Sudbury Neutrino Observatory

Calibration Source Manipulator

Reference Manual

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`surf//~manipulator/doc/manipulator_reference_manual.ps`

March 11, 1999

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Chapter 1

Introduction

The manipulator consists of three computer controlled ropes that allow a source to be positioned within a planer cross section of th acrylic vessel. The source will be moved in one of two orthoganal planes in the AV by moving the source pendant from one set of ropes to another set. In total there are seven motor controllers in the system, two side ropes for each plane (4) plus 3 central ropes that go with each of the three separate umbilical systems.

1.1 Umbilicals

At present there exist 4 umbilicals

- Laser Umbilical
- ^{16}N Umbilical
- Rotating Source / Sonoball Umbilical
- Dark Sampler Umbilical

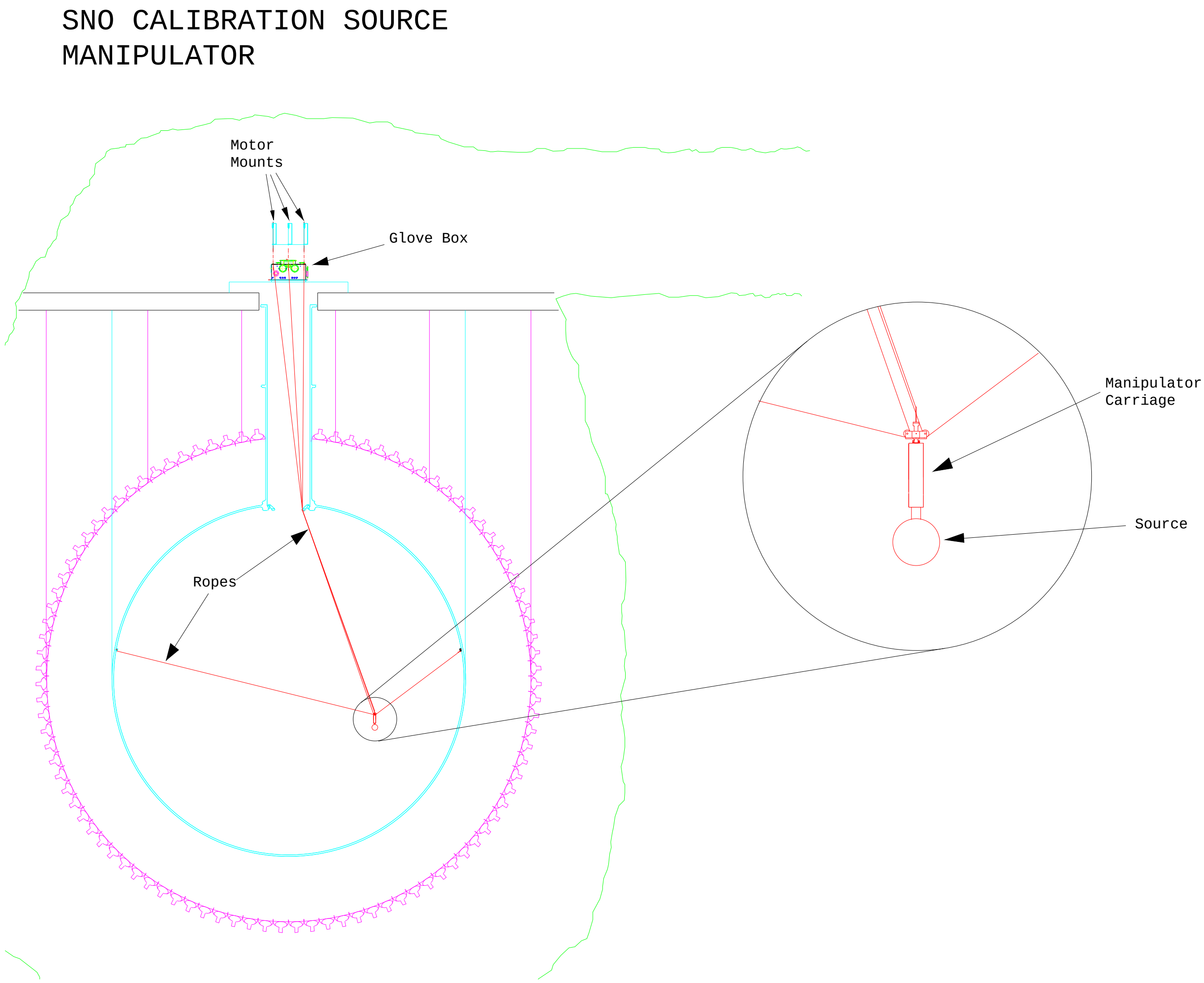

Figure 1.1: SNO manipulator

Chapter 2

Manipulator Geometry

The design specs for the AV indicate,

```
distance from top of chimmney to centre of vessel at 23 C
      42' 2 3/8''
nominal outside radius
      236.6''
nominal thickness 2.15''
```

This can be compared to the results found in SNO-STR-98-003 (R. Komar) for actual measurements of the AV.

measurement	design	as built
Vessel Inner Radius	236.43”	236.38±0.23”
Top of Chimney to AV centre	506.375”	506.16±0.12”
Top of Chimney to bottom of AV	742.59”	742.59±0.05”

Chapter 3

Manipulator Components

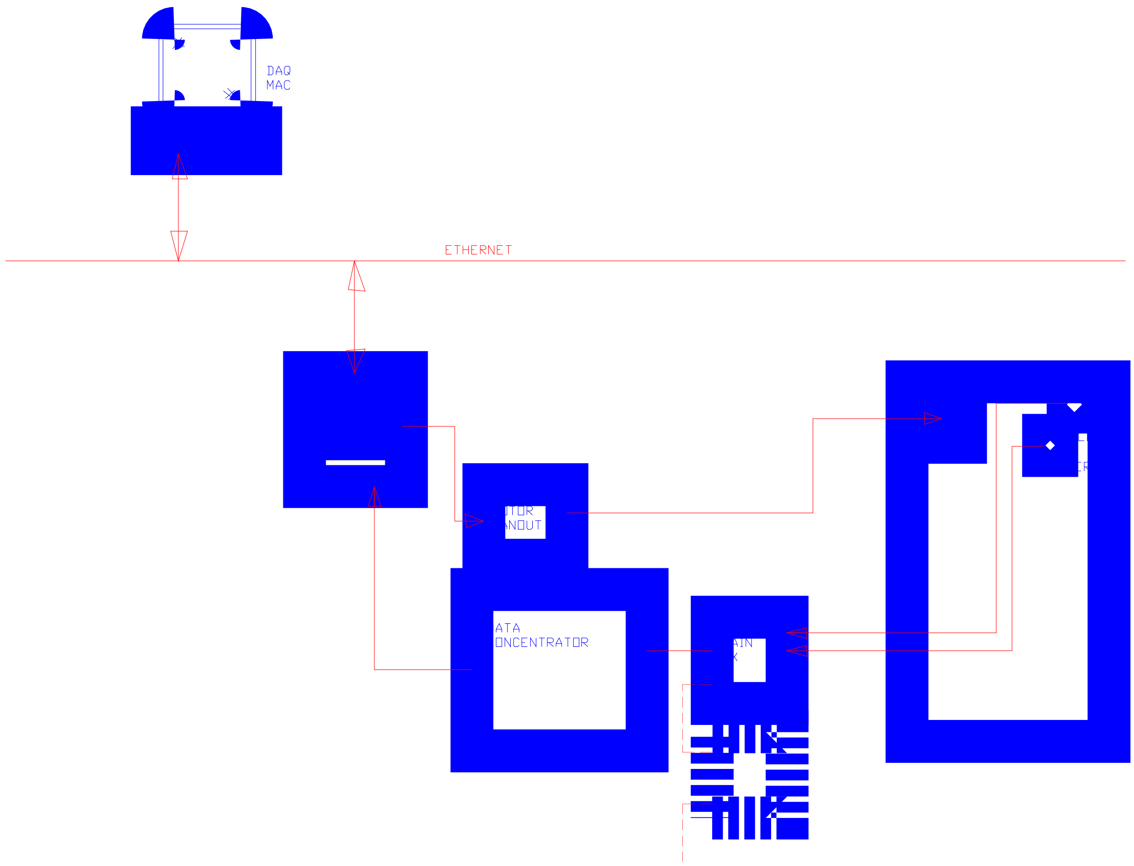

Figure 3.1: SNO manipulator control

3.1 Umbilical Retrival Mechanism (URM)

The Umbilical Retrival Mechanism (or URM for short) is a combination of an umbilical stretcher box and a central rope in one gas tight housing.

3.1.1 Wiring

The wiring for URM-2 is shown in figure 3.2.

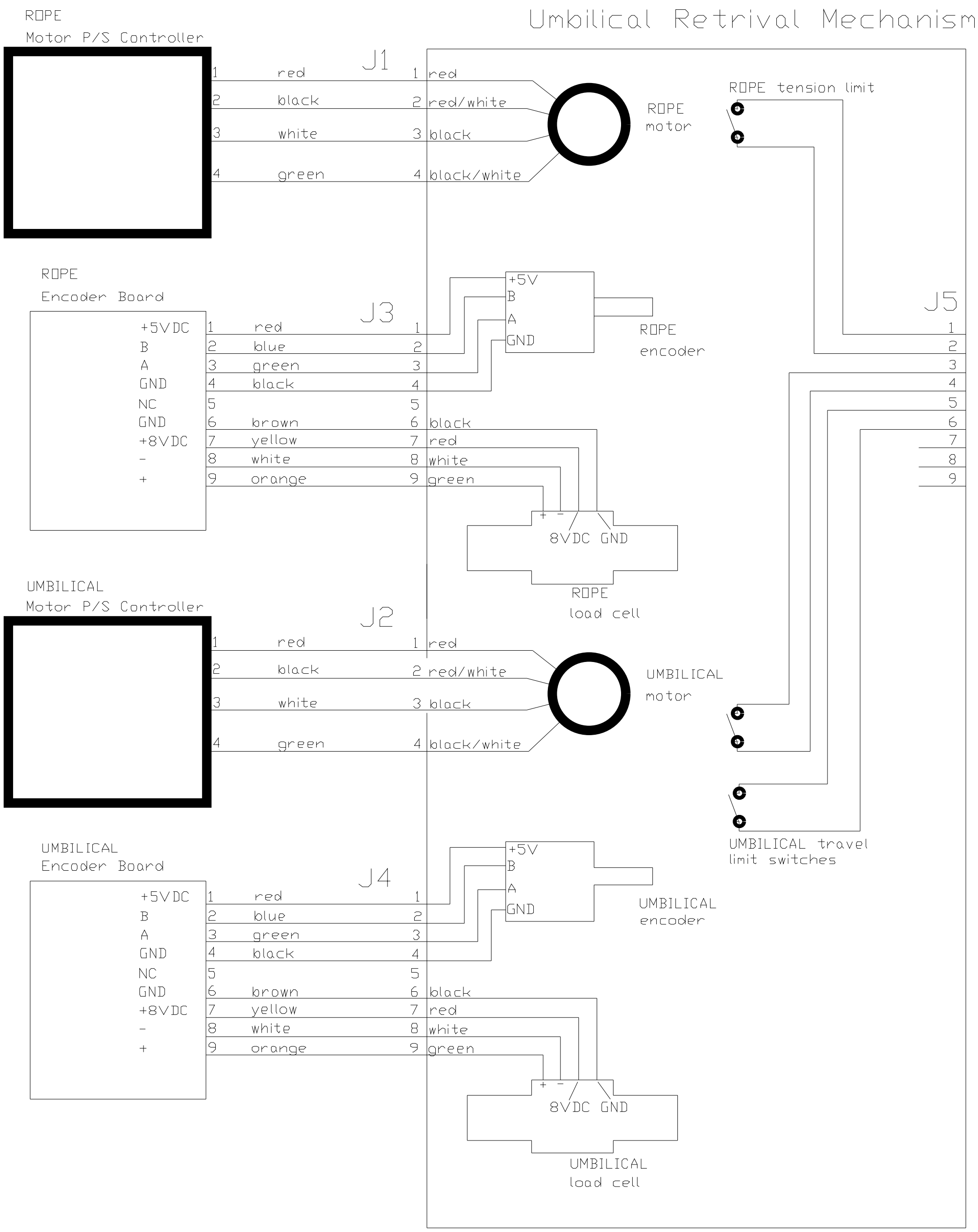

Figure 3.2: URM-2 wiring

Connector	pin	colour	function
j1	1	red	rope motor-1
	2	black	rope motor-2
	3	white	rope motor-3
	4	green	rope motor-4
j2	1	red	umbilical motor-1
	2	black	umbilical motor-2
	3	white	umbilical motor-3
	4	green	umbilical motor-4
j3	1	red	rope encoder +5V
	2	blue	rope encoder B
	3	green	rope encoder A
	4	black	rope encoder GND
	5		NC
	6	brown	rope loadcell GND
	7	yellow	rope loadcell +8VDC
	8	white	rope loadcell +
	9	orange	rope loadcell -
j4	1	red	umbilical encoder +5V
	2	blue	umbilical encoder B
	3	green	umbilical encoder A
	4	black	umbilical encoder GND
	5		NC
	6	brown	umbilical loadcell GND
	7	yellow	umbilical loadcell +8VDC
	8	white	umbilical loadcell +
	9	orange	umbilical loadcell -
j5	1		rope tension limit switch
	2		rope tension limit switch
	3		umbilical travel limit switch 1
	4		umbilical travel limit switch 1
	5		umbilical travel limit switch 2
	6		umbilical travel limit switch 2
	7		
	8		
	9		

Table 3.1: URM-2 Wiring

Chapter 4

Control Hardware

Each of the ropes is referred to as an "axis" and each axis has a

- stepping motor to wind rope in or out.
- shaft encoder to measure length of rope.
- load cell to measure tension of rope.

The stepping motors are controlled from a National Instruments TIO 10 card in the control PC that has many clock signals. These signals are fanned out through the motor fanout box to the individual motor controllers. The readback from the axis is the load cell measuring the tension of the rope and the shaft encoder measuring the length of the rope. The input signals go into the counter boards which are gray boxes which are daisy chained together and are indvidually addressable. The address for the counters are set with jumpers on the boards as is the address for the analog circuit. Note that the analog circuit has a different address from the counter circuit. These boxes are read out by the data concentrator which is read by the computer.

The motors currently assigned in the control system are given in table 4.1. The counter boards

channel	motor	system
1	dyeLaser mirror	Laser
2	filterwheela	Laser
3	filterwheelb	Laser
4	laser trigger	Laser
5	centralrope	URM-1
6	laserumbilical	URM-1
7	westropemotor	
8	eastropemotor	
9	centralrope3	URM-2
10	gasumbilical	URM-2
11		
12		
13		
14		
15		
16		

Table 4.1: Manipulator Control Computer motors in Use

currently in use are shown in table 4.2 along with the analog channels used on each board.

DC Slot	CB address	analog address	Signal	system
1	0x80		SROPE1	
1	0x94		SROPE6	
1	0x98		SROPE7	
1				
2	0x84		SROPE2	
2	0x88		SROPE3	
2	0x8c		SROPE4	
2	0x90		SROPE5	
3				
3				
3				
3				
4				
4				
4				
4				
5	0xD8			
5				
5	0xD8	3	centralrope3	URM-2
5	0xDC	4	gasumbilical	URM-2
6	0xA0	1	westrope	
6	0xF8	2	laserumbilical	URM-1
6	0xA8	3	centralrope	URM-1
6	0xAC	4	eastrope	
7				
7				
7				
7				
8		1	N2LASERLOWPRESSURE	Laser
8		3	N2LASERHIPRESSURE	Laser
8	0xE4		DYELASERENCODER	Laser
8	0xE8		FILTERWHEELENCODER	Laser
8	0xEC		N2 laser and fileter wheel status bits	Laser

Table 4.2: Manipulator Control Computer counter boards in Use

4.1 Counter Boards

The Encoder counter boards contain circuitry for a digital shaft encoder and an analog circuit. The digital encoder circuitry consists of a debounce circuit and a 16 bit up/down counter to count the encoder pulses. The encoder is addressed with 8 address lines, A_0 — A_7. Bits A_0 and A_1 are not used and addresses 7C through 7F are a master reset that resets all counters on all boards.

```
            A: 7 6 5 4 3 2 1 0
  master reset  0 1 1 1 1 1 X X
```

The analog circuit consists of a 2 stage amplifier. The amplified signal is sent to the Data concentrator where a muliplexed ADC selects one of 4 possible channels as the data input. The set of jumpers at J2 on the circuit board allow selection of which analog channel is assigned to each counter board.

Counter Board J1/J2	
pin	assignment
1	+5 VDC
2	+12 VDC
3	-12 VDC
4	CLOCK +
5	ANALOG 1
6	ANALOG 2
7	ANALOG 3
8	ANALOG 4
9	ANALOG 5
10	ANALOG 6
11	ANALOG 7
12	SHIELD
13	SHIELD
14	DIG GND
15	ANL GND
16	ANL GND
17	CLOCK -
18	
19	
20	
21	
22	
23	
24	
25	

Table 4.3: Optical Encoder Counter Board Connectors J1 and J2. Analog Interface Daisy chain connectors. Connectors have identical connections for daisy chaining.

Counter Board J3/J4	
pin	assignment
1	D0
2	D2
3	D4
4	D6
5	D8
6	D10
7	D12
8	D14
9	GND
10	A7
11	A5
12	A3
13	A1
14	GND
15	FLAG 0
16	FLAG 2
17	
18	
19	
20	D1
21	D3
22	D5
23	D7
24	D9
25	D11
26	D13
27	D15
28	BUSEN
29	A6
30	A4
31	A2
32	A0
33	GND
34	FLAG 1
35	FLAG 3
36	
37	

Table 4.4: Optical Encoder Counter Board Connectors J3 and J4. Digital interface daisychain connectors. Connectors have identical connections for daisy chaining.

Counter Board J5	
pin	assignment
1	GND
2	A input, shaft encoder
3	B input, shaft encoder
4	+5 VDC
5	
6	GND to load cell
7	+8 VDC to load cell
8	neg load cell signal
9	pos load cell signal

Table 4.5: Optical Encoder Counter Board Connectors J5. Shaft Encoder and Analog channel input connector

4.2 Data Concentrator

The data concentrator consists of chasis and backplane that hold up to 8 data concentrator cards. Each concentrator card contains 4 single stage amplifiers to amplify the 4 allowed analog signals from the counter boards and a set of buffers to drive the digital signals from the counter boards. Up to 4 counter boards are connected to the data concentrator card via 2 daisy chain cables.

The signals to/from the data concentrator card go through an interface card in the data concentrator chasis and connect to the I/O card in the Manipulator Control Computer PC.

4.3 Motor Fanout and Watchdog Timer Box

This box takes fans out the TIO-10 card outputs to the stepper motor controls and has a watchdog timer circuit to detect a dead computer and shut off the stepper motors. The fanout to each motor goes through a 4 pin connector, The pinouts to a motor are shown in table 4.6 where,

pin	assignment
1	+5 VDC
2	PULSE
3	DIR
4	AWO

Table 4.6: Motor Connections on Motor Fanout Box

PULSE a pulse to step the motor one step

DIR sets direction of motion

AWO All Windings Off — warning, this means no holding torque.

The TIO-10 signals used to control each motor channel are listed in table 4.7 along with the pins on each connector associated with the signal.

motor	motor pin	motor function	TIO-10 pin	TIO-10 funtion
1	J2-1	+5 VDC		
	J2-2	PULSE	J1-3	OUT1
	J2-3	DIR	J1-35	A0
	J2-4	AWO	J1-36	A1
2	J3-1	+5 VDC		
	J3-2	PULSE	J1-6	OUT2
	J3-3	DIR	J1-37	A2
	J3-4	AWO	J1-38	A3
3	J4-1	+5 VDC		
	J4-2	PULSE	J1-9	OUT3
	J4-3	DIR	J1-41	A6
	J4-4	AWO	J1-42	A7
4	J5-1	+5 VDC		
	J5-2	PULSE	J1-17	OUT6
	J5-3	DIR	J1-39	A4
	J5-4	AWO	J1-40	A5
5	J6-1	+5 VDC		
	J6-2	PULSE	J1-20	OUT7
	J6-3	DIR	J1-45	B2
	J6-4	AWO	J1-46	B3
6	J7-1	+5 VDC		
	J7-2	PULSE	J1-23	OUT8
	J7-3	DIR	J1-47	B4
	J7-4	AWO	J1-48	B5
7	J8-1	+5 VDC		
	J8-2	PULSE	J1-26	OUT9
	J8-3	DIR	J1-43	B0
	J8-4	AWO	J1-44	B1
8	J9-1	+5 VDC		
	J9-2	PULSE	J1-28	OUT10
	J9-3	DIR	J1-49	B6
	J9-4	AWO	J1-50	B7

Table 4.7: TIO-10 signals used for motor control

4.4 Stepping Motors and Stepping Motor Controllers

The stepping motor controllers used for the manipulator are Superior Electric SLO-SYN Model SS2000MD4 Tranlator/Drive which is “a bipolar, adjustable speed, two-phase PWM drive which uses hybrid power devices”. The IO connections are shown in table 4.8 where the signals are:

pin	Assignment
1	OPTO
2	PULSE
3	DIR
4	AWO

Table 4.8: Stepping Motor Controller IO terminal block

OPTO Opto-Isolator Supply
User supplied power for the opto-isolators.

PULSE Pulse input
A low to high transition on this terminal advances the motor one step. The step size is determined by the Step Resolution switch settings.

DIR Direction Input
When this signal is high, motor rotation will be clockwise. Rotation will be counterclockwise when this signal is low. Clockwise and counterclockwise directions are properly oriented when viewing the motor from the end opposite the mounting flange.

AWO All windings Off Input
When this signal is low, AC and DC current to the motor will be zero. **Caution: There will be no holding torque when the AWO signal is low.**

OPTO
Voltage — 4.5 to 6.0 VDC
Current — 16 mA per signal used
Other Signals
Votage
Low:$\leq$0.8 VDC
$\geq$0.0 VDC
High$\leq$0.8 VDC
$\geq$0.0 VDC
Current
Low:$\leq$16 mA
High$\leq$0.2 mA

The Motor and power supply connections are given in table4.9 where Vm(+) is a 24VDC unregulated supply voltage and Vom(-) is it’s return. The motor current is determined by the dip switch 1-7 settings shown in table 4.10 The number of pulses per revolution is selected using dip switch 8. The settings are given in table 4.11

pin	Assignment
1	M1 (Phase A+)
2	M3 (Phase A-)
3	M4 (Phase B+)
4	M5 (Phase B-)
5	Vm(+)
6	Vom(-)

Table 4.9: Stepping Motor Controller Motor and Power Supply terminal block

switch	current
none	0.5 A
1	0.75 A
2	1.0 A
3	1.5 A
4	2.0 A
5	2.5 A
6	3.0 A
7	3.5 A

Table 4.10: Stepping Motor Controller Motor current settings. Only one switch should be set at a time.

switch position 8	Step Resolution	Pulses per Rev
0 (off)	Full-Step	200
1 (on)	Half-Step	400

Table 4.11: Stepping Motor Controller Motor step size

motor type	wire	drive pin	function
4-lead	red	1	phase A
	white/red	2	phase A
	black	3	phase B
	white/black	4	phase B

Table 4.12: Stepping Motor Connections

4.4.1 Stepping Motor Connections

pin	signal
1	SOURCE1
2	GATE1
3	OUT1
4	SOURCE2
5	GATE2
6	OUT2
7	SOURCE3
8	GATE3
9	OUT3
10	SOURC4
11	GATE4
12	OUT4
13	GATE5
14	OUT5
15	SOURCE6
16	GATE6
17	OUT6
18	SOURC7
19	GATE7
20	OUT7
21	SOURCE8
22	GATE8
23	OUT8
24	SOURCE9
25	GATE9

Table 4.13: PC-TIO-10 card connector pin assignments (pins 1-25)

4.5 PC-TIO-10 Card

The National Instruments PC-TIO-10 Card is located in the calibration computer and is used to control the manipulator stepping motors (it is also used to control stepping motors on the N_2 laser used for the laserball).

pin	signal
26	OUT9
27	GATE10
28	OUT10
29	FOUT1
30	FOUT2
31	EXTIRQ1
32	EXTIRQ2
33	GND
34	+5V
35	A0
36	A1
37	A2
38	A3
39	A4
40	A5
41	A6
42	A7
43	B0
44	B1
45	B2
46	B3
47	B4
48	B5
49	B6
50	B7

Table 4.14: PC-TIO-10 card connector pin assignments cont'd (pins 26-50) For the 8 IO lines A0-A7, the MSB is A7. for the 8 IO lines B0-B7, the MSB is B7.

4.6 Optical Encoders

The optical encoders used to measure the rope lengths in the system are made by Bourns. Part number? We use both the 128 steps per rotation and the 256 steps per rotation encoders. No index marks are on the encoders so no absolute zero can be determined. The encoder is driven by 5VDC and and supplies two TTL level quadrature signals, A and B. The pin assignment for the encoders is shown in table 4.15. The shaft

pin	assignment
1	GND
2	N.C.
3	A output
4	VCC
6	B output

Table 4.15: Bourns Optical Shaft Encoders Pin assignment. Pins numbered from left to right with the encoder shaft oriented away from viewer and pins at top.

encoders are read out by the *counter boards* which were designed inhouse at Queen's.

4.7 Load Cells

The load cells used in the manipulator are made by,

```
Tranducer Techniques
```

and are model MLP-100 (100 lb loads) Maximum allowed excitation is 12 VDC, calibration is done at 10 VDC. The connections for the load cells are shown in table 4.16. We drive the load cells at 8 VDC. The

wire	function
red	+ excitation
black	- excitation
green	+ signal
white	- signal
shield	ground

Table 4.16: Load Cell Connections

reponse of the load cells is,

type	load (lb)	reponse mV/V
100 lb cell	50	1
(MLP-100)	100	2
300 lb cell	150	1
(MLP-300)	300	2

where the reponse in mV/V means the output voltage (in mV) for a given driving voltage (in V). For an 8 volt driving voltage as used in the SNO manipulator, the output reponse is,

MLP-100		MLP-300	
load (N)	signal (mV)	load (N)	signal (mV)
1	0.036	1	0.012
5	0.180	5	0.060
10	0.360	10	0.120
50	1.780	50	0.599
100	3.596	100	1.199
500	17.978	500	5.993
		1000	11.985

Chapter 5

Software

5.1 Program Description

5.2 Data files

```
On PC
-----
c:\motors\manip\

   wiring.dat  -- TIO 10 wiring map
                   counter board wiring map
                   motor fanout wiring map

       -- both the manipulator and the AV position sensors

   motor.dat    -- physical parameters for motors

   encoder.dat  -- physical parameters for encoders

   loadcell.dat -- physical parameters for load cells

   axis.dat     -- combines motor loadcell and encoder infor plus other
                   stuff (i.e. wire tension etc) to form info on axis

   polyaxis.dat -- combines 3 axes into the manipulator

   av.dat       -- information on acrylic vesel geometry
```

Chapter 6

Sources

6.1 Laserball

weight(source and carriage)	61 N
d(pivot to centre)	62.6 cm
d(pivot to bottom)	67.7 cm
maximum diameter	10.16 cm (4")

Table 6.1: Laserball Parameters

6.2 ^{16}N

weight(source and carriage)	
d(pivot to centre)	
d(pivot to bottom)	
maximum diameter	

Table 6.2: ^{16}N Parameters

6.3 Rotating Source

function		T.S.	umbilical		ext cord	manip boxes
+5VDC	red	1	blue inner	1	black	theta motor pin 1
phi pulse	orange	2	red outer	2	brown	phi motor pin 2
phi dir	yellow	3	green outer	3	red	phi motor pin 3
AWO	blue	4	yellow inner	4	orange	theta motor pin 4
theta pulse	brown	5	blue outer	5	yellow	theta motor pin 2
theta dir	white	6	yellow outer	6	green	theta motor pin 3
VM+	red	7	red inner	8	blue	40VDC P/S pin 1
VM-	green	8	green inner	9	white	40VDC P/S pin 3

Table 6.3: Rotating Source Wiring

Appendix A

Usefull Names and Addresses

```
SUPERIOR ELECTRIC
  Warner Electric
  383 Middle Street
  Bristol, Connecticut 06010
  203-585-4500 (tel)
  203-589-2136 (fax)

National Instruments
  Corporate Headquarters
    6504 Bridge Point Parkway
    Austin, TX 78730-5039
    512-794-0100
    800-328-2203 (technical support fax)
    512-794-5678 (technical support fax)
  Branch Office:
    519-622-9310 (Ontario)

Tranducer Techniques
  Precision Measurement Systems

  43178 Business Park Drive, Temecula, CA 925990
  909-676-3965
  909-676-1200 (fax)
  URL:  http//www.ttloadcells.com
  Email: tti@ttloadcells.com
```

Appendix B

Electronics

CABLE 1/1	Data Concentrator Cable Interface Board
CALIBIN1/1	Data Concentrator Card
CALIBIN2/1	Data Concentrator Backplane
PCL76032/1	PCL750 32Bit Test Card with Watchdog timer (I/O card)
CNT_BRD/1	Optical Encoder Counter Board
WATCHDOG/1	Watchdog timer circuit and motor fanout
AVPSENSE/1	AV Position Sensor Board

Table B.1: Circuit Diagrams of electronics in SNO manipulator control system.