

Acutrol3000 Inner Loop Module

Technical Manual

TM-9375C

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Introduction

This document describes the Inner Loop Module that has been developed to work in conjunction with the Acutrol3000 Motion Control instrumentation. The use of an inner loop is warranted in systems that have servo components that produce a non-linear plant transfer characteristic. Since a non-linearity degrades the performance of a system, additional (analog) transducers are incorporated. These transducers are used by the Acutrol3000 to close a digital servo around the non-linear plant that produces linear, controllable states for the digital motion control.

A typical application is to implement a digital pressure loop in a hydraulic motion simulator to minimize the effect of the hydraulic resonance produced by fluid compressibility and to reduce the effect of servo valve and actuator non-linearity. The pressure loop bandwidth can be extended beyond the plant dynamics to achieve improved response and tracking.

Other applications include closing a digital torque loop around the hydraulic resonance (in place of pressure), a digital torque loop around the mechanical spring resonance of a harmonic drive, or even a digital torque loop around an electric motor to minimize the effects of cogging, torque ripple and friction.

1. Inner Loop Module Description

The Acutrol3000 Inner Loop Module (ILM) is a circuit board that is used to interface to sensor and actuators required for the digital inner servo loop. Several differences exist between the Acutrol3000 Inner Loop Module and the Inner Loop Servo Boards (ISLB) used with the Acutrol2000:

- The Acutrol3000 Inner Loop Module is designed to be DIN-rail mounted, the Acutrol2000 Inner Loop Servo Board was designed to mount in an ISA backplane. Optionally the Inner Loop Module can be mounted to a panel with four standoffs.
- The Acutrol3000 Inner Loop Module is designed to accommodate only one channel. Modules can be plugged together via the connectors on the edge to expand to as many channel as required.
- The Acutrol3000 Inner Loop Module is used to interface sensors and actuators to the Acutrol3000 to implement a digital servo loop. The Acutrol2000 Inner Loop Servo Board implemented an analog servo loop.

Figure 1-1 shows an Acutrol3000 Inner Loop Module. There are seven connectors on the module as defined in Table 1.

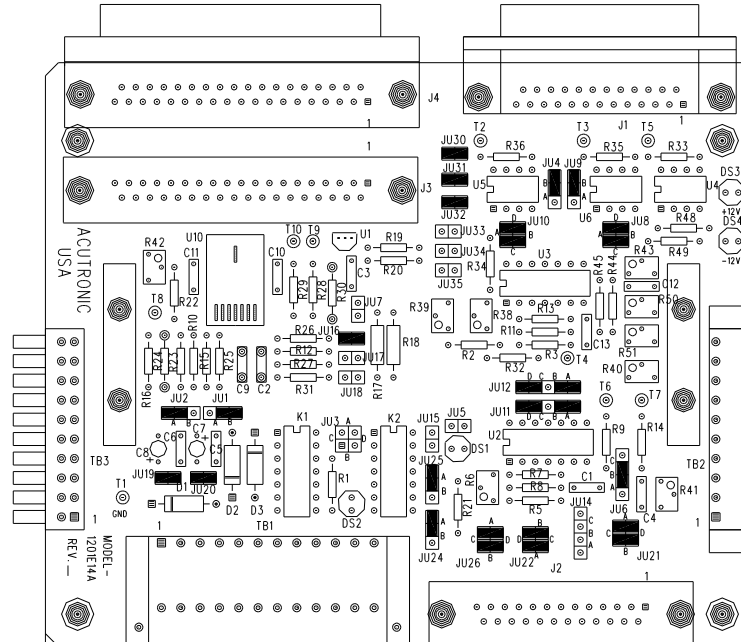


Figure 1-1 - Acutrol3000 Inner Loop Module

NAME	TYPE	SOURCE	DESTINATION	FUNCTION
J1	DB25M	Acutrol3000 Servo A Connector	ILM	Valve control and interlocks
J2	DB25F	ILM	Motion Table	Valve Drive, Inner Loop Feedback Sensors
J3	DC37F	ILM	Motion Table	Motion Transducer Drive/Feedback, End-of-Travel Limit Switches
J4	DC37M	Acutrol3000 DRV/FBK Connector	ILM	Motion Transducer Drive/Feedback
TB1	Terminal Block	ILM	Motion Table	Duplicates function of J2 for Field Wiring
TB2	Terminal Block	ILM	ILM/Field Wiring	Buses signal to next ILM or connects to field wiring
TB3	Terminal Block	ILM	ILM	Buses signal to next ILM.

Table 1 Acutrol3000 Inner Loop Module Connectors

Figure 1-2 shows three Acutrol3000 Inner Loop Modules connected together.

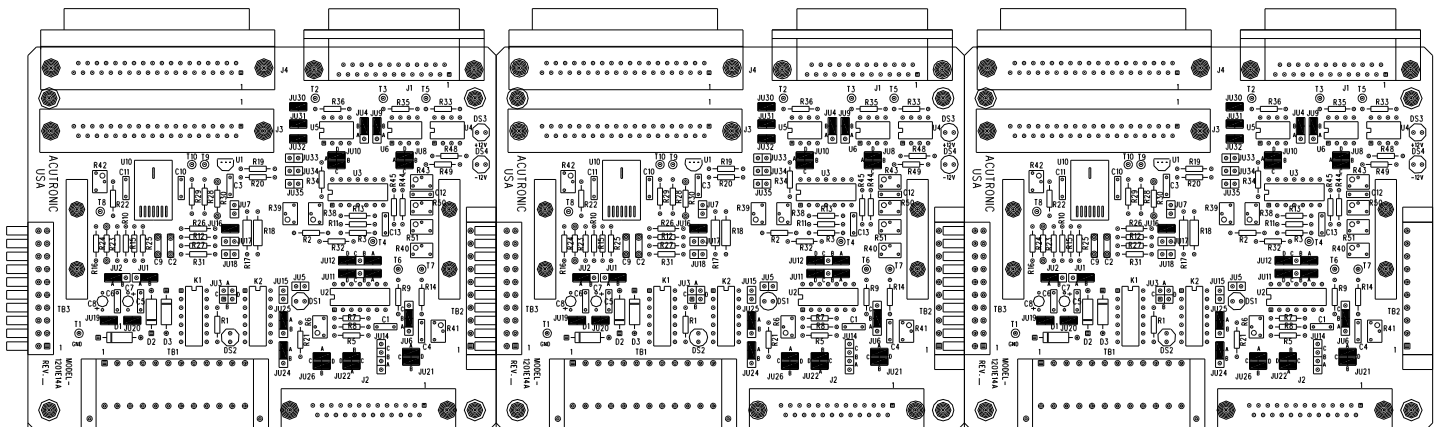


Figure 1-2 Three-Axis Acutrol3000 Inner Loop Module Configuration

There are three types of control connections that are made to the board:

- **Transducer Drive/Feedback Input/Output (J3/J4).** The Acutrol3000 Transducer Drive/Feedback cable is routed through the Inner Loop Module for two purposes:
 - The two pressure feedback channels (Average Pressure and Cross Pressure) are routed from the Actuator Interface Cable into **Analog Input 0** and **Analog Input 1** of the Transducer Drive/Feedback cable.
 - End-of-Travel Limit Switches from a transducer package can be routed into the Acutrol3000 Servo Out Cable.
- **Valve Control, Inner Loop Sensors, and Interlocks (J1, J2, TB1).** The Acutrol3000 Servo A connector mates to J1. **Servo Out 1** is used to drive the valve in either voltage or current mode. **Servo Out 2** is used to implement a low gain position loop during system initialization. **Enable 1** is used to enable the Output Amplifier. **Enable 0** is used to disable the low gain position loop. **ACK** and **FAULT** Interlocks can be generated by the Inner Loop Module, can be used for End-Of-Travel limit switches, or can be used to interface to an initialization sensor such as a system pressure switch.
- **Bussed Signals.** TB2 and TB3 are used to connect common signals between Inner Loop Modules. Alternatively TB2 can be used to connect the bus signals to field wiring.

Several potentiometers are used to configure the ILM. The potentiometers are:

<u>POT</u>	<u>Function</u>
R6	Dither Frequency
R38	Sensor Scaling
R39	Sensor Offset
R40	2 nd Order Filter Frequency Spread
R41	Dither Amplitude
R42	Output Amplifier Offset
R43	2 nd Order Filter Depth
R50	2 nd Order Filter Frequency Adjust #1
R51	2 nd Order Filter Frequency Adjust #2

Test points are also provided for measurement of critical signals. The test points are spread throughout the board and are best located by the top assembly drawing. Each test point is isolated from its signal with a 1 k Ω resistor. The test points are:

<u>TP</u>	<u>Signal</u>
T1	GND
T2	Raw Pressure Feedback 2
T3	Raw Pressure Feedback 1
T4	Scaled Feedback Sensor
T5	Cross Pressure
T6	Dither Generator
T7	Dither Voltage
T8	Output Amplifier Command
T9	Output Amplifier Current Sense
T10	Output Amplifier Voltage Output

Jumpers are used to configure the functions of the board. The jumpers are spread throughout the board and are best located by the top assembly drawing. Default locations for the jumpers are shown in bold. The jumpers are:

<u>Jumper</u>	<u>Location</u>	<u>Signal</u>
JU1	A	+V = +VEXT (from TB3)
	B	+V = +12 VDC (AIM)
JU2	A	-V = -12 VDC (AIM)
	B	-V = -VEXT (from J3)
JU3	OUT	Servo Out 2 Drives Output Amplifier till Enable 0 Asserted
	B	Servo Out 2 Drives Output Amplifier Always
	C	Servo Out 2 Drives TB1-17
	D	AUX IN (TB1-16) drives Output Amplifier Always
JU4	A	Use Feedback Sensor 1 and 2 for Average Pressure
	B	Use only Feedback Sensor 1 for Average Pressure
JU5	IN	Enable 1 connected to Enable Link
JU6	A	Bus Dither Enable
	B	Internal Dither Enable
	C	Drive Internal Dither onto Bus
JU7	OUT	R _s = 20 ohms
	IN	R _s = 5 ohms
JU8	AB	Feedback Sensor 1 Inverted Polarity
	CD	Feedback Sensor 1 Normal Polarity
JU9	A	Use Feedback Sensor 1 and 2 for Cross Pressure
	B	Use only Feedback Sensor 1 for Cross Pressure
JU10	AB	Feedback Sensor 2 Inverted Polarity
	CD	Feedback Sensor 2 Normal Polarity
JU11/JU12	A	Servo Out 1 Drives Output Amplifier

		Directly
	B	Servo Out 1 Drives Output Amplifier through Notch Filter
	C	Average Pressure Drives Analog Input 1 through Notch Filter
	D	Average Pressure Drives Analog Input 1 Directly
JU14	AC	Valve 1 and Valve 2 driven in parallel
	B	Valve 1 and Valve 2 drive in series
JU15	OUT	Output Amplifier Enabled by Enable 1
	IN	Output Amplifier Always Enabled
JU16	IN	$R_F = 499$ ohms
JU17	OUT	$R_F = 1240$ ohms
JU18	OUT	$R_F = 2550$ ohms
JU19	IN	Enable 1 connected to Pressure Switch
JU20	IN	FAULT(C) connected to Pressure Switch
JU21	AB	Valve 1 Drive Normal Polarity
	CD	Valve 1 Drive Inverted Polarity
JU22	AB	Valve 2 Drive Normal Polarity
	CD	Valve 2 Drive Inverted Polarity
JU24	A	Pressure Transducer EXC+ connected to +12 VDC
	B	Pressure Transducer EXC+ connected to +PP Bus
JU25	A	Pressure Transducer EXC- connected to -12 VDC
	B	Pressure Transducer EXC- connected to -PP Bus
JU26	AB	Valve 1 Drive Normal Polarity (TB1)
	CD	Valve 1 Drive Inverted Polarity (TB1)
JU30	IN	ACK(C) connected to Enable 0+
JU31	IN	ACK(A) connected to +12 VDC
JU32	IN	FAULT(A) connected to +12 VDC
JU33	OUT	ACK(C) connected to J3-10
JU34	OUT	FAULT(C) connected to J3-29
JU35	OUT	ACK(C) connected to J3-29

1.1 Multi-Channel Operation

As mentioned in Section 1, it is possible to link multiple Inner Loop Modules together via the TB2 and TB3 terminal blocks. Access to the bussed signals is by the TB2 terminal block on the last module in the chain.

Five signals can be bussed between boards:

- **Feedback Transducer Power (TB2/3-1,2).** The excitation voltages for the feedback transducer are bussed between modules to simplify wiring.

- **Enable 1 Signal (TB2/3-3).** The **Enable 1** signal is used to enable the output amplifier. Installing JU5 will bus the **Enable 1** signal to every card. This will cause the output amplifiers on **ALL** ILMs with JU5 installed to be enabled when **ANY** of the ILMs is enabled.
- **Output Amplifier External Power (TB2/3-4,5,6).** The output amplifier normally operates from a +/- 12 VDC supply (taken from the AIM). When operated in current mode, saturation of the output amplifier under high dynamic conditions can be a problem. If saturation does occur, it is possible to supply the output amplifier from an external supply up to +/-30 VDC supply. Jumpers JU1 and JU2 must be set accordingly. Power dissipation must be considered when using the higher supply voltages. Note that the output amplifier is internally thermally protected against overheating.
- **Pressure Switch (TB2/3-7,8).** These connections allow an external pressure switch to enable the output amplifier.
- **Dither (TB2/3-9).** Each Inner Loop Module has a triangle oscillator for dither generation. The frequency is adjustable from 20 to 550 Hz. The dither is connected to the Output Amplifier via JU6B. When two or more modules are connected together, only one dither signal should be used for all modules to prevent beat note frequencies from developing. The dither from the first Inner Loop Module should be connected to the **BUS DITHER** and output amplifier by setting jumper JU6 to the AC position. All other modules should use the **BUS DITHER** signal by setting JU6 to the A position. Dither amplitudes are controlled independently with potentiometer R41.

1.2 Analog Filter

A second order filter can be used to implement a low pass filter, a notch filter, or a combination notch/low pass filter, depending on the settings of the potentiometers.

Installing jumpers JU11 and JU12 in the A position activates the 2nd order filter on the Output Amplifier Command (**Servo Out 1**). Installing jumpers JU11 and JU12 in the C position activates the 2nd order filter on the Sensor Feedback.

The filter has four adjustments that allow the user to produce the desired response. These are:

- **SPREAD [R40]** - Typically for Notch Filters the complex poles and complex zeros occur at the same frequency with different levels of damping. However, at certain points it may be beneficial to offset the frequency of the zeroes with respect to the poles. The SPREAD adjustment provides this offset control. When the SPREAD adjustment is fully CCW, no separation occurs between the poles and the zeroes. As the SPREAD adjustment moves CW, the zeroes are shifted progressively higher in frequency. When the SPREAD adjustment is full CW, the zeroes have been shifted to infinity, and a second order low pass filter results. The SPREAD is sometimes useful to counteract antiresonance/resonance pairs. The ratio between the poles and the zeros is given as $(1/\gamma)^{1/2}$, where γ is the percentage of the SPREAD ($\gamma = 1 \rightarrow$ R40 full CCW).
- **FREQ1 [R50] and FREQ2 [R51]** – These two adjustments are used to determine both the frequency of the filter and the damping of the complex zeroes. Very high Q notch filters can be created by proper adjustment of FREQ1 and FREQ2. When the time constant created by FREQ1 [R50] and C12 equals the time constant created by FREQ2 [R51] and C13 the damping of the zeroes will be zero and a filter of infinite Q will result (theoretically). Practically, filters with depths over 40 dB can be obtained.

The two frequency adjustments are useful for other purposes as well. At times it is useful to synthesize a notch filter to be used for dampening a hydraulic plant. The zeroes of the filter are chosen to cancel the poles of the hydraulic plant and the poles of the filter are set to the desired damping of the damped plant. Adjustment of FREQ1 and FREQ2 are made to set the frequency and damping of the filter zeroes. The DEPTH adjustment is then used to set the damping of the filter poles.

- **DEPTH [R43]** – The DEPTH adjustment is used to set the damping of the filter poles. For a notch filter, this adjusts the filter Q, which is manifested as width and phase shift of the filter. For a 2nd order low pass, this also adjusts the Q that is manifested as filter phase shift and peaking.

1.3 Feedback Sensor(s)

The Inner Loop Module can accept either one or two feedback sensors. The polarity of the feedback sensors can be selected with jumper blocks JU8 (Sensor 1) and JU10 (Sensor 2). Normally the jumpers would be installed in the CD position. To reverse the polarity, move the jumpers to the AB position.

Both sensors are buffered with differential amplifiers U5 and U6. Then, an average and differential feedback is developed. The differential feedback is buffered with U4 and fed back to the Acutrol via J4 (**Analog Input 0**), or to terminal block TB1-19 (Cross Pressure). Jumper JU9 determines whether one or two sensors are used for the differential feedback. The average sensor feedback is scaled through the U3A amplifier and feedback resistor network. U3A has a variable gain adjustment via potentiometer R38 from 1 to 10. Jumper JU4 determines whether one or two sensors are used for the average feedback. The average feedback is buffered with U2C and fed back to the Acutrol via J4 (**Analog Input 1**), or to terminal block TB1-20 (Average Pressure).

The Inner Loop Module is operated on the +/- 12 VDC supplies from the AIM. The feedback sensors should be selected so that 8 volts is produced on T2/T3 when the pressure (torque) is at the peak of the usable range. This scaling is important to insure that the input to the Acutrol analog to digital converters does not saturate.

1.4 Output Amplifier

The input to the drive amplifier (**Servo Out 1**) should be scaled for 10 volts maximum to limit the peak output in a controlled manner.

Typically the output amplifier is used in current mode. Factory Select Components R24, C2, and C9 are provided for current loop compensation if required.

Relay K1 is used to enable the Output Amplifier. When disabled, connection to the output is removed, and R10 forms a low gain voltage loop around U10 to prevent saturation of the output amplifier.

Potentiometer R42 is remove any offset voltage from the output amplifier and should be adjusted with the output amplifier enabled.

JU21, JU22, and JU26 are used to set the polarity of the output amplifier. Normally the jumpers would be installed in the AB position. To reverse the polarity, move the jumpers to the CD position. JU14 is used to select whether one or two outputs are to be used, and if they are to be wired in series or parallel.

Jumpers JU7, JU16, JU17, and JU18 are used to select the full scale range of output current as shown in Table 2. Alternate full-scale ranges can be developed with the installation of R30.

JU7	JU16	JU17	JU18	RF (Ω)	RS (Ω)	I _{FS} (mA)
OUT	IN	IN	IN	314	20	6.2
OUT	IN	IN	OUT	358	20	7.0
OUT	IN	OUT	IN	419	20	8.2
OUT	IN	OUT	OUT	501	20	9.8
OUT	OUT	IN	IN	839	20	16.4
OUT	OUT	IN	OUT	1250	20	24.5
IN	IN	IN	IN	314	5	24.6
IN	IN	IN	OUT	358	5	28.1
IN	IN	OUT	IN	419	5	32.8
IN	IN	OUT	OUT	501	5	39.3
OUT	OUT	OUT	IN	2550	20	50.0
IN	OUT	IN	IN	839	5	65.8
IN	OUT	IN	OUT	1250	5	98.0
IN	OUT	OUT	IN	2550	5	200.0

Table 2 Acutrol3000 Inner Loop Module Current Loop Scaling

1.5 Low Gain Proportional Loop

Resistor R31 is used to create a low gain proportional loop. **Servo Out 2** is programmed to produce a signal proportional to actuator position. The value of R31 and the gain of **Servo Out 2** determine the gain of the position loop. This is typically used to implement a low gain position loop to center the actuator before the servo loop is initialized. R31 is chosen to limit the peak velocity of the actuator during initialization. Practically, a value for R31 should be $\sim 10 \times R23$. The gain of **Servo Out 2** is chosen to ensure adequate centering of the actuator.

1.6 Interlock Circuitry

The interface with the Inner Loop Module is designed to be plug compatible with the Acutrol3000 Servo Out A Connector.

The interlocks can be configured to operate in a variety of ways by jumper plug and software programming. The Acutrol3000 in conjunction with the Inner Loop Module can automatically sequence the system from shut down to full operation, always observing system and facility safety interlocks.

This sequence nominally occurs as follows for a hydraulic system:

- The operator closes the interlocks on all axes to be servoed.

- If all AIM interlocks are satisfied, **Enable 1** is asserted and the **ANY SERVO** output is enabled. The **ANY SERVO** output can be used to start the hydraulic power supply, and sequence any isolation valves at the motion table.
- Coincident with the assertion of **Enable 1**, a software dwell timer (**Drive Enable Delay**) is started that delays the attempt to servo until the timer expires. If a Pressure Sensor is used as the **ACK** feedback, the **Drive Enable Delay** timer allows the pressure to build to a safe minimum before the servo loops are initialized. If the pressure does not built up to a satisfactory level within the programmed delay time, the startup will be aborted by the AIM.
- On the Inner Loop Module, **Enable 1** activates K1, which enables the Output Amplifier. During the **Drive Enable Delay** period, the Output Amplifier is active, but the Acutrol servo loop is disabled until **Enable 0** is asserted at the end of the **Drive Enable Delay** period. However, it is possible to command the Output Amplifier with **Servo Out 2** through R31 prior to **Enable 0** being asserted. This path is often used with hydraulic systems to move the axis to a null position during startup. See Section 1.5
- After the **Drive Enable Delay** timer expires, **Enable 0** is asserted and the Acutrol servo loop is activated. On the Inner Loop Module **Enable 0** disables the low gain proportional loop formed with **Servo Out 2** (unless JU3B is inserted). **Enable 0** can also be used to generate **ACK** via JU30.

The following are the options available for the **ACK** signal:

- **ACK** generated by **Enable 0**. Insert JU31 to connect **ACK+** to +12 VDC. Insert JU31 to connect **ACK-** to **Enable 0**.
- **ACK** generated by a CW Limit Switch in the transducer package. In this case the **ACK** is used as a general fault condition to the Acutrol3000. Insert JU33 to connect **ACK-** to J3-10. Insert JU31 to connect **ACK+** to +12 VDC. Connect limit switch to J3-10 and J3-8.
- **ACK** generated by a CCW Limit Switch in the transducer package. In this case the **ACK** is used as a general fault condition to the Acutrol3000. Insert JU35 to connect **ACK-** to J3-29. Insert JU31 to connect **ACK+** to +12 VDC. Connect limit switch to J3-29 and J3-8.
- **ACK** generated by alternate sensor. Connect the sensor to TB1-21 and TB1-22.

The following are the options available for the **FAULT** signal:

- **FAULT** generated by a CCW Limit Switch in the transducer package. In this case the **FAULT** is used as a general fault condition to the Acutrol3000. Insert JU34 to connect **FAULT -** to J3-29. Insert JU32 to connect **FAULT +** to +12 VDC. Connect limit switch to J3-29 and J3-8.

- **FAULT** generated by system Pressure Switch sensor. Insert JU32 to connect **FAULT +** to +12 VDC. . Insert JU20 to connect **FAULT -** to Pressure Switch HI (TB2-7). Connect the Pressure Switch to TB2-7 and TB2-8.
- **FAULT** generated by alternate sensor. Connect the sensor to TB1-23 and TB1-24.

2. Inner Loop Module Checkout Procedure

- ☐ Verify the Inner Loop Module is configured per the assembly drawing (page 17) and schematic (page 18) (1201E14A,S).
- ☐ Connect the Transducer Drive/Feedback cable from the Acutrol Axis 1 to J4 of the Inner Loop Servo Module.
- ☐ Verify that LEDs DS3 (+12 VDC) and DS4 (-12 VDC) illuminate.
- ☐ Connect the Transducer Drive/Feedback cable from the J3 of the Inner Loop Servo Module to a transducer package. Verify proper operation of the transducer.
- ☐ With a multimeter, verify the voltage at U1 Pin 1 (or the lead of C3 closest to U1) is 5.00 +/-0.25 VDC. Verify the voltage at U3-14 is -5.00 +/- 0.01 VDC with respect to TP1 (GND).
- ☐ Attach an oscilloscope to T6 (Dither Output). Adjust R6 for a triangle wave of 3 msec period. Amplitude should be stable at approximately 10 Vp-p.
- ☐ Move the oscilloscope to T7 (Dither Amplitude). Adjust R41 to set the dither amplitude to minimum.
- ☐ Connect a voltage source to TB1-1 (High) and TB1-2 (Low). Parallel to TB1-5 (High) and TB1-6 (Low).
- ☐ Set the voltage source to 5.00 VDC.
 - ☐ Verify 5.00 +/- 0.01 VDC on T2 and T3.
 - ☐ Verify -5.00 VDC +/- 0.01 VDC on T5.
 - ☐ Display Variable 1087 on the Acutrol. Verify the voltage displayed is -5.00 +/- 0.01 VDC.
- ☐ Set the voltage source to 0.00 VDC
 - ☐ Adjust R39 till T4 measures 0.00 +/- 0.01 VDC.
- ☐ Set the voltage source to 5.00 VDC
 - ☐ Adjust R38 till T4 measures -5.00 +/- 0.01 VDC.
 - ☐ Display Variable 1088 on the Acutrol. Verify the voltage displayed is -5.00 +/- 0.01 VDC.
 - ☐ Remove the voltage source.
- ☐ Connect the Servo A Cable from the Acutrol to J1 of the Inner Loop Servo Module.

- ☐ Connect a 100 ohm load resistor across TB1-13 and TB1-14.
- ☐ Set Axis 1 Analog Output 5 (Servo Out 1) to reference variable 1000 (Position Demand). Set the Axis 1 Position Demand to 0.0.
- ☐ Close the Interlock on Axis 1.
 - ☐ Verify that LEDs DS1 (Enable 1) and DS2 (Enable0) illuminate.
 - ☐ With zero volts on Servo Out #1, Adjust R42 for 0.000 +/- 0.001 on T10.
 - ☐ Set the Axis 1 Position Demand to 10 degrees (10 VDC on Servo Out #1). Verify ~1.2 Volt on T10.
- ☐ Open the Interlock on Axis 1.

A. Drawings

The Inner Loop Module PCB Assembly is documented as the drawing series 1201E14 and consists of a parts list, assembly, and schematic.

<div>ACUTRONIC</div> <div>640 Alpha Drive, Pittsburgh, PA 15238</div> <div>(412) 963-9400 phone / (412) 963-0816 fax</div>			1201E14L	REVISION: C	
			Acutrol3000 Inner Loop Module		
ITEM	QTY	PART OR DWG NO	REFERENCE SYMBOLS	MANUFACTURER	PART DESCRIPTION AND NOTES
001	REF	1201E14A		ACUTRONIC USA	Inner Loop Module ASSEMBLY
002	REF	1201E14S		ACUTRONIC USA	Inner Loop Module SCHEMATIC
003	1	1201E14P	PC BOARD	ACUTRONIC USA	GERBER FILE
100	3	INA105KP	U4-6	TI/BURR-BROWN	DIFFERENTIAL AMPLIFIER
101	2	OPA4277PA	U2-U3	TI/BURR-BROWN	QUAD OP-AMP, PRECISION
102	1	OPA547F	U10	TI/BURR-BROWN	POWER OP-AMP
103	1	MC78L05ACP	U1	ANALOG DEVICES**	VOLTAGE REFERENCE, +5V PRECISION
104	4	CMD333UGD	DS1-DS4	CHICAGO MINIATURE**	LED,GRN,T-1 3/4
105	3	1N4001	D1-D3	**	DIODE
200	6	3266W-1-103	R38-R43	BOURNS**	POTENTIOMETER, 10 K, 1/4" SQR., CERMET
201	1	3266W-1-503	R6	BOURNS**	POTENTIOMETER, 50 K, 1/4" SQR., CERMET
202	2	3266W-1-104	R50-R51	BOURNS**	POTENTIOMETER, 100 K, 1/4" SQR., CERMET
203	1	5053YD4R990F	R18	PHILIPS**	RESISTOR, 4.99
204	1	RN55C15R0F	R17	**	RESISTOR, 15.0
205	1	RN55C4990F	R26	**	RESISTOR, 499
206	10	RN55C1001F	R9, R14, R16, R28-29, R32-36	**	RESISTOR, 1.00 K
207	1	RN55C1241F	R12	**	RESISTOR, 1.24 K
208	1	RN55C1501F	R5	**	RESISTOR, 1.50 K
209	4	RN55C2001F	R1, R21, R48-49	**	RESISTOR, 2.00 K
210	1	RN55C2551F	R27	**	RESISTOR, 2.55 K
211	1	RN55C5111F	R8	**	RESISTOR, 5.11 K
212	6	RN55C1002F	R3,R7,R11,R19,R20, R45	**	RESISTOR, 10.0 K
213	1	RN55C2002F	R44	**	RESISTOR, 20.0 K
214	2	RN55C2552F	R10, R23	**	RESISTOR, 25.5 K
215	1	RN55C3162F	R25	**	RESISTOR, 31.6 K
216	1	RN55C7502F	R15	**	RESISTOR, 75.0 K
217	2	RN55C1003F	R2, R22	**	RESISTOR, 100 K
218	1	RN55C2503F	R31	**	RESISTOR, 250 K
219	2	FS	R24, R30	**	RESISTOR
220	1	RN55C5001F	R13	**	RESISTOR, 5.00 K
300	2	199D476X0025FE2	C7, C8	SPRAGUE**	CAPACITOR, 47 mF, 25V, TANTALUM
301	5	IC20X7R104K050B	C3, C5-6, C10-11	**	CAPACITOR, 0.1 mF,10%
302	2	CK05BX682K	C12-13	MALLORY**	CAPACITOR, 0.0068 mF
303	1	CK06BX474K	C1	**	CAPACITOR, 0.47 mF
304	1	CK06BX105K	C4	MURATA-ERIE	CAPACITOR, 1.0 mF, 50V
305	2	FS	C2, C9	**	CAPACITOR
400	AS REQ	40-901-11	JU1-12, JU15-22, JU24-26, JU30-	ARIES**	HEADER, SINGLE ROW, 40 CON
401	3	08-3518-10	(U4-U6)	ARIES**	SOCKET, 8-PIN DIP
402	4	14-3518-10	(U2-U3,K2,K3)	ARIES**	SOCKET, 14-PIN, DIP
403	AS REQ	ML-100	See Assembly	ARIES	JUMPER
404	2	JWD-172-161	K1-K2	P+B**	RELAY, DIP, SPDT, 12V, W/DIODE
405	AS REQ	4-103-186-0		ARIES**	HEADER, DUAL ROW, 40 CON

501	1	1-745967-4	J2	AMP**	CONNECTOR,DB25, FEMALE, STRAIGHT, PCB MOUNT,W/FIXED SCREW
502	1	1-747301-4	J3	AMP**	CONNECTOR,DB37, FEMALE, STRAIGHT, PCB MOUNT,W/FIXED SCREW
503	1	747843-4	J4	AMP**	CONNECTOR,DB37, MALE, R ANGLE,BOARD LOCK,FIXED SCREW
504	1	747842-4	J1	AMP**	CONNECTOR,DB25, MALE, R ANGLE,BOARD LOCK,FIXED SCREW
506	1	1843017	TB1	PHOENIX**	TERMINAL BLOCK, PCB MOUNT, DOUBLE ROW, 24 POS
507	1	1862658	TB3	PHOENIX**	TERMINAL BLOCK, PCB MOUNT, SINGLE ROW, 10 POS,FEMALE
508	1	1827949	TB2	PHOENIX**	TERMINAL BLOCK, PCB MOUNT, SINGLE ROW, 10 POS
509	8	10-477-2-01	(R24, R30,C2, C9)	CONCORD**	TERMINAL, FORK, 0.093 DIA.
510	10	SPCJ-123-01	T1-T10	JOLO**	TEST TERMINAL, WHITE
700	2	209-120		WAGO**	MOUNTING FOOT,35MM DIN RAIL
701	4	209-119		WAGO**	FIXING SCREW
APPROVALS		INITIALS / DATE	NOTES: ** THESE COMPONENTS MAY BE SUBSTITUTED WITH VERIFIABLE EQUIVALENT PARTS AS NECESSARY		
ENGINEERING		MHS 6-12-04			
PROJECT MAN.		MHS 6-12-04			
PRODUCTION		KRK 6-12-04			
ECO:		773			

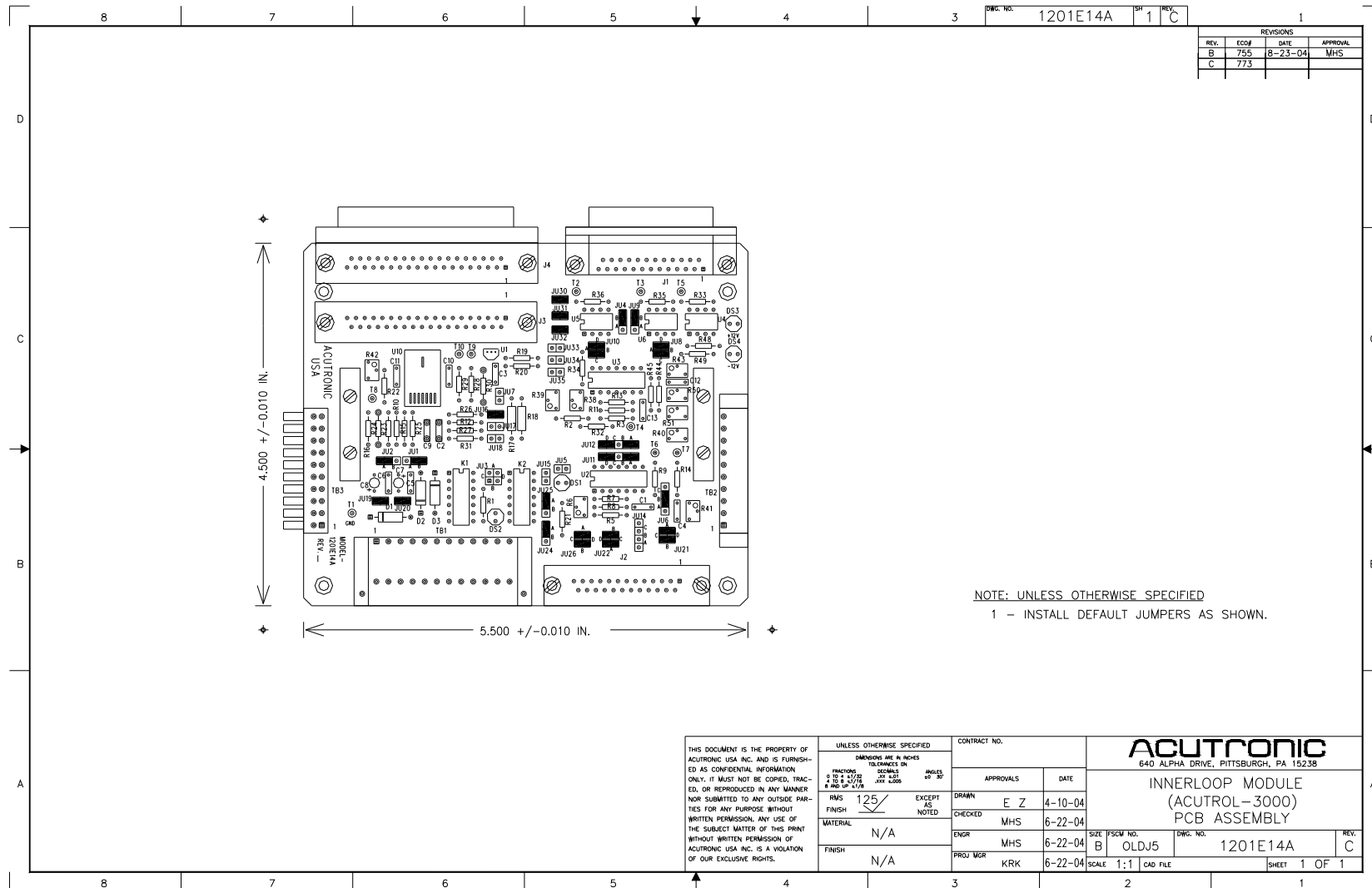


Figure A-1 Inner Loop Module Assembly

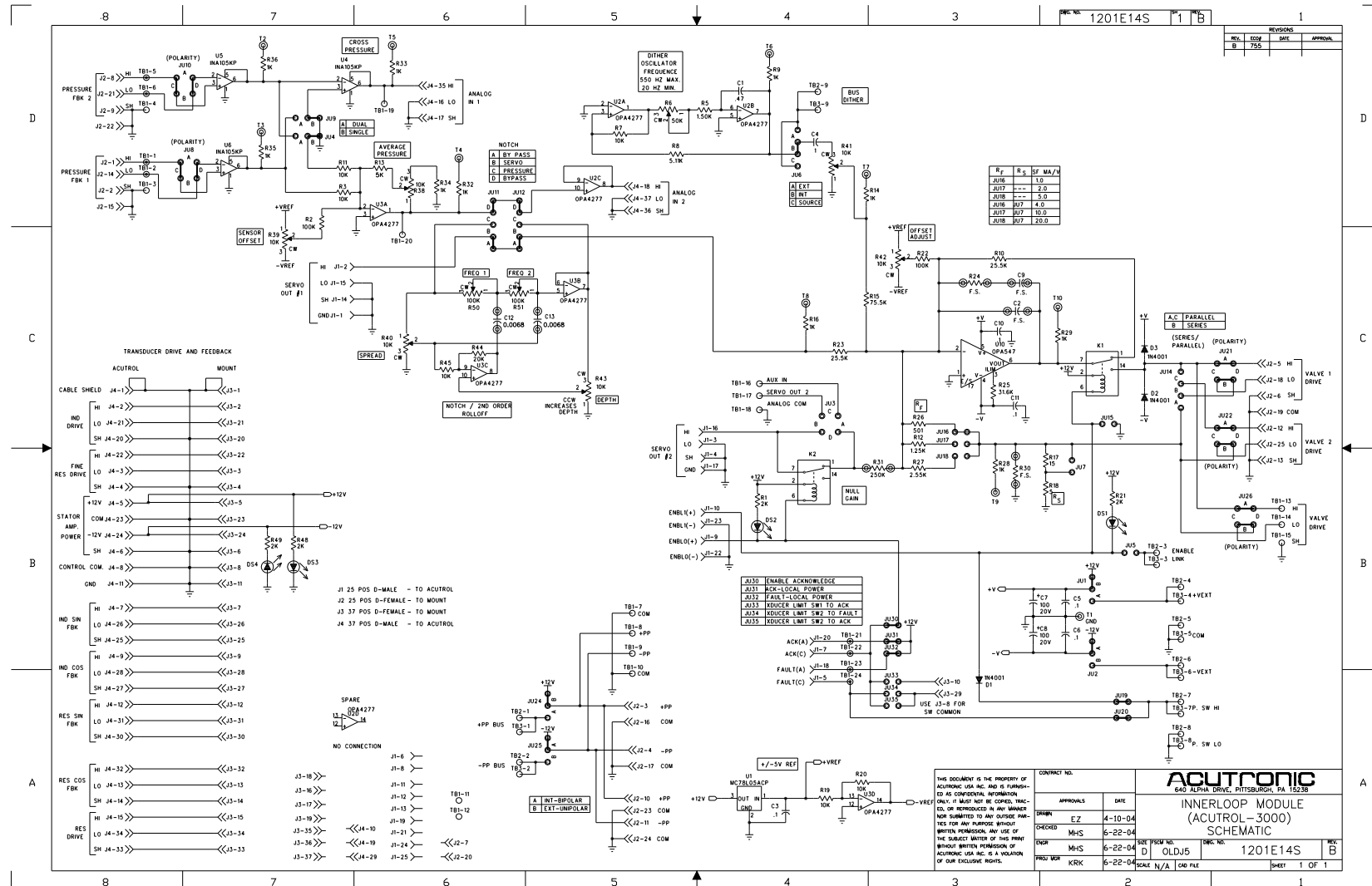


Figure A-2 Inner Loop Module Schematic

B. Connector Pinouts

Following are the pinout definitions for J1, J2, J3, J4, TB1, TB2, and TB3.

[illegible]

[illegible]

Acutronic			ACUTROL
Position Transducer Interface Connector			
Assembly ID: Transducer Drive/Feedback			Connector Reference: J3
Connector Type: 37 Pin D-sub (Female)			Part Number: AMP 1-747301-4
Pin I.D.	Signal Name	In/Out	Description
1	GND		Cable Shield (Drain)
20	GND		Inductosyn Drive Shield
2	INDH	O	Inductosyn Drive HI
21	INDL	O	Inductosyn Drive LO
3	FRDL	O	Fine Resolver Drive LO
22	FRDH	O	Fine Resolver Drive HI
4	GND		Fine Resolver Drive Shield
23	GND		12 Volt Power common
5	+12		+12 Volt Power
24	-12		-12 Volt Power
6	GND		12 Volt Power Shield
25	GND (Jumper)		Fine Sine Feedback Shield (Open)
7	FSFBKH	I	Fine Sine Feedback HI
26	FSFBKL	I	Fine Sine Feedback LO
8	GND		Control Line Common
27	GND (Jumper)		Fine Cosine Feedback Shield (Open)
9	FCFBKH	I	Fine Cosine Feedback HI
28	FCFBKL	I	Fine Cosine Feedback LO
10	LS+	O	CW Limit Switch
29	LS-	O	CCW Limit Switch
11	GND		Ground/Shield
30	GND (Jumper)		Coarse Sine Feedback Shield (installed)
12	CSFBKH	I	Coarse Sine Feedback HI
31	CSFBKL	I	Coarse Sine Feedback LO
13	CCFBKL	I	Coarse Cosine Feedback LO
32	CCFBKH	I	Coarse Cosine Feedback HI
14	GND (Jumper)		Coarse Cosine Feedback Shield (installed)
33	GND		Coarse Resolver Drive Shield
15	CRDH	O	Coarse Resolver Drive HI
34	CRDL	O	Coarse Resolver Drive LO
16	NC		
35	NC		
17	NC		
36	NC		
18	NC		
37	NC		
19	NC		

Acutronic			ACUTROL
Acutrol3000 Transducer Drive/Feedback Interface Connector			
Assembly ID: Transducer Drive/Feedback			Connector Reference: J4
Connector Type: 37 Pin D-sub (Female)			Part Number: AMP 747843-4
Pin I.D.	Signal Name	In/Out	Description
1	GND		Cable Shield (Drain)
20	GND		Inductosyn Drive Shield
2	INDH	I	Inductosyn Drive HI
21	INDL	I	Inductosyn Drive LO
3	FRDL	I	Fine Resolver Drive LO
22	FRDH	I	Fine Resolver Drive HI
4	GND		Fine Resolver Drive Shield
23	GND		12 Volt Power common
5	+12		+12 Volt Power
24	-12		-12 Volt Power
6	GND		12 Volt Power Shield
25	GND (Jumper)		Fine Sine Feedback Shield (Open)
7	FSFBKH	O	Fine Sine Feedback HI
26	FSFBKL	O	Fine Sine Feedback LO
8	GND		Control Line Common
27	GND (Jumper)		Fine Cosine Feedback Shield (Open)
9	FCFBKH	O	Fine Cosine Feedback HI
28	FCFBKL	O	Fine Cosine Feedback LO
10	NC		
29	NC		
11	GND		Ground/Shield
30	GND (Jumper)		Coarse Sine Feedback Shield (installed)
12	CSFBKH	O	Coarse Sine Feedback HI
31	CSFBKL	O	Coarse Sine Feedback LO
13	CCFBKL	O	Coarse Cosine Feedback LO
32	CCFBKH	O	Coarse Cosine Feedback HI
14	GND (Jumper)		Coarse Cosine Feedback Shield (installed)
33	GND		Coarse Resolver Drive Shield
15	CRDH	I	Coarse Resolver Drive HI
34	CRDL	I	Coarse Resolver Drive LO
16	ANALOGLO	O	Analog Input 0 LO
35	ANALOGHO	O	Analog Input 0 HI
17	GND		Analog Input 0 Shield
36	GND		Analog Input 1 Shield
18	ANALOGH1	O	Analog Input 1 HI
37	ANALOGL1	O	Analog Input 1 LO
19	NC		

[illegible]

[illegible]

[illegible]