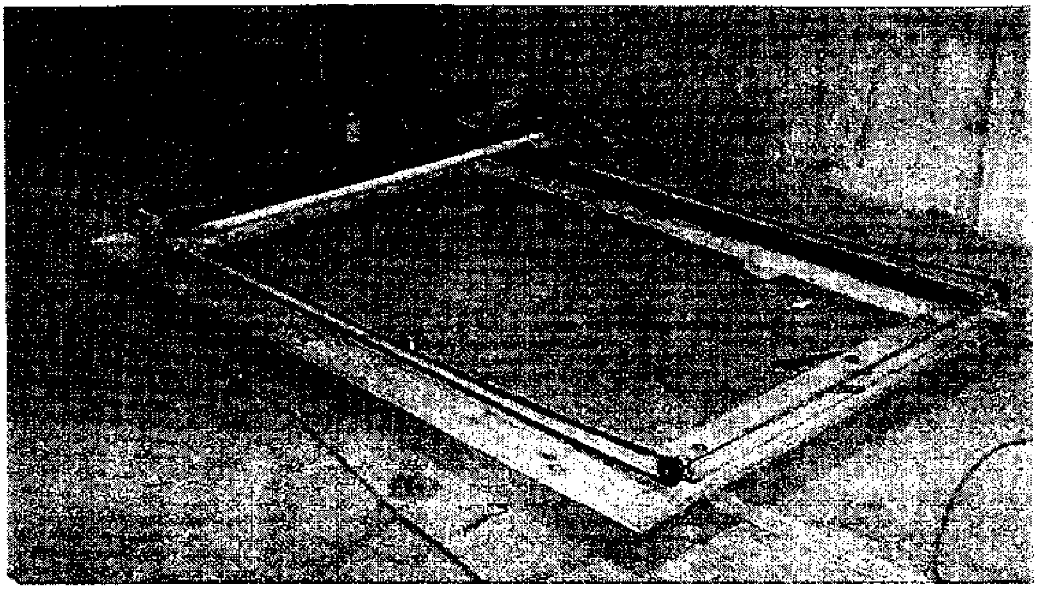
Automated X-Y Positioning System for the UNH COE



4/21/00

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UNHMP-TR-SG-00-6

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Table of Contents:

Introduction

The engineering basin of the Jere A. Chase Ocean Engineering Building is currently lacking effective means to position equipment within the basin. To date, a large float has been used to move equipment to varying locations on the water surface. This method is time consuming and imprecise. To effectively position equipment in the basin, a positioning system must be implemented. The system should ideally be computer controlled, allowing an operator to enter a desired position and have the system respond accordingly. Many considerations and constraints must be considered when designing what is essentially a large-scale positioning table.

The initial scope of this project was to design and implement a full size position control system. Over the course of the 1999 fall semester, many of the required components of such a system were investigated for their possible implementation into the system. As the semester ended, it became apparent that the full-scale system could not be completed in the limited time remaining. The scope of the project was changed to a proof of concept project in which the ideas intended for use on the full scale were implemented on a scaled down model of the engineering basin.

Most of the mechanical system, electrical system, and control system ideas were implemented into the small scale positioning system. This was done to investigate the effectiveness of the various ideas in a physical system. The system was constructed and tested successfully, employing concepts from the initial considerations regarding the full-scale system.

Preliminary Design Considerations for Full Scale a Positioning System

Basic System Requirements

The essential requirements of the design require that the carriage be able to move to any location within the tank, excluding only a small area adjacent to the tank edges. To provide motion control, the carriage must be driven by computer-controlled electric motors. These requirements dictate that the system must be free of obstacles within the carriage travel range, have computer support, and utilize at least two electric motors.

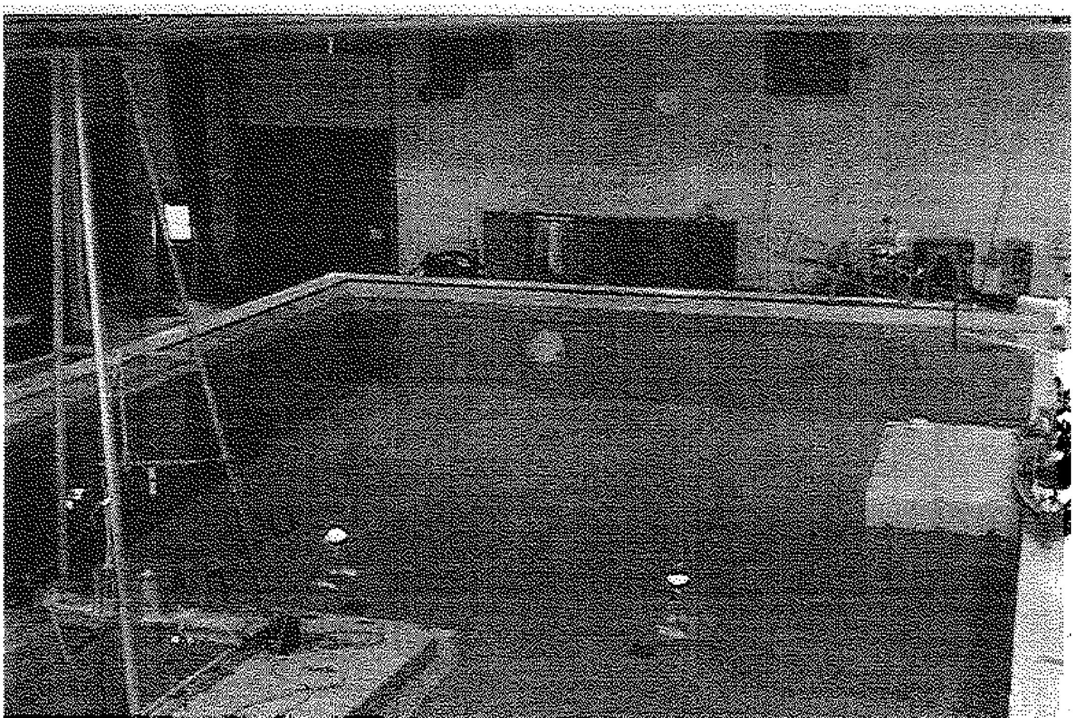


Figure 1: UNH COE Acoustic Tank

In accordance with these requirements, the preliminary design consists of a carriage sliding on a set of rails spanning the tank. The rails spanning the width of the tank will slide on rails running the length of the tank. The carriage will be driven by an electric motor mounted on the rail system spanning the tank; a motor mounted on the side of the basin will drive the spanning rail system. The schematic on following page illustrates the preliminary system arrangement.

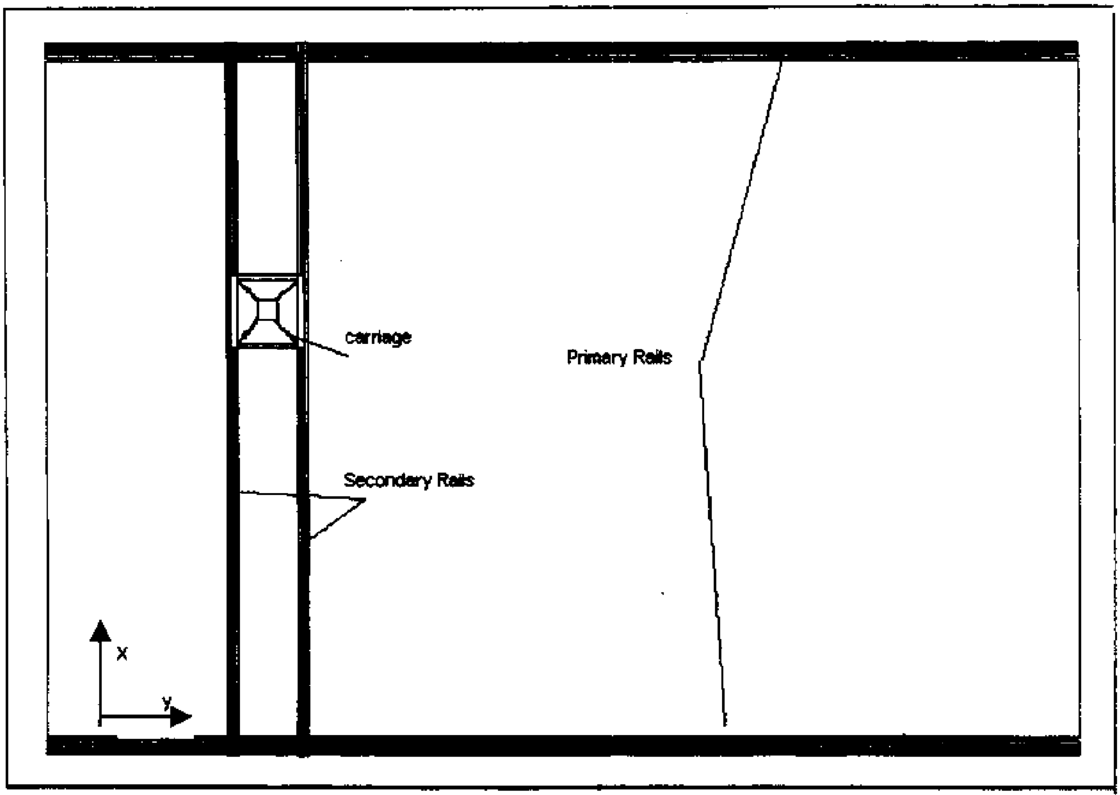


Figure 2: Schematic of Preliminary System Arrangement.

Rail Design

The basin has a forty-foot span and is sixty feet long. The sixty-foot rails are the primary rails; the rails spanning the width of the tank are the secondary rails. The large span requires a rigid secondary rail system to support the carriage and its potentially heavy equipment. The target design rail deflection under maximum loading conditions is constrained to one half of an inch. Maximum design loading condition is the weight of an existing acoustic measurement tower, weighing 500 pounds, plus four people (in the case of a mid-span repair) at 175 pounds each. These conditions translate into a 1200 pound load at the midpoint of the secondary rails.

To support this weight, beams or trusses must be employed to support the rails spanning the tank. The weight of the support member is of special consideration for two reasons. First, the weight of the entire second rail system, including the support members, must be supported by the primary rails. The bearings used at the junction of the primary rail with the secondary rail will have to be selected according to the magnitude of the supported weight. More weight requires either a larger more expensive bearing or a reduction of bearing life. Second, the entire mass of the secondary rail system must be accelerated by the electric motor when moving along the length of the tank (i.e. movement along the y-axis). For a given acceleration, force is directly proportional to mass. An increase in required force translates to a higher torque requirement in the employed motor. The prices of electric motors are dominated by the torque and speed ratings of the individual motors. Motors delivering higher torque at a given motor speed are typically more expensive.

This project has many characteristics of both a positioning table and a basin tow carriage. Typical guidance rail setups from both systems were evaluated for potential implementation into the project. Guided wheels, linear bearings or a mixture of the two were the proposed system possibilities. The guided wheel option was rejected for two main reasons. First, if the wheels were ever to come out of perfect alignment, the carriage would heave or sway during system motion. This would greatly cripple the system's effectiveness in performing dynamic measurements. Second, if the wheels were to flatten and become elliptical over time, the system would tend to hobble when in motion. The possibility of linear bearings serving as one side of the primary rails and guided wheels as the opposite side was also investigated; however, the variation in the coefficient of friction between the wheel side and the bearing side could potentially damage the system. Typical linear bearing friction coefficients are on the order of 0.002 to 0.01 compared to typical wheel set-up friction coefficients of 0.08 to 0.2. The large resistance to motion on the wheel side would cause that side to move slightly slower than the bearing side during acceleration (assuming equal force applied to each side). The secondary rails would then act as a large lever, inducing detrimental stresses in the linear bearings. Due to their high precision, high load capacity, and low coefficient of friction, linear bearing guides are recommended as the primary rails.

Linear guides provide another benefit when used on the steel trusses as the secondary rails. Since there may be no obstacles in the path of the carriage, the steel trusses may not be hard connected anywhere in their mid-span. The carriage may be designed in such a way that the guide bearings on each side of the carriage are directly connected. This connection will serve to hold the guide bearings a certain distance apart, therefore the rails running through the guide bearing will also be held at that distance apart. The rails will be mounted to the steel trusses. This results in a connection between the steel trusses that is part of the carriage and therefore moves with the carriage. This connection, securing the steel trusses at a set distance apart, prevents the trusses from bowing apart.

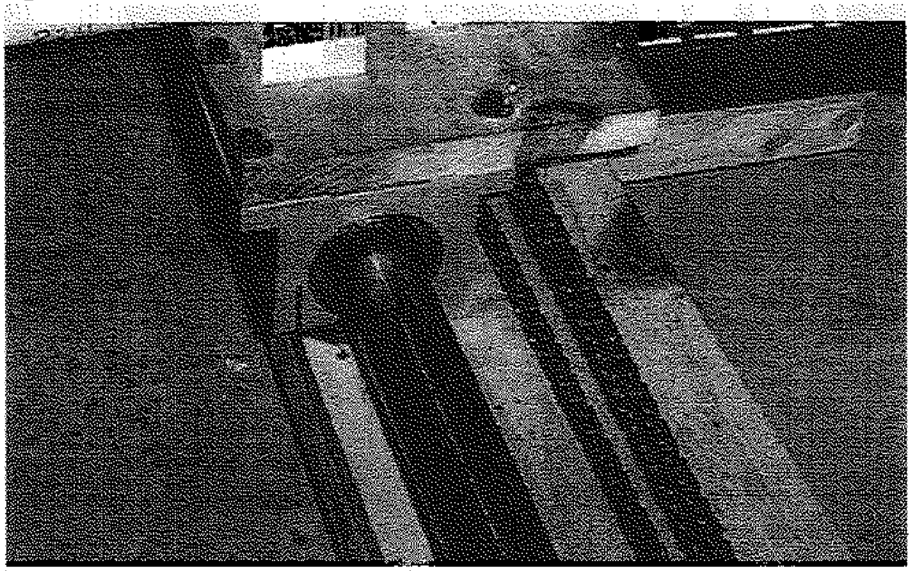


Figure 3: Linear Guide Rails and Pillow Block

Another major consideration in the development of the rail system design is the parallelism tolerance of the rails. Linear bearings are typically used in extremely high precision applications and therefore require a high degree of parallelism. Thompson™ brand linear bearing systems require parallelism within 0.001in. over the entire length of the rail. Maintaining such a tolerance over a sixty-foot span would be very difficult if not impossible. A compliance member must be implemented to compensate for the lack of parallelism. A small, less than three-inch stroke, linear bearing guide could be used as the compliant member. Mounted at one end of both steel trusses and oriented perpendicular to the primary rail, the small linear guides will prevent slight rail misalignments from damaging the system.

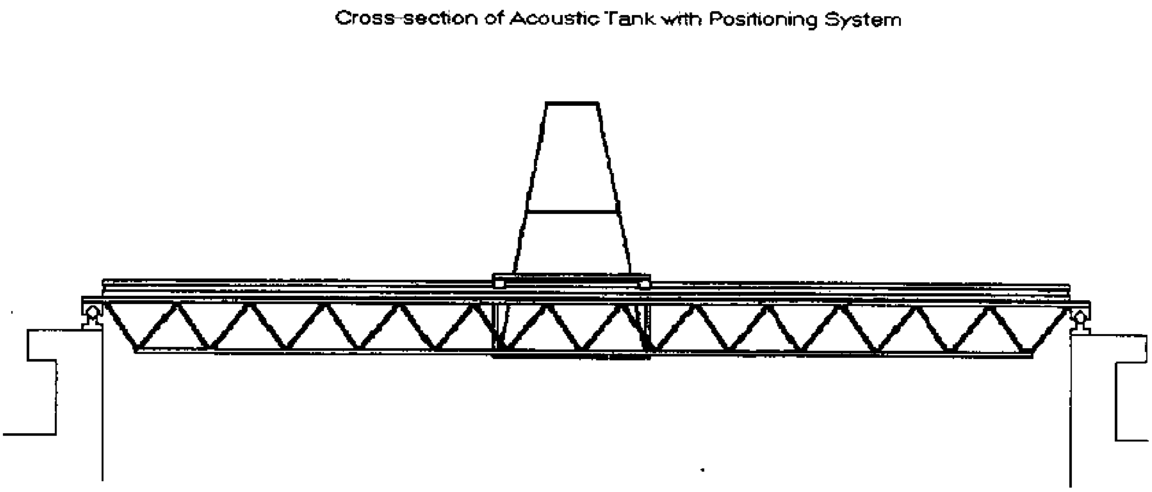


Figure 4: Cross-section of Acoustic Tank with Positioning System

One final rail consideration is the depth and under slung shape of the steel trusses. The ends of the steel truss must be built up to keep the bottom of the steel truss out of the water and to prevent the under slung sides of the truss from rubbing on the side of the basin.

Drive System Considerations

The drive system must provide two directions of motion, x and y. To efficiently accomplish this, two electric motors must be used, one to drive the secondary rail along the primary rail (defined as the primary drive system) and one to drive the carriage along the secondary rail (defined as the secondary drive system). Due to the large span of the secondary rail, a dual sided drive system must be used in the primary drive system. For the secondary drive system, either a single or dual sided drive system is conceivable. However, previously designed systems driven by an eccentric single drive have been observed to heave due to the lack of evenly distributed propulsion. The secondary drive system should also use a dual sided drive system to avoid the possibility of heaving.

The motor in the primary drive system will be immobile and may be mounted on the side of the basin; its power and control cables may be routed through conduit. The motor in the secondary drive system must be mounted to the secondary rail system and will therefore be mobile. To avoid using cumbersome umbilicals, a battery and required power inverter should be used to power the secondary motor.

Preliminary Control System Considerations

The control used to precisely position the carriage will require a dual axis control system (x and y). Position control typically requires two feedback loops - position and velocity. However, only hardware providing position feedback is required since position feedback may be differentiated to provide velocity feedback.

Rotary encoders, optical encoded tape and magnetic encoded tape are the most utilized forms of position feedback. The advantages and disadvantages of these possibilities have yet to be investigated for implementation into this project.

The above feedback systems will require a mode of data feedback to the controlling computer. If encoded tape is used, tape-reading heads must be mounted on the secondary rails and on the carriage. In this case, the mode of data feedback may be through a set of umbilicals or transmitted through wireless feedback. If the rotary encoders are used, data must be transferred from the primary drive system motor and the secondary drive system motor. In this case, the primary feedback may be routed through conduit but the secondary feedback must still be routed through an umbilical or through wireless methods. Although it would eliminate cumbersome umbilical setups, wireless feedback has not been commonly used on similar applications and its effectiveness must still be examined.

Model Design and Implementation

Mechanical System

Primary Components

--Thompson Linear Guides and Pillow Blocks (Primary Rail)

--Crowned Track-Roller System w/ ball bearing rollers (Secondary Rail)

--Steel Roller Chain ANSI #35

--Steel Roller Chain Sprocket for ANSI #35 w/ 19 teeth, 3/8" pitch and ½" bore

--Steel Idler Pulley for ANSI #35 w/ 19 teeth, 3/8" pitch and ½" bore

--Stamped Steel-Mount Steel Ball Bushings w/ ½" bore

--Alloy 2011 Aluminum Rods w/ ½" O.D.

--1 x 8 boards and 2 x 4 lumber

--Assorted hardware (hex bolts, screws, carriage bolts and hex key bolts)

Model Design and Construction

The model is a one tenth scale (1 ft: 10 ft) representation of the acoustic tank. The actual size of all the hardware is not to scale due to limitations in off-the-shelf hardware of that size. The model is more a platform for testing the control system and software then an actual scaled model of the acoustic tank.

Platform and Rails

The base platform is 2 x 4 framing with 1 x 8 boards as decking. The primary rails are through bolted onto the platform. The rails were mounted on overlapping support blocks to ensure a smooth continuous joint. The pillow blocks have recirculating ball bearing raceways, which are excellent for providing low friction at high loads. The secondary rails are a unistrut style made of sturdy black powder-coated steel. The rollers have a hardened crown, providing self-alignment, strength, and durability. The double sealed ball bearings keep out contamination and provide low friction.

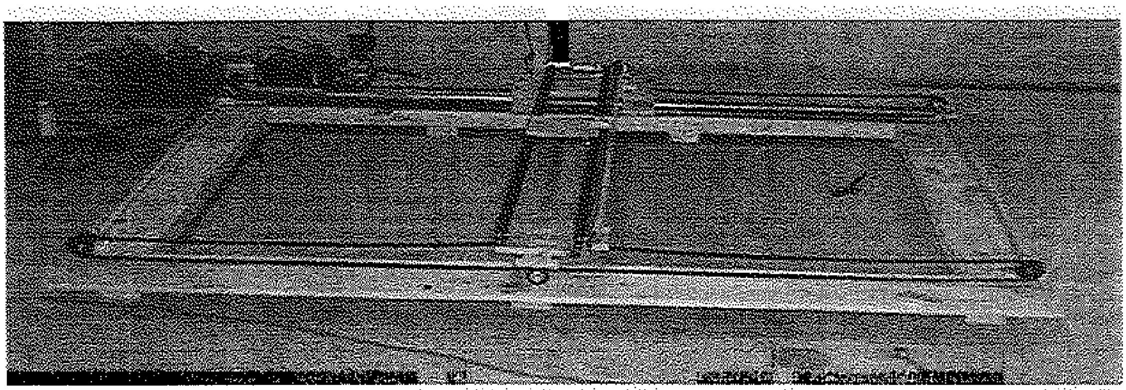


Figure 5: Wooden Platform and Rails

A double-sided drive was implemented to eliminate pitching movement of the secondary rails. Vibrations caused by such pitching moments can render positioning system useless. When working with wood moisture variations can cause significant dimensional change so an outrigger style main drive system was used to eliminate the need for a second rail. Had we used rails on both sides any misalignment would cause unneeded stress on the pillow blocks and could potentially cause a seizing of the bearings.

Drive System

The drive system is an important part of any positioning system. Selection of the drive system was based on several important factors: functionality, safety and ease of implementation. Options for drive systems include wound steel cable, steel ribbon cable and steel chain. Chain was the best choice for our drive system for several reasons. Firstly, chain doesn't need high tension to ensure proper function and high efficiency. Steel cable drives need high tension to created friction between the cable and drive spindle. Any failure can create a large hazard due to the backlash of the cable. The lower tension also keeps the stress on the supports and platform lower. This allowed the use of a wood platform instead of metal platform, which is advantageous because wood is easier to work with and lighter, so the platform can be easily moved. Secondly, the functionality of chain is greater for this application. Chain has a much lower spring constant than steel cable. When driving the system, a high spring constant could lead to vibration and system instability. This factor alone makes chain a much more attractive option. Finally, chain is much easier to work with. The length of chain can easily be adjusted using simple pin extracting tools. Steel requires cutting and seizing ends to prevent fraying. These factors lead to the choice of chain for the drive system. ANSI #35 chain with 3/8" pitch was chosen due to its availability and standardization.

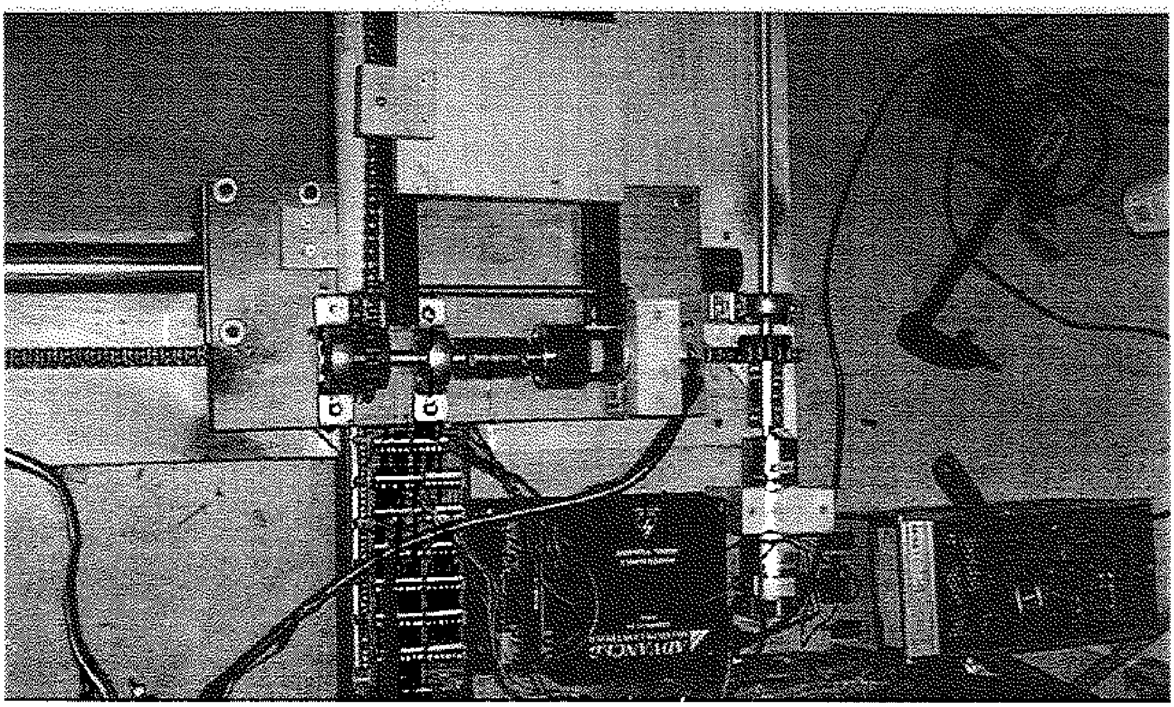


Figure 6: Drive System

The motors are connected to the drive sprockets with flexible couplers. The secondary drive is only one sided while the main drive is dual sided. The aluminum rod that drives the opposite side of the main drive system can be seen at the right most of the platform

Electrical System

Primary Components

--National Instruments Universal Motion Interface (UMI) Accessory (breakout board)

--Advanced Motion Controls 12A8 Brush Type Servo Amplifier (2)

--Advanced Motion Controls PS2X3W24 24 Volt Power Supply

--Pittman GM9236S021 DC Brush Gearmotor with Encoder (motor 2)

--Pittman GM14904S016 DC Brush Gearmotor with Encoder (motor 1)

--Harrison Laboratories 6224A Power Supply (set at 5 Volts)

Basic Application

The task of the electrical system is to accept input information from the control system software and drive the two motors in accordance with the input. The electrical system must also feedback information to the control system software regarding the motion of the two motors.

The Universal Motion Interface (UMI) is the link between computer (control software) and the electrical system. Input information is fed in the form of a low power voltage signal from the breakout board to the amplifier. The amplifier has two inputs, the high power voltage supply and the low power signal voltage input from the UMI. The amplifier takes the low power voltage signal and amplifies its power content by increasing its current. The voltage signal is preserved but now has the power necessary to drive the motor. The amplifier receives this high power from the high power voltage supply. The output of the amplifier is a high power signal voltage fed to the motor.

Each motor is equipped with an encoder. As the motor rotates, the encoder outputs ticks. These ticks tell the control software the direction and the magnitude of the motor position. A time rate of encoder ticks yields motor velocity, and a time rate of motor velocity change yields motor acceleration. The encoder information is fed back to the control software via the UMI board. The encoder is an active device meaning it requires power to operate. This low power is fed to the encoder from the UMI. The UMI must have power input in order to supply the encoders with power so an external five-volt power supply is connected to provide this energy.

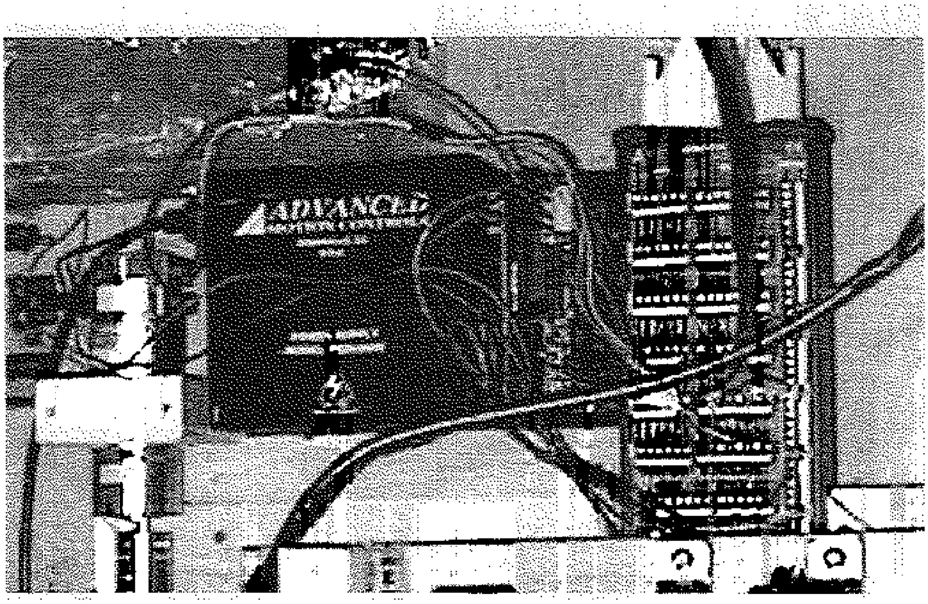


Figure 7: Power Supply, Amplifiers and UMI board.

The power supply is the large black box on the left most part of the picture. The amplifiers are mounted next to the power supply. The UMI board is on the rightmost part of the picture

Component Selection

The National Instruments equipment was used because it had already been purchased by the Center for Ocean Engineering for application on another project. Automation consultant Neil Burgard of Automation Solutions Atlantic was consulted for his expertise in motor, amplifier, and power supply selection. The two motors were selected based on torque requirements to drive the system. Once the motors were selected, the amplifiers and power supply were selected based on their ability to provide the motors with their power requirements.

Control System and Graphic User Interface (GUI)

Primary Components

--National Instrument Universal Motion Interface (UMI) Accessory (breakout board)

--LabView Software

--FlexMotion Software from National Instrument (NI) for LabView

Overview

The Universal Motion Interface (UMI) and FlexMotion software used together provide a powerful digital control system for motion control. The UMI is the interface between the FlexMotion software and the motors that are controlled. The FlexMotion software relies on the LabView software to provide a platform for the actual motion control programming. LabView is a graphic program that provides an icon based drag and wire approach to computer programming. Instead of writing line of code as in computer programming, LabView allows you to choose icons from a palette and place them on a diagram. The different icons can be wired together to create complicated systems. The FlexMotion software is an addition to the LabView program. It adds different icons to the LabView palette that are specially programmed to communicate with the UMI breakout board. The actual FlexMotion and LabView icons and functions used for this purpose will be discussed later.

Control System

The digital controller is a PID controller. The user inputs the values of each of the PID values. The FlexMotion software comes with a servomotor tuning program. The user changes the PID values and the program applies a step function to the motor and displays it response. Through a testing process, the desired response is found by fine tuning the PID values. The PID values for our two motors were identical. The proportional gain is set at one, the integral gain is set to zero and the derivative gain is set the 150. This gave a response with a damping constant (ζ) of approximately .7. This provides a under damped system with a more than adequate speed of response.

Before running the Positioning System program, the user must initialize the control board and control system parameters. The Initialization program is named Init.flx

(Appendix G). Once the program has been opened, the user should run the program. A screen will pop up asking for the Setup file. The setup file used for the model is named rail.fsf. Select this setup file and press return. To adjust the control parameters or axis parameter the 'Open Setup Panel' button on the Initialization panel is pressed which starts the Setup.flx program (Appendix Setup). From this panel the user can modify the control loop parameter, motion I/O parameters and axis configuration. Once the necessary changes have been made press the 'Save Setup File' and save the parameters to the appropriate file then press 'Return' and the control board is initialized and the control parameters are set.

Graphic User Interface (GUI) Layout and Use

The graphic user interface (GUI) was programmed using LabView and FlexMotion software. The GUI takes the user inputs and sends the information to the appropriate addresses in the controller. The GUI has two different modes: multiple point input mode and single point input mode. This reflects the dual uses of the actual carriage. The multiple point input mode would be used for dynamic testing. An example of this sort of test is the testing of side scan sonar capability. The acoustic transducer would be towed through the water and take acoustic images of the bottom. The positioning system would track a specified path while towing the tested equipment. The single point input mode would be used in conjunction with the transducer-positioning tower. The positioning system would move the entire tower to a specified point and stay there while testing was performed. The actual GUI is most easily explained by looking at the positioning system GUI layout. The GUI control panel is shown in Appendix I.

Target and Motion Parameter Input

In the lower left hand corner of the control panel, you can see an icon named 'Motion Input'. By selecting this, the user is able to select between four modes: Single Point, Multipoint, From File and Home Position. The Single Point mode receives the target position from the user input called 'Single Point Target' which is next to the X-Y graph on the control panel. The Multipoint mode receives the sequence of target position from the user input called 'Sequence of Target Positions' on the control panel. The sequence of target positions is limited to a maximum of 11 targets. The From File mode reads in data from a tab delimited text file that the user specifies. This is useful for calling test patterns that need to be repeated numerous times and for sequences of target positions greater than eleven targets long. All the units of target positions are in inches. The maximum usable range of the system is 60 inches in the X direction and 45 inches in the Y direction.

The velocity and acceleration parameters are modified in the user inputs called 'Vector Velocity' and 'Vector Acceleration' respectively. The maximum velocity of the system is 20 in/sec while the maximum acceleration is 25 rps/s. The software has internal torque limits on the motor so inputting 20 in/sec at an acceleration of 25 rps/s will cut power to the motors. The maximum allowable acceleration at 20 in/sec is 5 rps/s. If the torque limit is exceeded, only the axis that has exceeded it will stop so it is important to hit the 'Kill Switch' button when this occurs. Once all motion is stopped, the user must stop the program and restart the program to reinitialize the torque limit.

Motion Start/Stop and Lockout

The starting and stopping of motion are controlled by the 'Start Motion' and 'Kill Switch' respectively. They are located in the middle of the control panel and are denoted by round buttons. Once the target input mode has been selected, the user should press the 'Start Motion' button. The motion will start and will continue until the final target position has been reached. The motors will then stop and standby. If at any point there is something wrong, the user should press the 'Kill Switch'. This decelerates the motors until they are stopped, then stands by. The position of the system can be locked so testing can be preformed without accidental motion. The 'Lock Position' button disables any motion input to the motors. The LED light next to the button indicates the lock position status (light on indicates position lock). The 'Lock Position' button stays depress when selected. To unlock the position, the 'Lock Position' button must be pressed again.

Position Output and Rezeroing

The actual position of the system is displayed in two places. The X-Y position plot is a graphical representation of the current position as well as the current path of the system. The X-axis is on the horizontal scale of the graph while the Y-axis is on the vertical scale. From the graph the actual position of the system is hard to discern, so two digital indicators to the left of the graph show the current position.

If the home position of 0-0 is lost the system can be driven back to the home position and the 0-0 position reset by pressing the 'Rezero' bottom at the top left of the X-Y graph. This should not be used unless the system is in the actual 0-0 position because the software limits that prevent the system from overshooting the ends of the track due to errant data will be rendered useless.

Graphic User Interface (GUI) Programming

The control panel for the motion control software is the front end of the motion control programming. The programming takes user inputs and processes them to create two-axis motion. The facets of the program that will be explained are: motion start/stop/lock & target input path and target & motion parameter loading.

Motion Start/Stop/Lock & Target Input Path

The motion start/stop/lock functions are all Boolean variables (the value is either true or false). The wiring diagram (Appendix J) displays these Boolean variables as small rectangles with T F inside them. Each of these variables is wired to a different case function. Each variable is connected to a button on the front panel. When the button is pushed it changes its value, when released, the variable is changed back to its default value. Each of the start/stop/lock variables controls a separate case function.

The 'Motion Input' variable is a case variable, but instead of just having a true/false value, it has four cases; zero, one, two and three. This allows for more choices then a Boolean variable, which has just two. The 'Motion Input' variable is wired to a case function that specifies whether the user has selected a single input, multiple input, from file input or home position. To aid in understanding the programming, printouts of the actual wiring diagram have been included in the appendix.

The 'Start Motion' variable has a default value of false. Once the 'Start Motion' button is pushed it registers a true value, which makes the 'Main Motion Control' case true (see Appendix J). The 'Kill Switch' variable also has a default value of false. Once the 'Kill Switch' button is pushed, it registers a true value and sends the value to a local variable that has been placed inside the main motion control case. Where the local variable is used will be explained in a latter section. The 'Lock Position' variable controls the 'Lock Position' case that either allows the start motion signal to reach the main motion control case or cuts the signal, thereby disabling any motion to occur (see Appendix J). The 'Motion Input' button on the front panel can be set to Single Point, MultiPoint, From File, and Home Position, which correspond to 'Motion Input' case variable values of 0,1,2 and 3 respectively. The 'Motion Input' variable is fed into the main motion control loop when the 'Start Motion' variable begins the main motion control case (see Appendix J).

Target & Motion Parameter Loading

Once the 'Start Motion' variable has been selected as true and the 'Lock Position' variable is false the main motion control loop is started. The 'Motion Input' variable is sent into the 'Target Input' case function. This variable dictates which user input will be used as the target position. If the Single Point input is selected the case will pass the 1x2 user inputted array from the front panel. If the MulitPoint input is selected the case will pass the 11x2 user inputted array of target positions from the front panel. If the From File input is selected, the case will pass and Nx2 array of target positions from a user specified text file (must be tab delimited and in two columns, X and Y respectively). If the Home Position input is selected the case passes a constant 1x2 array with values of zero for both X and Y.

The 'Target Input' case is located in the leftmost part of the diagram (see Appendix K). From this case box the Nx2 array are broken into two separate arrays, an Nx1 array of X target positions and an Nx1 array of Y target positions. These values are then sent to the 'Main Motion Control' loop. The user inputted velocity, acceleration and current position of the system are also sent to the 'Main Motion Control' loop. The 'Main Motion Control' loop is a while loop so it runs until its value is set to false. This allows the program to handle a virtually infinite amount of points.

Once the 'Main Motion Control' loop is started, the first target positions in the array are multiplied by conversion factor to convert from a target position in inches to a target position in encoder ticks. These positions are then loaded into the FlexMotion software through the target position icon (denoted by the square with a picture of a road with a sign next to it). These target positions, along with the current positions, are wired into an icon that results in the X and Y unit vectors that are needed to move from the current position to the target position. These two vectors are then wired into another icon, which returns the axis specific velocity and acceleration needed for both axes to start and stop motion at the same time. These velocities are always positive values because the FlexMotion software determines the direction from the current position and target position. The axis specific velocities and accelerations are then loaded into the FlexMotion software using the 'Load RPM' and 'Load RPS/S' icons. Once all the parameters are loaded, the FlexMotion software is told to start motion using the 'Multi-Start' icons.

Once the motion is started, the program enters the 'Position Status' loop (see Appendix L). The current position is read from the read position icon (denoted by a small square with a picture of a road and a sign with a question mark) and is sent to the local variables 'X-Position' and 'Y-position' and to the X-Y Position Plot. The local variables sent the data to the two indicators on the front panel and the X-Y plot displays the progress. The while loop runs until the 'Profile Complete' icons both return true values. Once the loop is completed (both profiles complete), the values of the current position are sent to a shift register (denoted by a rectangular icon with a triangle inside) on the edge of the while loop. This shift register sends the current position to the opposite side of the while loop (see Appendix L) to an identical icon. This shift register now inputs the current position that will again be subtracted from the new target position. The whole process is repeated until the end of the input array is reached.

To stop the motion of the system at any time the user must press the 'Kill Switch' button on the front panel. This sets the 'Position Status' loop value to true, which stops the loop. It then sets the value of the 'Stop Motion' case next to it to true (see Appendix L). In the case structure, the true value stops the motion of both axes using the 'Stop' icon (denoted by a square icon with a stop sign) inside the true case. Once this is complete, the 'Main Motion Control' loop is set to true, which stops the entire motion loop.

Budget

Item	Price
2 Motors	$350.00
2 Amplifiers	$550.00
Power Supply	$198.00
Drive System Hardware	$480.00
Model Frame Hardware	$50.00
Miscellaneous	$100.00
Total Cost:	$1,728.00

Acknowledgements

This work is the result of research sponsored by the National Sea Grant Program, NOAA, Department of Commerce, under grant #NA96RG0102 through the University of New Hampshire/University of Maine Sea Grant College Program.

We would like to thank the following people who contributed greatly to the success of our project:

Paul Lavoie

Neil Burgard of Automated Solutions Atlantic

Derek Michelin

Dr. Kenneth Baldwin

Appendix

Appendix A-F: Electrical Specifications

Appendix A: Electrical System Wiring

Although the basic function of the electrical system is relatively simple, the wiring required to make the necessary connections is slightly more complicated. The following wiring description is intended to provide the user with a simple connection reference.

Universal Motion Interface

This system requires the use of seven of the UMI connection windows plus connection to the computer.

Connection window J26 (labeled on the UMI) is the five-volt power input. Pin 1 is the +5volt pin; this is connected to the +5volt from the 6224A power supply. Pin 4 is the ground for this connection and is connected to the ground from the 6224A.

Connection window J2 is the Axis 1 (long span axis) encoder connection window. Pin 1 is the phase A connection and is connected to the blue wire from encoder 1. Pin 3 is the phase B connection and is connected to the yellow wire from encoder 1. Pin 5 is the index and is connected to the green wire from encoder 1. Pin 7 is the 5 Volt power supply for the encoder and is connected to the red wire from encoder 1. Pin 8 is the encoder ground and is connected to the black wire from encoder 1.

Connection window J18 is the Axis 1 motor command connection window. Pin 1 is the analog output pin and is connected to "+ref in" pin on the axis 1 amplifier. Pin 2 is the analog output ground and is connected to the "signal gnd" pin on the axis 1 amplifier.

Connection window J4 is the Axis 2 (short span axis) encoder connection window. Pin 1 is the phase A connection and is connected to the phase A wire from encoder 2. Pin 3 is the phase B connection and is connected to the phase B wire from encoder 2. Pin 5 is the index and is connected to the index wire from encoder 2. Pin 7 is the 5 Volt power supply for the encoder and is connected to the supply wire from encoder 2. Pin 8 is the encoder ground and is connected to the ground wire from encoder 2.

Connection window J19 is the Axis 2 motor command connection window. Pin 1 is the analog output pin and is connected to the "+ref in" pin on the axis 2 amplifier. Pin 2 is the analog output ground and is connected to the "signal gnd" pin on the axis 2 amplifier.

A

Amplifiers

The system uses two amplifiers. Amplifier 1 drives motor 1 on axis 1 (long span axis) and amplifier 2 drives motor 2 on axis 2 (short span axis).

The "+ref in" pin on amplifier 1 is connected to connection window J18 pin 1 on the UMI. "Signal gnd" on amplifier 1 is connected to connection window J18 pin 2 on the UMI. The "-motor" pin on amplifier 1 is connected to the positive terminal of motor 1 (the reverse polarity is an effect of defining positive rotation of the motor). The "+motor" pin of amplifier 1 is connected to the negative terminal of motor 1. "Power gnd" (pin 4) is connected to a negative lead from the PS2X3W24 power supply. "High voltage" pin is connected to a positive lead from the PS2X3W24 power supply.

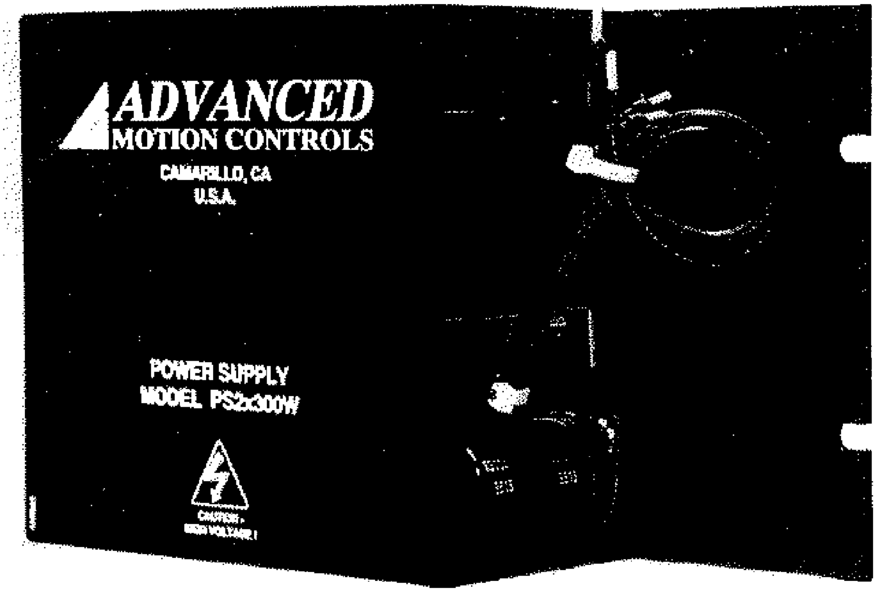
The "+ref in" pin on amplifier 2 is connected to connection window J19 pin 1 on the UMI. "Signal gnd" on amplifier 2 is connected to connection window J19 pin 2 on the UMI. The "-motor" pin on amplifier 2 is connected to the negative terminal of motor 2. The "+motor" pin of amplifier 2 is connected to the positive terminal of motor 2. "Power gnd" (pin 4) is connected to a negative lead from the PS2X3W24 power supply. "High voltage" pin is connected to a positive lead from the PS2X3W24 power supply.

PS2X300W SERIES POWER SUPPLIES

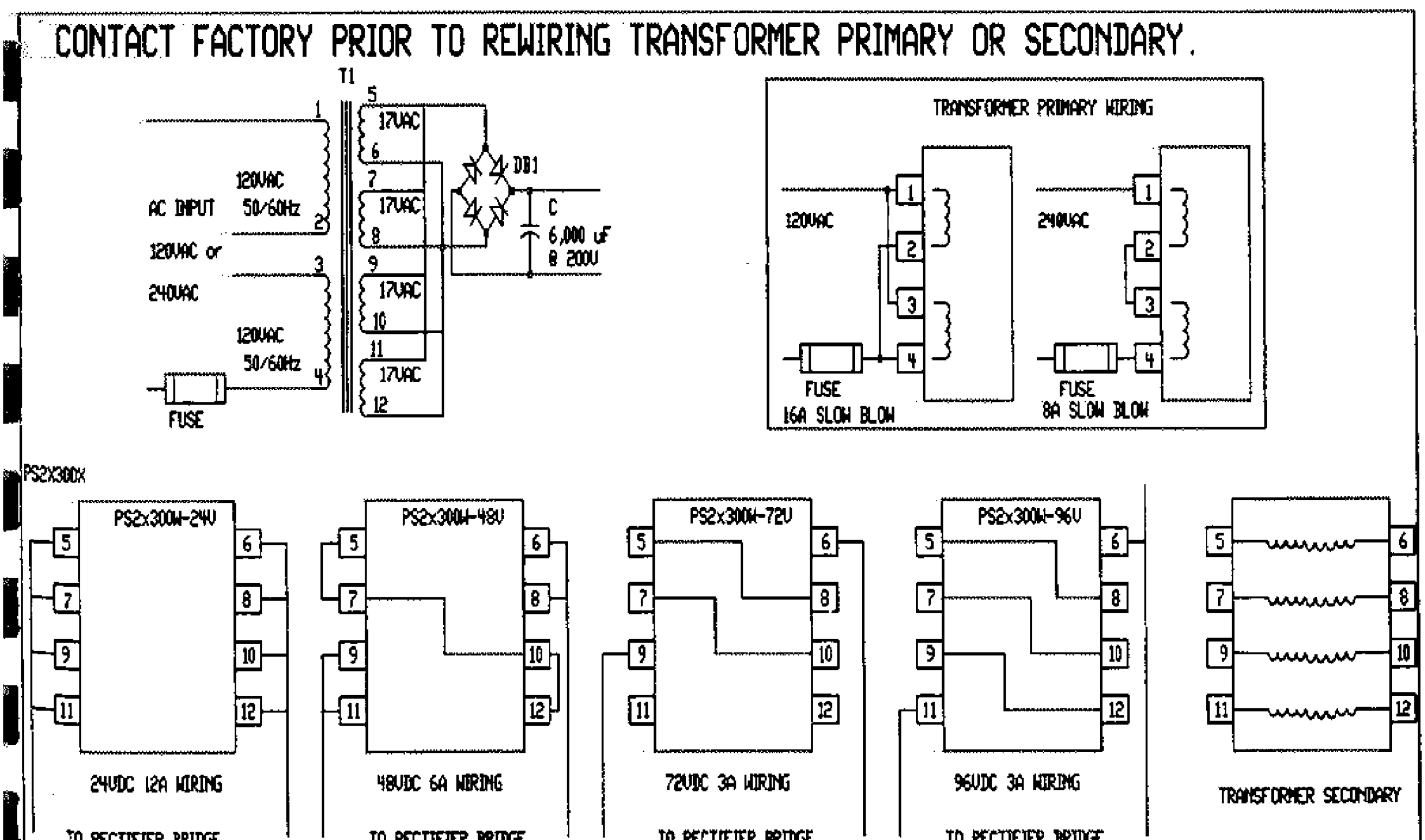
FEATURES:

- Multiple primary windings: either 120 VAC or 240 VAC, 50/60 Hz operation
- 24 VDC secondary output winding taps
- Low cost
- Agency approvals:

CE



BLOCK DIAGRAM:



ADVANCED MOTION CONTROLS
3629 Vista Mercado, Camarillo, CA 93012 Tel: (805) 389-1935, Fax: (805) 389-1165

DESCRIPTION: The PS2X300W series unregulated power supplies have been designed to complement ***ADVANCED* MOTION CONTROLS'** servo amplifiers and to provide the user with a complete solution to single and multi-axes DC drive applications. These unregulated DC power sources are an acceptable solution for most applications as ***ADVANCED* MOTION CONTROLS'** servo amplifiers compensate for power supply output variations and AC ripple components. Series PS2X300W power supplies are designed to provide the best cost-per-watt value while mechanically hosting two of B15A, BE15A or 25A Series servo amplifiers. They have multiple primary windings for 120VAC and 240 VAC 50/60 Hz operation. These power supplies feature four identical secondary windings that can be connected in series or in parallel for different output voltages and currents.

	MODEL
MECHANICAL SPECIFICATIONS	**PS2X300W**
AC INPUT CONNECTOR (female three prong plug)	AC cord (not supplied)
DC OUTPUT CONNECTOR	Flying Leads
SIZE	9.00 x 5.75 x 3.47 inches 228.6 x 146.1 x 88.1 mm
WEIGHT	9 lb. 4.1 Kg.

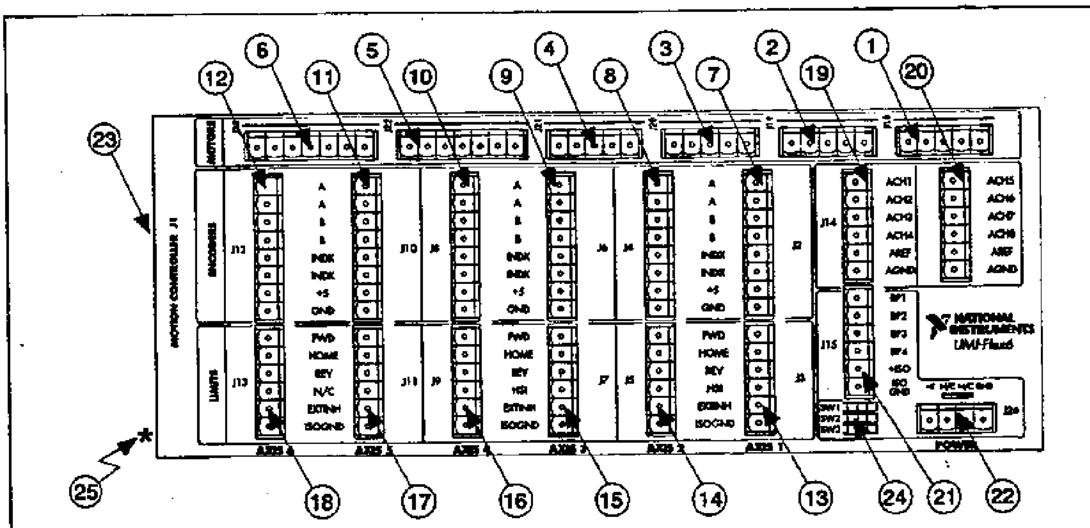
ORDERING INFORMATION:

AMC PART NUMBER			
Input Voltage (240VAC)	**Input voltage (120VAC)**	**Output Voltage (VDC)**	**Nominal Output Current (Amps)**
PS2X3H24	PS2X3W24	24	12
PS2X3H48	PS2X3W48	48	6
PS2X3H72	PS2X3W72	72	3
PS2X3H96	PS2X3W96	96	3

MOUNTING DIMENSIONS: See page F-23.

UMI-Flex6

This section describes the UMI-Flex6 terminal block. Refer to Figure 23 to help you locate the different parts of the UMI-Flex6 accessory.



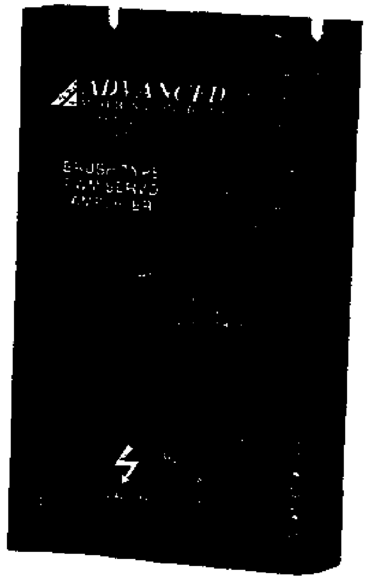
Amplifier Connectors	Encoder Connectors	Limits Connectors	Analog Input Connectors	Miscellaneous
1 Axis 1 (J18)	7 Axis 1 (J2)	13 Axis 1 (J3)	19 1-4 (J14)	21 Breakpoint Connector (J15)
2 Axis 2 (J19)	8 Axis 2 (J4)	14 Axis 2 (J5)	20 5-8 (J16)	22 Power Connector (J26)
3 Axis 3 (J20)	9 Axis 3 (J6)	15 Axis 3 (J7)		23 FlexMotion Controller (J1)
4 Axis 4 (J21)	10 Axis 4 (J8)	16 Axis 4 (J9)		24 Switches
5 Axis 5 (J22)	11 Axis 5 (J10)	17 Axis 5 (J11)		25 Assembly and serial number (bottom)
6 Axis 6 (J23)	12 Axis 6 (J12)	18 Axis 6 (J13)		

Figure 23. UMI-Flex6 Parts Locator Diagram

Amplifier/Driver Terminal Block

For amplifier/driver wiring, each UMI-Flex6 axis has a separate 5- or 7-position terminal block. Refer to Figure 23 to help you locate the amplifier/driver terminal blocks on your UMI-Flex6 accessory. Figure 24 shows the UMI-Flex6 amplifier/driver terminal block pin assignment for the servo and combined servo/stepper axes. The 5-position UMI-Flex6 terminal block supports the servo axes, and the 7-position terminal block adds stepper support.

SERIES 25A SERVO AMPLIFIERS
Models: 12A8, 25A8, 20A14, 20A20
Miniature Series

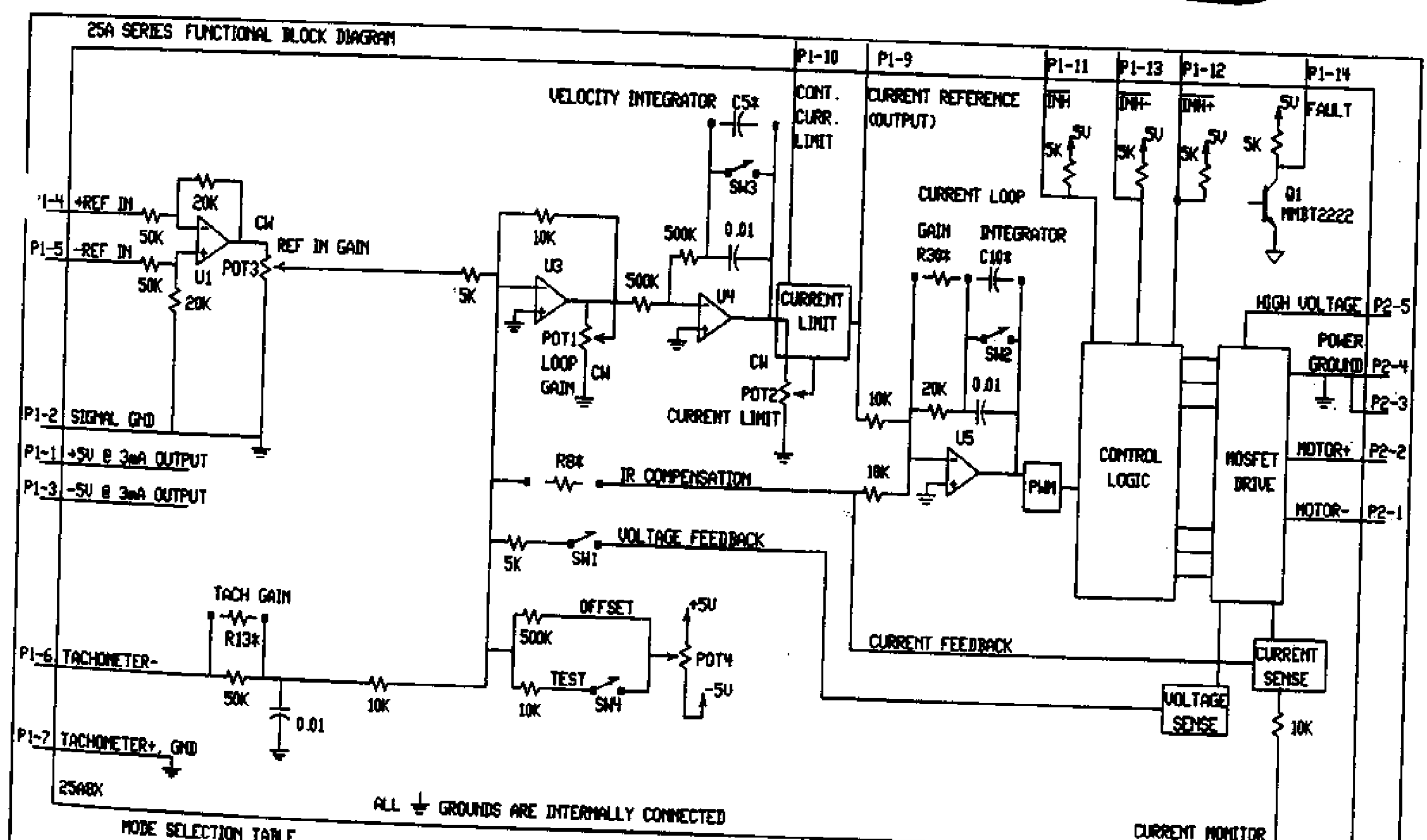


FEATURES:

- Surface-mount technology
- Small size, low cost, ease of use
- DIP switch selectable: current, voltage, velocity, analog position loop
- Four quadrant regenerative operation
- Agency Approvals:

c UL us CE

BLOCK DIAGRAM:



	SW1	SW2	SW3
CURRENT MODE	OFF	OFF	ON
VOLTAGE MODE	ON	OFF	OFF
IR COMPENSATION	ON	OFF	OFF
TACHOMETER MODE	OFF	OFF	OFF

SW2 SHOULD BE OFF FOR MOST APPLICATIONS

LED GREEN - NORMAL OPERATION, LED RED - FAULT
RECOMMENDED SETTING FOR CURRENT MODE - POT1 FULLY CCW, POT3 FULLY CW
AMPLIFIERS ARE SHIPPED IN CURRENT MODE WITH MAXIMUM CURRENT SETTINGS
FOR OTHER SWITCH FUNCTIONS SEE SWITCH DESCRIPTION
* OPTIONAL USER INSTALLED THROUGH HOLE COMPONENT

ADVANCED MOTION CONTROLS
3629 Vista Mercado, Camarillo, CA 93012

Tel: (805) 389-1935, Fax: (805) 389-1165

DESCRIPTION: The 25A Series PWM servo amplifiers are designed to drive brush type DC motors at a high switching frequency. A single red/green LED indicates operating status. All models are fully protected against over-voltage, over-current, over-heating and short-circuits across motor, ground and power leads. All models interface with digital controllers or can be used as a stand-alone drive. They require only a single unregulated DC power supply. Loop gain, current limit, input gain and offset can be adjusted using 14-turn potentiometers. The offset adjusting potentiometer can also be used as an on-board input signal for testing purposes when SW4 (DIP switch) is ON.

SPECIFICATIONS:

	MODELS			
POWER STAGE SPECIFICATIONS	**12A8**	**25A8**	**20A14**	**20A20**
DC SUPPLY VOLTAGE	20 - 80 V	20 - 80 V	40 - 140 V	40 - 190 V
PEAK CURRENT (2 sec. Max., internally limited)	± 12 A	± 25 A	± 20 A	± 20 A
MAXIMUM CONTINUOUS CURRENT (internally limited)	± 6 A	± 12.5 A	± 10 A	± 10 A
MINIMUM LOAD INDUCTANCE*	200 µH	200 µH	250 µH	250 µH
SWITCHING FREQUENCY	36 kHz	22 kHz ± 15%		
HEATSINK (BASE) TEMPERATURE RANGE	-25° to + 65° C, disables if > 65° C			
POWER DISSIPATION AT CONTINUOUS CURRENT	24 W	50 W	70 W	100 W
OVER-VOLTAGE SHUT-DOWN (self-reset)	86 V	86 V	142 V	195 V
BANDWIDTH (load dependent)	2.5 kHz			

MECHANICAL SPECIFICATIONS	
POWER CONNECTOR	Screw terminals
SIGNAL CONNECTOR	Molex connector
SIZE	5.09 x 2.98 x 0.99 inches 129.3 x 75.8 x 25.1 mm
WEIGHT	10 oz. 0.28 kg

* Low inductance motors ("pancake" and "basket-wound") require external inductors.

PIN FUNCTIONS:

CONNECTOR	PIN	NAME	DESCRIPTION / NOTES	I/O
P1	1	+5V OUT	Internal DC-to-DC converter, outputs regulated voltages of ±5 V @ 3 mA for customer use. Short circuit protected.	O
	2	SIGNAL GND		GND
	3	-5V OUT		O
	4	+REF IN	Differential analog input, maximum ±15 V, 50K input resistance.	I
	5	-REF IN		
	6	-TACH IN	Maximum ± 60 VDC, 60K input resistance.	I
	7	+TACH (GND)		
	8	CURRENT MONITOR OUT	This signal is proportional to the actual current in the motor leads. Scaling is 2A/V for 12A8 and 4 A/V for 25A8, 20A14 and 20A20.	O
	9	CURRENT REFERENCE OUT	Command signal to the internal current-loop. The maximum peak current rating of the amplifier always equals 7.25V at this pin. See current limit adjustment information below.	O
	10	CONTINUOUS CURRENT LIMIT	Can be used to reduce the factory-preset maximum continuous current limit.	I
	11	$\overline{\text{INHIBIT}}$	This TTL level input signal turns off all four power devices of the "H" bridge drive when pulled to ground. This inhibit will cause a FAULT condition and a red LED. For inverted inhibit inputs; see section "G".	I
	12	+$\overline{\text{INHIBIT}}$	Disables the amplifier for the "+" direction only. This inhibit will not cause a FAULT condition or a red LED.	I
	13	-$\overline{\text{INHIBIT}}$	Disables the amplifier for the "-" direction only. This inhibit will not cause a FAULT condition or a red LED.	I
	14	FAULT OUT (red LED)	TTL compatible output. It becomes high during output short-circuit, over-voltage, over-heating, inhibit, and during "power-on reset". Fault condition indicated by a red LED.	O
	15	NC	Not connected	
	16			
P2	1	-MOTOR	Motor minus connection.	O
	2	+MOTOR	Motor plus connection.	O
	3	POWER GROUND	Power Ground.	GND
	4	POWER GROUND	Power Ground.	GND
	5	HIGH VOLTAGE	DC voltage input.	I

SWITCH FUNCTIONS:

SWITCH	FUNCTION DESCRIPTION	SETTING	
		ON	OFF
1	Internal voltage feedback	On	Off
2	It is recommended to leave SW2 in OFF position.	Shorts out the current loop integrator capacitor.	Current loop integrator operating
3	This capacitor normally ensures "error-free" operation by reducing the error-signal (output of summing amplifier) to zero.	Shorts out the outer velocity/voltage loop integrator capacitor	Velocity/Voltage integrator operating
4	Offset / test. Controls sensitivity of the "offset" pot. Used as an on-board reference signal in test mode.	Test	Offset

POTENTIOMETER FUNCTIONS:

POTENTIOMETER	DESCRIPTION	TURNING CW
Pot 1	Loop gain adjustment in voltage & velocity modes. Turn this pot fully ccw in current mode.	Increases loop gain
Pot 2	Current limit. It adjusts both continuous and peak current limit by maintaining their ratio (50 %).	Increases current limit
Pot 3	Reference gain. It adjusts the ratio between input signal and output variables (voltage, current, or velocity).	Increases reference input gain
Pot 4	Offset / test. Used to adjust any imbalance in the input signal or in the amplifier. When SW4 (DIP switch) is ON, the sensitivity of this pot is greatly increased thus it can be used as an on-board signal source for testing purposes. See section "G".	N/A

TEST POINTS FOR POTENTIOMETERS: See section "G"

-UP: See section "G" for engineering and installation notes.

OPERATING MODE SELECTION:

These modes can be selected by the DIP-switches according to the chart in the functional block diagram:

- Current Mode
- Voltage Mode
- IR Compensation Mode*
- Tachometer Mode

APPLICATION NOTES:

For IR compensation mode, a resistor must be added to location R8. See the functional block diagram above and section "G" for more information. The combination of the resistor addition and the switches set for voltage mode will configure the amplifier for IR compensation mode. See section "G" for more information.

See section G for more information on analog position loop mode.

CURRENT LIMIT ADJUSTMENTS:

These amplifiers feature separate peak and continuous current limit adjustments.

current limit adjusting Pot 2 adjusts both peak and continuous current limit at the same time. It has 12 active turns plus 1 inactive turn at each end and is approximately linear. Thus, to adjust the current limit, turn the potentiometer fully counter-clockwise, then turn clockwise to the appropriate value. If the desired limit is, for example, 10 amperes, and the servo amplifier peak current is 20 amperes, turn the potentiometer 7 turns clockwise from the fully counter-clockwise position.

Pin P1-9 is the input to the internal current amplifier stage. Since the output current is proportional to P1-9, the adjusted current limit can easily be observed at this pin. Note that a command signal must be applied to the reference inputs to obtain a reading on P1-9. The maximum peak current value equals 7.25 V at this pin and the maximum continuous current value equals 3.63 V at this pin.

The actual current can be monitored at pin P1-8.

The continuous current can be reduced without affecting the peak current limit by connecting an external current limiting resistor R-lmt between P1-10 and P1-2. See table below.

Current Limit Resistor (Ω)	15K	6.6K	3.4K	2.1K	1.2K	810	500	250	0
Continuous Current Limit %	90 %	80 %	70 %	60 %	50 %	40%	30 %	20 %	10 %

TYPICAL SYSTEM WIRING: See section "G".

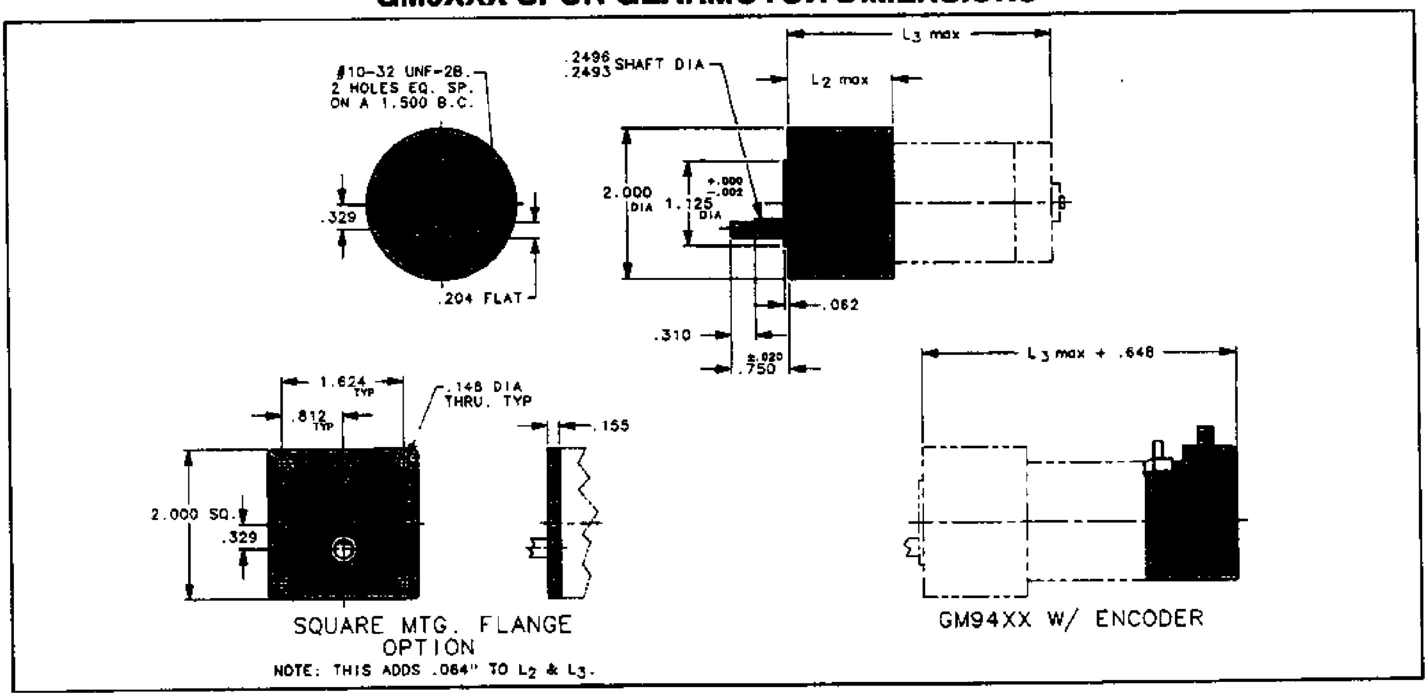
GM9XXX SPUR GEARMOTOR DATA (25° C)

PARAMETER	SYM	UNITS	5.8974	11.500	19.658	38.333	65.527	127.78	218.42	425.93	728.08	1419.8	2426.9	4732.5
38 Load, High Torque Option †	T_L	oz•in max	—	—	300	300	300	300	300	300	300	300	300	300
40 N.L. Speed, GM9X12	S_g	rpm	1399	717	420	215	126	64.6	37.8	19.4	11.3	5.81	3.40	1.74
42 N.L. Speed, GM9X13	S_g	rpm	948	486	284	146	85.3	43.8	25.6	13.1	7.68	3.94	2.30	1.18
44 N.L. Speed, GM9X14	S_g	rpm	1300	667	390	200	117	60.0	35.1	18.0	10.5	5.40	3.16	1.62
46 Gearbox Shaft Rotation ‡	—	—	cw	cw	ccw	ccw	cw	cw	ccw	ccw	cw	cw	ccw	ccw
48 Gearbox Weight, Std./H.T.	W_G	oz	5.90	5.90	6.26	6.26	6.62	6.62	6.98	6.98	7.34	7.34	8.18	8.18
50 Gearbox Length, Std./H.T.	L_2	in max	1.373	1.373	1.373	1.373	1.373	1.373	1.373	1.373	1.373	1.373	1.528	1.528
52 Length, GM94X2, Std./H.T.	L_3	in max	3.101	3.101	3.101	3.101	3.101	3.101	3.101	3.101	3.101	3.101	3.256	3.256
54 Length, GM94X3, Std./H.T.	L_3	in max	3.476	3.476	3.476	3.476	3.476	3.476	3.476	3.476	3.476	3.476	3.631	3.631
56 Length, GM94X4, Std./H.T.	L_3	in max	3.676	3.676	3.676	3.676	3.676	3.676	3.676	3.676	3.676	3.676	3.831	3.831
58 Length, GM95X2, Std./H.T.	L_3	in max	3.052	3.052	3.052	3.052	3.052	3.052	3.052	3.052	3.052	3.052	3.207	3.207
60 Length, GM95X3, Std./H.T.	L_3	in max	3.427	3.427	3.427	3.427	3.427	3.427	3.427	3.427	3.427	3.427	3.582	3.582
62 Length, GM95X4, Std./H.T.	L_3	in max	3.627	3.627	3.627	3.627	3.627	3.627	3.627	3.627	3.627	3.627	3.782	3.782

† Represents gearbox capability only. Continuous load torque capability will vary with gear ratio, motor selection, and operating conditions. See pages 3 and 4, section IV, in "Servo Motor Application Notes".

‡ Shaft rotation is designated while looking at output shaft of gearbox with positive voltage (+) on number 1 terminal. Gearmotor is polarity reversible.

GM9XXX SPUR GEARMOTOR DIMENSIONS



HEDS 90X0 OPTICAL ENCODER DATA (25° C)

64 Encoder Resolution, HEDS 91X0	N	CPR	96	500	512
66 Encoder Weight, HEDS 91X0	W_E	oz	—	1.58	—

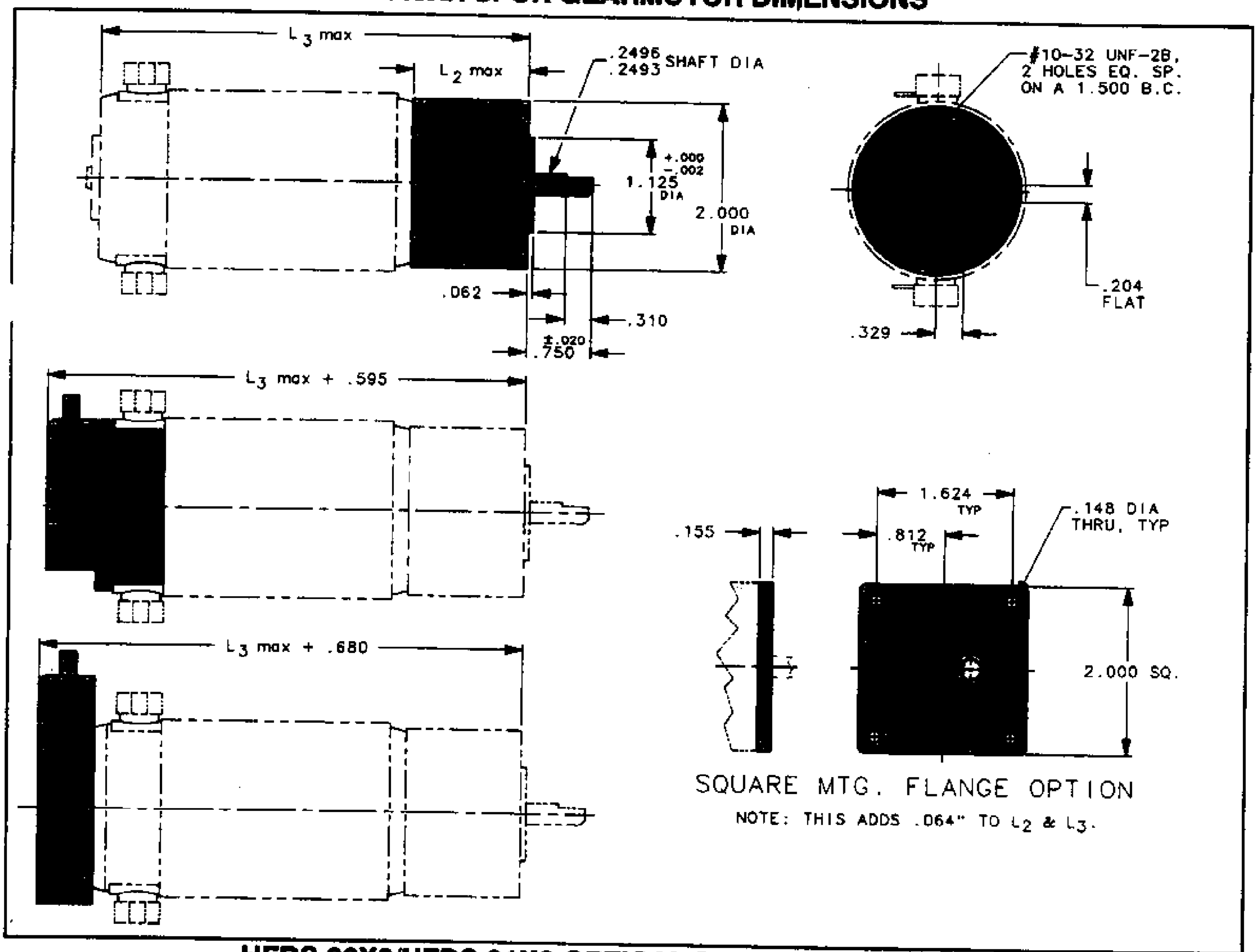
GM149XX SPUR GEARMOTOR DATA (25° C)

PARAMETER	SYMBOL	UNITS	5.8974	19.658	65.527	218.42
37 Load, High Torque Option	T_L	oz•in max	—	300	300	300
39 N.L. Speed, GM14901	S_0	rpm	713	214	64.2	19.3
41 Gearbox Shaft Rotation			cw	ccw	cw	ccw
43 Gearbox Weight, Std./H.T.	W_G	oz	5.90	6.26	6.62	6.98
45 Gearbox Length, Std./H.T.	L_2	in max	1.373	1.373	1.373	1.373
47 Length, GM14901, Std./H.T.	L_3	in max	4.322	4.322	4.322	4.322
49 Length, GM14902, Std./H.T.	L_3	in max	4.572	4.572	4.572	4.572

† Represents gearbox capability only. Gear life expectancy varies significantly with output torque and speed. Please consult Pittman Product Engineering Department for application data.

‡ Shaft rotation is designated while looking at output shaft of gearbox with positive voltage (+) on number 1 terminal. Gearmotor is polarity reversible.

GM149XX SPUR GEARMOTOR DIMENSIONS

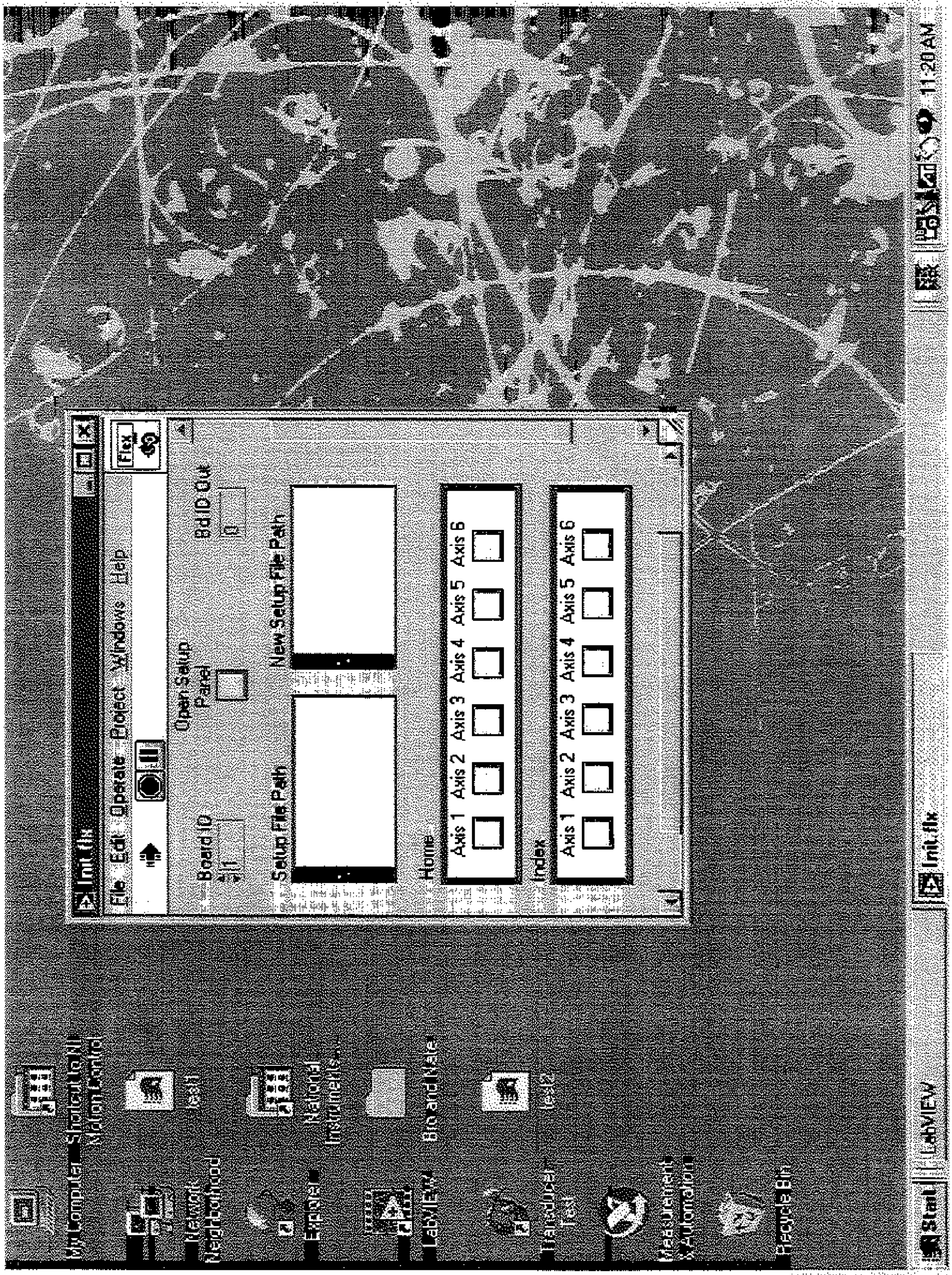


HEDS 90X0/HEDS 91X0 OPTICAL ENCODER DATA (25° C)

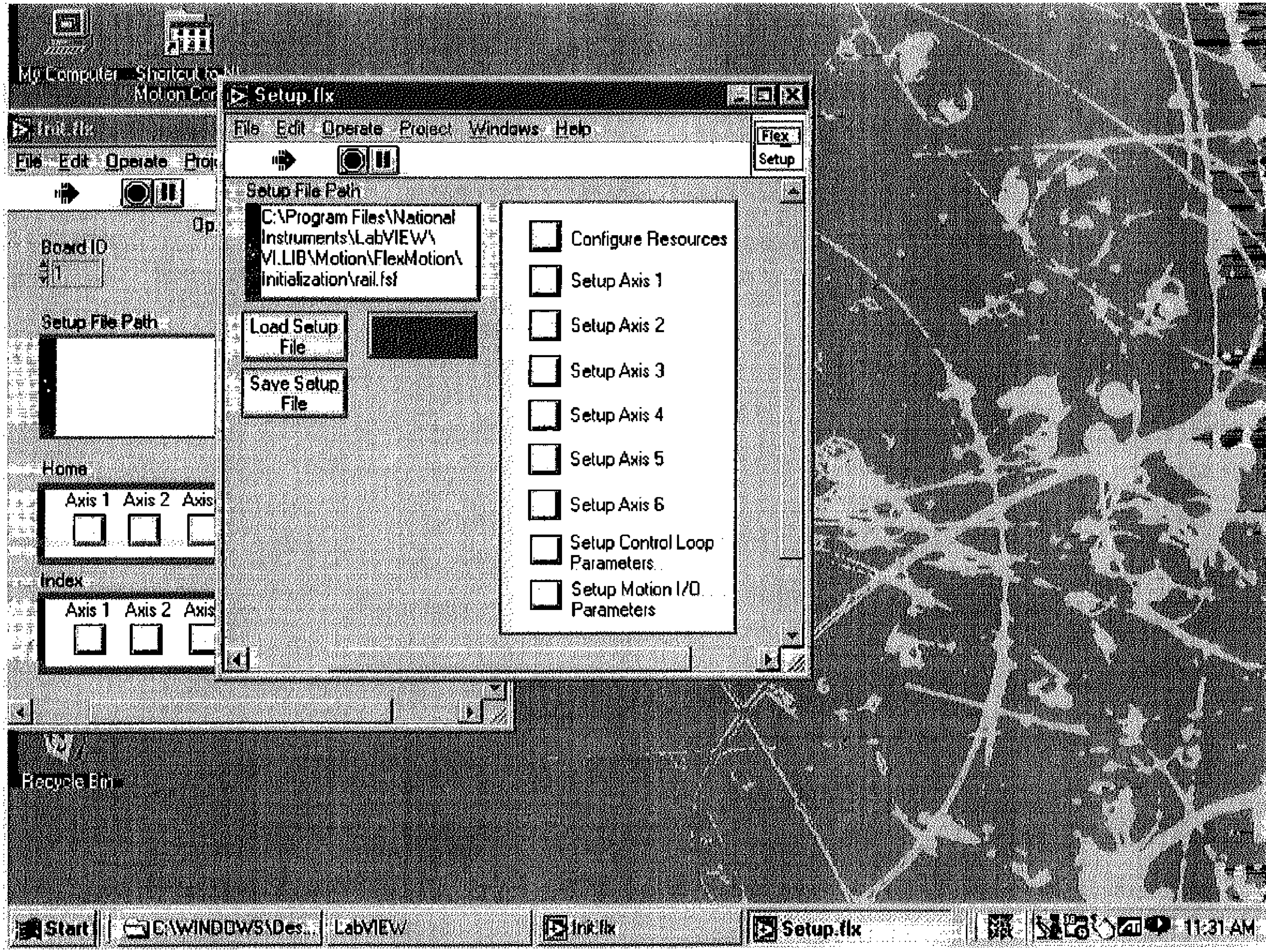
51 Encoder Resolution, HEDS 91X0	N	CPR	96	500	512
53 Encoder Inertia, HEDS 91X0	J_E	$oz\cdot in\cdot s^2$	—	8.0×10^{-6}	—
55 Encoder Weight, HEDS 91X0	W_E	oz	—	1.58	—
57 Encoder Length, HEDS 91X0	L_4	in max	—	—	0.595

Appendix G-H: FlexMotion Software and GUI Wiring Diagrams

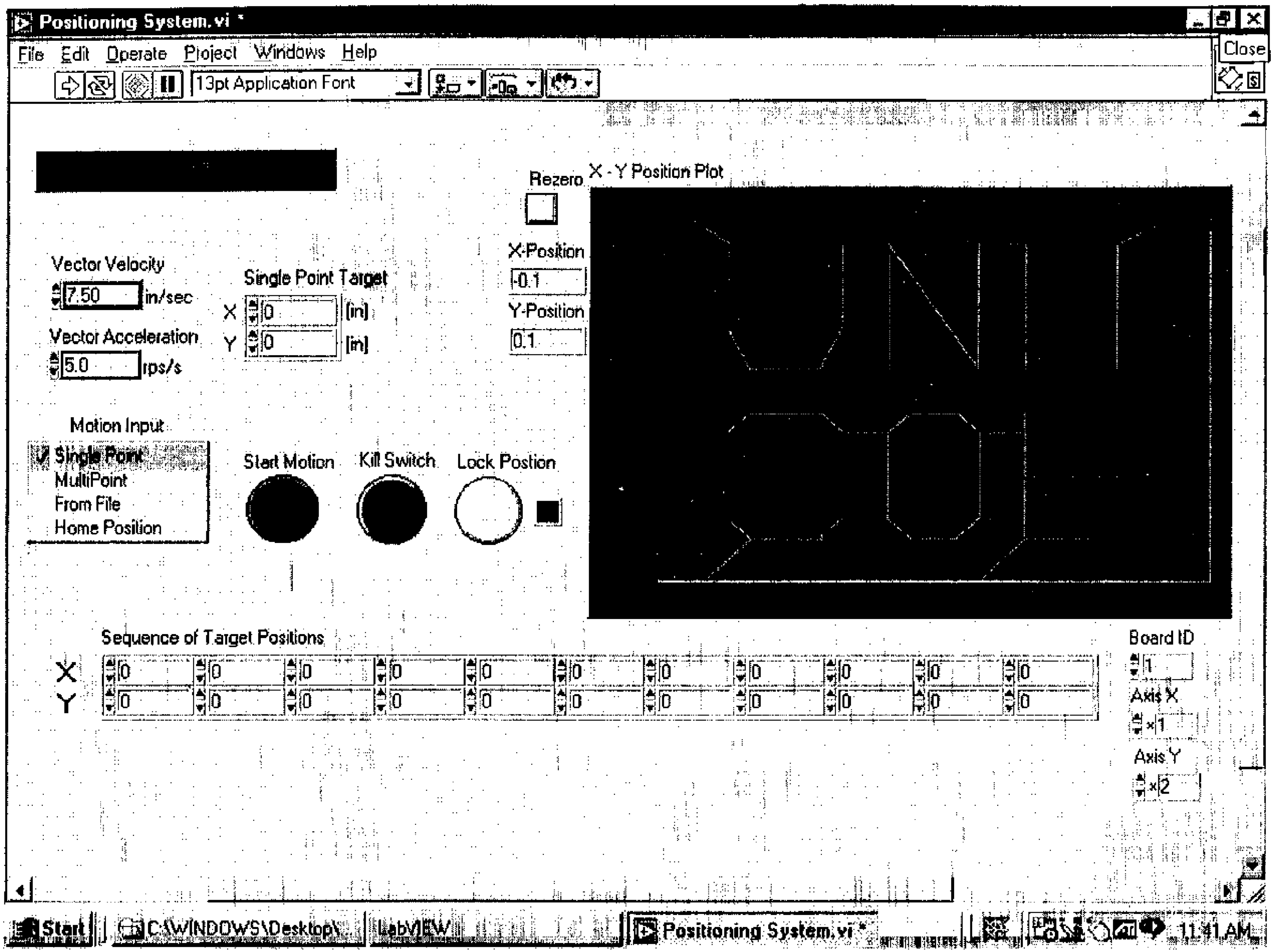
G



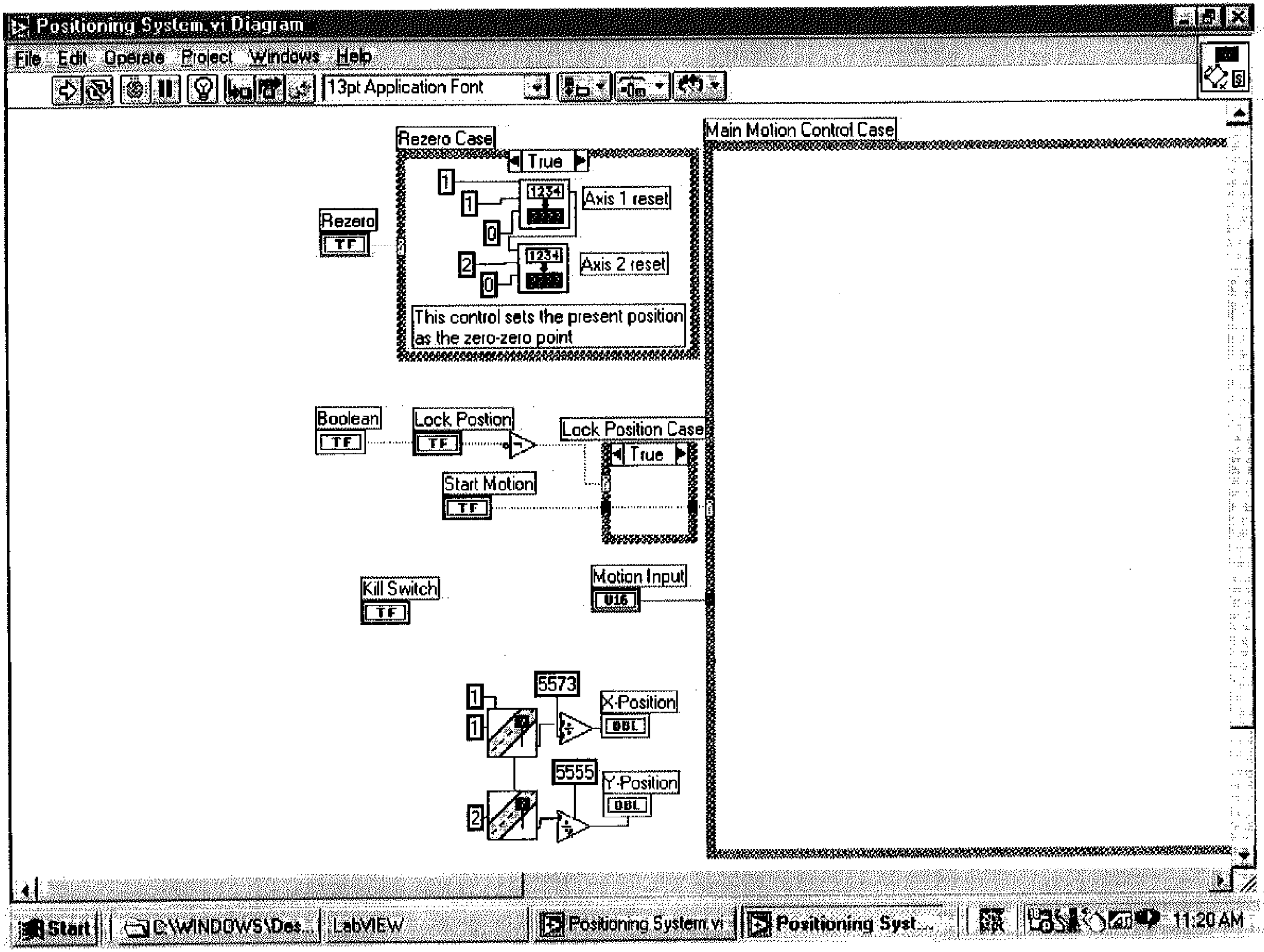
Init.flx
File Edit Operate Project Windows Help
Board ID
Open Setup Panel
Bd ID Out
Setup File Path
New Setup File Path
Home
Axis 1 Axis 2 Axis 3 Axis 4 Axis 5 Axis 6
Index
Axis 1 Axis 2 Axis 3 Axis 4 Axis 5 Axis 6
Flex
My Computer
Network Neighborhood
Explorer
LabVIEW
Transducer Test
Measurement & Automation
Recycle Bin
test1
test2
National Instruments...
Start
LabVIEW
Init.flx
11:20 AM


My Computer
Shortcut to NI Motion Con
Init.flx
File Edit Operate Proj
Op
Board ID
1
Setup File Path
Home
Axis 1 Axis 2 Axis
Index
Axis 1 Axis 2 Axis
Recycle Bin
Setup.flx
File Edit Operate Project Windows Help
Flex Setup
Setup File Path
C:\Program Files\National Instruments\LabVIEW\VI.LIB\Motion\FlexMotion\Initialization\rail.fsf
Load Setup File
Save Setup File
Configure Resources
Setup Axis 1
Setup Axis 2
Setup Axis 3
Setup Axis 4
Setup Axis 5
Setup Axis 6
Setup Control Loop Parameters
Setup Motion I/O Parameters
Start
C:\WINDOWS\Des...
LabVIEW
Init.flx
Setup.flx
11:31 AM

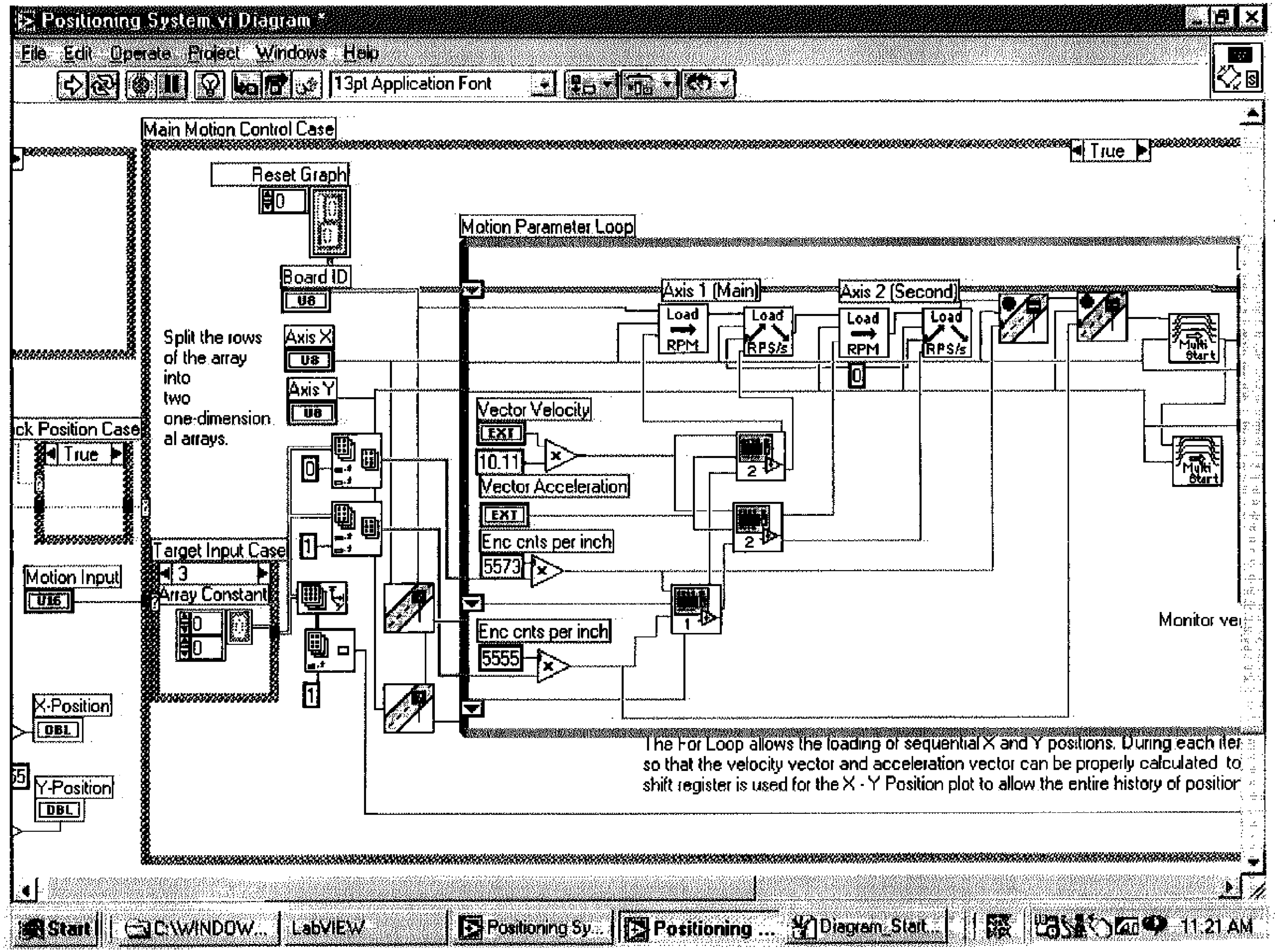
H


Positioning System.vi *
File Edit Operate Project Windows Help
13pt Application Font
Close
Rezero
X - Y Position Plot
Vector Velocity
7.50 in/sec
Single Point Target
X 0 [in]
Y 0 [in]
X-Position
-0.1
Y-Position
0.1
Vector Acceleration
5.0 rps/s
Motion Input
Single Point
MultiPoint
From File
Home Position
Start Motion
Kill Switch
Lock Postion
Sequence of Target Positions
X
Y
Board ID
1
Axis X
x1
Axis Y
x2
Start
C:\WINDOWS\Desktop\...
LabVIEW
Positioning System.vi *
11:41 AM

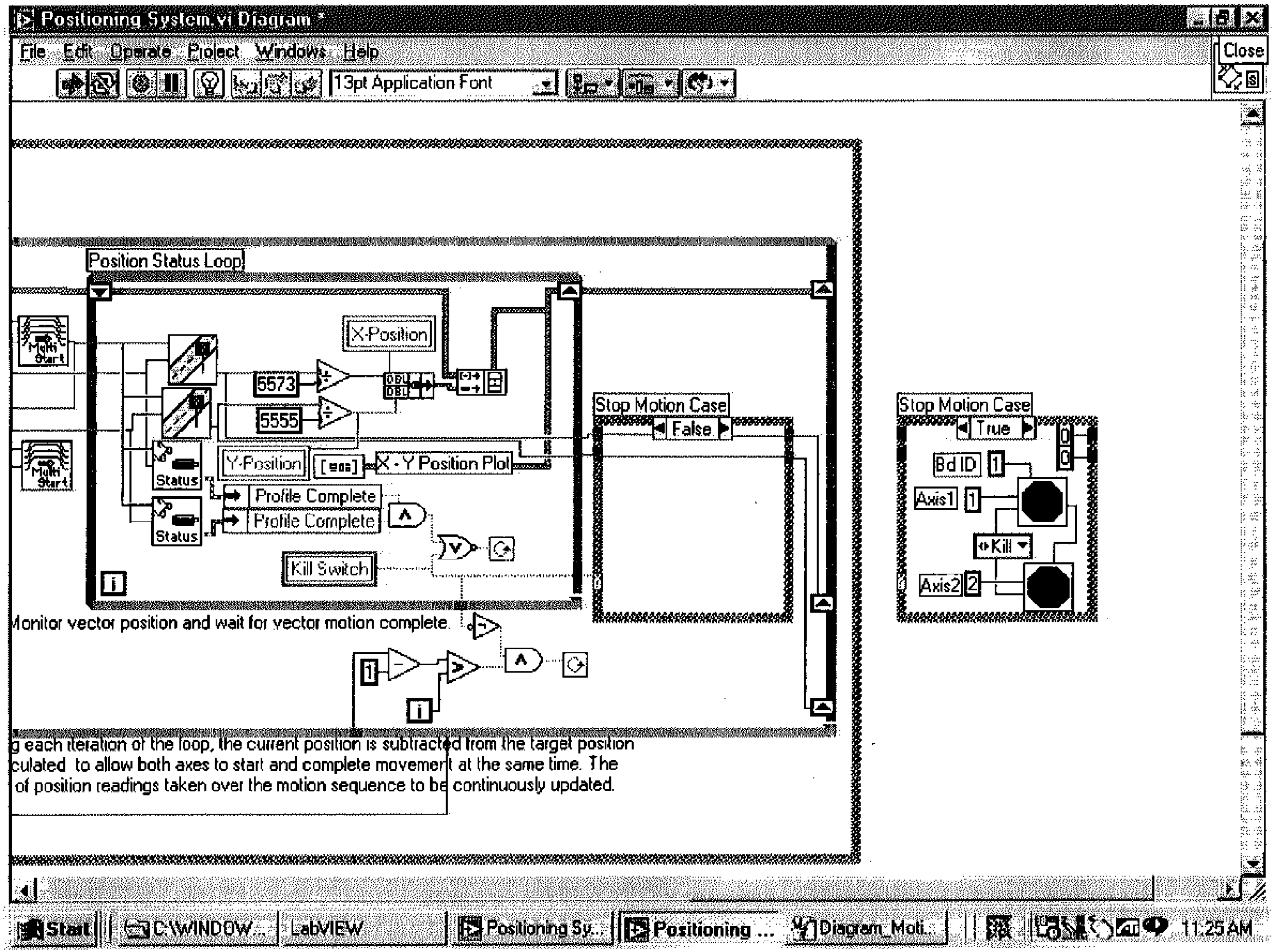
I


Positioning System.vi Diagram
File Edit Operate Project Windows Help
13pt Application Font
Rezero Case
True
1
1
0
2
0
Axis 1 reset
Axis 2 reset
This control sets the present position as the zero-zero point
Rezero
TF
Boolean
TF
Lock Postion
TF
Lock Position Case
True
Start Motion
TF
Kill Switch
TF
Motion Input
U16
Main Motion Control Case
5573
X-Position
DBL
5555
Y-Position
DBL
Start
C:\WINDOWS\Des...
LabVIEW
Positioning System.vi
Positioning Syst...
11:20 AM

J


Positioning System.vi Diagram *
File Edit Operate Project Windows Help
13pt Application Font
Main Motion Control Case
True
Reset Graph
Motion Parameter Loop
Board ID
U8
Axis 1 (Main)
Axis 2 (Second)
Load RPM
Load RPS/s
Split the rows of the array into two one-dimensional arrays.
Axis X
Axis Y
ck Position Case
Vector Velocity
EXT
10.11
Vector Acceleration
Enc cnts per inch
5573
5555
Target Input Case
3
Array Constant
Motion Input
U16
Multi Start
Monitor ve
X-Position
DBL
Y-Position
The For Loop allows the loading of sequential X and Y positions. During each ite
so that the velocity vector and acceleration vector can be properly calculated to
shift register is used for the X - Y Position plot to allow the entire history of positio
Start
C:\WINDOW...
LabVIEW
Positioning Sy...
Positioning ...
Diagram_Start...
11:21 AM

K


Positioning System.vi Diagram *
File Edit Operate Project Windows Help
13pt Application Font
Close
Position Status Loop
X-Position
5573
5555
Y-Position
X - Y Position Plot
Status
Status
Profile Complete
Profile Complete
Kill Switch
Multi Start
Multi Start
Stop Motion Case
False
Stop Motion Case
True
Bd ID
1
Axis1
1
Kill
Axis2
2
Monitor vector position and wait for vector motion complete.
g each iteration of the loop, the current position is subtracted from the target position
culated to allow both axes to start and complete movement at the same time. The
of position readings taken over the motion sequence to be continuously updated.
Start
C:\WINDOW...
LabVIEW
Positioning Sy...
Positioning ...
Diagram_Moti...
11:25 AM