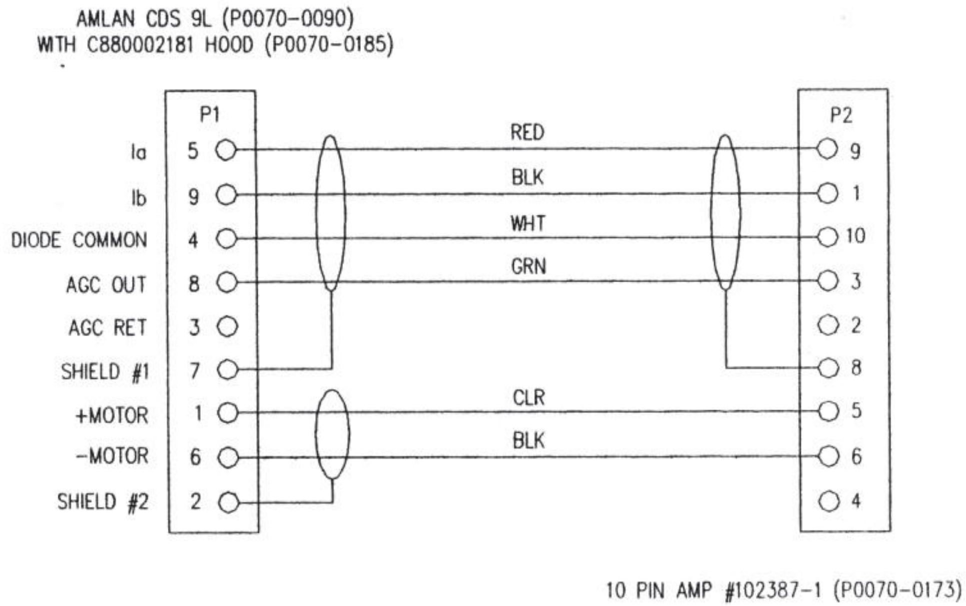
REVISION				
ECO	REV	DESCRIPTION	APPR	DATE
1069	B	MTL HOOD MFG # CHG'D	PTH	7/97
1188	C	NOTE 4 P0430-0017 WAS P0430-0014	PTH	2/98



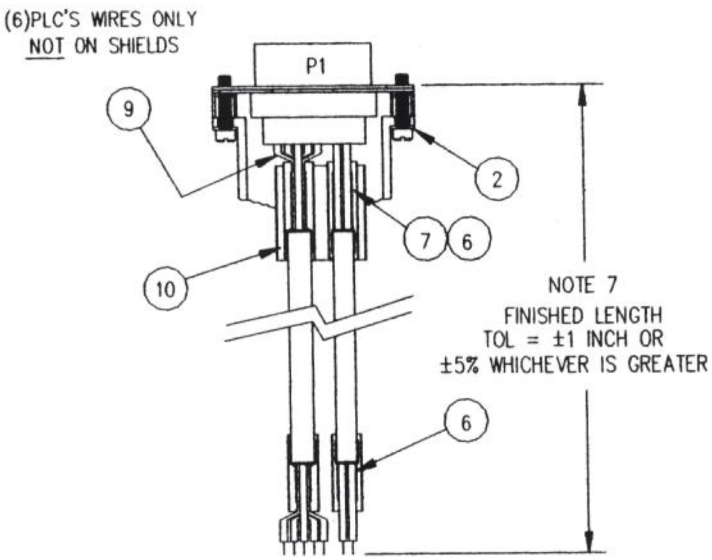


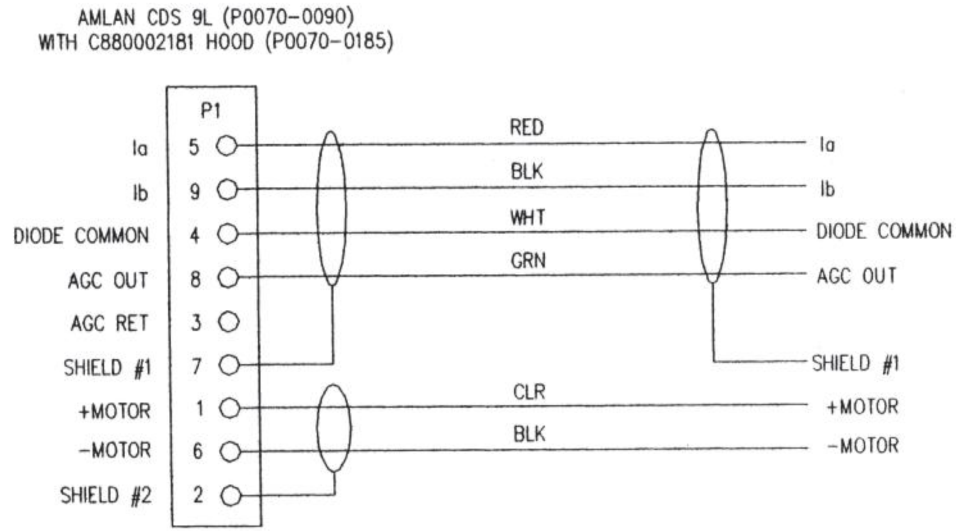
NOTES:

1. 4 CONDUCTOR WIRE - CTI #P0400-0065 (NEEWC#N11-40T-402)
2. 2 CONDUCTOR WIRE - CTI #P0400-0068 (BELDEN 8760)
3. STRIP CABLE INSULATION BACK 3/4", STRIP & TIN WIRE INSULATION BACK 1/8" BOTH ENDS.
4. USE HEATSHRINK TUBING #P0430-0017 OVERALL EVERY 12" CAPTURE FIRST PIECE UNDER HOOD (P0070-0091)
5. USE COPPER FOIL - CTI #P0700-0047 ON BOTH ENDS OF EACH CABLE. FOIL MUST CONDUCT TO ITS CABLE'S DRAIN WIRE, AND MUST BE ISOLATED FROM EACH OTHER WITH HEATSHRINK #P0430-0015
6. +MOTOR IS DEFINED AS CAUSING A CW ROTATION OF THE OUTPUT SHAFT WHEN +MOTOR IS DRIVEN POSITIVE WITH RESPECT TO -MOTOR
7. "FINISHED LENGTH" DEFINED BY -XXX. EXAMPLE : 6010-17-012 FINISHED LENGTH = 12"
8. MEDIAN CUT LENGTH (ON BOM) = FINISHED LENGTH.

UNLESS OTHERWISE SPECIFIED TOLERANCES +0,-1 INCH ( ) INDICATES mm ANGLES± 0°-30'	DRN 02/2797	PTH	CAMBRIDGE TECHNOLOGY, INC. 23 ELM ST. WATERTOWN, MA. 02172 - USA
	DES		6010-17-XXX 68XX DRIVE CABLE
	CHK		
	ENG		
	APPR		
MATERIAL N/A	PROJECTION		D03190
FINISH N/A	REVISION C		SCALE NONE	SHEET 1 OF 1
USED ON				

ECO	REV	DESCRIPTION	APPR	DATE
978A	B	NOTE 8 ADDED	PTH	3/97
1069	C	MTL HOOD MFG # CHG'D	PTH	7/97
1188	D	NOTE 4 P0430-0017 WAS P0430-0014	PTH	2/98





NOTES:

1. 4 CONDUCTOR WIRE - CTI #P0400-0065 (NEEWC#N11-40T-402)
2. 2 CONDUCTOR WIRE - CTI #P0400-0068 (BELDEN 8760)
3. STRIP CABLE INSULATION BACK 3/4", STRIP & TIN WIRE INSULATION BACK 1/8" BOTH ENDS.
4. USE HEATSHRINK TUBING #P0430-0017 OVERALL EVERY 12" CAPTURE FIRST PIECE UNDER HOOD (P0070-0091)
5. USE COPPER FOIL - CTI #P0700-0047 ON 9 PIN 'D' END OF EACH CABLE. FOIL MUST CONDUCT TO ITS CABLE'S DRAIN WIRE, AND MUST BE ISOLATED FROM EACH OTHER WITH HEATSHRINK #P0430-0015
6. +MOTOR IS DEFINED AS CAUSING A CW ROTATION OF THE OUTPUT SHAFT WHEN +MOTOR IS DRIVEN POSITIVE WITH RESPECT TO -MOTOR
7. "FINISHED LENGTH" DEFINED BY -XXX. EXAMPLE : 6010-17L-012 FINISHED LENGTH = 12"
8. MEDIAN CUT LENGTH (ON BOM) = FINISHED LENGTH.
9. 1/16" HEATSHRINK TUBING (P0430-0018) TO BE USED ON SHIELD DRAIN WIRE ON NON-P1 END

UNLESS OTHERWISE SPECIFIED
TOLERANCES
+0,-1 INCH

( ) INDICATES mm
ANGLES± 0°-30'

MATERIAL N/A

FINISH N/A

USED ON

DRN 03/04/97	PTH
DES	
CHK	
ENG	
APPR	

PROJECTION

REVISION D

CAMBRIDGE TECHNOLOGY, INC.
23 ELM ST.
WATERTOWN, MA. 02172 - USA

6010-17L-XXX
68XX DRIVE CABLE

D03189

SCALE NONE | SHEET 1 OF 1

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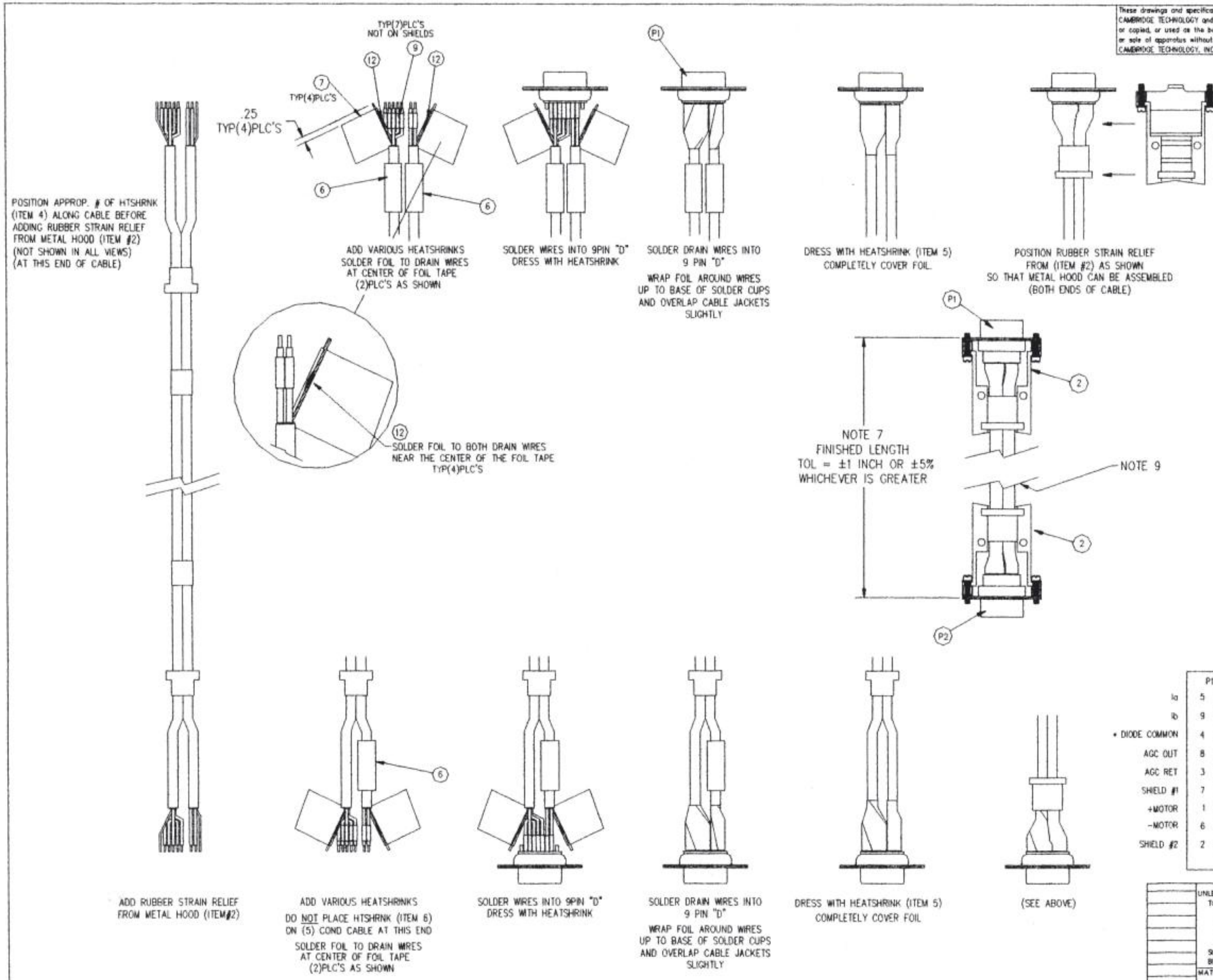
REVISION				
ECO	REV	DESCRIPTION	CHK	DATE
1698	C	DRESSING HTSHRNK REMOVED FROM (5) COND CABLE AT P2 END	PTH	7/00

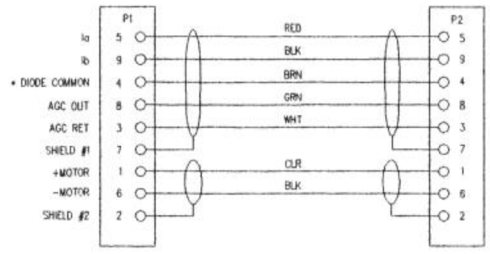


NOTES:

1. 5 CONDUCTOR CABLE (9535 WIRE)
2. 2 CONDUCTOR CABLE (18AWG WIRE)
3. STRIP CABLE INSULATION BACK 3/4", STRIP & TIN WIRE INSULATION BACK 1/8" BOTH ENDS.
4. USE HEATSHRINK TUBING (ITEM #10) OVERALL EVERY 12"
5. USE COPPER FOIL – (ITEM #7) ON BOTH ENDS OF CABLE. FOIL MUST CONDUCT TO EACH OF ITS CABLE'S DRAIN WIRES, AND MUST BE ISOLATED FROM EACH OTHER WITH HEATSHRINK (ITEM #6) BOTH CABLES
6. +MOTOR IS DEFINED AS CAUSING A CW ROTATION OF THE OUTPUT SHAFT WHEN +MOTOR IS DRIVEN POSITIVE WITH RESPECT TO –MOTOR

* SIGNAL USED FOR 68XX SYSTEMS ONLY

7. "FINISHED LENGTH" DEFINED BY -XXX. EXAMPLE : D03365-120 FINISHED LENGTH = 10FT
8. MEDIAN CUT LENGTH (ON BOM) = FINISHED LENGTH.
9. PLACE LABEL AT THE CENTER OF CABLE. LABEL SHOULD CONTAIN THE FOLLOWING:
   a. CABLE NUMBER (SEE NOTE 7), AND REVISION CABLE WAS BUILT TO.
   b. VENDOR DESIGNATION ("MAN02" FOR MRG)



UNLESS OTHERWISE SPECIFIED TOLERANCES .XX = ±0.010 .XXX = ±0.005 ( ) INDICATES mm ANGLES± 0°–30' SURFACE ROUGHNESS 63 BREAK ALL SHARP EDGES	DRN PTH 8/97; DES; CHK; ENG; APPR; PROJECTION
MATERIAL N/A	REVISION C
USED ON; FINISH N/A	

CAMBRIDGE TECHNOLOGY, INC.
109 SMITH PLACE
CAMBRIDGE, MA. 02138 – USA

6010-18-XXX
CABLE ASSY

D03365

SCALE NONE | SHEET 1 OF 1

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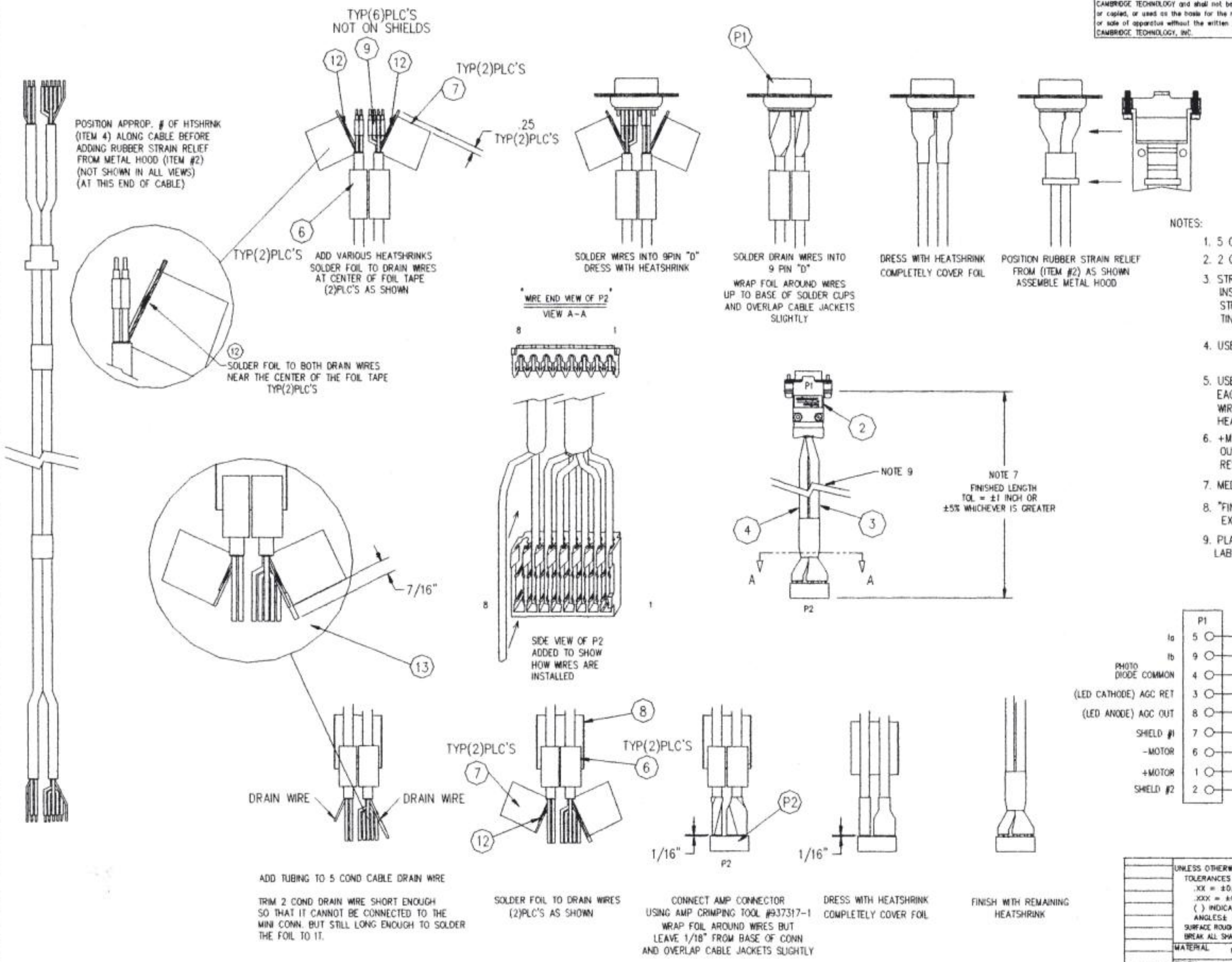
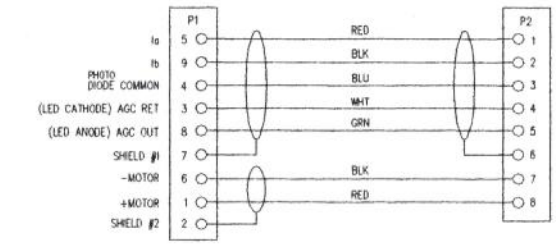
REVISION				
ECO	REV	DESCRIPTION	CHK	DATE
1691	C	SCHEM. DIAG. UPDATED	PTH	6/00



NOTES:

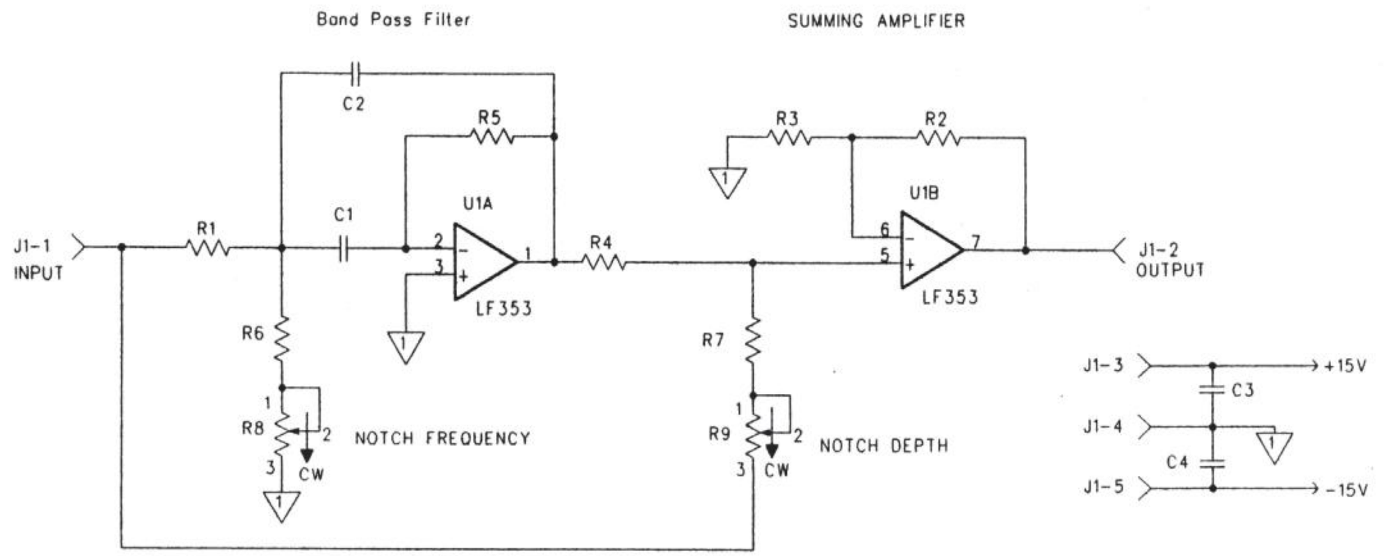
1. 5 CONDUCTOR WIRE – ITEM 3 ON BOM
2. 2 CONDUCTOR WIRE – ITEM 4 ON BOM
3. STRIP CABLE JACKET BACK 3/4", STRIP & TIN WIRE INSULATION BACK 1/8" AT THE 9 PIN "D" END ONLY. STRIP CABLE JACKET BACK 3/4", DO NOT STRIP AND TIN INDIVIDUAL WIRES AT THE MINI CONNECTOR END.
4. USE HEATSHRINK TUBING ITEM 10 ON BOM OVERALL EVERY 12"
5. USE COPPER FOIL – ITEM 7 ON BOM ON BOTH ENDS OF EACH CABLE. FOIL MUST CONDUCT TO ITS CABLE'S DRAIN WIRE, AND MUST BE ISOLATED FROM EACH OTHER WITH HEATSHRINK ITEM 6 ON BOM
6. +MOTOR IS DEFINED AS CAUSING A CW ROTATION OF THE OUTPUT SHAFT WHEN +MOTOR IS DRIVEN POSITIVE WITH RESPECT TO –MOTOR
7. MEDIAN CUT LENGTH (ON BOM) = FINISHED LENGTH.
8. "FINISHED LENGTH" DEFINED BY -XXX. EXAMPLE 6010-19-012 FINISHED LENGTH = 12'
9. PLACE LABEL AT THE CENTER OF CABLE. LABEL SHOULD CONTAIN THE FOLLOWING INFORMATION:
   a. CABLE NUMBER (SEE NOTE 8)
   b. VENDOR DESIGNATION ("MAN02" FOR MRG)



UNLESS OTHERWISE SPECIFIED
TOLERANCES
.XX = ±0.010
.XXX = ±0.005
( ) INDICATES mm
ANGLES± 0°-30'
SURFACE ROUGHNESS 63
BREAK ALL SHARP EDGES
MATERIAL N/A
FINISH N/A
USED ON

DRN	PTH	09/99	CAMBRIDGE TECHNOLOGY, INC. 109 SMITH PLACE CAMBRIDGE, MA. 02138 – USA
DES			
CHK			
ENG			6010-19
APPR			62XX DRIVE CABLE
PROJECTION			D04067
REVISION	C		SCALE NONE SHEET 1 OF 1

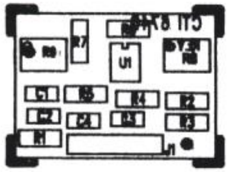
REVISION RECORD			
LTR	ECO NO:	APPROVED:	DATE:



BPF FORMULAS

C1=C2=C B=BANDWIDTH
Q=Wr/B Wr=RENSONANT FREQUENCY
R5=2/BC Ar=GAIN AT Wr
R1=R5/2Ar
"R6"=R5/[4Q^2-2Ar]

DRAWN: PNB	DATED: 9/25/97	COMPANY: CAMBRIDGE TECHNOLOGY, INC.			
CHECKED:	DATED:	TITLE: 6740 SCHEMATIC NOTCH FILTER MODULE			
QUALITY CONTROL:	DATED:	CODE:	SIZE: B	DRAWING NO: D03233	REV: C
RELEASED:	DATED:	SCALE:		SHEET: OF	



AS VIEWED FROM COMPONENT SIDE

NOTES:
1. SQUARE PADS INDICATE THE FOLLOWING:
   A. PIN "1" OF MULTILEAD DEVICES.(DIPS, SIPS, POTS, ETC.)
   B. POLARITY PINS OF DISCRETE COMPONENTS.
   (CATHODE, EMITTER, "+", ETC.)

UNLESS OTHERWISE SPECIFIED

REMOVE ALL BURRS & BREAK SHARP EDGES .005 MAX.
DIMENSIONS ARE IN INCHES TOLERANCE ON

DECIMALS
.XX +/-.015
.XXX +/-.005
FRACTIONS +/- 1/32
ANGLES +/- 1°

SURFACE ROUGHNESS ✓

DO NOT SCALE PRINT

DRAWN PN BAKALOS 6/26/97

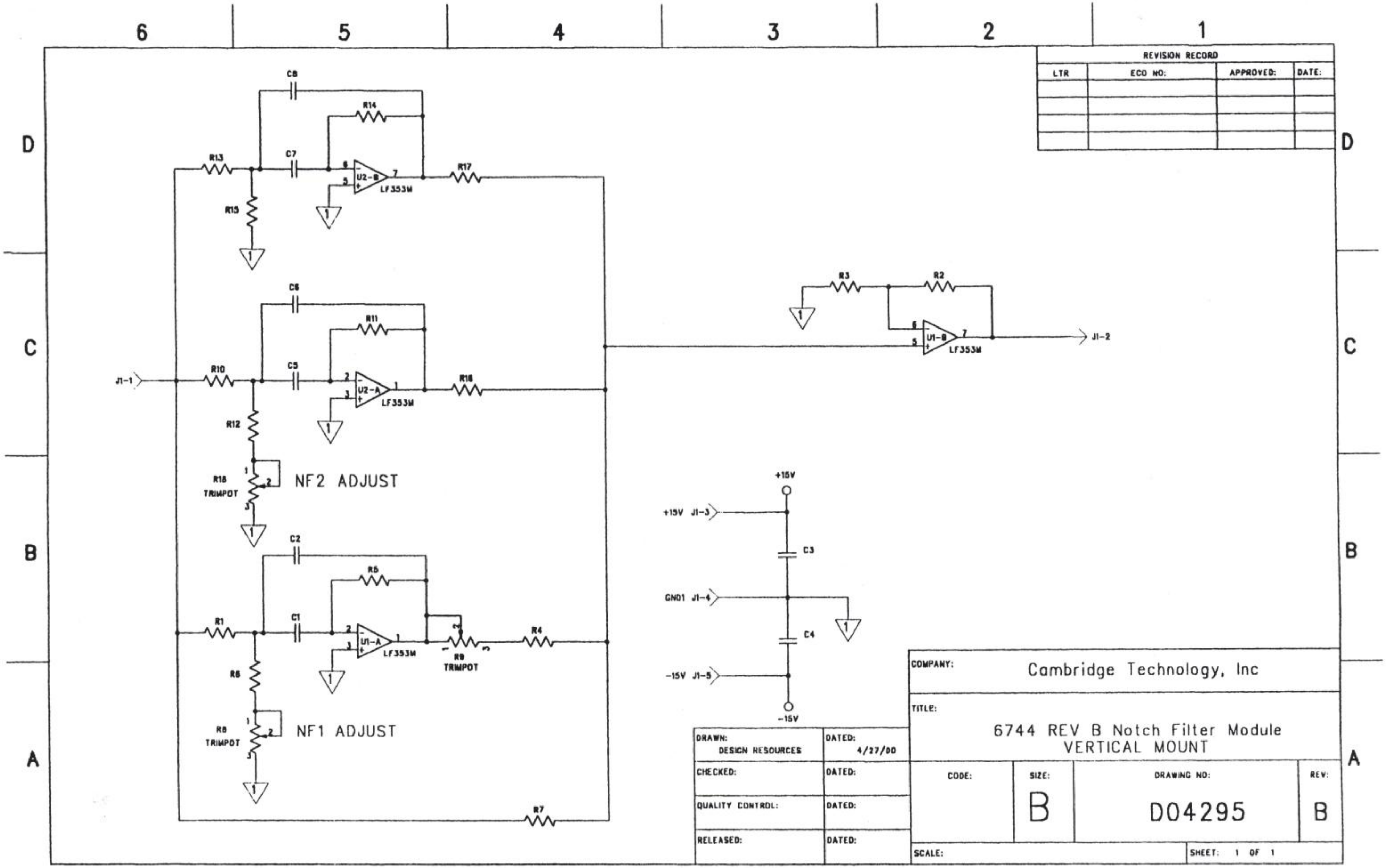
PROJECT APPROVAL

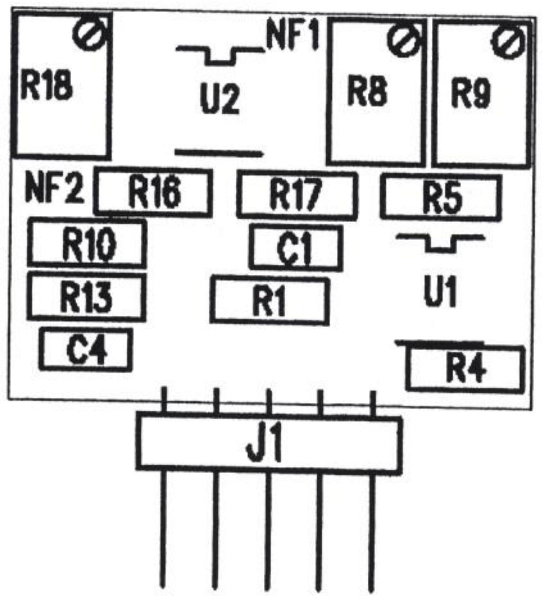
CAMBRIDGE TECHNOLOGY, INC.

ASSEMBLY DRAWING
6740 NOTCH FILTER MODULE

SIZE	CODE IDENT NO.	TYPE		REV
C			D03234	C

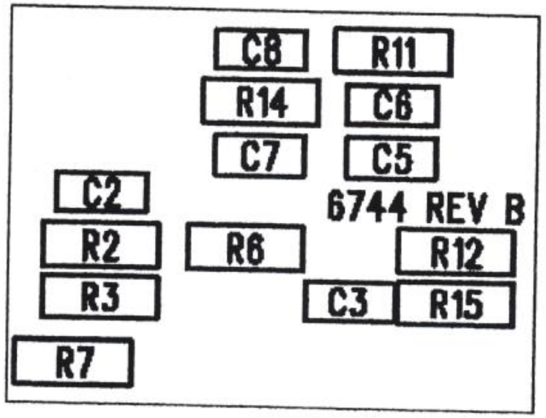
SCALE 2/1 SHEET 1 OF 1


REVISION RECORD
LTR
ECO NO:
APPROVED:
DATE:
C8
R14
R13
C7
U2-B
LF353M
R17
R15
C6
R11
J1-1
R10
C5
U2-A
LF353M
R18
R12
R16 TRIMPOT
NF2 ADJUST
R3
R2
U1-B
LF353M
J1-2
C2
R5
R1
C1
U1-A
LF353M
R9 TRIMPOT
R4
R6
R8 TRIMPOT
NF1 ADJUST
R7
+15V
+15V J1-3
C3
GND1 J1-4
C4
-15V J1-5
-15V
COMPANY: Cambridge Technology, Inc
TITLE: 6744 REV B Notch Filter Module
VERTICAL MOUNT
DRAWN: DESIGN RESOURCES
DATED: 4/27/00
CHECKED:
DATED:
QUALITY CONTROL:
DATED:
RELEASED:
DATED:
CODE:
SIZE: B
DRAWING NO: D04295
REV: B
SCALE:
SHEET: 1 OF 1



TOP ASSEMBLY

D04305



BOTTOM ASSEMBLY D04306