INDUSTRIAL ELECTROHYDRAULIC SERVO CONTROL SYSTEMS WORKSHOP

M2000 PROGRAMMABLE SERVO CONTROL

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1.0 OVERVIEW

Background - Moog servo control system electronics has been supplied into industrial applications for some years. Analog and digital versions are available, both of which complement the Moog range of servo valves. Whilst servo axis control is the primary function, Moog system electronics may also be used for command generation and system sequencing.

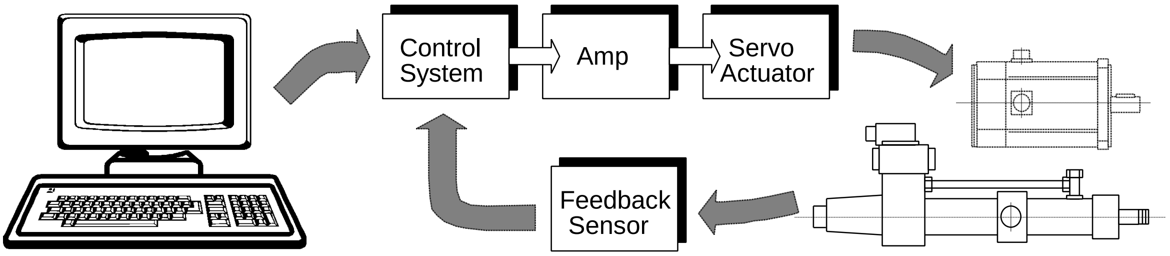


Figure 1 - Servo Axis Control

Moog Experience -
A wealth of hydraulic servo experience has culminated in the so called ‘M2000’ digital product range where flexibility in control system design and a modular hardware structure has enabled M2000 to be used in a diverse range of applications.

Underlying M2000 control capability is made accessible to the machine integrator via the Moog Graphical Operator Interface (GOUI). For example Figure 2 shows the step response of a load control servo system using the PC oscilloscope display.

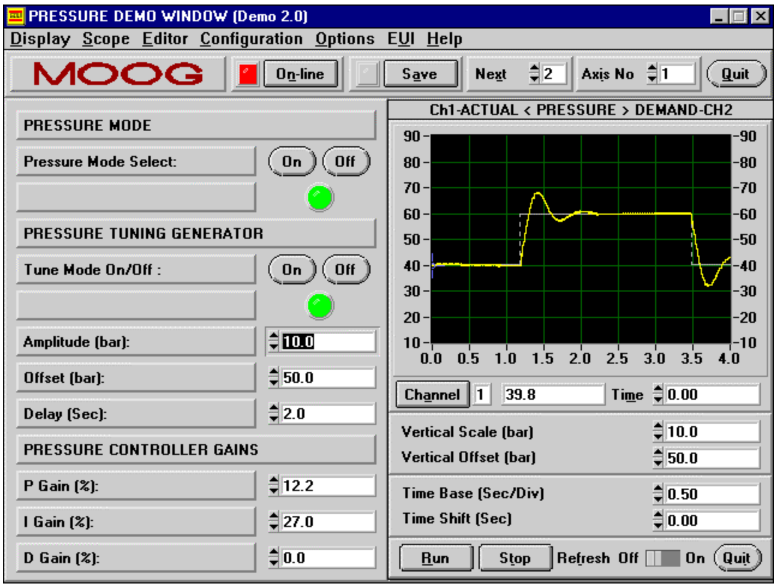


Figure 2 - GOUI Interface and Oscilloscope Trace

About M2000 - The Moog M2000 system was conceived in 1990 as a unified approach to solving the diverse control problems found in hydraulic servo systems. Currently in it’s second phase of development; the M2000 system has been used in well over 1000 installations. These cover a wide variety of applications ranging from one off special purposes component test machines through high speed panel press NC machine tools to marine vessel stabilisation systems.

Workshop Outline - These workshop notes outline in more detail the package of electronics based on Moog’s M2000 digital control product range which can be offered in association with Moog servo valves. The described hardware whilst shown in a hydraulic servo context is also suitable for controlling electric servo drives and may also be used for open loop on/off axes. The described M2000 software concept offers the opportunity to improve servo performance in a number of areas as outlined in the application examples.

2.0 THE MOOG M2000 AXIS CONTROL PRODUCT RANGE

2.1 Hardware Modules

The heart of the M2000 product range is the Programmable Servo Control (PSC) unit as shown in Figure 3. PSC boards are of Single Eurocard format with a DIN41612 connector for I/O purposes and a front panel 9 pin 'D' type for PC commissioning. The on-board 2 axes of control are supported by a range of I/O conditioning and expansion modules - Table 1 - which may be arranged in 19 inch or 3 slot mini rack format. See Figure 4.

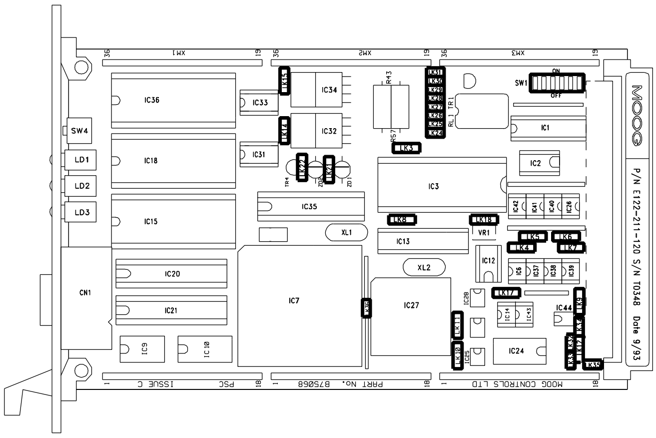


Figure 3 - Programmable Servo Control Module

M2000 Product Range	**Description**	**Model No**
Controllers	Programmable Servo Controller	E122-211
	Programmable Pressure/Position (P/X) Controller	E122-215-002
Rack and PSU Systems	19 Inch Rack System	E127-101/103
	3 slot Mini Rack	T127-401
	Mini DC/DC Power Supply	E128-211
Analog I/O (XM3) Piggyback Products	Analog Input Signal Conditioning	E129-018
	Analog Output Expansion	J123-022
PSC, (XMO Bus) I/O Expansion Products	Dual Encoder Input and DC/DC PSU	E124-714
PSC (Serial Bus) I/O Expansion Products	Parallel Input Card	E124-216
PSC Communications (XM1) Modules	CANBus Communications	E129-016
	Configurable Operator Terminal	-
PSC Software Products	PC User Interface and User Manual	B75432
	Communications for LabWindows	B86272

Table 1 - M2000 Controller and I/O Expansion Range

The 3 slot rack configuration (Figure 4) allows for up to 4 axes of control to be installed in a DIN rail mounted rack complete with front access screw terminals and 9-pin 'D' type connectors for inter-axis communication. Alternatively, for bigger systems the M2000 boards may be assembled in a 19 inch rack format with rear mounted screw terminal access.

Either mounting format uses the Moog M2000 standard for inter module communication and power distribution and may be fitted with a Moog approved 24V or mains input power supply unit. The communication standards for inter-module, host computer and serial sensor communications are as follows:

- ***XMO Processor Bus*** - for close coupled high speed operations as used in the dual encoder interface module.
- ***Set-Up Link*** - for RS232 serial communications during machine set-up via a PC.
- ***Sync-Link*** - for RS485 multi-drop applications. Normally used for multi-board PC set-up or for slow on-line host co-ordination.
- ***SSI Serial Tx*** - for RS422 serially encoded absolute transducers. Both linear and multi-turn options are available.
- ***CANBus -*** RS485 communications for high speed on-line multi axis host communications and inter-axis communications.

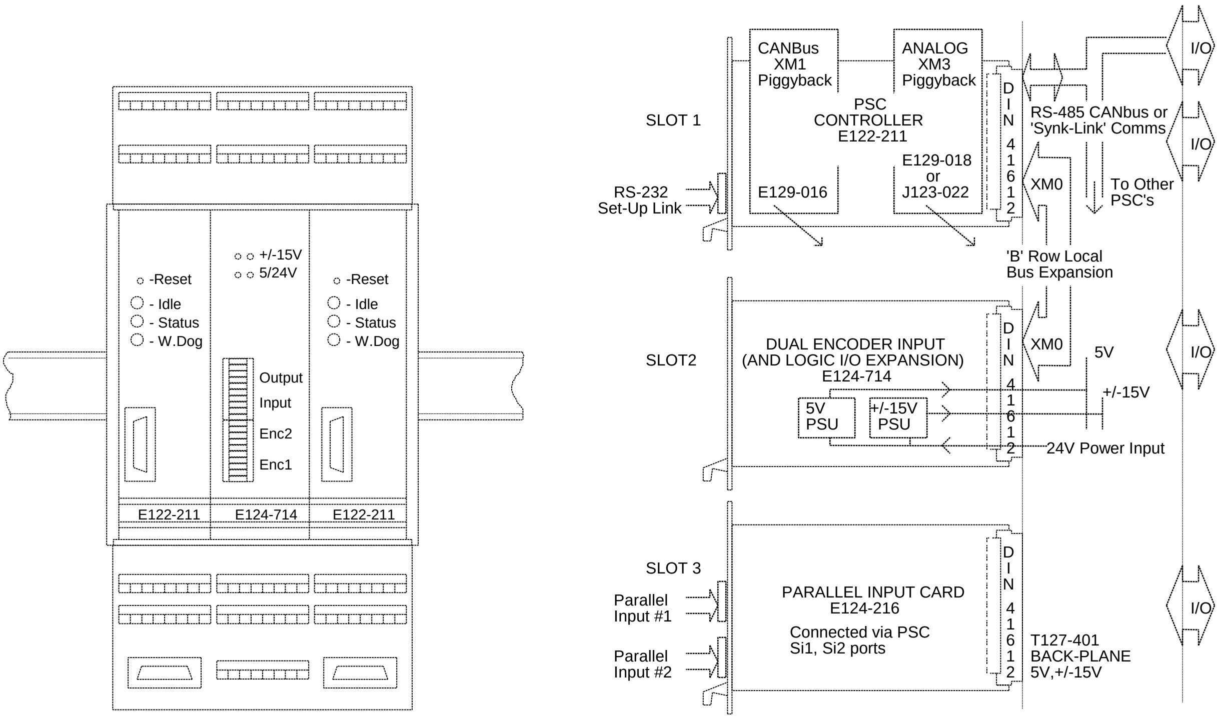


Figure 4 - Three Slot Rack and Hardware Configuration Options

As a result of these communication possibilities the system hardware architecture is flexible enough to accommodate a variety of formats. The classic 'host master / slave axis' format where all events at the axis controllers are triggered from the master host system may be used over the RS485 link or CANBus for high speed operations Alternatively the M2000 system may be configured for masterless inter-axis communications. This allows clusters of axes to operate in a stand alone manner. Any host system apart from issuing start/stop signals behaves in a supervisory manner. The later approach provides a means of reducing the processing demands of the host system and allows for high speed operation where tight coupling of axes is required.

2.2 Standardised Axis Control

Many servo applications are solvable using simple PID closed loop control. Each M2000 module can be supplied with this as standard. The features are shown and highlighted in Figure 5 below which shows a single axis of the +/-10V analog I/O, 24V logic version of the controller. The modular approach to the low level software (see Section 2.4) allows for easy connection of other sensor types and some alternative means of logic interfacing.

Configuration of the many on-board features is achieved via the Graphical Operator Interface (GOUI) described in the next section.

Command Generation -
- Built in Home/Run positions.
- Ramp functions between modes.
- Command ramp and level limiting.
- Internal wave generation.

Error and Status Logic -
- Mode select logic.
- Start-Up Status logic.
- Axis Ready logic.
- Control Sensor/Error Logic.

Control Loop Functions -
- PID Standard Controller.
- Velocity feed forward
- Feedback D term

Smooth Operation -
- Soft start up.
- Soft manual/auto select.
- Controlled mode switch over.
- Bumpless transfer

Tuning and Calibration -
- Built in Tune Generator
- Amplitude Offset
- User friendly PC based parameter adjustment.
- PC based performance indication and oscilloscope display.

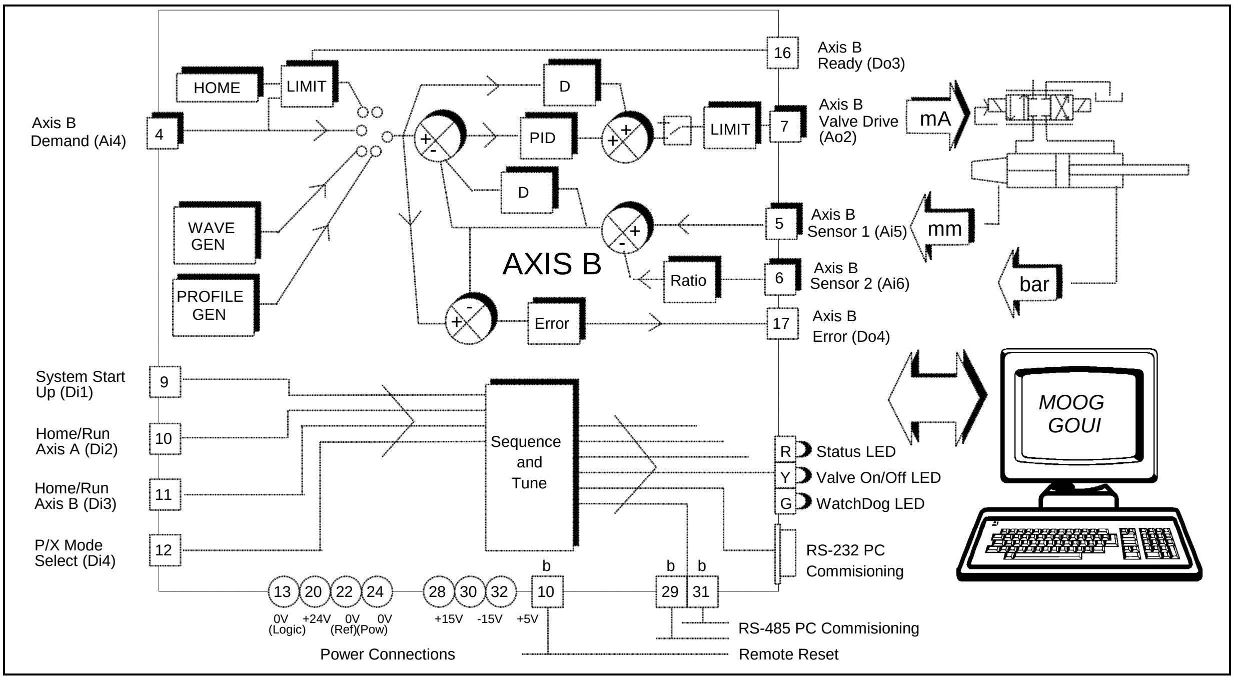


Figure 5 - Moog Controller Standard Axis Format (2 off per board)

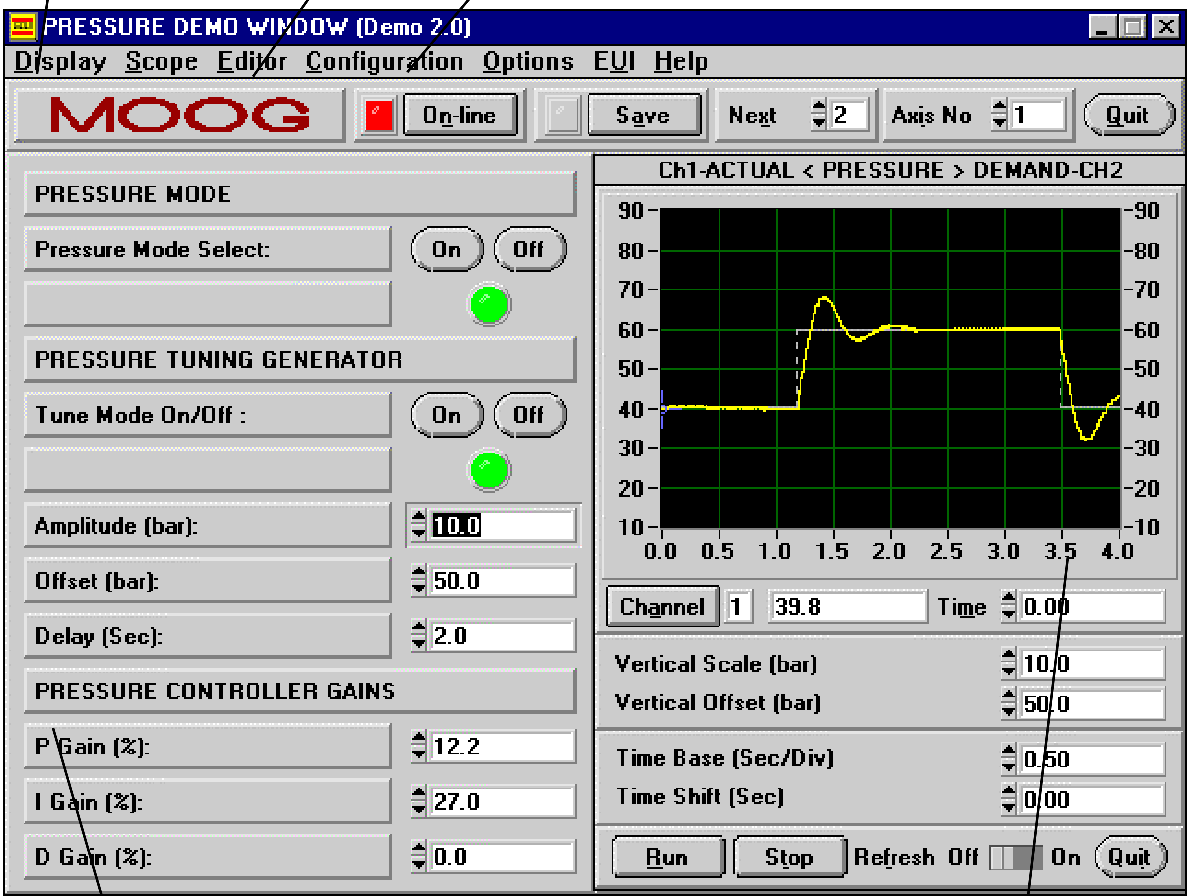
2.3 PC Configuration Interface

(2) Display - Display the appropriate operator screen; e.g in this case press loop tune.

(5) Display Redefine - Use the file driven display definition format to change the information being displayed; e.g physical units.

(1) Download - Download a 'Standard controller from the template library; e.g:

- Dual PID
- Bumpless P/Q
- Pressure Damping



(4) Oscilloscope - Use the scale and offset functions to observe performance

(3) Tune Mode - Select the generator parameters and controller gains for good control.

Figure 6 - GOUI LabWindows Configuration Interface

2.4 Underlying Software Flexibility

The M2000 system recognises the diversity of applications encountered using hydraulic servo drives and therefore provides easy access to lower levels so that control architectures other than the standard PID format can be built rapidly.

The software may be divided into 2 parts as listed in Table 2 below:

CONTROLLER FUNCTION BLOCKS	
Description	**No Off**
Summing Junction (4 input)	4
Limiter/Summing (3 input)	6
Filter (up to 3rd order)	24
Ratio Block (2 input)	4
Signal Generator	2
Trajectory Generator	2
Control Error Monitor	4
Flag Generator (Comparator)	16
Flag Handler (Logic Switch)	16
Nonlinear Table	4
Scale	2
Data Logging Channel	3
Timer	16

SEQUENCE PROGRAM COMMANDS	
Command	**Type**
Motion:	Move Abs./Rel.
	Move Time, Jog
	Stop/Quick Stop
Programming:	Assign/Set
	Comment
	If/Then/Else
	GoTo
	Repeat
	Units
	Wait True/False
Expressions:	Arithmetic
	Bitwise Logic
	Boolean Logic
	Set Connection
	Greater/Less Than

Table 2 - Real-Time Function Block Modules and Motion Control Language (MCL) Commands

The real-time function modules cover all aspects of closed loop control requirements including linear and nonlinear closed loop control, gain scheduling, and the use of high speed logic within the closed loop control strategy. Individual blocks may be connected together in any manner to build up an overall control scheme for example Figure 7 shows how function blocks are coupled to achieve a bumpless transfer controller for switching between position and pressure control modes in a hydraulic servo system.

Access to the controller design interface is via the GOUI. A controller design user manual is provided giving a full description of each function block and its connection to other function blocks within the library.

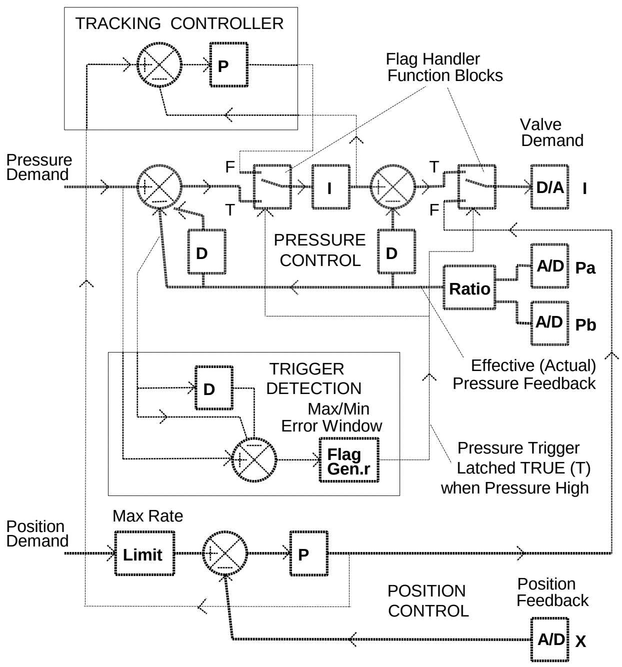


Figure 7 - Real-time Function Block Scheme

As an example of an individual function block, Figure 8 shows the M2000 limiter function which may be used for both level and rate limiting. As with other M2000 blocks there are Input/Output connections carrying the real-time signal which may be connected with other function blocks. There are also function control and data parameters which determine the characteristics of the function.

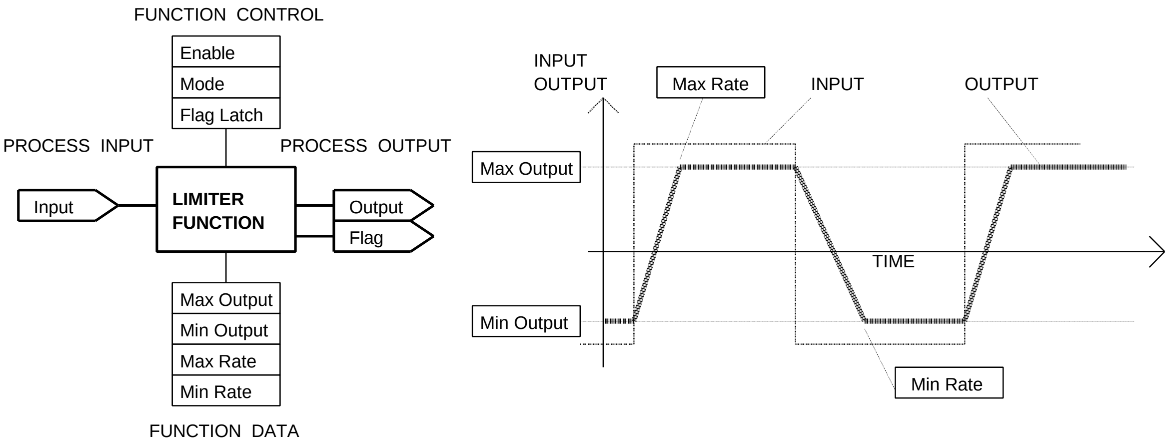


Figure 8 - Typical M2000 Real-Time Function Block - The Limiter

Although designed as an axis controller it is recognised that every closed loop servo has an associated set of sequential activities, either to co-ordinate the commanded axes of the servo drive or simply to handle start up, shut down and error detection functions. In the M2000 system these functions are user programmable via the Motion Control Language (MCL). Similar to BASIC programming, MCL offers a range of programming commands some of which are listed in Table 2. In the standard PID controller (Figure 5) MCL is used to deal with all of the mode switching tasks to ensure smooth operation. In other applications; - for example the 2 axis blade positioner shown in Figure 9 - MCL is used to co-ordinate high speed collision free sequencing of the 2 axes. In this application the host controller is used in a supervisory role for start/stop of the process, error handling and process monitoring.

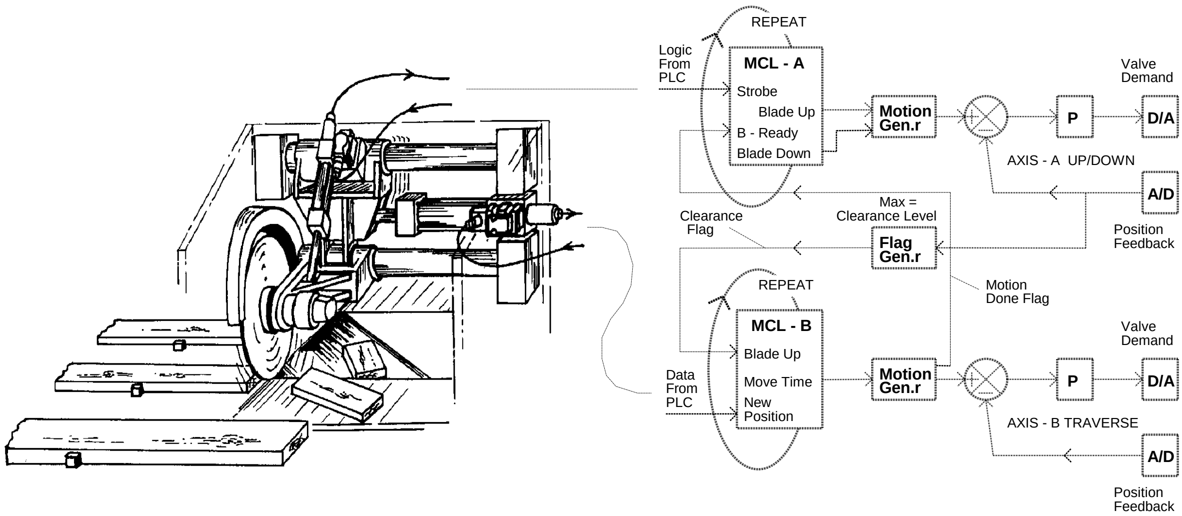


Figure 9 - Motion Control Language (MCL) Used for Axis Co-ordination

2.5 Improved Control Possibilities

Example - Large scale manipulators;

M2000 servo control flexibility is ideally suited to situations where extreme nonlinearities and poor dynamics occur. In hydraulic servo systems this usually means quite low gain systems where large payloads are being shifted and where up to 95% of the available pressure is being used to lift or accelerate the load. See Figure 10. Here the logical, and tabulated data capabilities of the M2000 system can be used for introduction of gain scheduling and active damping.

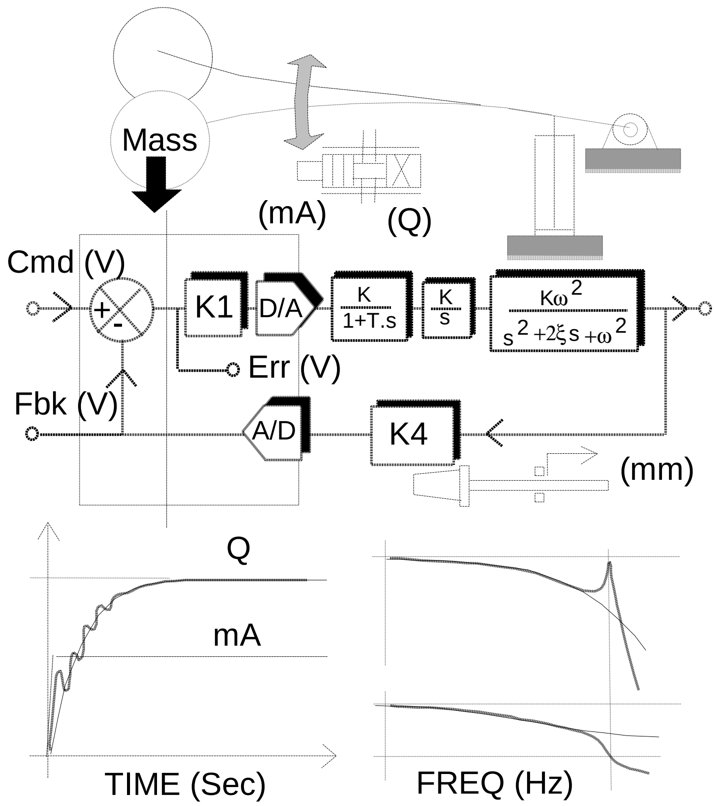


Figure 10 - High Payload System Dynamics

As a further example Figure 11 shows an improved control scheme with the following features:

- Correction for flow gain changes as a result of the high loads.
- Correction for saturation in the valve and pipe work.
- Directional gain change correction.

Features such as these offer the possibility of cost savings in mechanical design, power pack sizing and energy saving whilst at the same time improving performance.

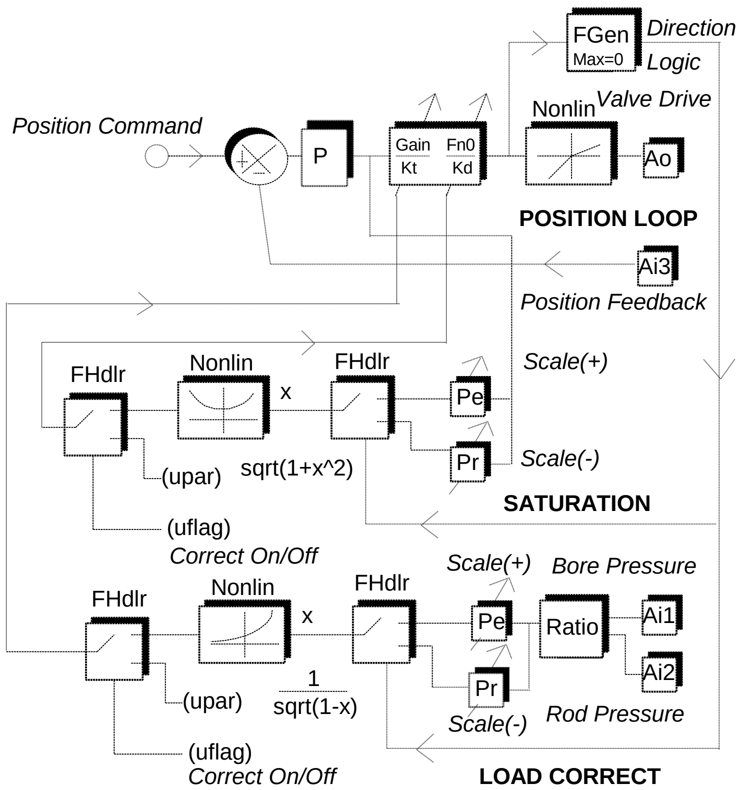


Figure 11 - Advanced M2000 Control Strategies

2.6 M2000 Users - A Typical Installation

The Moog M2000 PSC control system is used in a wide variety of control applications. Applications range from simple test machines where the PSC itself provides the operator interface, through to large machine installations where the PSC's are co-ordinated by a PLC host controller. For example Figure 12 shows a typical installation in the paper industry.

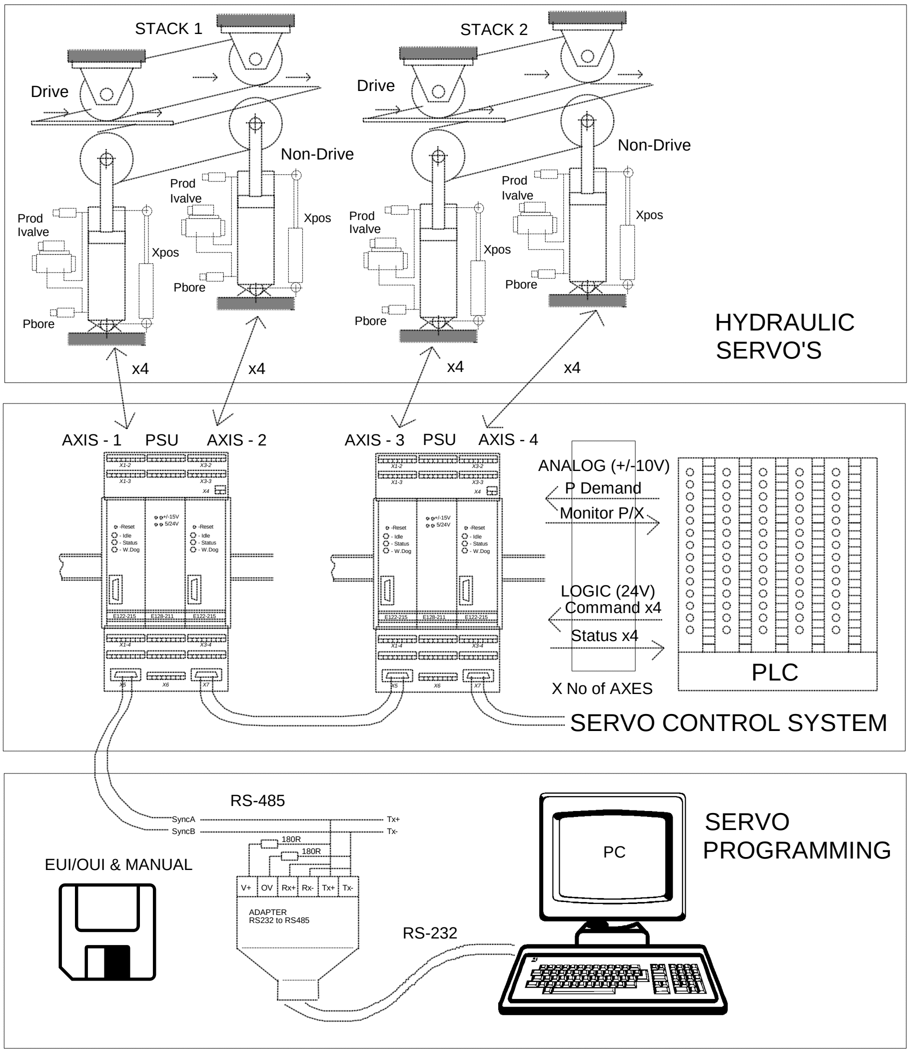


Figure 12 - Typical M2000 Application - Roll Control in the Paper Industry

M2000 is also diverse in terms of the variety of users. Table 3 below shows some of the main users and the type of application.

User	Application	User	Application
Lucas	Aero Component Test	Dunlop	Test Machine
Voith	Paper Calendaring	Rolls Royce	Engine Test
Kvaerner Metals	Rod Mill	Mercedes Benz	Press Cushion
Valmet	Reel Winder	Beloit	Paper Calendaring

Table 3 - M2000 Users

3.0 EXAMPLE APPLICATION - TUBE FORMING MACHINE

3.1 System Architecture

Distributed Architecture - A system architecture as shown in Figure 13 is assumed where the machine sequencing tasks are carried out using a sequence controller of the machine builders choosing/design. The principle means of communication between this and the M2000 axis controllers is via a CANBus link. This may be used for command and status bit data transfer between host and slave axis controllers. Local CANBus inter-axis communication is also possible where required. Figure 15 overleaf shows a typical M2000 CANBus data transfer function block.

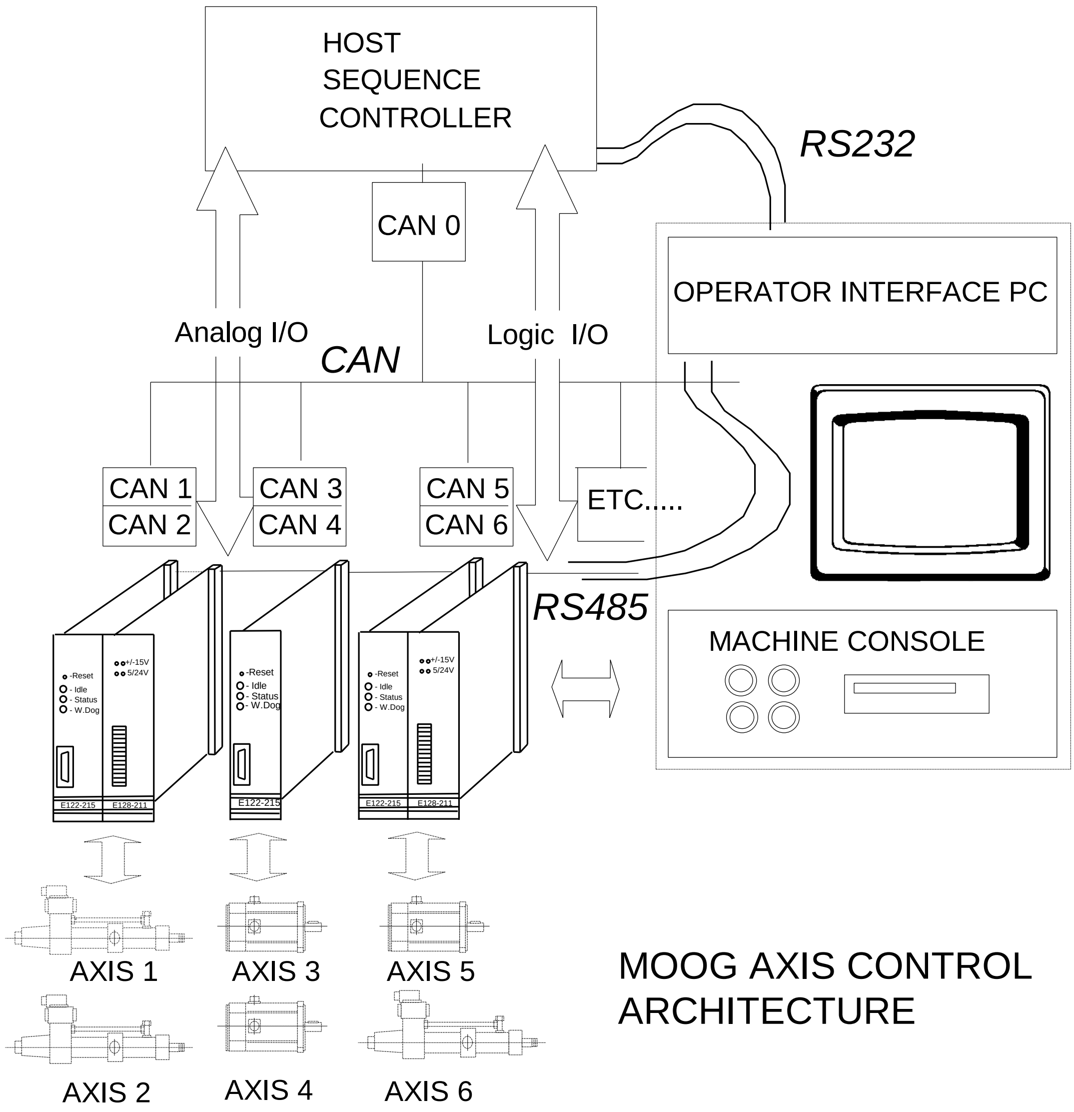


Figure 13 - Proposed M2000 Axis Control Installation Using CANBus

PSC Controller Extent of Use - Although the Moog PSC dual axis card is designed for hydraulic servo's it may also be used for electric drives as shown above. The ability to handle logic I/O also makes the axis card suitable for use with on/off axes. These features means that the M2000 system may be considered a unified approach to axis control irrespective of the actual drive technology used.

3.2 Axis Control Using Incremental Encoders

The Moog incremental encoder axis control arrangement uses an external input encoder interface card which communicates with the PSC controller via the XMO processor bus. The DIN41612 connector 'b' row is used for this purpose and forms an integral part of Moog rack systems.

The encoder card also carries 24V PSU and logic I/O expansion so that same control modules can be used for switching on/off axes and feeding back logic input information (e.g microswitch status) to either the axis controllers or the host system over the CANBus link.

The programming interface is the LabWindows based GOUI (see Section 2.3) and may be installed at the operator interface PC with RS485 communication via the Moog SyncLink protocol.

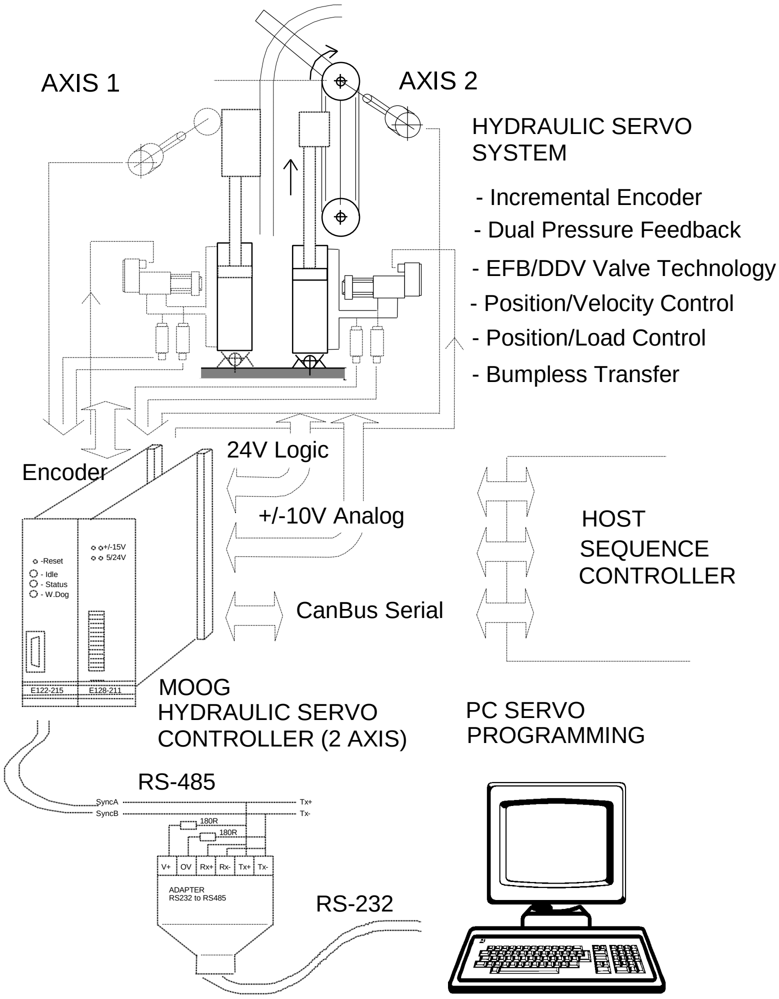


FIGURE 14 - Incremental Encoder Servo Control

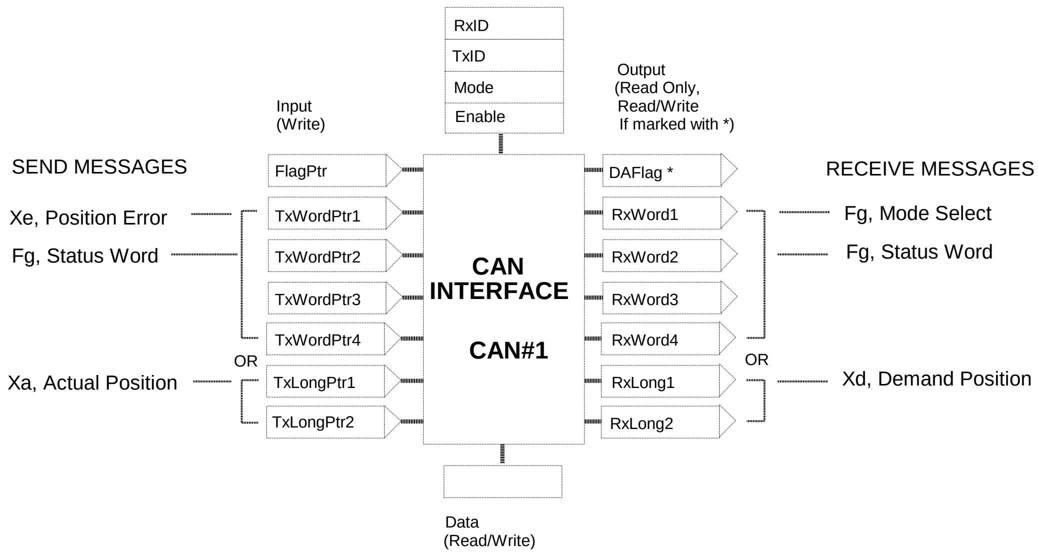


Figure 15 - CANBus Typical Data Transfer

3.3 Axis Control Using SSI Absolute Incremental Encoders

An alternative approach is to use SSI (Synchronous Serial Interface) transducers. These are multi-turn incremental devices which have the characteristic of being absolute over the operating range.

The benefit of SSI transducers (see Figure 16) is in the elimination of a homing routine from the machine power up sequence and controller hardware and installation cost savings. The encoder interface card is eliminated and the SSI transducers interface directly with the PSC.

SSI transducers are also available in linear position measurement form if necessary.

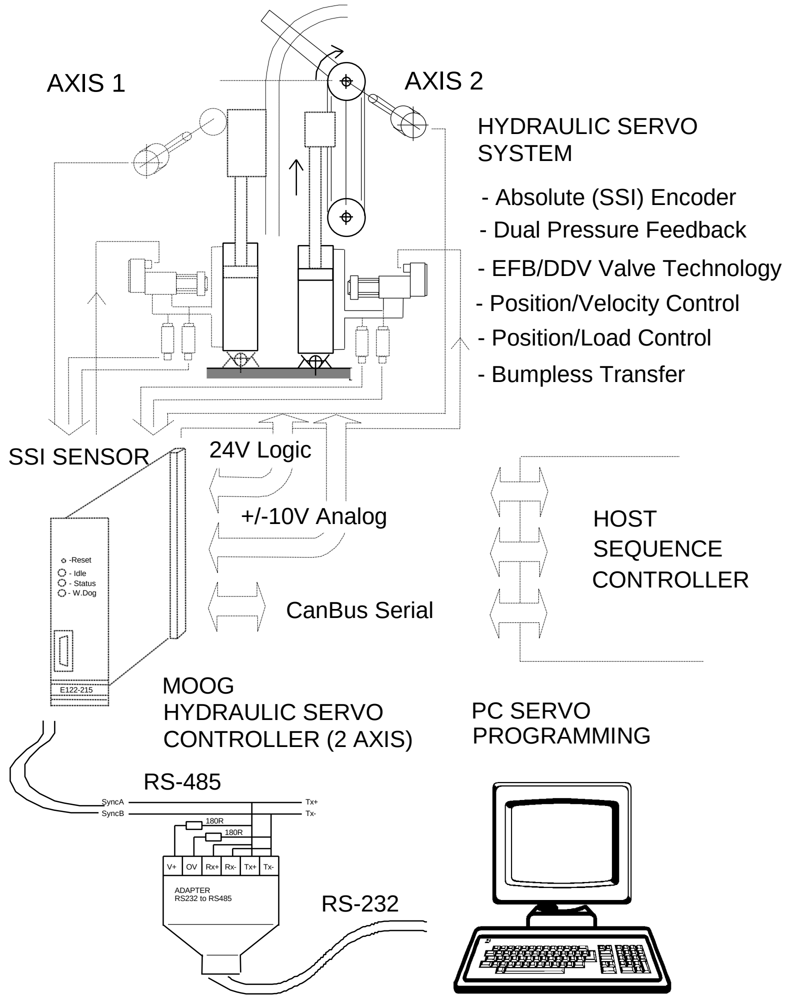


Figure 16 - SSI Absolute Encoder Servo Control

3.4 Pressure Transducers, Valves and Other Hardware Interfaces

Analog Input - The PSC controller is provided with 6 channels of +/-10V analog input. These may be used for interfacing pressure transducers or load cells should load control be required. The M2000 software can be configured appropriately (see next Section).

Valve Drives - The 2 valve drive output channels may be configured for current or voltage drive modes suitable fro driving the full range of Moog valves; e.g D062, D633, D634 series.

Analog Input Conditioning - Is provided via a piggyback module and may be used for unipolar/bipolar signals of +/-10 and +/-5V input range, or alternatively can be used with potentiometers. All channels are fitted with variable cut-off analog noise filters.

Logic Input/Output - Is 24V optoisolated. Output drivers (50mA) must be amplified externally for the purposes of driving 24V input solenoid valves.

Note: Whilst designed for hydraulic drives the M2000 system is also suitable for electric drive closed loop control.

3.5 Axis Control Templates

In addition to the standard PID format presented in Section 2.2 Moog has used the M2000 programming flexibility to produce a number of other controller ‘template options’. Figure 17 shows 2 templates which may be of assistance in the bending machines.

Active Damping Template - Is where pressure transducers are actively used within the control strategy as a means of adding damping to low frequency low damped load resonance’s. These are often experienced in hydraulic servo drives where large inertia loads are present.

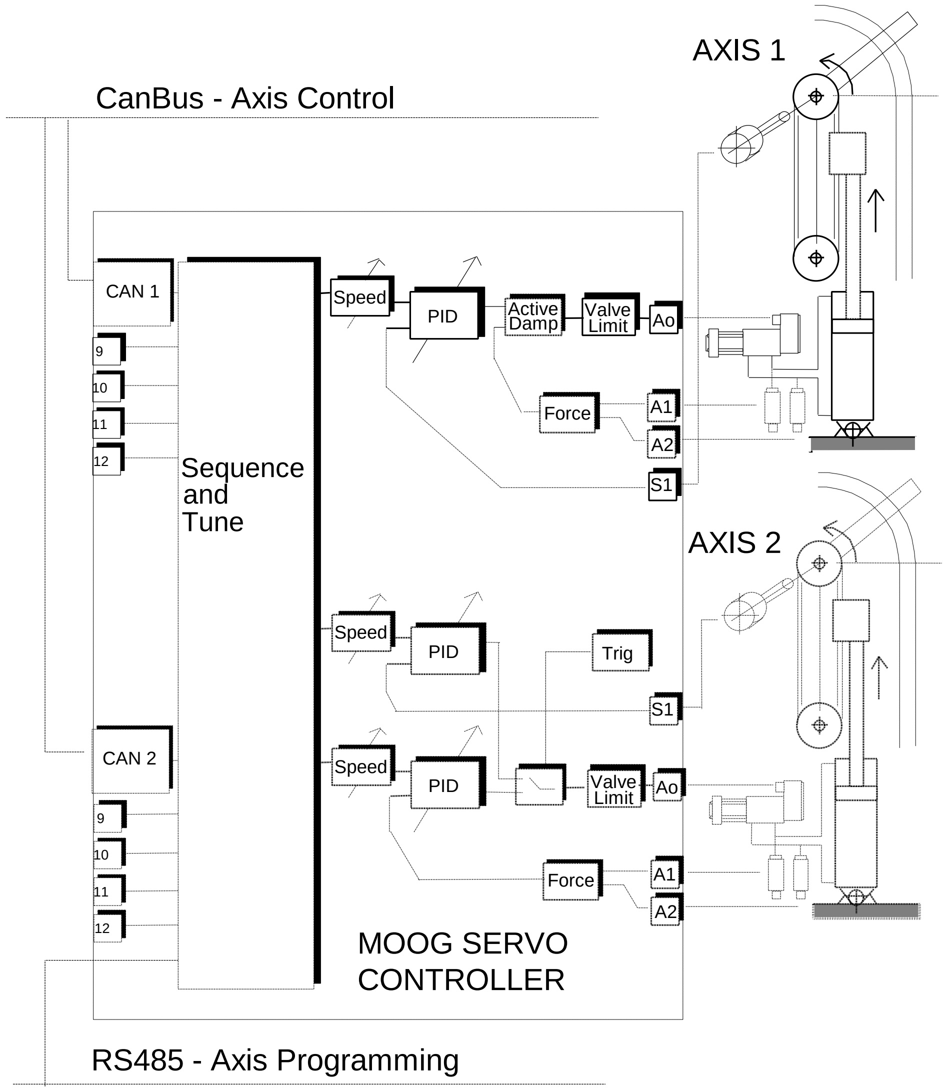


Figure 17 - Active Damping and Bumpless Transfer M2000 Templates

Bumpless Transfer Template - May be helpful where switch over between position and pressure control modes is required. A number of ‘switch over’ strategies are possible where smooth transition at high operating speed is required.