Technical Report

Subject:	JLab Q1 JSA-09-C1564 Instrumentation Design Summary Milestone D-13	Author:	PDD
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The Instrumentation design details provided in the JSA-09-C1564 contract documentation includes the following documents and descriptions for subcontractor supplied parts:

- Temperature sensors as defined in section 8.1 of the SHMS technical specification dated 14th July 2008 and wiring with pin outs defined on drawing 67125-E-00110.
- Strain Gauges for cold and warm support as defined in section 8.6 of the SHMS technical specification dated 14th July 2008 and wiring with pin outs defined on drawing 67125-E-00112.
- Voltage taps for magnet and current leads as defined in section 8.7 of the SHMS technical specification dated 14th July 2008 and wiring with pin outs defined on drawing 67125-E-00111 and overall schematic 67125-D-00113.

Each temperature and strain sensor has a duplicate redundant sensor to allow use of an alternative if the primary stops functioning.

Generally the sensor layout is understood by Scientific Magnetics and no changes would be proposed except those outlined in this document which require a response from JLab. There are several questions arising from review of the proposed instrumentation scheme before implementation directly which are summarised below as requested actions for JLab:

Temperature Sensors

- JLab to confirm they will furnish fully pre-wired 41 pin connector with flying lead to the CCR contractor who will use the appropriate leads, leaving the remaining flying leads for use by Scientific Magnetics when the CCR is delivered.

JLab to confirm that the sensor requirements in the wiring drawing 67125-E-00100 defines all the sensors that require supplying with the system and that all other sensors shown in 67304-E-00001 will not be required.

Strain gauge sensors:

- The original Q1 magnet was supplied with two single strain gauges on the support rods in single gauge configuration. The proposed scheme indicates 8 strain gauges in full bridge configuration. Discussion between JLab and Scientific Magnetics is required to determine if the proposed scheme can be realised.

Recommendations for voltage taps

- JLab to confirm they will furnish fully pre-wired 41 pin connector with flying lead to the CCR contractor who will use the appropriate leads, leaving the remaining flying leads for use by Scientific Magnetics when the CCR is delivered.

Temperature Sensors Ref 67125-E-00110

PT100 temperature sensors:

We propose to use our standard PT100 sensor which conforms with IEC751 class B which is equivalent to the required DIN 43760 (Class B). A data sheet is attached in Appendix 1 for information. It has successfully been used on superconducting magnet systems for measurement of temperatures above 10K (with the use of a suitable calibration curve).

It is noted that these sensors have been configured in three wire mode, mainly due to the lack of pins on the CCR connectors.

Carbon Sensors:

We propose to use our standard carbon-ceramic sensor TVO type D2 which is 3 point calibrated, a calibration curve to interpolate between these 3 points will be provided. A data sheet on this sensor is attached in Appendix 2 for information:

The responsibility for PT100 and Carbon temperature sensor wiring is shown in the following four tables

Primary Sensors as defined in 67125-E-00110

Sensor ID	Location	Connector	Pins	Fit and Wiring Responsibility
CG-1 T_Coil_1	Magnet coil 1	A	1,2,3,4	Scientific Magnetics
CG-2 T_Coil_2	Magnet coil 2	A	5,6,7,8	Scientific Magnetics
CG_3 T_Coil_3	Magnet coil 3	A	9,10,11,12	Scientific Magnetics
CG_4 T_Coil_4	Magnet coil 4	A	13,14,15,16	Scientific Magnetics
CG_5 T_CL_N_C	Current lead negative in CCR	A	17,18,19,20	CCR Contractor
CG_6 T_CL_P_C	Current Lead positive in CCR	A	21,22,23,24	CCR Contractor
PT102-1 PT_Yoke_1	Yoke	A	25,26,27,28	Scientific Magnetics
PT102-2 PT_Yoke_2	Yoke	A	29,30,31,32	Scientific Magnetics
PT102-3 PT_Yoke_3	Yoke	A	33,34,35,36	Scientific Magnetics
PT102-4 PT_Yoke_4	Yoke	A	37,38,39,40	Scientific Magnetics

Redundant Sensors as defined in 67125-E-00110

Sensor ID	Location	Connector	Pins	Fit and Wiring Responsibility
CG-1_R T_Coil_1	Magnet coil 1	AR	1,2,3,4	Scientific Magnetics
CG-2-R T_Coil_2	Magnet coil 2	AR	5,6,7,8	Scientific Magnetics
CG_3-R T_Coil_3	Magnet coil 3	AR	9,10,11,12	Scientific Magnetics
CG_4-R T_Coil_4	Magnet coil 4	AR	13,14,15,16	Scientific Magnetics
CG_5-R T_CL_N_C	Current lead negative in CCR	AR	17,18,19,20	CCR Contractor
CG_6-R T_CL_P_C	Current Lead positive in CCR	AR	21,22,23,24	CCR Contractor
PT102-1-R PT_Yoke_1	Yoke	AR	25,26,27	Scientific Magnetics
PT102-2-R PT_Yoke_2	Yoke	AR	28,29,30	Scientific Magnetics
PT102-3-R PT_Yoke_3	Yoke	AR	31,32,33	Scientific Magnetics
PT102-4-R PT_Yoke_4	Yoke	AR	34,35,36	Scientific Magnetics

Primary Sensors as defined in 67125-E-00110

Sensor ID	Location	Connector	Pins	Fit and Wiring Responsibility
PT102_5 PT_N2_IN	Nitrogen feed line	B	1,2,3	CCR Contractor
PT102_6 PT_N2_OUTER_TOP	Magnet outer nitrogen shield top	B	4,5,6	Scientific Magnetics
PT102_7 PT_N2_OUTER_BOTTOM	Magnet outer nitrogen shield bottom	B	7,8,9	Scientific Magnetics
PT102_8 PT_N2_BORE_TOP	Magnet bore nitrogen shield top	B	10,11,12	Scientific Magnetics
PT102_9 PT_N2_BORE_BOTTOM	Magnet bore nitrogen shield bottom	B	13,14,15	Scientific Magnetics
PT102_10 PT_N2_RETURN	Nitrogen return line	B	16,17,18	CCR Contractor
DIODE-1 TD_HE_COOLDOWN	He pipework	B	19,20,21,22	CCR Contractor
DIODE-2 TD_HE_SUPPLY	He pipework	B	23,24,25,26	CCR Contractor
DIODE-3 TD_HE_COLD_RETURN	He pipework	B	27,28,29,30	CCR Contractor
DIODE-4 TD_HE_WARM_RETURN	He pipework	B	31,32,33,34	CCR Contractor
CG_7 T_HE_RESV	Helium reservoir	B	35,36,37,38	CCR Contractor

Redundant Sensors as defined in 67125-E-00110

Sensor ID	Location	Connector	Pins	Fit and Wiring Responsibility
PT102_5_R PT_N2_IN	Nitrogen feed line	BR	1,2,3	CCR Contractor
PT102_6_R PT_N2_OUTER_TOP	Magnet outer nitrogen shield top	BR	4,5,6	Scientific Magnetics
PT102_7_R PT_N2_OUTER_BOTTOM	Magnet outer nitrogen shield bottom	BR	7,8,9	Scientific Magnetics
PT102_8_R PT_N2_BORE_TOP	Magnet bore nitrogen shield top	BR	10,11,12	Scientific Magnetics
PT102_9_R PT_N2_BORE_BOTTOM	Magnet bore nitrogen shield bottom	BR	13,14,15	Scientific Magnetics
PT102_10_R PT_N2_RETURN	Nitrogen return line	BR	16,17,18	CCR Contractor
DIODE-1_R TD_HE_COOLDOWN	He pipework	BR	19,20,21,22	CCR Contractor
DIODE-2_R TD_HE_SUPPLY	He pipework	BR	23,24,25,26	CCR Contractor
DIODE-3_R TD_HE_COLD_RETURN	He pipework	BR	27,28,29,30	CCR Contractor
DIODE-4_R TD_HE_WARM_RETURN	He pipework	BR	31,32,33,34	CCR Contractor
CG-7_R T_HE_RESV	Helium reservoir	BR	35,36,37,38	CCR Contractor

Recommendations for Temperature Sensors

For connectors A, AR, B and BR there is a mix of responsibility for wiring the connector, and the pins to be used by the CCR contractor and Scientific Magnetics are not separated by pin such that it is highly likely that the current configuration will be damaged during the two step wiring operation because the pin selection is not aligned to the construction by two separate contractors.

In order to prevent this it is proposed that JLab consider the following:

- Provide separate connectors for use by CCR contractor and Scientific Magnetics – this will require more pins for the Scientific Magnetics connections.

- JLab furnish a completely pre-wired plug to the CCR contractor with sufficient flying lead that both the CCR contractor and Scientific Magnetics can join their sensors to the wires, by use of a connector or soldered joint in the relevant vacuum space as appropriate. For avoidance of doubt this means the CCR contractor will use the JLab furnished pre wired 41 way connector to attach its sensors via appropriate pins, leaving the remaining flying leads accessible in the CCR base so that Scientific Magnetics can use the assigned leads for wiring its sensors later. This avoids any possibility of damaging leads already connected to the 41 way connector. This is the preferred option as it does not require any re-configuration of pins or re-design of the instrumentation schematics.
- Re assign the existing connectors and wiring so that there is one for the CCR contractor and one for Scientific Magnetics, but with one less sensor so that there are enough pins on the connector.

Note: Temperature sensor labels on the assembly drawings, instrumentation schematic and pin wiring appear to have inconsistent quantities of sensors and locations. Scientific Magnetics will assume that the wiring drawing 67125-E-00100 defines all the sensors that require supplying with the system and that all other sensors shown in 67304-E-00001 will not be required.

Strain Gauges Ref 67125-E-00012

Strain gauge sensors:

The original Q1 magnet was supplied with single strain gauges on the support rods. These were attached as single element gauges and made into either a half or full bridge externally to the system. There were only two wires on each gauge occupying two pins on each four pin connector. 67125-E-00012 shows that there is a full bridge configuration on the rods using four pins per gauge using two element strain gauge rosettes CEA-06-125UT-350, terminating in an eight pin connector.

Recommendations for strain gauges

It is recommended that the strain gauge instrumentation be reviewed between JLab and Scientific Magnetics as soon as possible as the configuration described in 67125-E-00012 is not self consistent.

Voltage Taps Ref 67125-E-00111 and 67125-D-00113

Voltage taps and the responsibility for making them are shown in the following tables

Flying cable

Pot Tap ID	Location	Connector	Pins	Fit and Wiring Responsibility
POT TAP I+U	+ current lead top	N/A	N/A	CCR Contractor
POT TAP I-U	- current lead top	N/A	N/A	CCR Contractor
POT TAP I+U_R	Magnet outer nitrogen shield bottom	N/A	N/A	CCR Contractor
POT TAP I-U_R	Magnet bore nitrogen shield top	N/A	N/A	CCR Contractor

41 pin connector – Primary pot taps

Pot Tap ID	Location	Connector	Pins	Fit and Wiring Responsibility
POT TAP I+M1	+ current lead lap joint in CCR top	Pot Tap	1	CCR Contractor
POT TAP I+M2	+ current lead lap joint in CCR bottom	Pot Tap	2	CCR Contractor
POT TAP I+L1	+ current lead lap joint in interface top	Pot Tap	3	Scientific Magnetics
POT TAP I+L2	+ current lead lap joint in interface bottom / coil 1 start	Pot Tap	4	Scientific Magnetics
POT TAP 1/1B	Coil 1 end/ coil 2 start	Pot Tap	5	Scientific Magnetics
POT TAP 2/1A	Coil 1 end / Coil 2 start	Pot Tap	6	Scientific Magnetics
POT TAP 2/1B	Coil 2 end / Coil 3 start	Pot Tap	7	Scientific Magnetics
POT TAP 3/1A	Coil 2 end / Coil 3 start	Pot Tap	8	Scientific Magnetics
POT TAP 3/1B	Coil 3 end / Coil 4 start	Pot Tap	9	Scientific Magnetics
POT TAP 4/1A	Coil 3 end / Coil 4 start	Pot Tap	10	Scientific Magnetics
POT TAP I-L2	- current lead lap joint in interface bottom / coil 4 end	Pot Tap	11	Scientific Magnetics
POT TAP I-L1	- current lead lap joint in interface top	Pot Tap	12	Scientific Magnetics
POT TAP I-M2	- current lead lap joint in CCR top	Pot Tap	13	CCR Contractor
POT TAP I-M1	+-current lead lap joint in CCR bottom	Pot Tap	14	CCR Contractor

41 pin connector – Redundant pot taps

Pot Tap ID	Location	Connector	Pins	Fit and Wiring Responsibility
POT TAP I+M1_R	+ current lead lap joint in CCR top	Pot Tap	15	CCR Contractor
POT TAP I+M2_R	+ current lead lap joint in CCR bottom	Pot Tap	16	CCR Contractor
POT TAP I+L1_R	+ current lead lap joint in interface top	Pot Tap	17	Scientific Magnetics
POT TAP I+L2_R	+ current lead lap joint in interface bottom / coil 1 start	Pot Tap	18	Scientific Magnetics
POT TAP 1/1B_R	Coil 1 end/ coil 2 start	Pot Tap	19	Scientific Magnetics
POT TAP 2/1A_R	Coil 1 end / Coil 2 start	Pot Tap	20	Scientific Magnetics
POT TAP 2/1B_R	Coil 2 end / Coil 3 start	Pot Tap	21	Scientific Magnetics
POT TAP 3/1A_R	Coil 2 end / Coil 3 start	Pot Tap	22	Scientific Magnetics
POT TAP 3/1B_R	Coil 3 end / Coil 4 start	Pot Tap	23	Scientific Magnetics
POT TAP 4/1A_R	Coil 3 end / Coil 4 start	Pot Tap	24	Scientific Magnetics
POT TAP I-L2_R	- current lead lap joint in interface bottom / coil 4 end	Pot Tap	25	Scientific Magnetics
POT TAP I-L1_R	- current lead lap joint in interface top	Pot Tap	26	Scientific Magnetics
POT TAP I-M2_R	- current lead lap joint in CCR top	Pot Tap	27	CCR Contractor
POT TAP I-M1_R	+-current lead lap joint in CCR bottom	Pot Tap	28	CCR Contractor

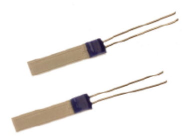
Recommendations for voltage taps

For this connector there is a mix of responsibility for wiring the connector, and the pins to be used by the CCR contractor and Scientific Magnetics are not separated by pin such that it is highly likely that the current configuration will be damaged during the two step wiring operation because the pin selection is not aligned to the construction by two separate contractors. In order to prevent this it is proposed that JLab consider the following:

- JLab furnish a completely pre-wired plug to the CCR contractor with sufficient flying lead that both the CCR contractor and Scientific Magnetics can join their voltage taps to the wires, by use of a connector or soldered joint in the relevant helium space as appropriate.

- **Appendix 1 – PT100 Sensor data sheet**

Platinum Resistance Thermometry



Platinum Resistance Thermometers (PRT), constructed using thin film element

The sensor is platinum layered, laser trimmed and sits on a ceramic substrate, ideal for gas and surface measurements, giving rapid response due to low mass and good thermal transfer.

Pt100 Element, Thin Film Type (100 Ohm)

- Conforms to IEC751 Class B
- −50°C to +550°C temperature measurement range
- 10mm tails
- Ideal solution for surface mounting measurement applications
- Immersion applications where protected
- Fast response times
- Good vibration resistance
- Long-term stability

Specifications of element

Temperature range	−50°C to +550°C
Ice point resistance	100Ω
Fundamental interval (0°C to 100°C)	38.5Ω nom.
Self heating	0.005°C/mW
Thermal response	0.1s
Stability	±0.05%

Dimensions & Class	**RS Stock No**
Dimensions L x W x H 2 x 5 x 1.1mm Class B	290-5070

RS Data 290-5070 12.11-08 GC

Appendix 2 – TVO Carbon ceramic sensor data sheet

MODEL TMi-A1 CCS

CCS Carbon-Ceramic Resistor

The Series TMi-A1 CCS, from the TVO family of resistors, is based on a carbon-ceramic composite construction which adheres to a single resistance verses temperature curve. They offer excellent performance and stability characteristics in magnetic field and high dose radiation environments. TMi-CCS resistors have little magneto-resistance in fields up to 6T over their range. No orientation dependence of resistor mounting relative to the magnetic field has been observed. TMi-CCS resistors are available in calibrated, sorted and un-calibrated forms featuring fast response times, excellent repeatability and high mechanical, thermal and radiation stability - all at reasonable cost.

CCS-A1 Specifications

Useful Temperature Range
1.5K - 375K

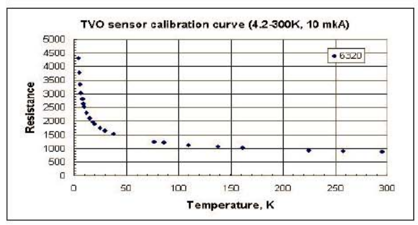
Maximum Operating Temperature
450K

Nominal Resistivity (typical)
4363 Ω @ 4.2K
1900 Ω @ 20K
1238 Ω @ 77K
1156 Ω @ 100K
850 Ω @ 295K

Key Product Features
- excellent long-term stability (< 0.015K/15yr)
- thermal response < 1mS @ 4.2K
- high sensitivity 1000-1500 Ω/K @ 4.2K
- low magnetic field error <1% for B<6T
- low neutron-radiation error <1% for $F<10^{17} n/m^2$
- superior mechanical stability

Typical Sensitivity R/T (Ohm/K)

K / Ohm	300	250	200	150	100	77	30	20	10	4,2
$R_{4,2}$=6300	1	1,25	1,7	2,5	4	6	25	50	180	1135
$R_{4,2}$=5700	0,85	1,1	1,5	2,4	3,8	6	20	40	165	1005
$R_{4,2}$=4500	0,83	1	1,5	2,3	3,7	5	20	35	120	620
$R_{4,2}$=3500	0,6	0,8	1	1,4	2,5	3,5	15	25	75	390



Standard Configuration
Special glass coated carbon-ceramic matrix approximately 2mm x 8mm x 1mm (deep)

Available Models

Band	Temp. Range	Ω @4.2k	Sensitivity (Ω/K)	Status
A1	1.5K - 375k	4000 - 5000	1000 - 1500	calibrated
A2	1.5K – 375k	3000 - 4000	600 - 1000	calibrated
B1	2.5K – 375k	3500 - 4000	800 - 1200	calibrated
B2	2.5K – 375k	2800 - 3500	500 - 800	calibrated
C1	4.2K – 375k	3500 - 4000	800 - 1200	calibrated
C2	4.2K – 375k	2800 - 3500	500 - 800	calibrated
D1	1.5K – 375k	4000 - 6000		selected
D2	4.2K – 375k	2600 - 4000		selected

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