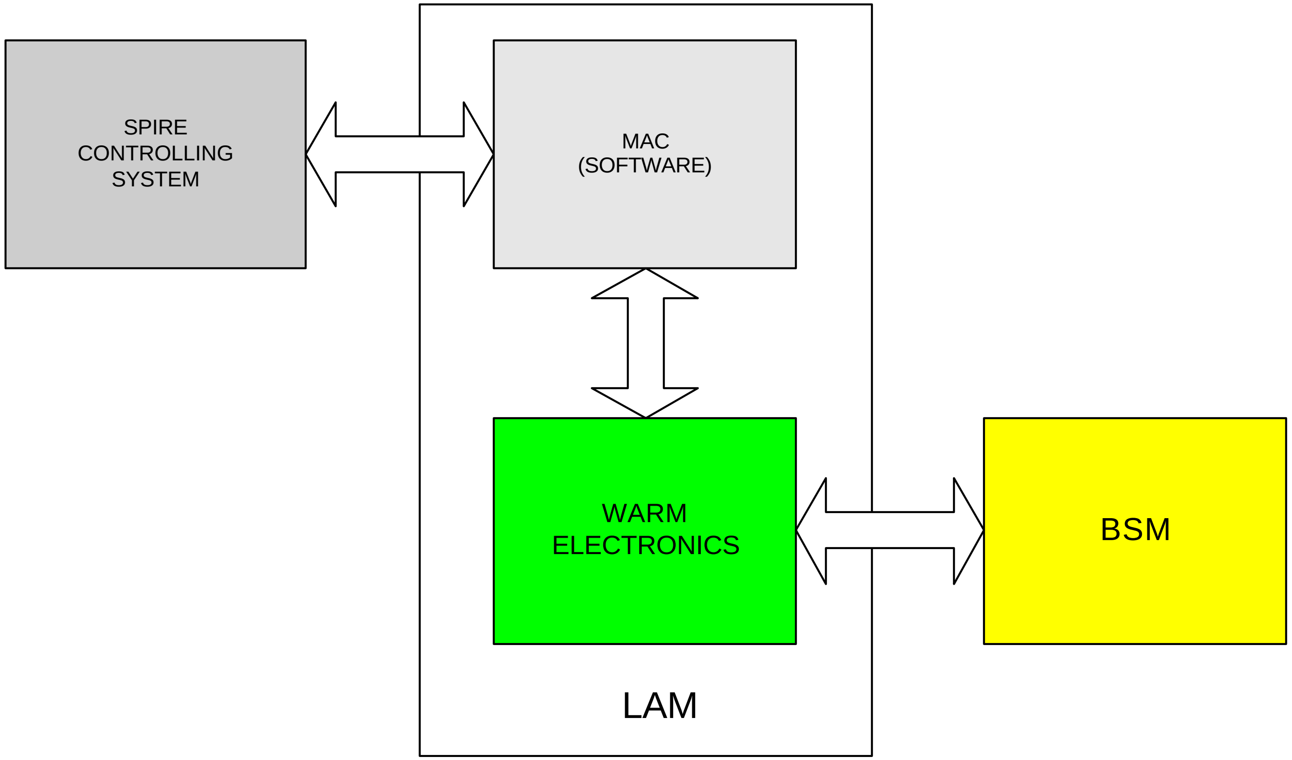
UK Astronomy Technology Centre

Beam Steering Mirror : Control and Electronics

Brian Stobie

BSM Electronics and Software



BSM Electronics and Software

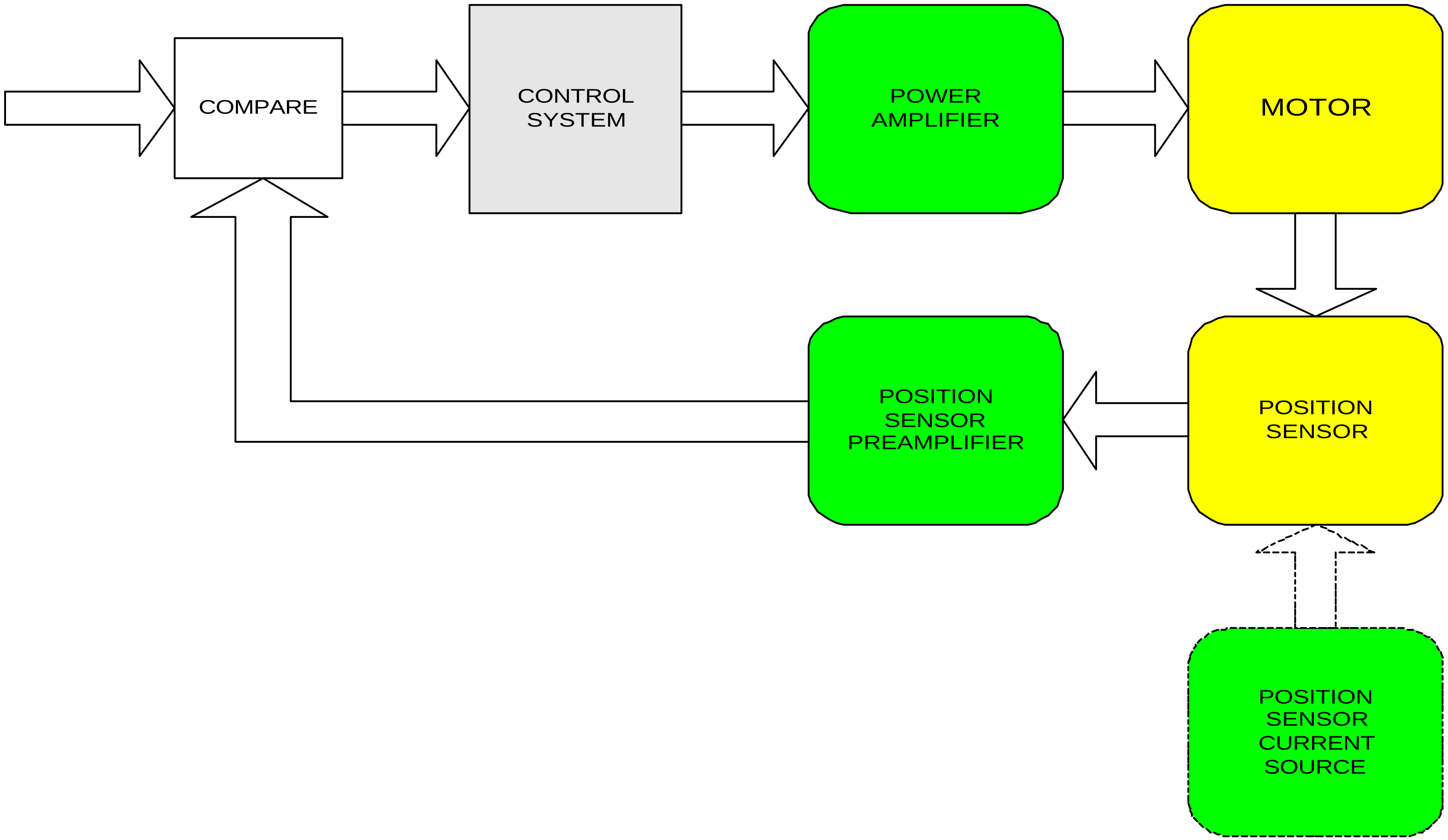
The BSM electronics, comprising position sensor preamplifiers and motor power amplifiers, is defined by UKATC, but built by Laboratiore D'Astrophysique de Marseille (LAM).

The electronics *functionality* is defined in the BSM Electronics Interface document - the LAM detailed design will comply with this and be agreed by UKATC.

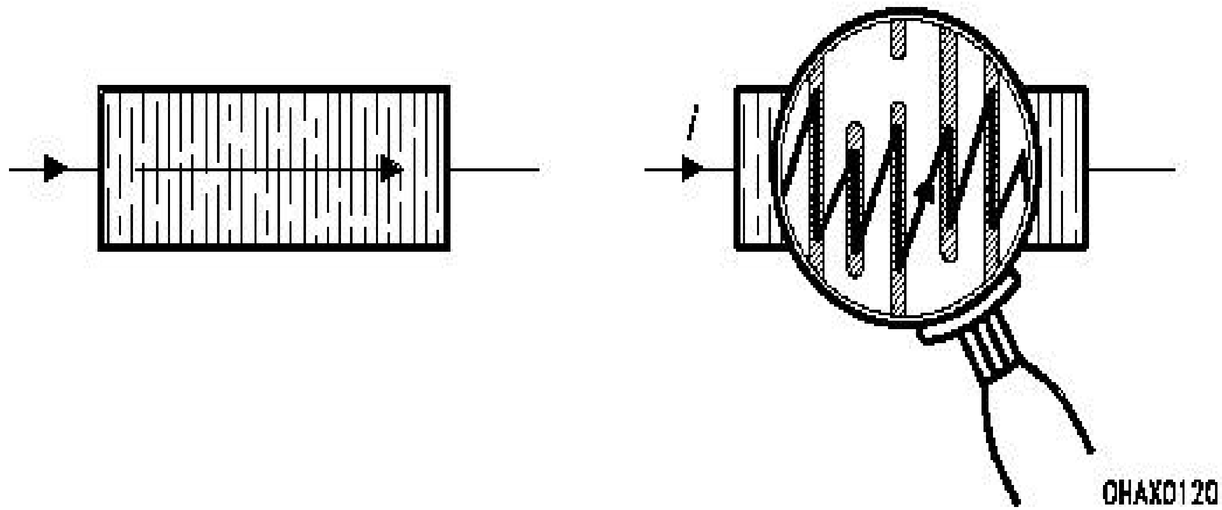
The control software *functionality* is defined by UKATC in the form of a 'C' code file, automatically produced by Matlab's Real Time Workshop, and an explanatory pseudo-code document and Simulink block diagram.

This 'C' code file will then be translated by LAM into DSP assembly code.

BSM Position Control Loop



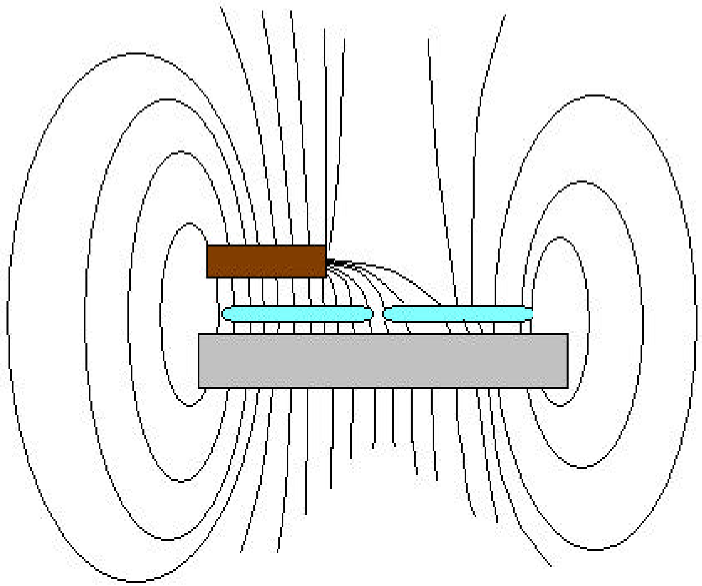
BSM Position Sensors (magneto-resistive)

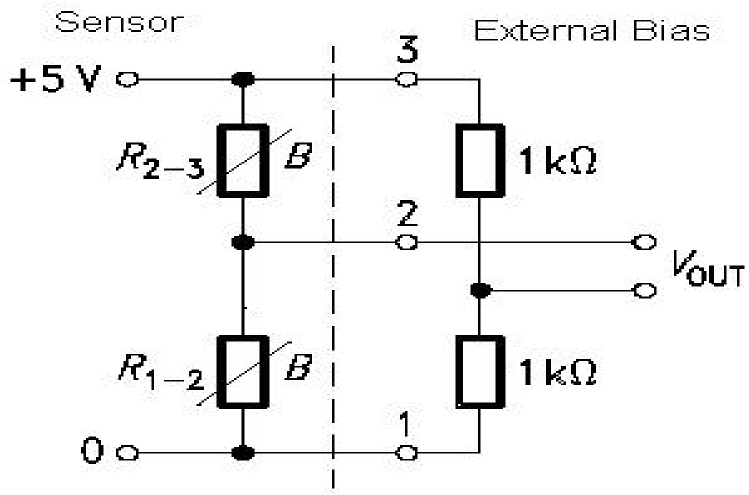


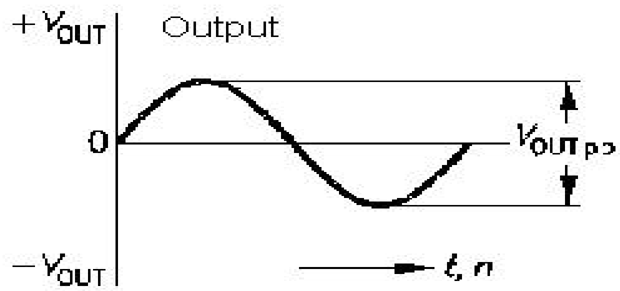
a) without magnetic field induction $B = 0$

b) with magnetic field induction $B \neq 0$ (about 1T)

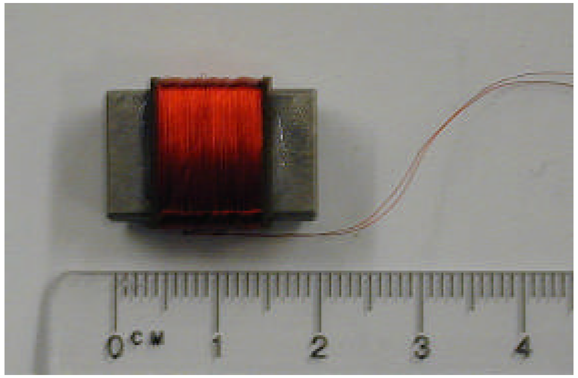
BSM Position Sensors







BSM Motors



The BSM motors comprise two flat rectangular coils and a small circular magnet between them.

It is based on an MPIA design for PACS, and will probably be manufactured by ZEISS.

The coils are made from high-purity copper (however aluminium would give lower power dissipation)

Warm electronics : Power Amplifiers

The motor power amplifier is driven via a D-A converter by the BSM software.

It takes the form of a voltage to current amplifier with a scale factor of about 10 mA/V, and a bandwidth of about 1000Hz.

The amplifier can operate over a wide range of motor resistance and is safe for a short-circuit.

EMC filtering is used on the current detector feedback line from the motor, as it is connected to the instrument harness.

It should be noted that high precision is not required in the power amplifier circuits, but definitely is required in the position sensor electronics.

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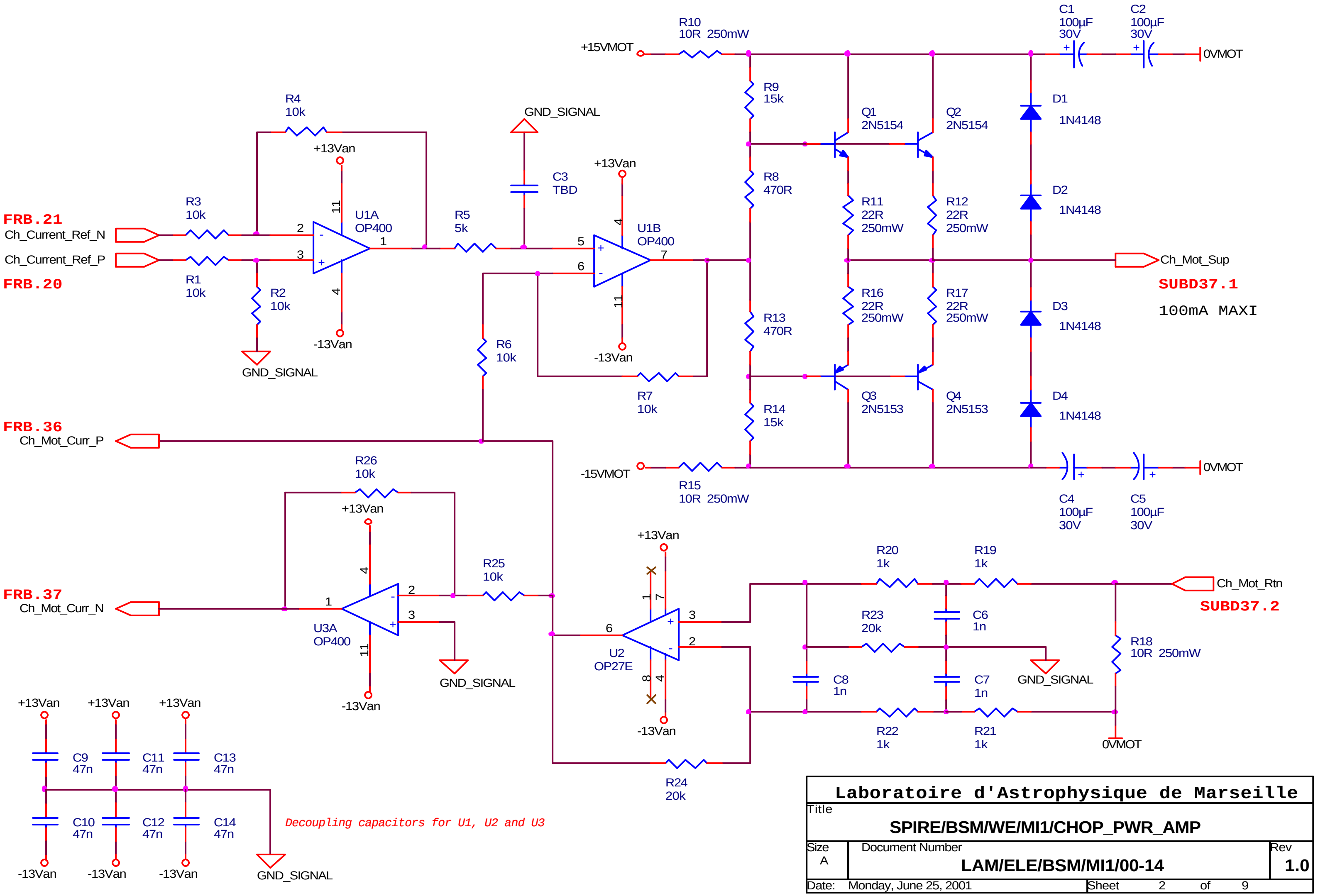
Warm electronics : Power Amplifiers (x2)



Warm electronics : Current sources (x2)

The BSM position sensor current sources employ precision voltage sources and voltage-to-current conversion stages, resulting in an extremely stable load current independent of load resistance changes, which occur with varying magnetic fields.

Also, the voltage sensing system used emulates a Wheatstone bridge arrangement, which has very low sensitivity to common changes between sensed voltage and applied voltage.

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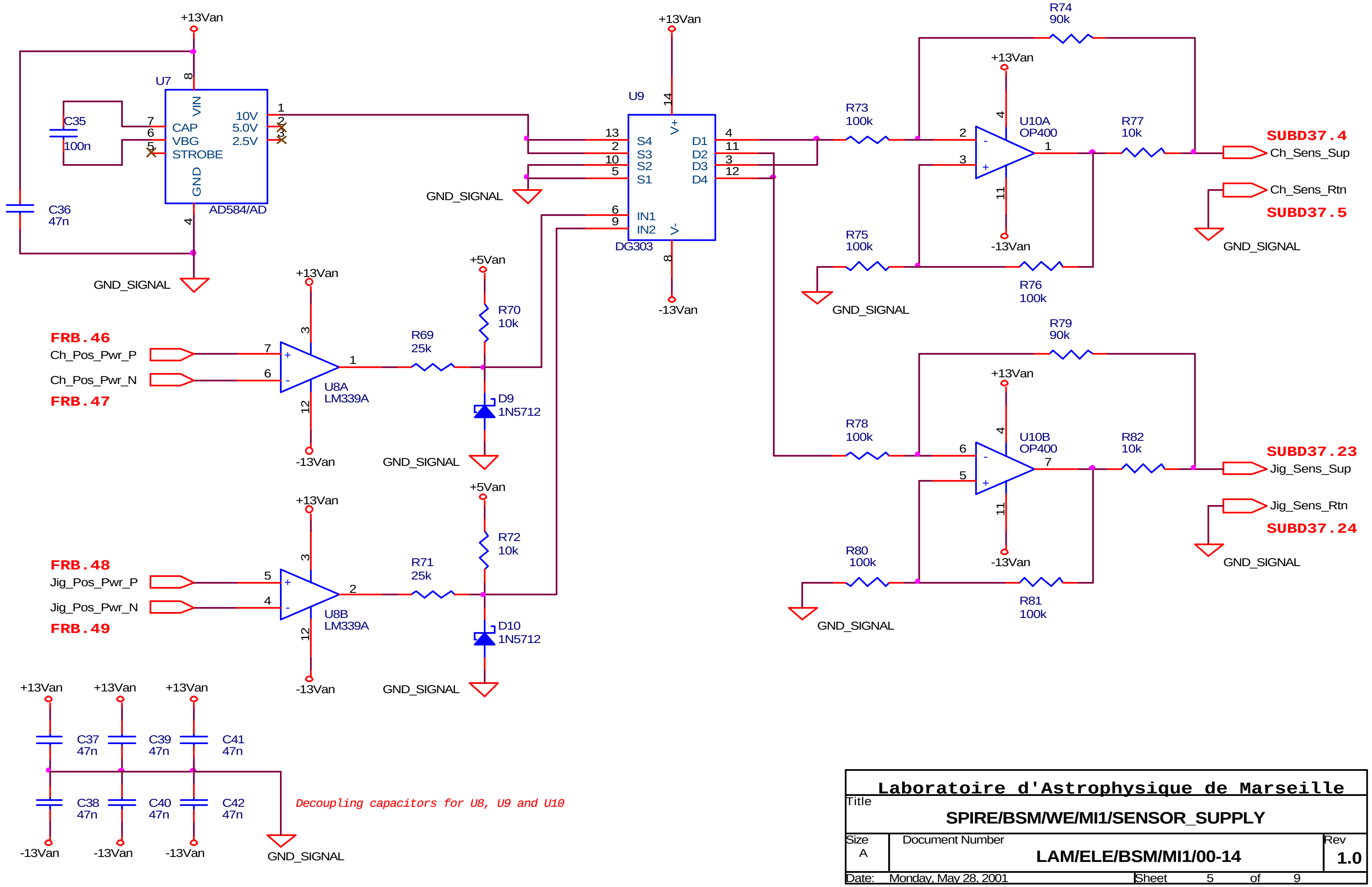
Warm electronics : Current sources

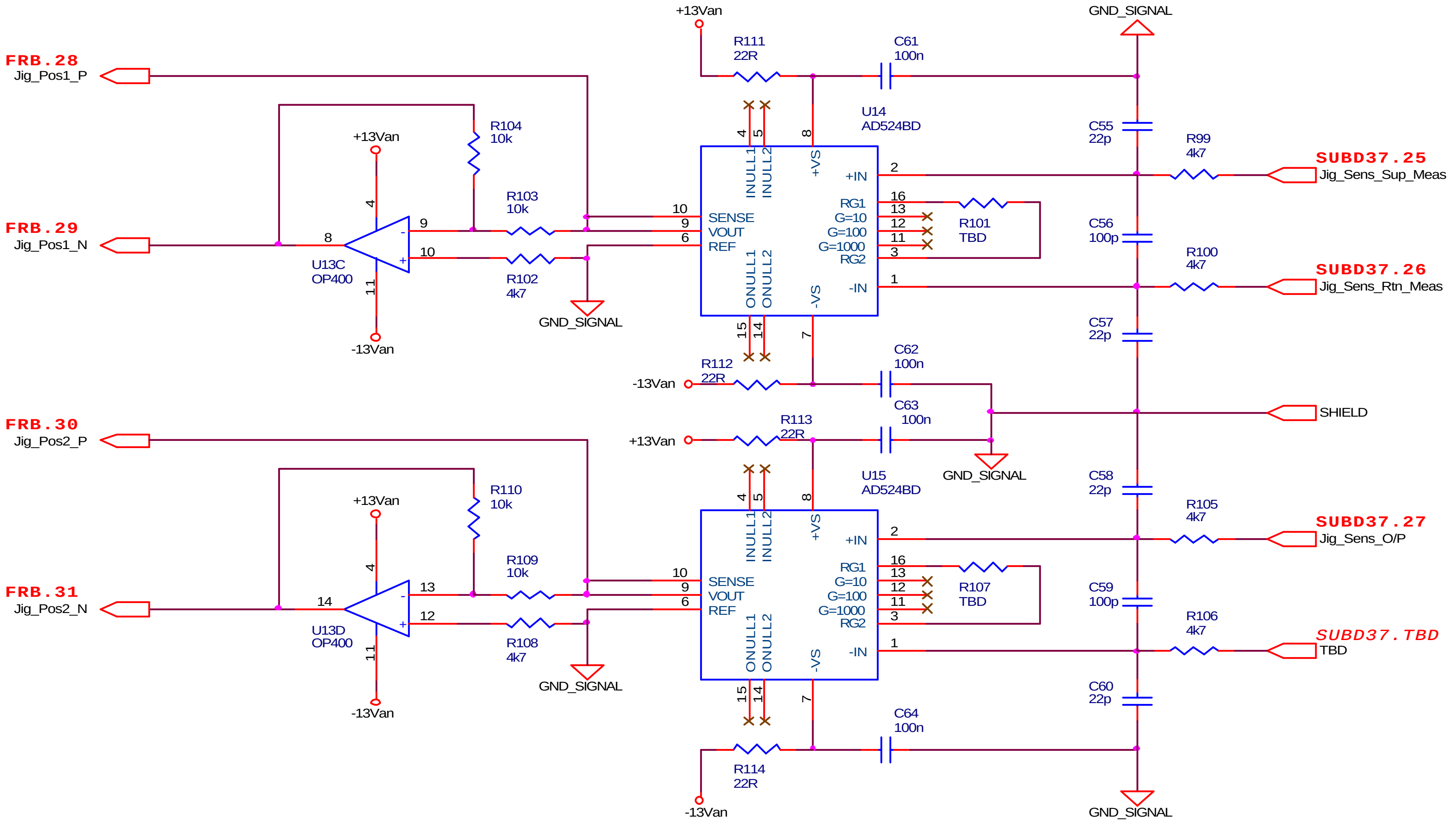


Warm electronics : Preamplifiers (x4)

The BSM position sensor preamplifiers use monolithic laser-trimmed instrumentation amplifiers (Analog Devices AD524) to reject common-mode noise, and output scaling amplifiers using OP400's with 0.1% 15ppm/deg.C resistors. EMC filtering on the input connections to the BSM position sensors minimise line noise from the wiring harness.

This arrangement ensures low-noise, low error transfer of the position sensor outputs to the control loop.

Warm electronics : Preamplifiers (x4)



Laboratoire d'Astrophysique de Marseille		
Title: SPIRE/BSM/WE/MI1/JIG_SENSOR_CONDITIONNER		
Size: A	Document Number: LAM/ELE/BSM/MI1/00-14	Rev: 1.0
Date: Monday, May 28, 2001	Sheet 7 of 9	

BSM Control Development Process

The BSM is being developed using the same development system as that used by LAM for their SMEC assembly, namely dSPACE.

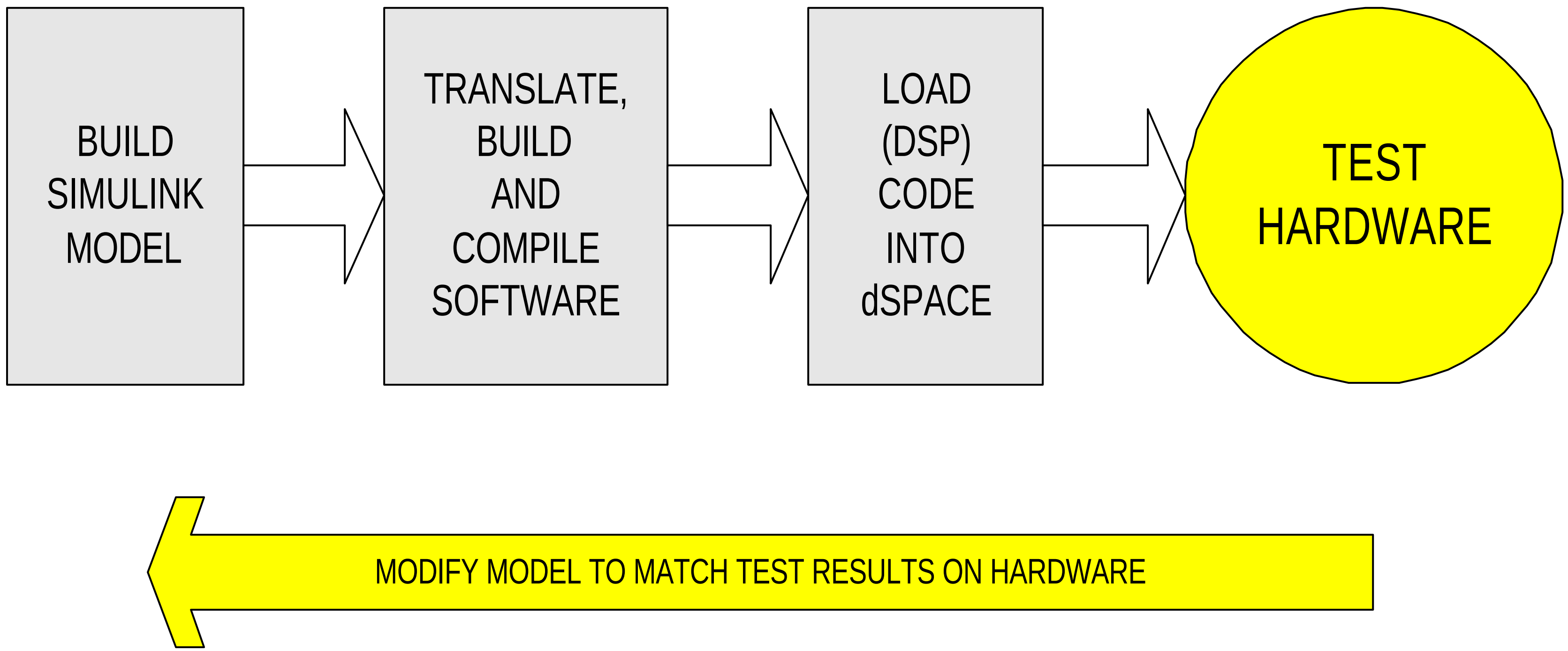
dSPACE allows a Matlab-Simulink model of the BSM control system to interface with the actual BSM hardware using A-D and D-A converters, thus allowing control system development.

The actual code used by dSPACE to verify operation is the same code supplied to LAM.

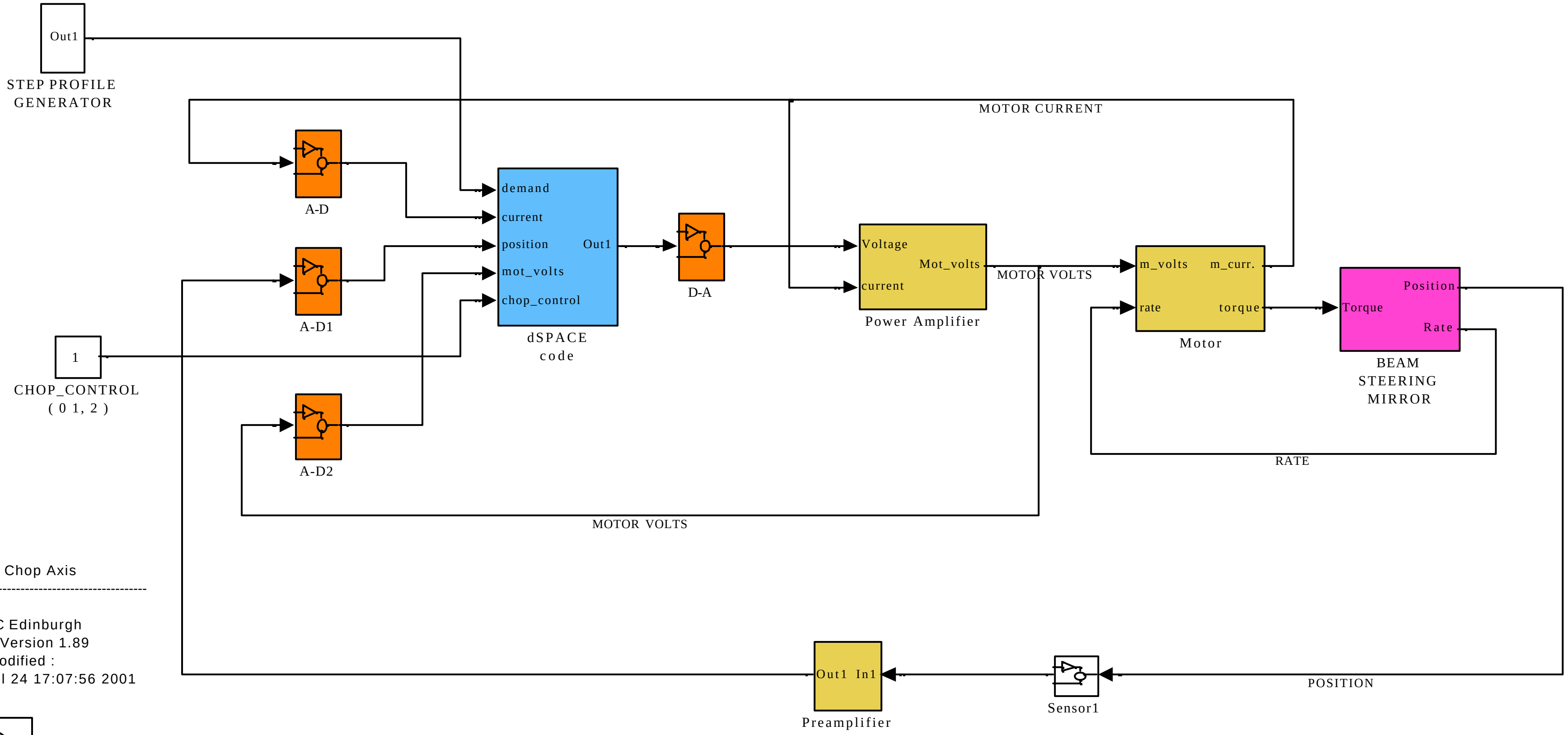
As the position sensor preamplifiers and motor power amplifiers are used with the BSM, these parts are verified also.

BSM Control Development Process

The BSM control software is primarily defined as
a 'C' code file produced as part of the development process :

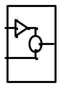


BSM Simulink Model - complete system

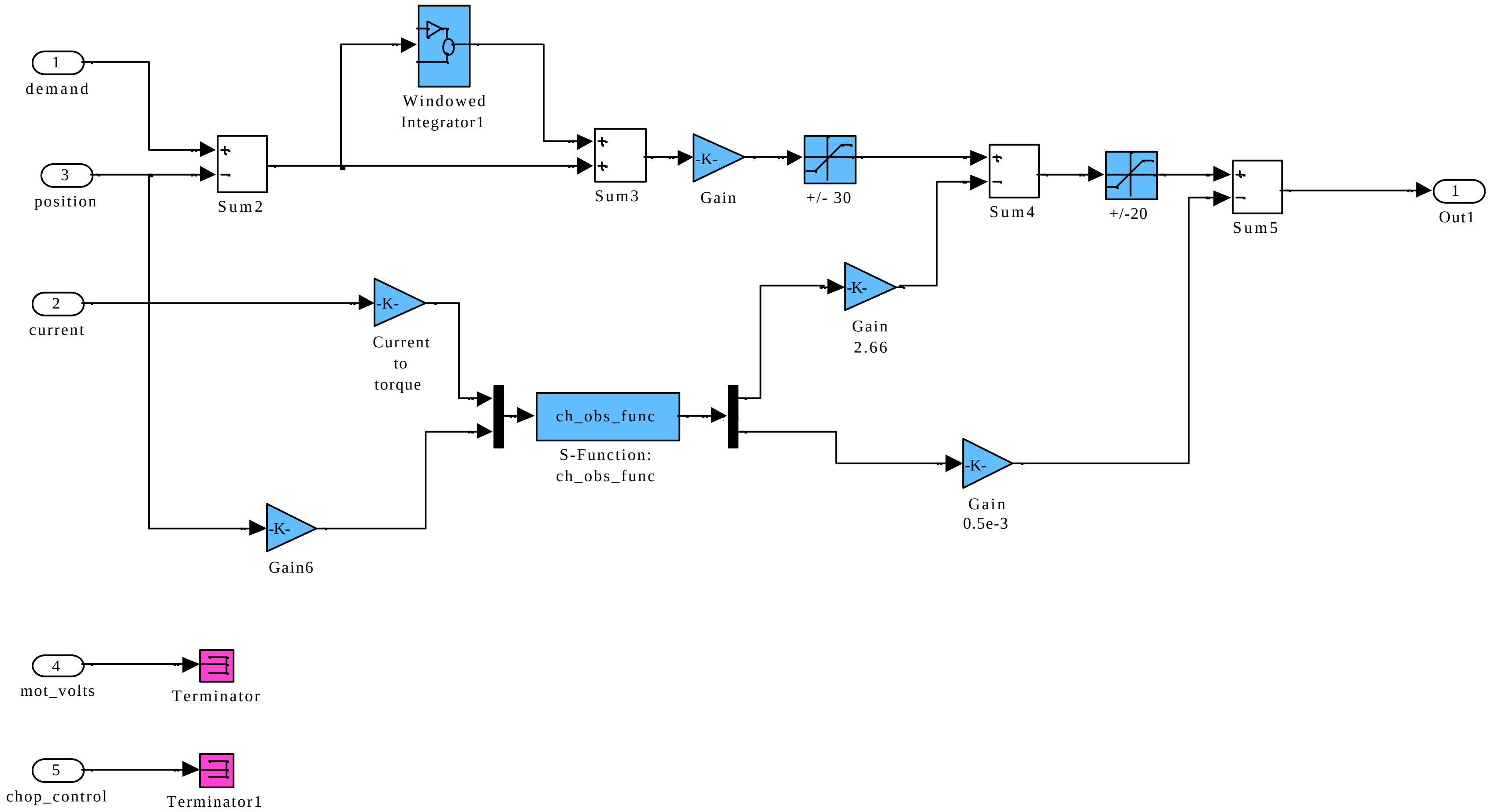


SPIRE Chop Axis

UKATC Edinburgh
Model Version 1.89
Last Modified :
Tue Jul 24 17:07:56 2001



BSM Simulink Model - for control code

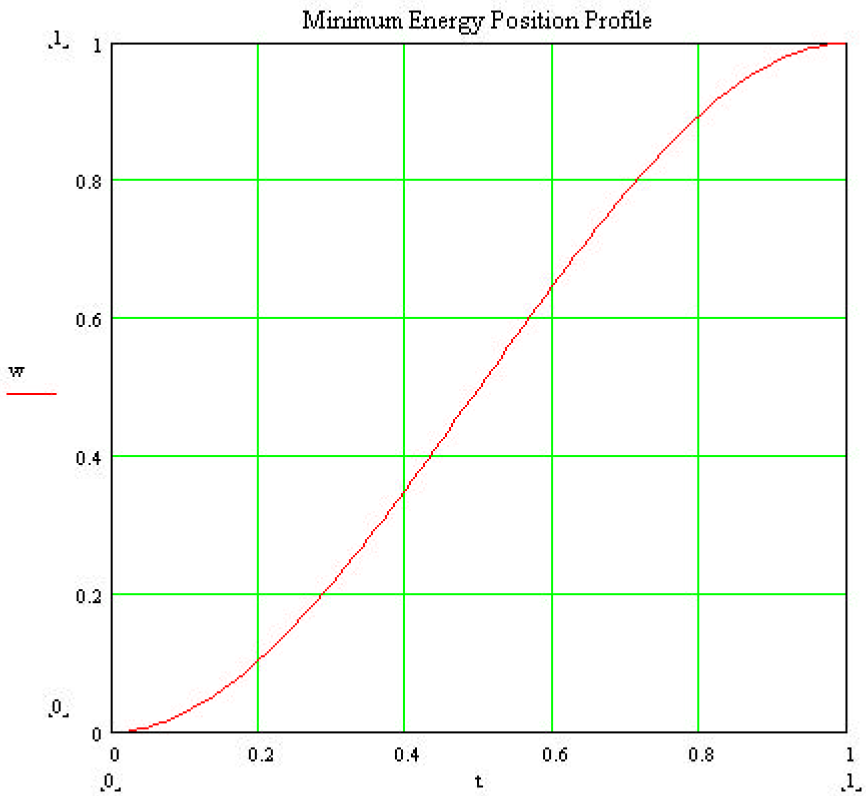


Control Software : Waveform Commands

A look-up table defines a sinusoidal step trajectory :

5.1.2.2 CHOP PROFILE TABLE

n	Prc(n)
1	0.0
2	0.013
3	0.05
4	0.109
5	0.188
6	0.283
7	0.389
8	0.5
9	0.611
10	0.717
11	0.812
12	0.891
13	0.95
14	0.987
15	1.0



Control Software (waveform profile pseudo-code)

```
FOR n = 1 to 15
BEGIN
        %   Generate discrete sine steps :
        Psc = Pc0 + (Pc1-Pc0)*Prc(n)
        FOR m = 1 to 10
        BEGIN
                %   Interpolate between steps :
                IF (n<15)
                THEN
                        %   Generate interpolations :
                        Pic = (Pc1-Pc0)*(Prc(n+1)-Prc(n))*m/10
                ELSE
                        %   Don't interpolate last discrete step :
                        Pic = 0
                END IF
                %   Calculate complete profile value for this step :
                Pdc = Psc + Pic
                %   ( Insert code to output 'Pdc' to mirror axis D-A converter )
                %  Re-set flag to allow another sequence if this is the last sequence value :
                IF ((m+n) = 25) THEN sequencer = FALSE
        END
END
```

Control Software Parameters

All control parameters can be modified in the event of a fault condition, for example a broken flex joint or missing position sensor, to give the maximum possible performance.

In addition, different control algorithms can be invoked to suit the detected fault, by means of software switches.

In the event a fault being detected, the control loop can be tested, and the measured performance data downloaded via the telemetry link to allow diagnosis. The existing Matlab-Simulink model will be essential for this diagnosis process.

Control Software Parameters

Parameter	Description	Value
prime	prime control scheme	0
broken_flex	control scheme for broken flex joint	1
no_sensor	control scheme for no position sensor	2
chop_control	Select control scheme	prime, broken_flex, no_sensor

Parameter	Description			
		Control Scheme Value		
		Prime	Broken Flex	No Pos. Sensor
Kt	motor torque const.	TBD	TBD	not used
ch_perr_gain	position loop gain	TBD	TBD	not used
ch_rat_gain	rate loop s.f.	TBD	TBD	TBD
ch_acc_gain	acceleration loop s.f.	TBD	TBD	not used
ch_acc_lim	acceleration limit	TBD	TBD	not used
ch_int_gain	integral gain	TBD	TBD	not used
ch_rat_lim	rate limit	TBD	TBD	not used
ch_int_th	integration threshold	TBD	TBD	not used
ch_obs_a1	state coefficient 1	TBD	TBD	not used
ch_obs_a2	state coefficient 2	TBD	TBD	not used
ch_obs_a3	state coefficient 3	TBD	TBD	not used
ch_obs_a4	state coefficient 4	TBD	TBD	not used
ch_obs_b1	input coefficient 1	TBD	TBD	not used
ch_obs_b2	input coefficient 2	TBD	TBD	not used
ch_obs_b3	input coefficient 3	TBD	TBD	not used
ch_obs_b4	input coefficient 4	TBD	TBD	not used
ch_obs_c1	output coefficient 1	TBD	TBD	not used
ch_obs_c2	output coefficient 2	TBD	TBD	not used
ch_obs_d3	output coefficient 3	TBD	TBD	not used
ch_obs_d4	output coefficient 4	TBD	TBD	not used
ch_pos_sf	position s.f.	not used	not used	TBD
ch_cur_sf	current s.f.	not used	not used	TBD
ch_curd_sf	current_dot s.f.	not used	not used	TBD
ch_ddif1	diff. filter coeff1	not used	not used	TBD
ch_ddif2	diff. filter coeff2	not used	not used	TBD

Control Software Diagnostic Data

Some control variables will be available for telemetry to aid diagnosis of specific faults :
(to be agreed with SPIRE Systems and LAM)

Measured Position (Chop, Jiggle)

Motor Current (Chop, Jiggle)

Axis Settled - to less than 0.02 deg.
(Chop,Jiggle)

Control Software Modes

The BSM will operate in specific operational 'Modes'

(to be agreed with SPIRE Systems and LAM)

1. OFF (launch latch and motor shorting active)

2. ON

2a. - POSITION (- Moving or Settled
at commanded position)

2b. - UPDATING (to modify control parameters)

2c. - DATA RECORDING for diagnostics

BSM Interfaces

The BSM has interfaces to its electronics and controlling software and the rest of SPIRE :

TO Hardware and Software built by L.A.M.:

- BSM to Warm Electronics via wiring harness
- Warm electronics design definition (document)
- Control Software definition (document, file)

To other parts of the instrument :

- Transfer of PCAL connections
- Mechanical (to structure and PCAL)
- Optical

BSM Interfaces

The BSM wiring is defined in the BSM Electrical Interface document. It specifies connections, wire types and screening requirements. The wiring is defined in the form of a table and a circuit diagram.

The wiring has also been agreed by the SPIRE systems group at Rutherford Appleton Laboratory (RAL) to allow parallel definition of the complete instrument harness wiring.

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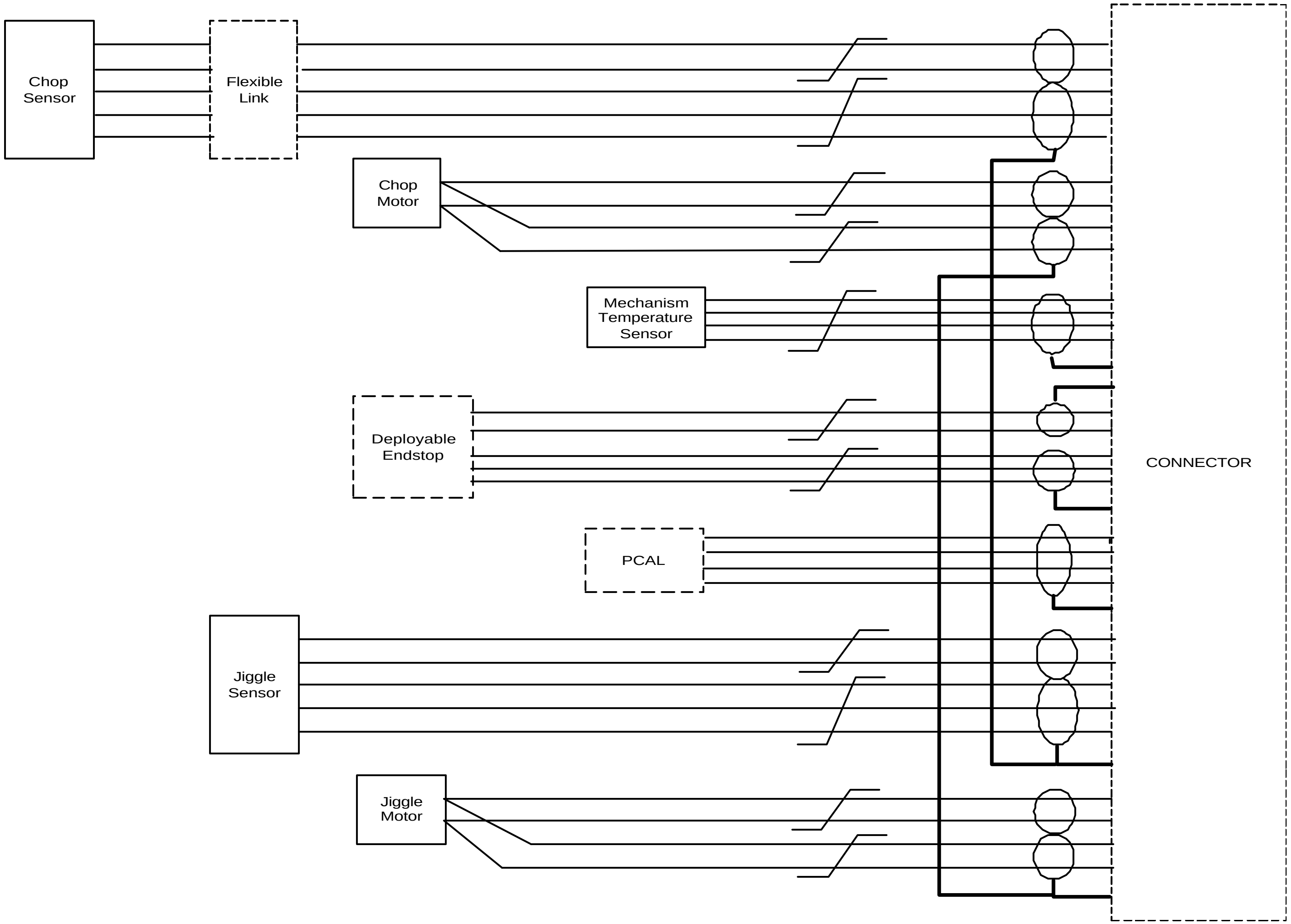
BSM wiring harness

Pin	Title	Max Voltage	Max Current	Wire Type /Comment
15	Chop motor supply	+/- 15 V	40 mA	STP(15,34)
34	Chop motor return	0V	40 mA	STP(15,34)
16	Chop motor supply sense	+/- 15 V	10 µA	STP(16,35)
35	Chop motor return sense	0V	10 µA	STP(16,35)
36	Jiggle motor supply	+/- 15 V	40 mA	STP(36,18)
18	Jiggle motor return	0V	40 mA	STP(36,18)
37	Jiggle motor supply sense	+/- 15 V	10 µA	STP(37,19)
19	Jiggle motor return sense	0V	10 µA	STP(37,19)
17	Motor screen	0V	0	Screen (commoned)
1	Chop sensor supply	0.4 V	1 mA	STP(1,20)
20	Chop sensor return	0V	1 mA	STP(1,20)
2	Chop sensor supply sense	0.4 V	10 µA	STT(2,3,21)
3	Chop sensor return sense	0V	10 µA	STT(2,3,21)
21	Chop sensor o/p	0.4V	10 µA	STT(2,3,21)
4	Jiggle sensor supply	0.4 V	1 mA	STP(4,23)
23	Jiggle sensor return	0V	1 mA	STP(4,23)
5	Jiggle sensor supply sense	0.4 V	10 µA	STT(5,6,24)
6	Jiggle sensor return sense	0V	10 µA	STT(5,6,24)
24	Jiggle sensor o/p	0.4V	10 µA	STT(5,6,24)
22	Sensor screen	0V	0	Screen (commoned)
7	Mechanism Thermometer 1	0V	2.5 nA	STQ(7,26,8,27)
26	Mechanism Thermometer 2	0V	2.5 nA	STQ(7,26,8,27)
8	Mechanism Thermometer 3	0V	2.5 nA	STQ(7,26,8,27)
27	Mechanism Thermometer 4	0V	2.5 nA	STQ(7,26,8,27)
25	Thermometer Screen	0V	0	Screen(7,26,8,27)
29	Deployable Endstop Engage	+28V	100 mA	STT(29,30,11)
30	Deployable Endstop Retract	+28V	100 mA	STT(29,30,11)
11	Deployable Endstop Common	0V	100 mA	STT(29,30,11)
12	Dep. Endstop Actuator Screen			Screen(29,30,11)
28	Deployable Endstop Sensor	5 V	10 mA	STP(28,10)
10	Deployable Endstop Sensor Return	0 V	10 mA	STP(28,10)
9	Deployable Endstop Sensor Screen	0 V	0	Screen(28,10)
31	PCAL 1	TBD	TBD	STQ(31,13,32,14)
13	PCAL 2	TBD	TBD	STQ(31,13,32,14)
32	PCAL 3	TBD	TBD	STQ(31,13,32,14)
14	PCAL 4	TBD	TBD	STQ(31,13,32,14)
33	PCAL Screen	0V	0	Screen(31,13,32,14)

BSM wiring harness



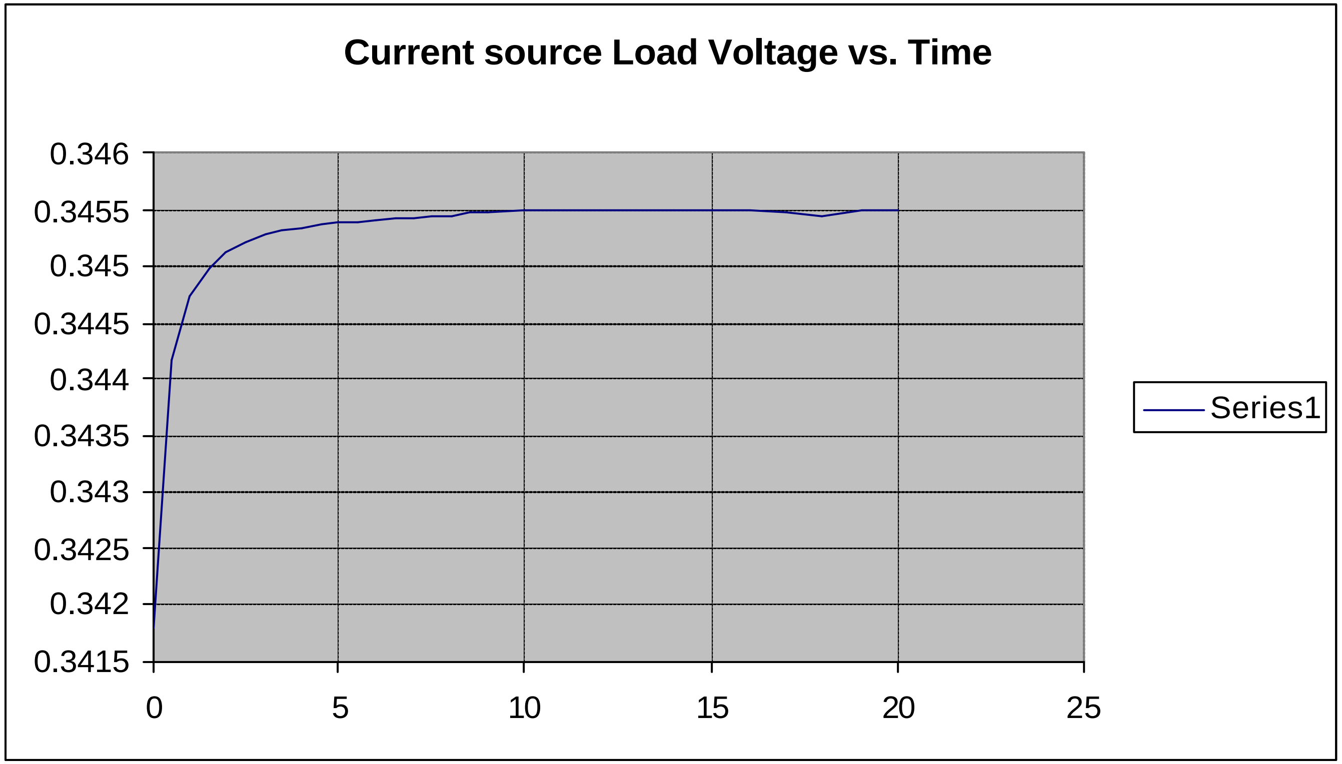
BSM Prototype Test Results (1)

The BSM motors, based on designs by the Max-Planck-Institut für Astronomie (MPIA), have been tested on the single-axis prototype, giving an average torque constant of 0.11Nm/A.

Volts	Current	TMA o/p	angle	Torque	Kt Nm/A	Kf N/A
5	0.002906977	655	5.00E-03	3.20E-04	0.109972917	6.47E+00
4	0.002325581	522	3.98E-03	2.55E-04	0.109553173	6.44E+00
3	0.001744186	390	2.97E-03	1.90E-04	0.109133429	6.42E+00
2	0.001162791	259	1.98E-03	1.26E-04	0.108713685	6.39E+00
1	0.000581395	130	9.91E-04	6.34E-05	0.109133429	6.42E+00
-1	-0.000581395	-132	-1.01E-03	-6.44E-05	0.110812405	6.52E+00
-2	-0.001162791	-265	-2.02E-03	-1.29E-04	0.111232149	6.54E+00
-3	-0.001744186	-398	-3.04E-03	-1.94E-04	0.111372064	6.55E+00
-4	-0.002325581	-532	-4.06E-03	-2.60E-04	0.111651893	6.57E+00
-5	-0.002906977	-662	-5.05E-03	-3.23E-04	0.1111482	6.54E+00

BSM Prototype Test Results (2)

The BSM current source has been tested, and shows high stability after an initial warm -up period (~5 min) :



BSM Prototype Test Results (3)

The BSM control loop Chop axis step response time has been verified with the single-axis prototype :