LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Fibre Pulling and Welding Machine Electronics

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1 Introduction

1.1 Purpose and Scope

The IGR ribbon-pulling rig needs to be documented and cloned, initially for installation at LASTI and later at the observatories. This document describes the electronic components. This revision (-00) is descriptive – it documents the as-built system at LASTI. A future revision will give a cleaned up design to be used for the production version.

1.2 Version history

1/8/07: Pre-rev-00 draft #1.

1/12/07: Pre-rev-00 draft #2. Added DCC number (T070005). Added more links to manuals etc. Added note on mirror galvos for welding.

10/1/09: Pre-rev-v1 draft. Changed baseline to LASTI machine. Updated for change from ribbons to fibres. Fixed MIT address.

2 Overview

2.1 Desired operation

The beam from a 100 W CO2 laser is directed from above onto a 45° mirror spinning about a vertical axis, to produce a beam rotating in a horizontal plane. The beam is directed upwards by a fixed 45° ring mirror, and then inwards by a second 45° ring mirror on the lower of two carriages on a vertical track. This periscope arrangement allows symmetric heating of any point on the vertical symmetry axis within the range of the lower carriage. The motion of the carriages is largely automated, under the control of a PC running LabView.

A piece of fused silica rod is mounted in the beam target zone between a fixed clamp and a clamp on the upper of the two carriages. First the beam is scanned extremely slowly (10 minute for 40 mm) down and then up the stock to fire-polish the surface over the full length from which the fibre (including necks) will be drawn.

Then the beam is repositioned to a point a neck-length down from the top of the polished zone and scanned down moderately slowly while the upper carriage moves up, drawing out a fibre. The diameter of the fibre can be changed from point to point along its length by varying the ratio of the speeds of the upper and lower arms.

Each carriage has a “hard” and a “soft” limit switch at the outside end of its normal operating range. There is also a similar pair of switches between the carriages to stop them bumping. The soft limit switches are monitored by LabView, which is responsible for setting the velocity to zero if they are triggered. The default initial position for the carriages is found by running the lower carriage down until the soft switch below it triggers, and then the upper carriage down until the soft intercarriage switch triggers.

The hard limit switches are wired directly to the motor controllers and act as an emergency backup. If they are triggered they cut the power to the motors and the operator needs to manually defeat them and use a special LabView program to move the carriages into a safe state.

Both arms of the pulling machine have magnetic tape linear encoders for sensing position, although only the encoder for the upper arm is currently used. Before each pulling run, the LabView program loads from disk a table of velocity values for the two arms. (There is a third column in the table intended for setting the power of the laser, but this feature is currently unimplemented.)

To start the pull, the operator loads the data set, powers up the laser with the shutter closed, waits for it to stabilize and then opens the shutter, which is motorized to allow it to be used from outside the laser safety enclosure. The LabView program detects the shutter opening and begins a countdown. At the end of the countdown, the stock is presumed to be molten and the arms are set in motion. As pulses come in from the upper arm encoder, the LabView program steps through the table and sets the velocity outputs accordingly. The length of the resulting fibre is determined by the number of entries in the table. When a requested velocity of zero is encountered, LabView terminates the pull by setting the velocity output to zero (and applying the brakes for good measure).

After the pull is completed, the operator undoes the lower clamp and clicks a screen button to raise the upper arm a short distance so the lower end of the fibre is clear of the lower clamp. The operator then removes the fibre and clicks a second screen button to have LabView wind the carriages back to the start position as detected from the soft limit switches.

The intensity of the laser tends to fluctuate, especially at higher powers, so it can be stabilized by a simple digital control loop built into the LabView program for the pulling machine. Sensing is via a power meter on a pickoff beam and feedback is via a voltage to the laser controller (which uses it to modulate the pulse width of the laser control signal). However attempting to control the laser power tends to increase the number of glitch events and make the problem worse, so the control is normally left off.

An attachment to the pulling machine is used for welding. The welding component includes two mirror galvanometers controlled by a separate LabView program to steer the beam to the welding area.

2.2 Commercial components

This section gives details and links to on-line documentation for the major commercial items.

2.2.1 PC and DAQ

The control of most of the operation is done by a PC running Windows XP and LabView. Currently this is a Dell Optiplex GX280, but it barely matters and will probably change in the copy. The only critical requirement is a PCI bus.

There are two DAQ cards, an NI-PCI-6221 all-purpose IO board (http://sine.ni.com/nips/cds/view/p/lang/en/nid/14132), and an NI-PCI-6723 32-channel output board (http://sine.ni.com/nips/cds/view/p/lang/en/nid/12551). These are connected to three CB-68LP screw-type connector blocks (http://sine.ni.com/nips/cds/view/p/lang/en/nid/12082) via two SH68-C68-S cables and one SHC68-68-EPM cable.

2.2.2 Stepper motors

The two carriages are driven by Allen-Bradley MPL-A330P-MJ24AA stepper motors (http://www.ab.com/motion/servo/motor.html) via ULTRA3000 2098-DSD-010 drivers

(http://www.ab.com/motion/drives/ultra3000.html, http://literature.rockwellautomation.com/idc/groups/literature/documents/in/2098-in003_-en-p.pdf).

Key part numbers:

Controller: 2098-DSD-010

Motors: MPL-A330P-MJ24AA

Control breakout boards: 2090-U3BB2-DM44 (from kit, 2090-U3BK-D4401)

Cables, controller to breakout boards: 2090-U3BC-D4401 (from kit, 2090-U3BK-D4401)

Cables, controller to motors (feedback): 2090-XXNFBMP-S03

Cables, controller to motors (power): 2090-XXNPMP-S03

Cables, motor brakes: 2090-UXNBMP-18S03

AC Line Filter (power supply): 2090-UXLF-110

(http://literature.rockwellautomation.com/idc/groups/literature/documents/in/2090-in007_-en-p.pdf).

2.2.3 Laser

The laser is a Synrad Firestar F100 (http://www.synrad.com/fseries/f100.htm, (http://www.synrad.com/Manuals/f_SeriesManual.pdf). Its intensity is stabilized by a digital control loop running in LabView on the PC. The sensor used is a Gentec UP-19K-150W (http://www.gentec-eo.com/en/up19k.html) interfaced via a TPM300 readout (http://www.gentec-eo.com/en/tpm300.html). The feedback is via the UC-2000 controller (http://www.synrad.com/Manuals/UC2000UniversalLaserController.pdf) associated with the laser, which accepts a voltage and generates a pulse-width modulated drive signal.

2.2.4 Linear Encoder

The position sensor is a SIKO MSK320 (http://www.todescato.com/Doc/Encoder/Magnetici/CAT_MSK320_MR01_MR320.pdf).

2.2.5 Mirror Galvanometers

Each galvanometer is a Nutfield QS-10 (http://www.nutfieldtech.com/galvo/qs10.asp), driven by a Nutfield QD-1500 servo driver (http://www.nutfieldtech.com/electronics/qd1500.asp).

2.2.6 Chiller

The chiller is a Neslab HX-75 (water cooled version):

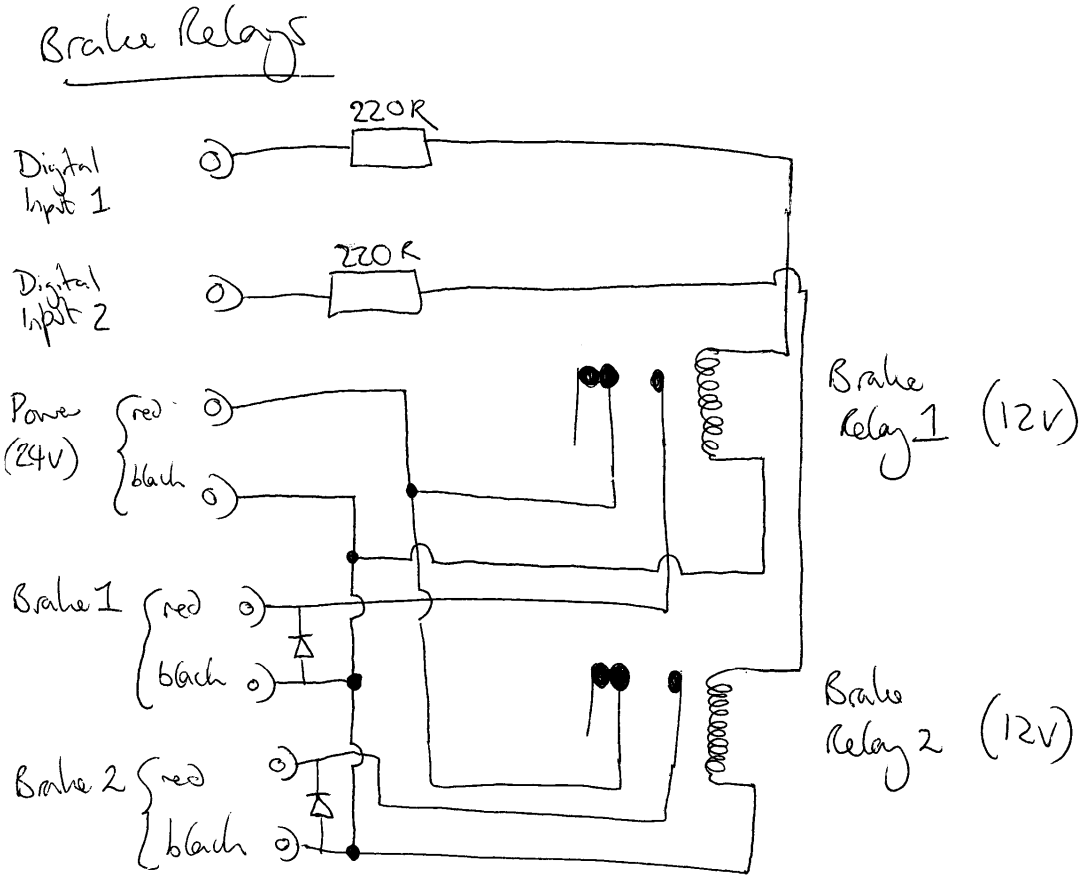
http://www.thermo.com/com/cda/product/detail/1,,1000001155250,00.html

3 Custom boxes

This section gives circuit diagrams for the major custom boxes.

3.1.1 Brake Relay Box

This box accepts digital signals from the ULTRA3000 and generates high-power versions for driving the stepper motor brakes.



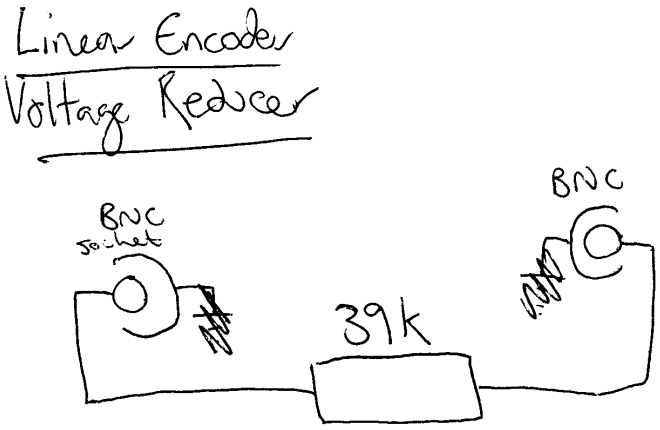
Notes:

The diodes are to prevent arcing due to collapse of the magnetic field in the brake relay coils. The orientation may not have been correctly drawn and needs to be checked.

The 220 ohm resistors are to allow operation of 12 V relays from a 24 V supply.

3.1.2 Linear Encoder Voltage Reducer

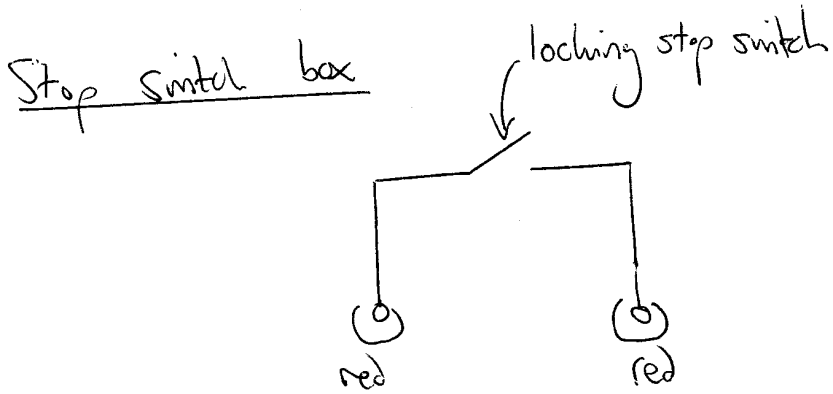
This box contains exactly one 39K resistor and converts the output of the linear encoder for reading by LabView. It might well be a candidate for elimination or consolidation in a redesign.



The resistor can be very low power – 0.5 W is plenty.

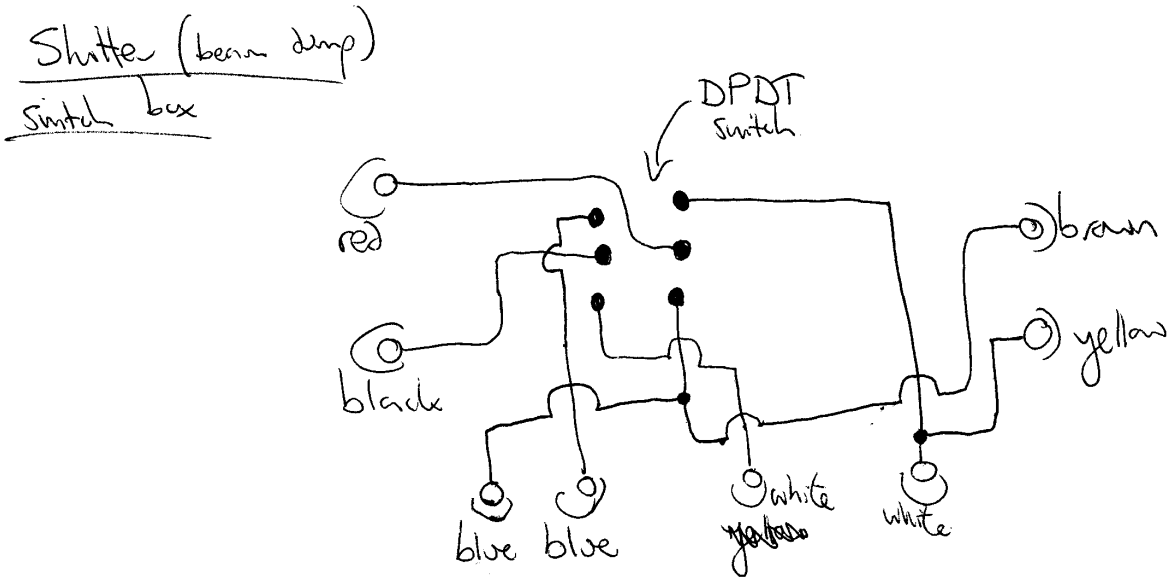
3.1.3 Emergency Stop Switch Box

This box needs to be separate and robust because the stop switch is mounted on the top of it for ready access by the operator in an emergency. The switch is N.C. and locks open when pressed.



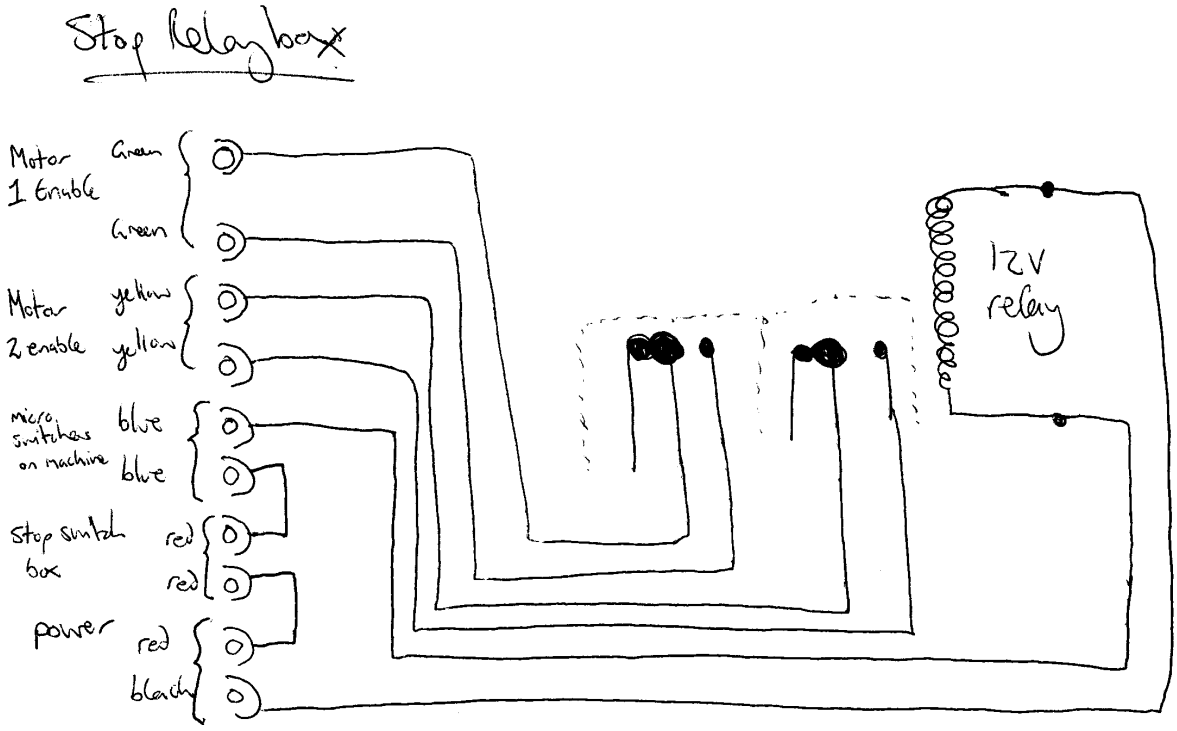
3.1.4 Shutter Switch Box

This box drives the laser shutter open or closed by sending 12 V DC with the appropriate polarity to a car aerial motor.



3.1.5 Stop Relay Box

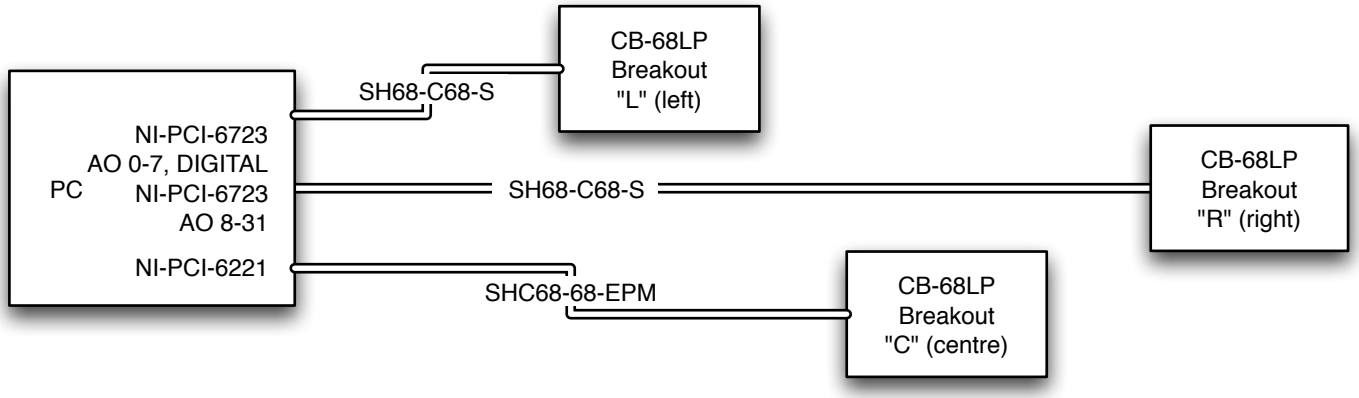
This box enables the stepper motors only if the emergency stop switch and all the limit microswitches are closed. The circuit given below departs from the general principle that the -00 revision of this document is purely descriptive. The real Stop Relay Box had so many obsolete features and dependencies that it would be confusing.


Stop Relay box
Motor 1 Enable
Green
Green
Motor 2 enable
yellow
yellow
micro switches on machine
blue
blue
Stop switch box
red
red
power
red
black
12V relay

Pulling/Welding Machine Electronics - LASTI as-built - Version of 11 Sep 2009

(This diagram forms part of T070005. It has been produced with the Mac OS X program OmniGraffle Pro.)

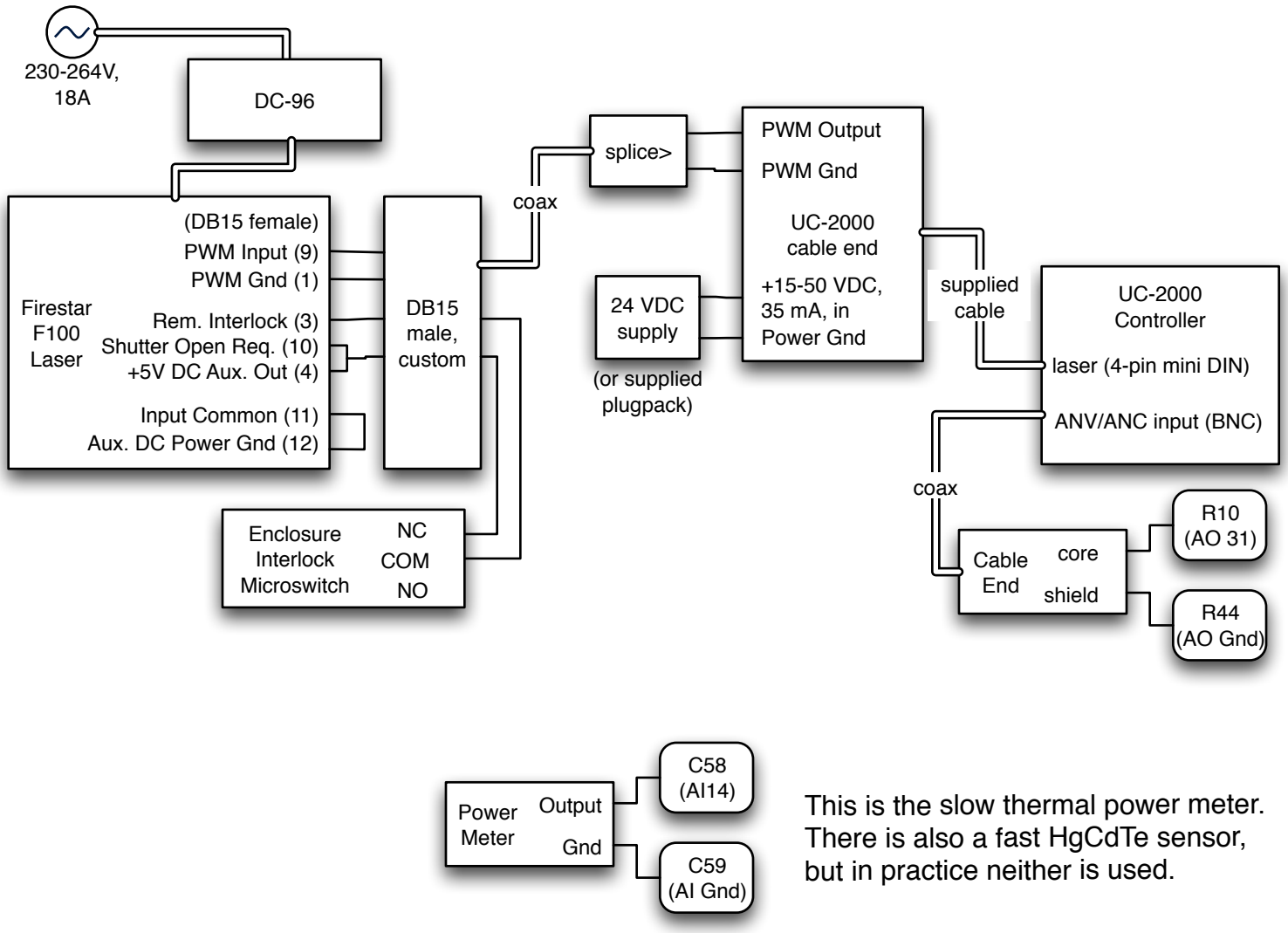
PC/DAC, Laser



The names L, R and C refer to the mounting locations at Glasgow, preserved at LASTI.

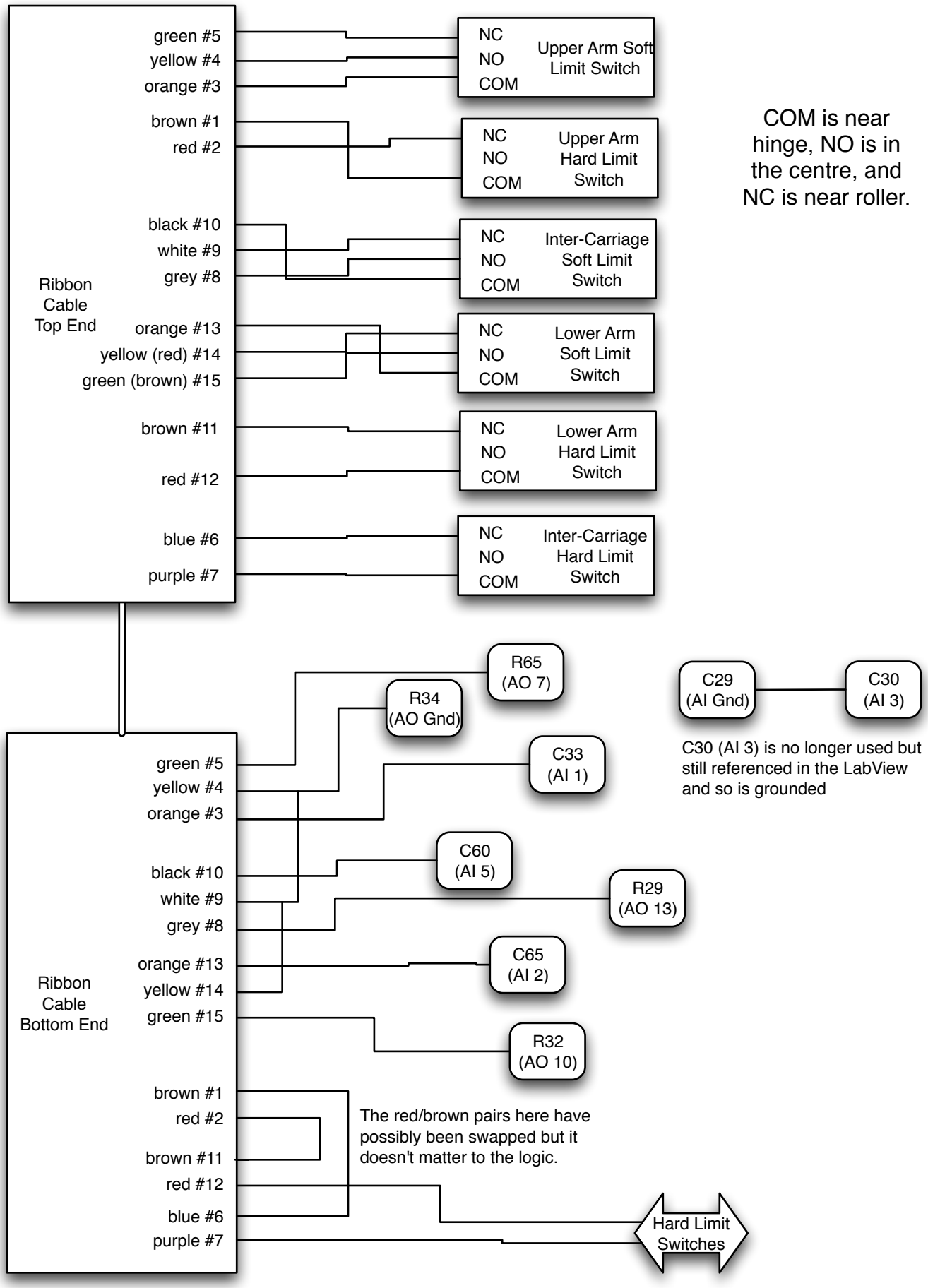
Rather than turning this schematic into a rat's nest, connectors on these three breakouts are shown as individual boxes with labels Lnn, Cnn or Rnn, plus a comment giving the LabView function, e.g.:

L16
(AO 16)

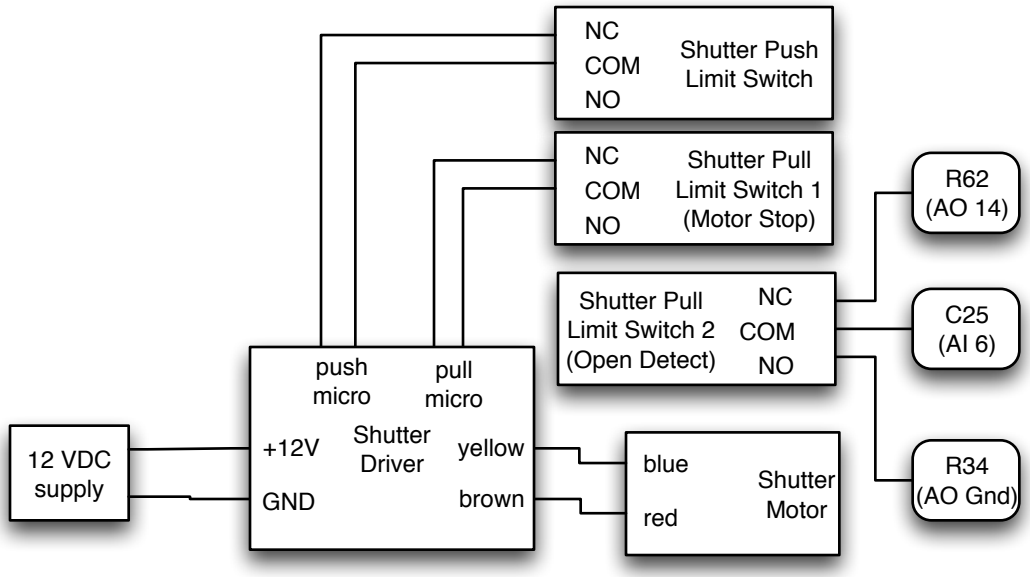


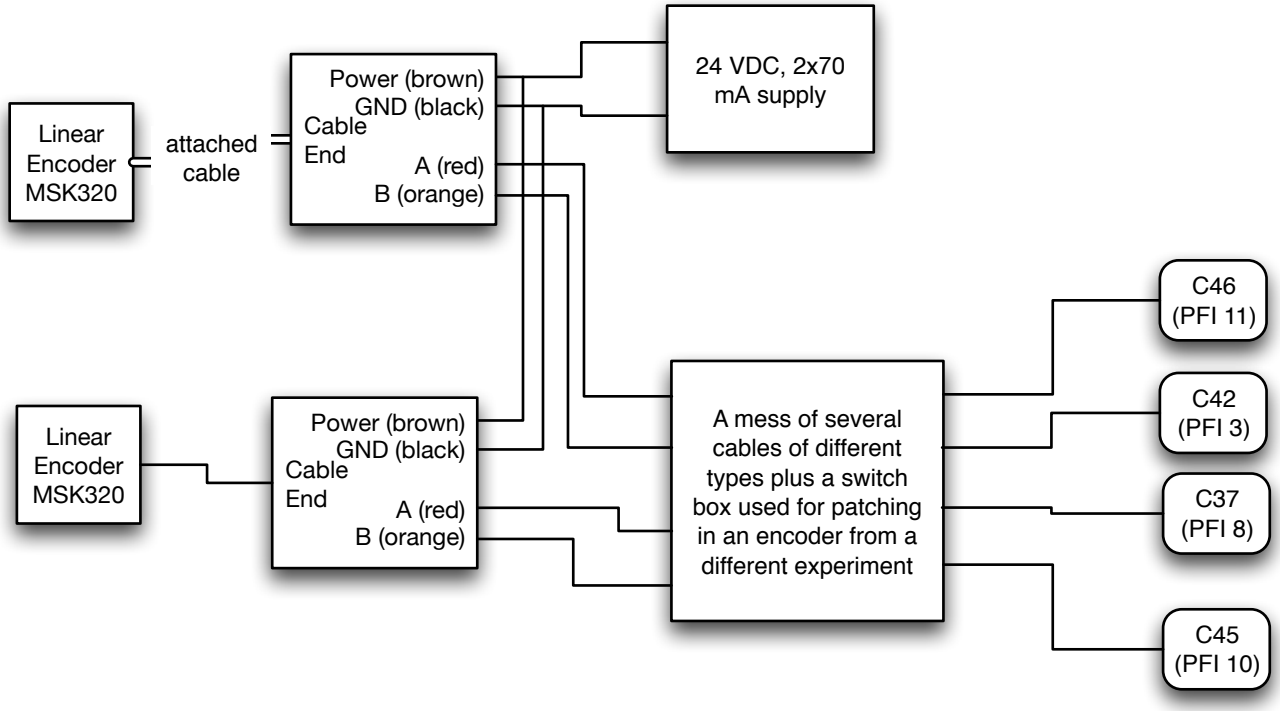
This is the slow thermal power meter. There is also a fast HgCdTe sensor, but in practice neither is used.

Microswitch Ribbon Cable

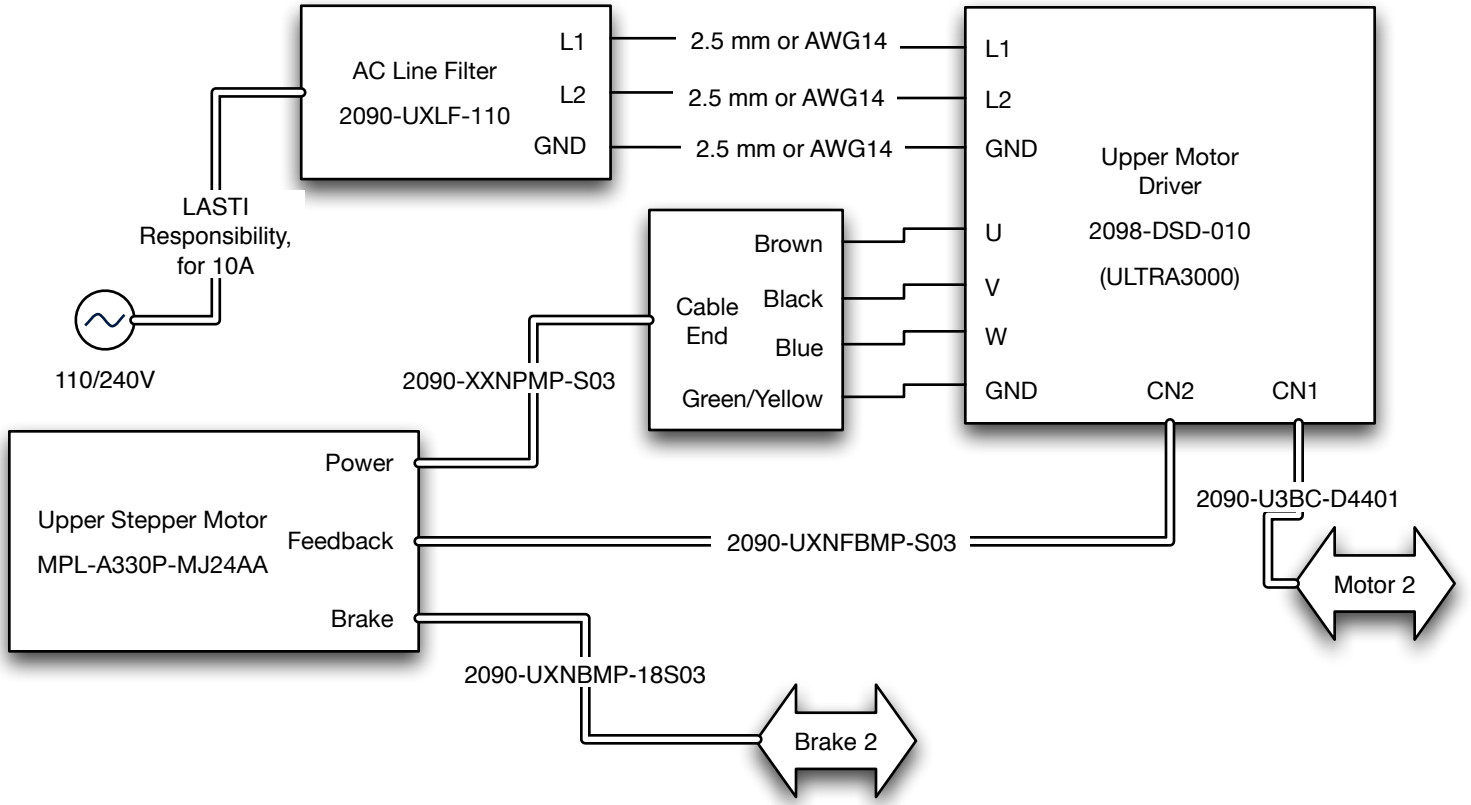


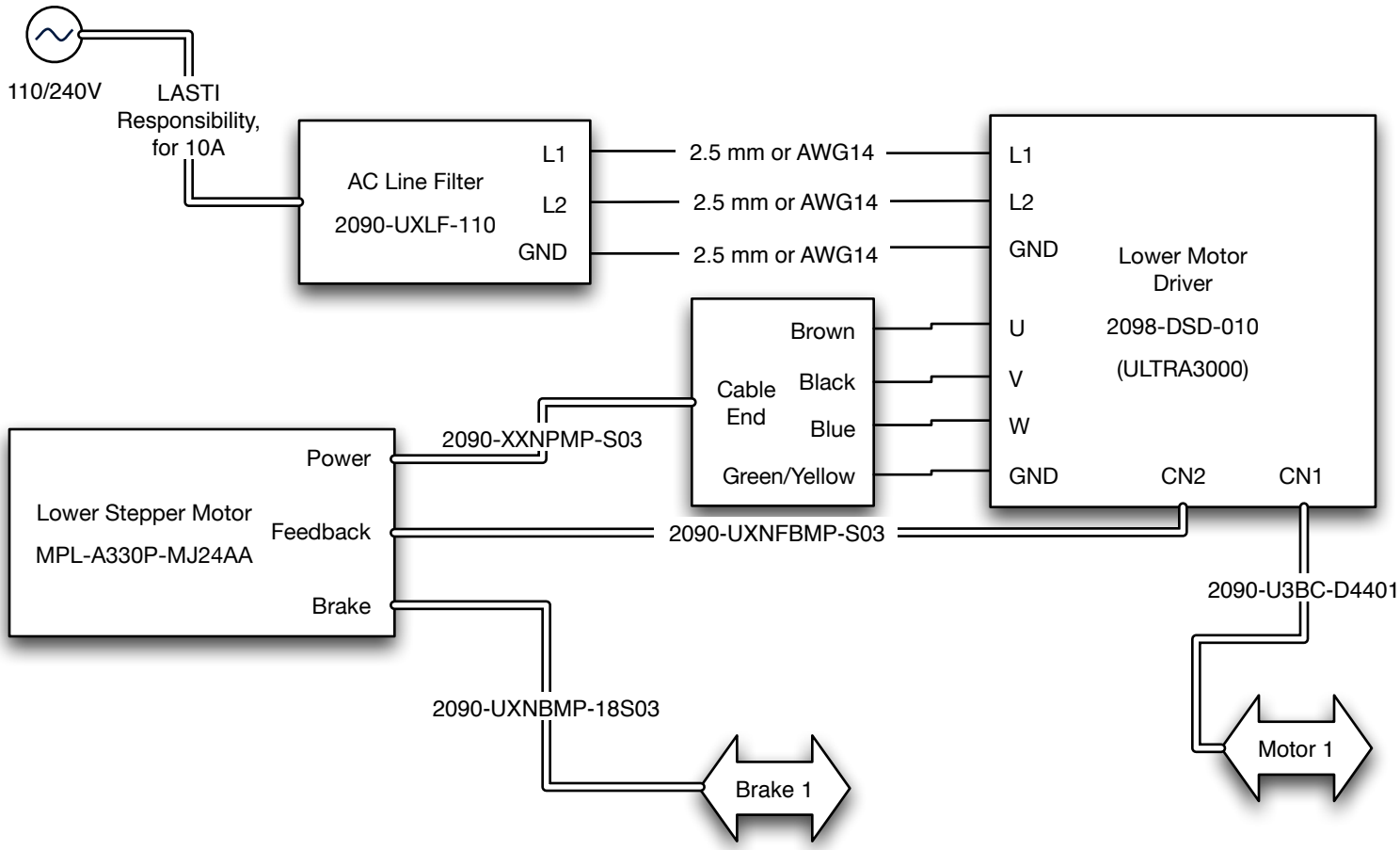
Linear Encoder, Motorized Shutter



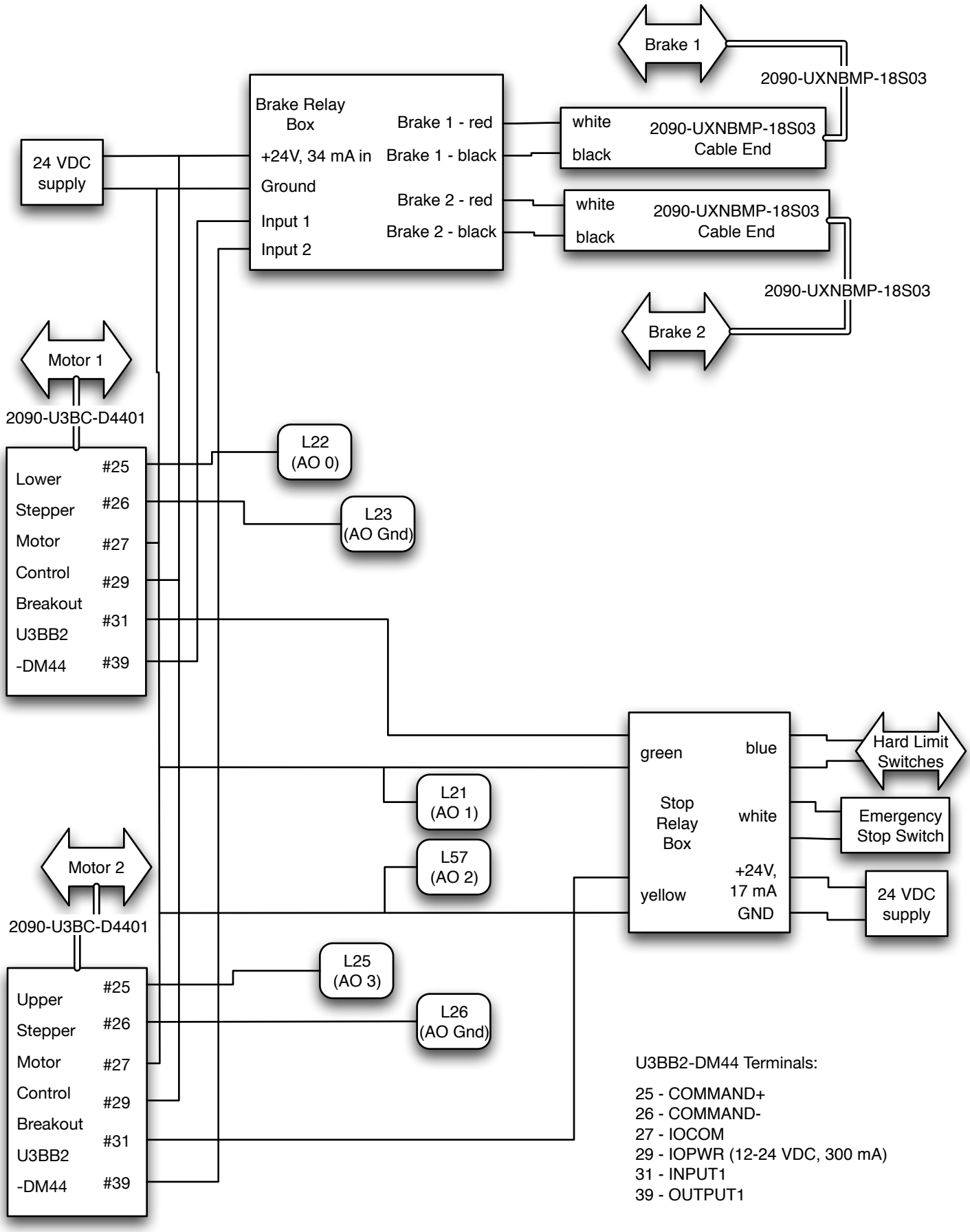


Stepper Motor Stuff (i)





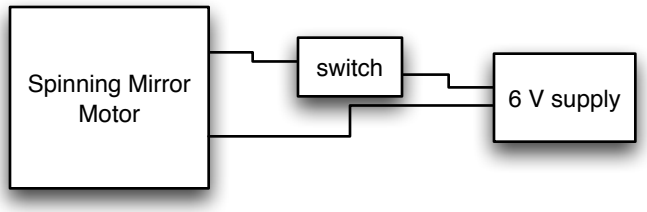
Stepper Motor Stuff (ii)



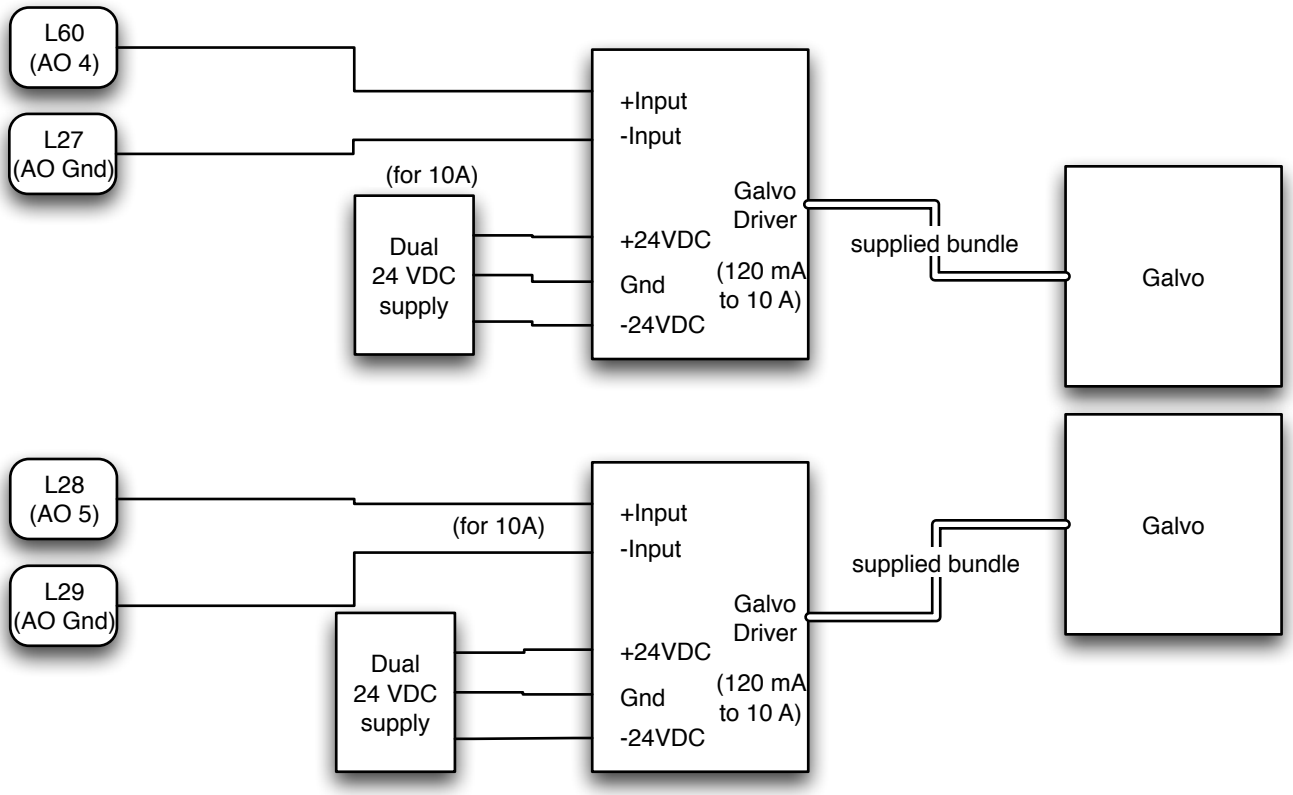
U3BB2-DM44 Terminals:

25 - COMMAND+
26 - COMMAND-
27 - IOCOM
29 - IOPWR (12-24 VDC, 300 mA)
31 - INPUT1
39 - OUTPUT1

Galvos and Spinning Mirror



Welding Machine Steering Galvos



Note: The quiescent current draw from the galvo drives is 120 mA. Since the present application drives them at DC or only a few Hz, the actual current should be only barely above that (e.g., 140 mA, measured), rather than the 10 A worst case.

LabView & Motor Setup

The following DAQmx task groups need to be defined using the Measurement and Automation utility (MAX) for use by the pulling/welding machine VI.

For each task is given (i) the task name, (ii) the device, (iii) the voltage limits.

All analog input and output tasks should be set to 1 sample on demand

For each signal is given (i) the signal name, (ii) the breakout board and terminal number, (iii) the function

"Kill All"
Dev1 = NI-PCI-6723
-10 to 10 V
ao0 (L22) motor 1 speed
ao3 (L25) motor 2 speed
ao25 (R16) not used

"Enable"
Dev1 = NI-PCI-6723
0 to 10 V
ao1 (L21) motor 1 brake

"Enable2"
Dev1 = NI-PCI-6723
0 to 10 V
ao2 (L21) motor 2 brake

"Output Voltage"
Dev1 = NI-PCI-6723
0 to 10 V
ao31 (R10) laser power output

"Switch Monitor"
Dev2 = NI-PCI-6221
-10 to 10 V
ai1 (C33) upper soft limit switch
ai2 (C65) lower soft limit switch
ai5 (C60) intermediate soft limit switch
ai3 (C30) not used
ai14 (C58) laser power readback
ai6 (C25) motorized shutter position

"welding galvo"
Dev1 = NI-PCI-6723
ao4 (ao19 at Glasgow)
ao5 (ao20 at Glasgow)

"Dev2/ctr0"
Dev2 = NI-PCI-6221
pfi8 (C37) linear encoder

The following additional DAQmx task groups need to be defined for use by the Sliders VI

"Motoroutputtest1"
Dev1 = NI-PCI-6723
-10 to 10 V
ao0 (L22) motor 1 speed

"Motoroutputtest2"
Dev1 = NI-PCI-6723
-10 to 10 V
ao3 (L25) motor 2 speed

Both motor controllers need to be programmed using the Ultraware utility program and a serial cable as follows:

Mode Configuration->Analog->Velocity Scale at 5 rpm/V for lower arm motor (was 500) and 50 rpm/V for upper arm.
Mode Configuration->Analog->Velocity Offset at 25 and 0 mV (or whatever required to ensure no drift)
Digital input 1 set to enable.
Digital output 1 set to enable.

Version History

12 Jan 2007: Glasgow as-built version
08 Mar 2007: Initial plan of LASTI version
09 Mar 2007: correction: galvos use *dual* 24 V supplies
17 Dec 2007: correct feedback cable number ("XX"->"UX")
01 Feb 2008: updated ribbon cable section and stop relay box labels for LASTI changes, added laser power meter, added LabView task info, corrected a01, a02 connections.
12 Feb 2008: further updates to ribbon cable section
11 Sep 2009: further updates to ribbon cable to correct one error and reflect rewiring of a switch, updated encoder section for second encoder and quad readout, added spinning mirror motor, removed dithering galvo, updated motor settings