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PEM Data Acquisition Preliminary Design

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PEM DAS DRR Committee

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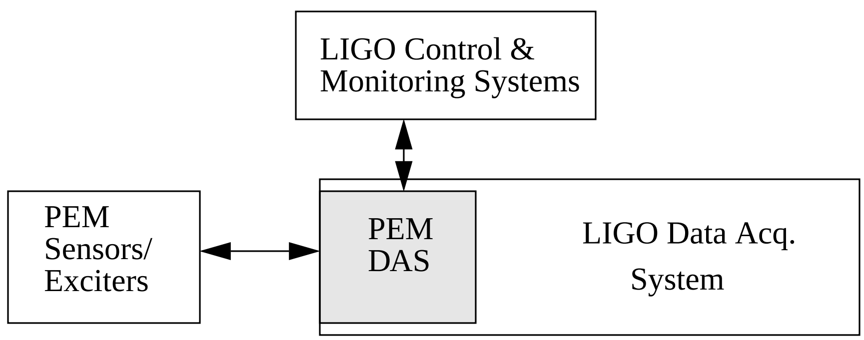
1 INTRODUCTION

1.1. Purpose

The purpose of this document is to describe the preliminary design for the Physical Environment Monitoring (PEM) Data Acquisition System (DAS).

1.2. Scope

In the overall design of LIGO systems, the PEM DAS is an integral part of the LIGO data acquisition (DAQ) system. Therefore, the scope of the PEM DAS is that portion of the LIGO DAQ system which directly interfaces to PEM system devices. The overall design of the LIGO DAQ is described in LIGO Data Acquisition System Preliminary Design (LIGO-T970136-00-C). This document describes all of the components of the LIGO DAQ, hardware and software, which will also be used for the PEM DAS portion as well. Therefore, the scope of this document is limited to provide information on how the PEM system devices are to be interfaced into the LIGO DAQ and the components the LIGO CDS group will provide for this purpose.



1.3. Document Organization

The document is organized as follows:

- Section 2.0 provides a description of each PEM device or system and how it will be connected to the PEM DAS system. The typical connection of devices is described and any special considerations for devices mounted on the PEM moveable cart or inside the BTE are described.
- Section 3.0 provides a description of the initial PEM moveable cart and the devices mounted on the cart will be connected to the PEM DAS system.
- Section 4.0 provides a description of the overall system architecture, along with communications which are specific to the PEM DAS.

1.4. Acronyms

- ADC- Analog to Digital Converter
- BSC- Beam Splitter Chamber
- BTE- Beam Tube Enclosure
- CDS- Control and Data System
- CPU- Central Processing Unit
- DAQ- LIGO CDS Data Acquisition
- EPICS- Experimental Physics Industrial Control System
- F/O- Fiber Optic
- GPIB- General Purpose Interface Bus
- GPS- Global Positioning System
- HAM- Horizontal Access Module
- LA- Louisiana Site
- LIGO- Laser Interferometer Gravitational-wave Observatory
- LPF- Low Pass Filter
- LVEA- Laser Vacuum and Equipment Area
- OSB- Operations Support Building
- PEM- Physical and Environmental Monitoring
- RCVR- Receiver
- RFI- Radio Frequency Interference
- RGA- Residual Gas Analyzer
- RMS- Root Mean Squared
- TBD- To Be Determined
- VEA- Vacuum Equipment Area
- XMTR- Transmitter
- WA- Washington Site

2 DESCRIPTION OF PEM DEVICES AND CONNECTION TO PEM DAS

The various instruments that are used by the PEM system are specified and developed by others and described in detail in PEM System Final Design LIGO-T970112-00-D. It will be the function of the PEM DAS to interface to these instruments and provide the functionality that is required. Physical placement locations for these devices are shown in PEM Sensor Locations, LIGO-D970210-00-H. An overview of the sensor locations and quantities, by building, to be interfaced into the PEM DAS is shown in Figure 1: Placement of “Fixed” PEM Sensors (WA site). The subsections that follow detail each of the devices and their connection to the PEM DAS system.

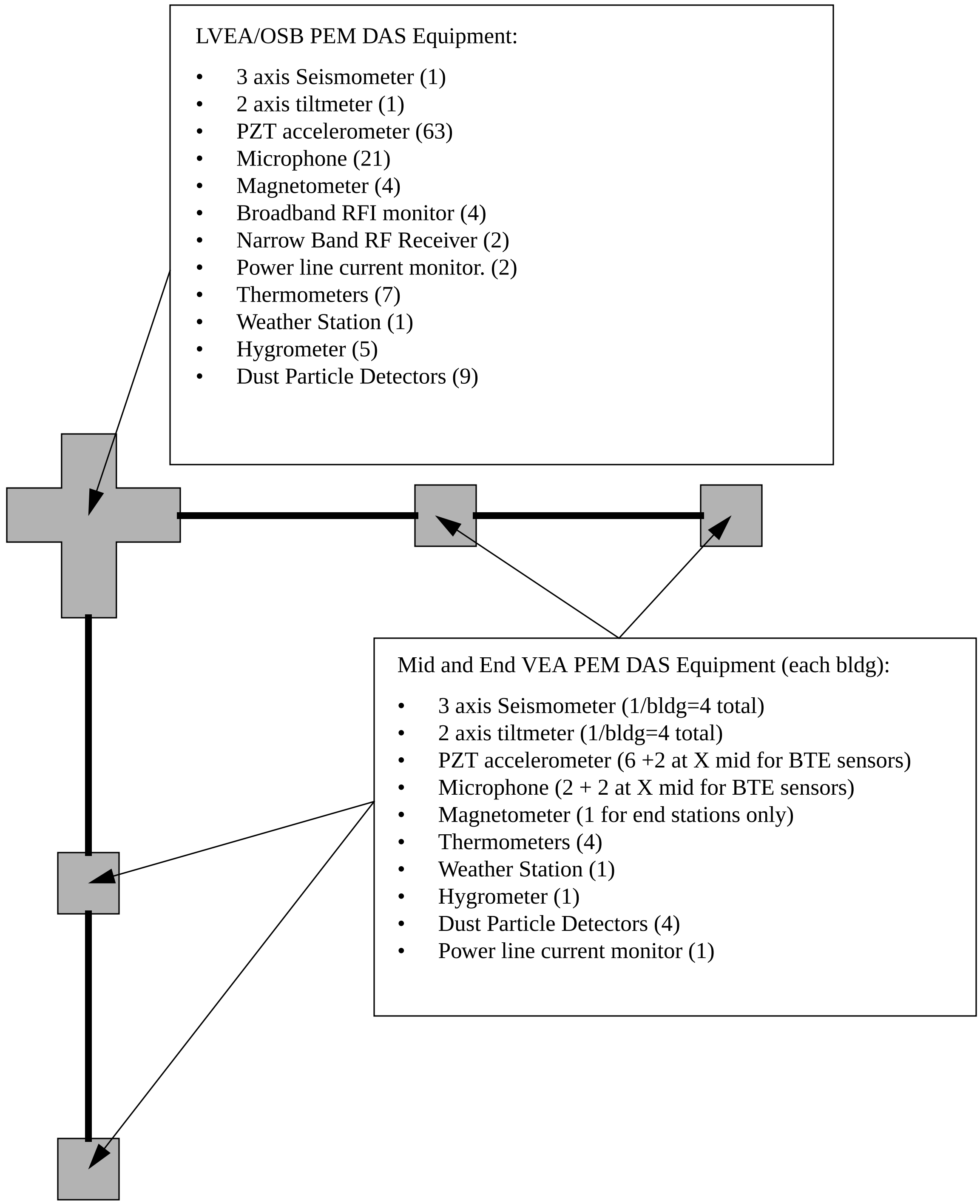


Figure 1: Placement of "Fixed" PEM Sensors (WA site)

2.1. Low Frequency 3 Axis Seismometer

The three axis low frequency seismometers used by the PEM system are Guralp model CMG-40T with attached model CMG-DM16 digitizer modules. The specifications for the seismometers are summarized in the table below.

Table 1: Summary of 3 Axis Seismometer Specifications

Voltage Range	*Resolution*	*Sample Rate*
RS232 communications	16 bits	32 samples per second per axis

The interface to the digitizer module is via RS232 with TBD protocol. The figure below shows how the seismometer will be connected to the PEM DAS. Equipment in the shaded region is provided by CDS.

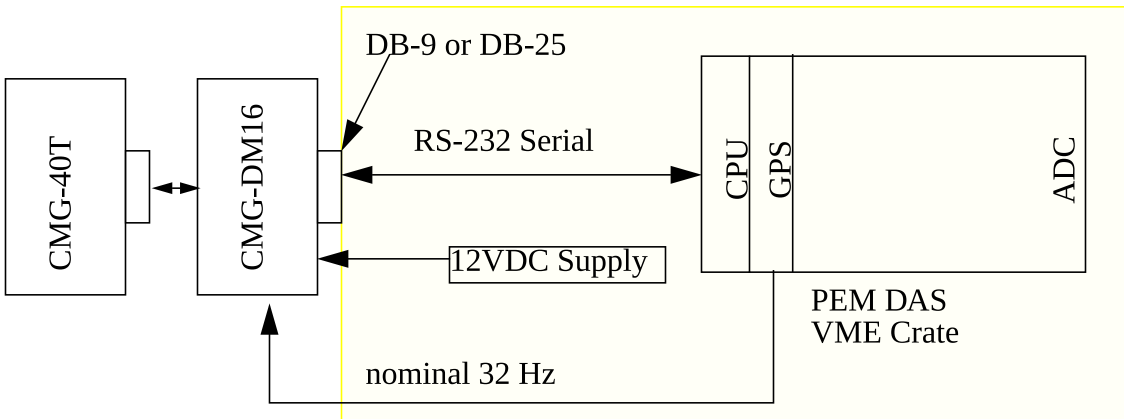


Figure 2: Connection of 3 Axis Seismometer to PEM DAS

In addition to the data acquisition capability shown in the table, CDS will provide the hardware and software controls necessary to control the seismometer and digitizer module. Control capabilities will include:

- Sampling rate
- anti-alias filter control
- trigger mode

2.2. 2 Axis Tiltmeters

The two axis tiltmeters to be used by the PEM system are Applied Geomechanics model 520 Biaxial Clinometers. The specifications for the model 520 are summarized in the table below.

Table 2: Summary of 2 Axis Tilt Meter Specifications

Voltage Range	*Resolution*	*Sample Rate*
+/- 7 Volts (+/- 100 urad/volt for gain setting 1)	16 bits	32 samples per second per axis

The interface connector to the model 520 is a terminal strip. The pin definitions are TBD. The figure below shows how each model 520 will be connected to the PEM DAS system. Equipment in the shaded region is provided by CDS.

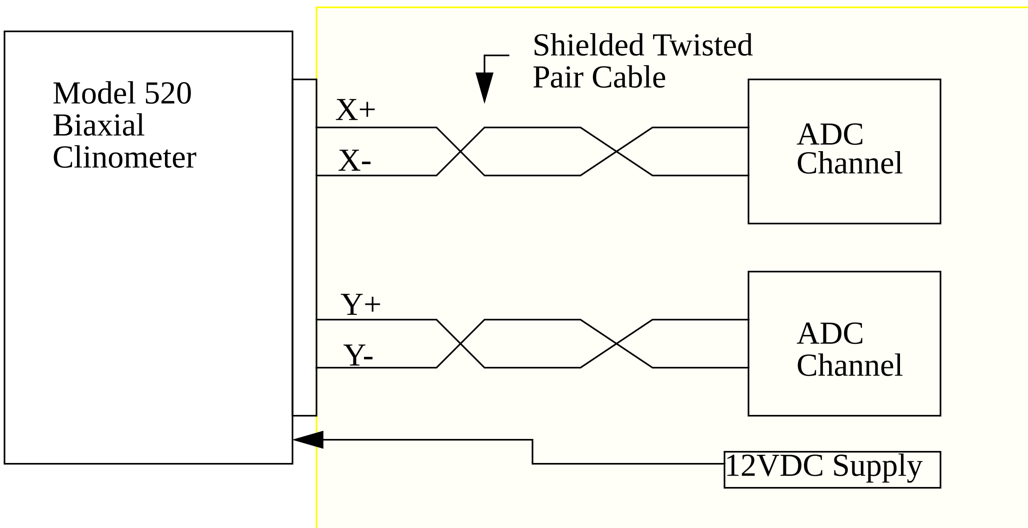


Figure 3: Connection of 2 Axis Tiltmeter to PEM DAS

Note: The model 520 tiltmeter comes with front panel controls for gain, power and filtering. These functions will not be controlled by the PEM DAS.

2.3. Accelerometers

The accelerometers used by the PEM system are Endevco model 7754-1000 Isotron Accelerometer. The specifications for the model 7754-1000 are summarized in the table below.

Table 3: Summary of PZT Accelerometer Specifications

Voltage Range	*Resolution*	*Sample Rate*
+/- 10 Volts (+/- 5 G)	16 bits	2048 samples per second per axis

The model 7754-1000 requires a model 2793M1 constant current supply for operation. This supply is supplied by PEM. The interface connector is BNC. The figure below shows how each model 7754-1000 will be connected to the PEM DAS. Equipment in the shaded region is provided by CDS.

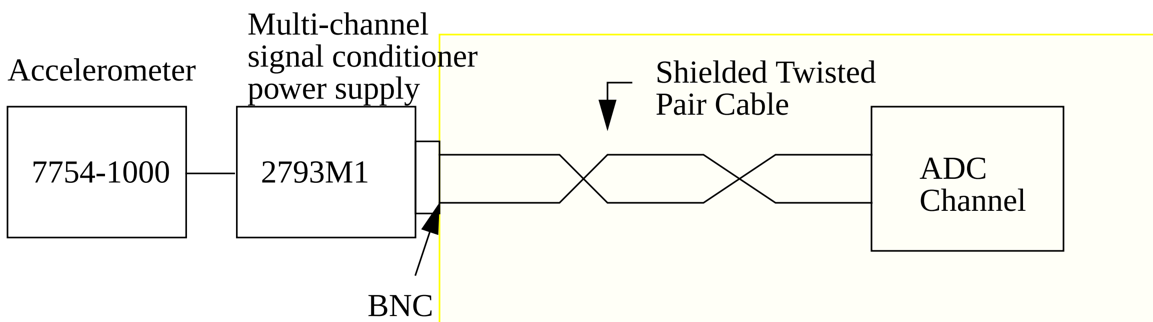


Figure 4: Connection of Accelerometers to PEM DAS

Accelerometers located in the BTE will be connected to the power supply unit (located in a building) using long cables run inside the BTE. The cable will be a minimum 18AWG shielded twisted pair cable for each accelerometer.

2.4. Microphones

The microphones used by the PEM system are Bruel & Kjaer model 4130 with preamp model 2642 and dual microphone power supply model 2810. The specifications for the microphones are summarized in the table below.

Table 4: Summary of Electret Microphone Specifications

Voltage Range	*Resolution*	*Sample Rate*
+/- 5 Volts (+/- TBD dBA)	16 bits	2048 samples per second per microphone

The interface connector to the microphone is a BNC. The figure below shows how each microphone will be connected to the PEM DAS system. Equipment in the shaded region is provided by CDS.

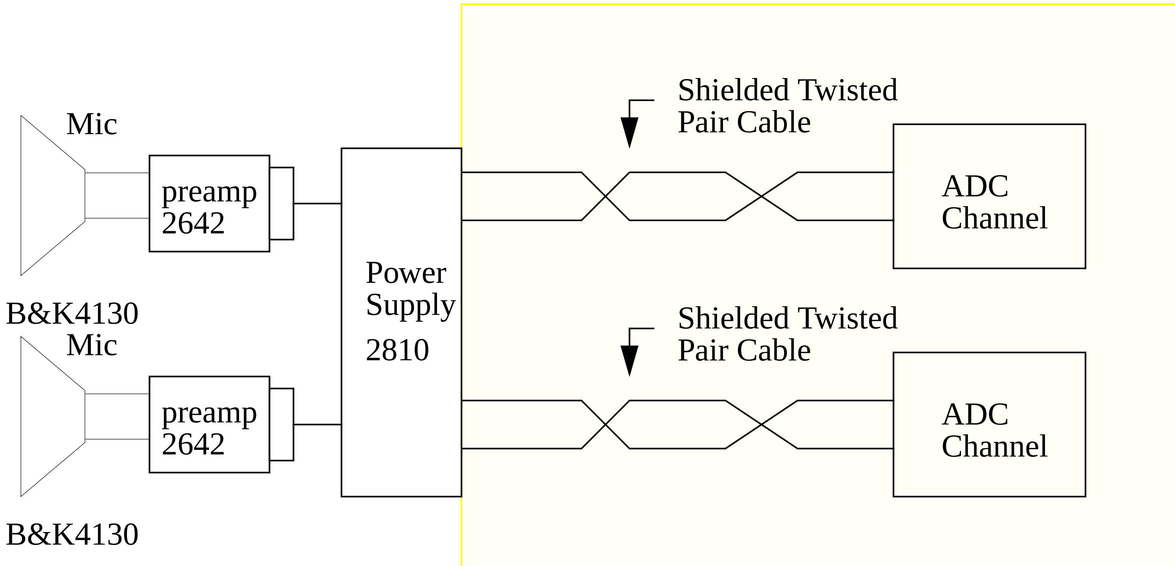


Figure 5: Connection of Microphones to PEM DAS

2.5. Magnetometers

The magnetometers used by the PEM system are Bartington Model MAG-03MC three axis flux-gate magnetometers. The units require a MAG-03M power supply and connecting PSU cable for operation. The specifications for the magnetometers are summarized in the table below.

Table 5: Summary of Magnetometer specifications)

Voltage Range	*Resolution*	*Sample Rate*
+/- 10 Volts (+/-70 uT) each axis	16 bits	2048 samples per second per axis

The interface connectors to the magnetometer outputs are BNC. The figure below shows how each MAG-03MC and power supply will be connected to the PEM DAS. Equipment in the shaded region is provided by CDS.

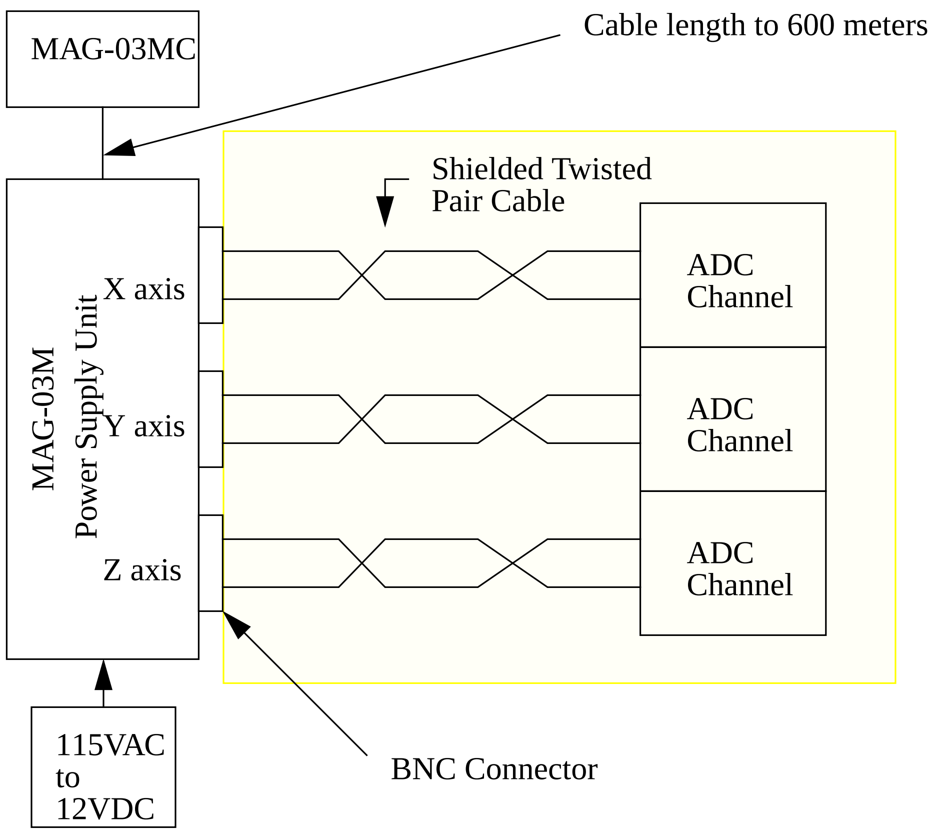


Figure 6: Connection of Magnetometers to PEM DAS

2.6. Broadband Antenna/Receiver

The broadband receiver to be used by the PEM system is an AOR AR5000 wide band receiver with AOR WA7000 antennas. There are to be four of these receivers/antenna permanently mounted and one mobile unit. The PEM DAS will connect to the IF output of each of the four permanent units, provide a baseband to RMS convertor, and monitor this signal on a data acquisition system ADC channel..

Table 6: Summary of Multi-channel Antenna/Receiver Specifications

Voltage Range	*Resolution*	*Sample Rate*
+/- 10VDC TBD Signal Strength	16 bits	2048 samples per second per axis

In addition to the data acquisition capability shown in the table, CDS will provide RS-232 connections to the four receivers for future additions to control the receivers remotely. Equipment in the shaded region is provided by CDS.

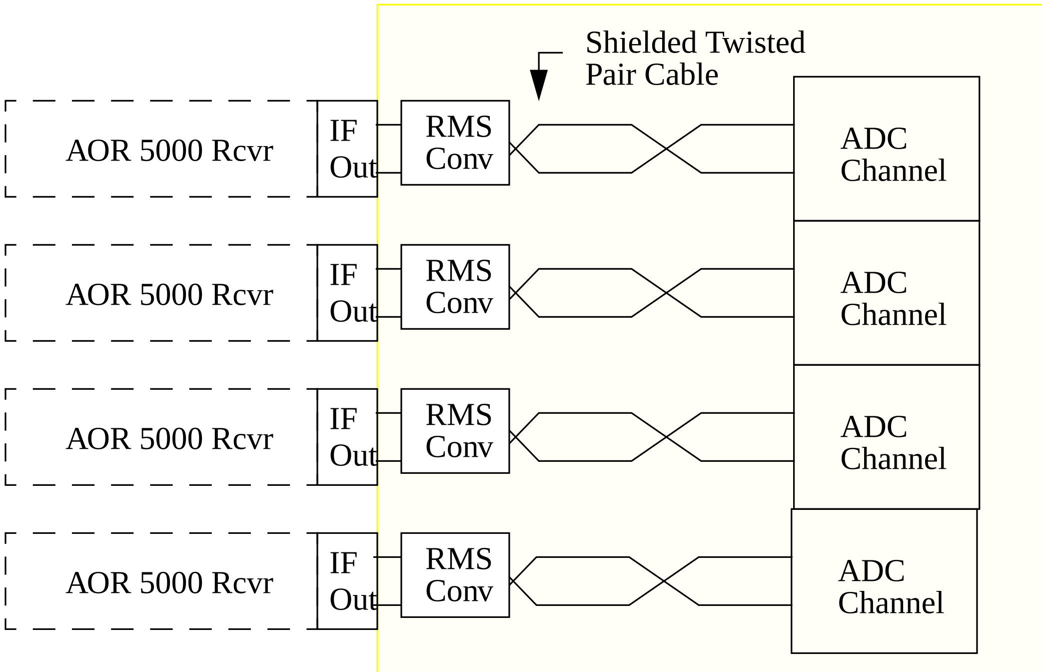


Figure 7: Broadband Receiver/Antenna Connection to PEM DAS

2.7. Narrowband RF Receiver

The narrowband receiver used by the PEM system will be a TBD commercial shortwave receiver provided as part of the PEM DAS. The receiver will be tuned to each resonant sideband frequency and provide a continuous monitor of the RF pick up near the anti-symmetric photodiode. This is to be implemented only on the Hanford 4km IFO.

The PEM DAS requirements call for a continuous sampling of the output of the detector at 20 samples per second until a 1 dB change is detected. The sampling rate is then increased to 2K samples per second. It is proposed that the output of each narrowband RF receiver be sampled at a continuous rate of 2K samples per second and, if required, a marker signal be inserted into the data stream whenever a 1 dB change in the level is detected by the PEM DAS software. The table below summarizes the data acquisition specification for the narrowband RF receiver.

Table 7: Summary of Narrowband RF Receiver Specifications

Voltage Range	*Resolution*	*Sample Rate*
Receiver Output: +/- 1VDC	16 bits	2048 samples per second per receiver

2.8. Charged Particle Detectors

The charged particle detectors are to be custom developed by LIGO. There is to be one unit per site, located within the LVEA..

Table 8: Summary of Narrowband RF Receiver Specifications

Voltage Range	*Resolution*	*Sample Rate*
+/-10 VDC (4 channels/detector)	16 bits	2048 samples per second

The figure below shows how each receiver will be connected to the PEM DAS system. Equipment in the shaded region is provided by CDS.

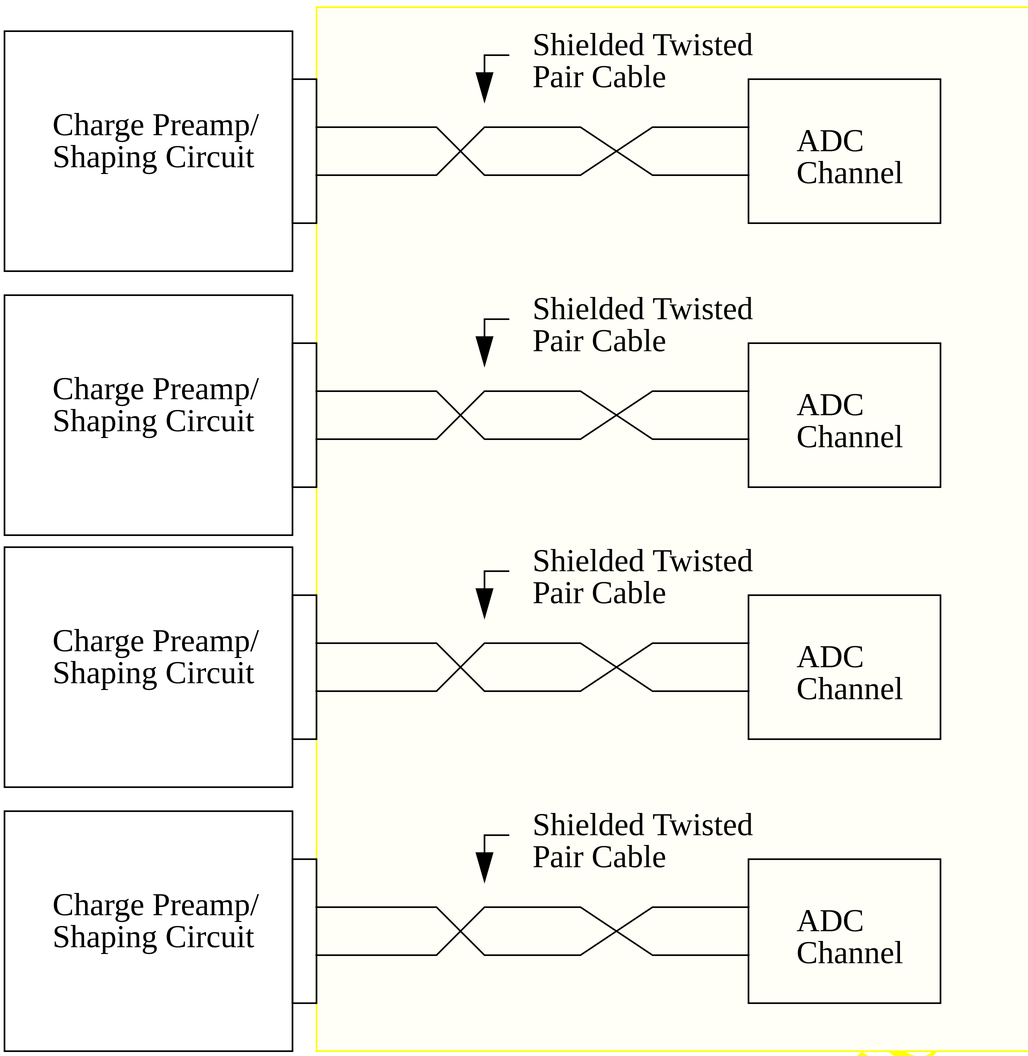


Figure 8: Connection of Charged Particle Detector to PEM DAS

2.9. Power Line Fluctuations

As part of the civil construction, current toroids have been installed on the power feeds to the chiller plant, technical power bus and the facility power bus for each building. The outputs of these toroids will be connected to and monitored by the PEM DAS system. The data rates, sensitivity and resolution requirements are summarized in the following table.

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Table 9: Summary of Narrowband RF Receiver Specifications

Voltage Range	*Resolution*	*Sample Rate*
+/-10 VDC	16 bits	2048 samples per second

2.10. Residual Gas Analyzer

A number of RGA heads are to be permanently installed in LIGO, with a single, portable, controller at each site. The initial requirement on the PEM DAS is to provide for operation of the RGA controller remotely from the Facility Control Room (FCR). To provide this functionality, the PEM DAS will provide a Personal Computer (PC) in the FCR for running RGA software, as well as network connections to the vacinity of RGA heads, as shown in D970210-00-H, for network connection of the RGA controller.

2.11. Weather Station

The weather station used by the PEM system is a Cole Palmer model 9980-20, with the optional temperature/humidity sensor and rain collector. The connection to the PEM DAS system will be a serial connection via the weather link option that is available for the unit. Inside and outside temperature, barometric pressure, dew point, wind speed and direction, inside and outside humidity, rainfall and wind chill can read at a maximum rate of once per minute via the connection. The figure below shows how each weather station will be connected to the PEM DAS system. Equipment in the shaded region is provided by CDS.

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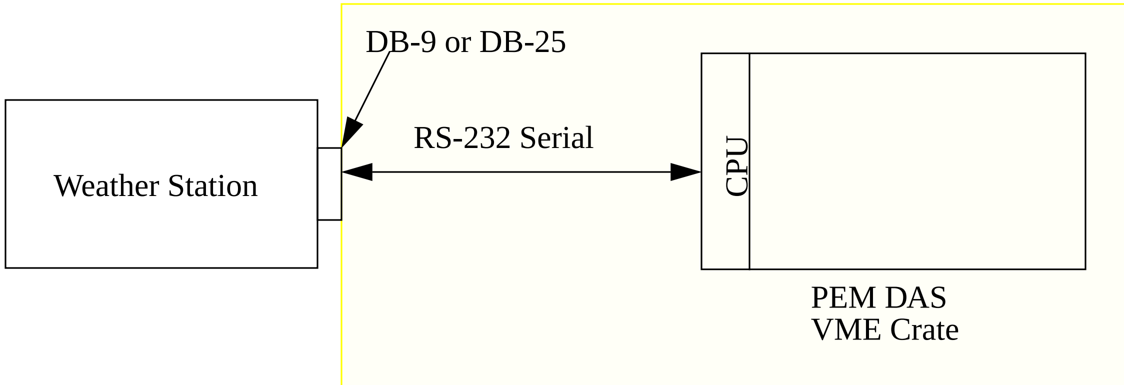

Figure 9: Typical Weather Station Connection to PEM DAS

2.12. Thermometers and Hygrometers

Temperature and humidity inside the BTE will be monitored using Omega model HX 93 temperature/humidity transmitters. Temperature outside buildings will be measured with Omega model TX 92 temperature transmitters. Humidity inside buildings will be monitored with Omega model HX-92 humidity transmitters. Each transmitter requires +24 VDC power and provides a 4-20 mA or 0-1V output proportional to temperature and/or humidity. The interface connector is a 4 pin header internal to the transmitter. The specifications for the transmitter are shown in the table below.

Table 10: Summary of Thermometer/Hygrometer Specifications)

Current Range	*Resolution*	*Sample Rate*
Temp: 4-20 mA or 0-1V (-20 to +75 C) Humidity: 4-20 mA or 0-1V (3 to 95% RH)	16 bits	2 samples per second per measured parameter

The figure below shows how each transmitter will be connected to the PEM DAS system. Equipment in the shaded region is provided by CDS.

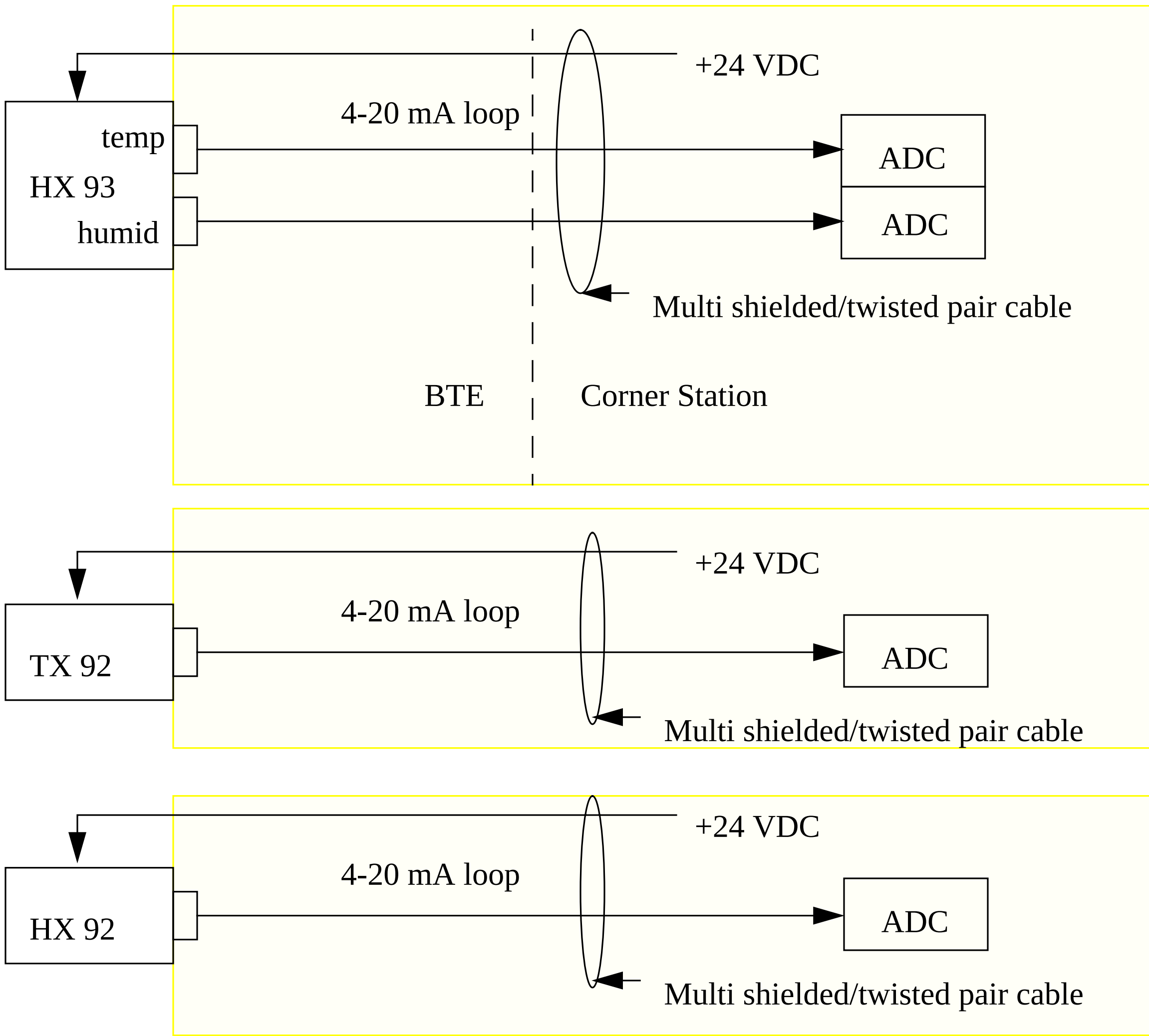

Figure 10: Typical HX 93, TX 92 and HX 92 Connection to PEM DAS

The cable used to connect the 4-20 mA loop will be a minimum AWG 18 gauge shielded twisted pair cable. Connection of BTE devices will be run inside the BTE from the corner station to each device. Power will be supplied using the same cable.

2.13. Thunderstorm Monitor

A thunderstorm monitoring service is to be provided by PEM from the National Lightning Detection Network. The PEM DAS will be required to connect to the PEM provided receiver via RS-232. Exact interface definitions (data transfer command sets / data structures) are TBD.

2.14. Dust Particle Detectors

The dust particle detectors used by the PEM system are Met One model 227B Remote Airborne-Particle Counters. The connection to the PEM DAS will be via an RS485 multidrop serial communications link. Software will be developed with the following capabilities:

- Control each monitor
- poll each monitor on approximately 10 minute intervals
- monitor internal alarms and status registers.
- Start and stop monitor

The figure below shows how multiple devices will be connected to the PEM DAS system. Equipment in the shaded region is provided by CDS.

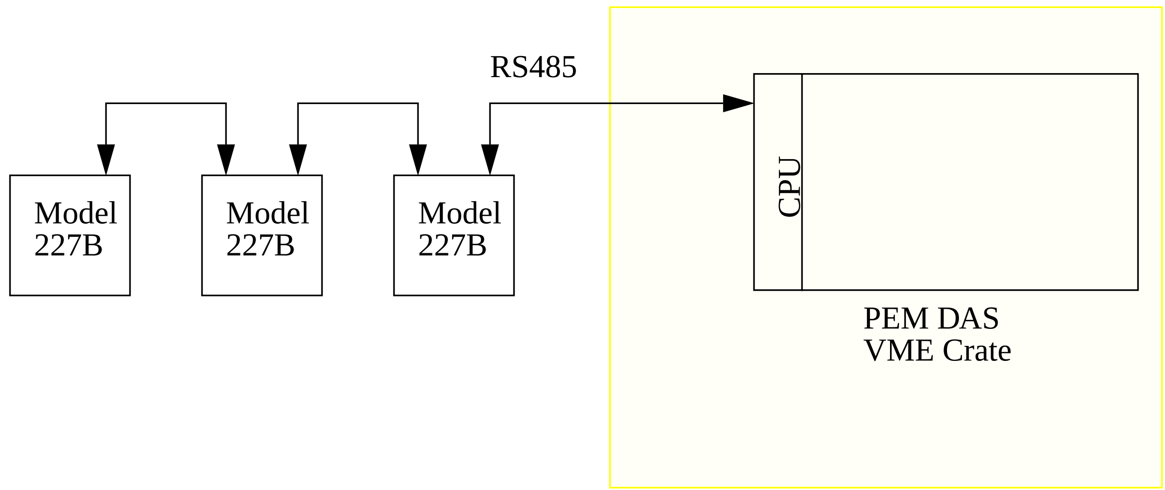

Figure 11: Typical Dust Particle Monitor Connection to PEM DAS

Monitors that are mounted in the portable clean rooms will be connected via communications “outlets” provided near the areas in which the clean rooms will be used. For connection of the monitors in OSB spaces (Optics lab and vacuum prep areas), RS-485 cable will be run overhead above the ceiling tiles from connections in the FCR.

3 PEM CART CONTROL AND DATA ACQUISITION

3.1. PEM Cart Devices

The devices located on the PEM cart are listed in the tables below..

Table 11: Summary of PEM Cart Devices Connected to Communications Buses

Device Type	*Interface Type*
Broadband RF Antenna/ Receiver	RS-232
RGA	RS232/LAN

Table 12: Summary of PEM Cart Devices Connected to ADCs

Device Type	*Voltage Range & Scaling*	*Sample Rate (Samples/sec)*
PZT Accelerometer (3 each x 3 axis)	+/- 5 Volts = +/- 5 G	2048
Magnetometer (1 each x 3 axis)	+/- 10 Volts = +/- 70 uT	2048
Microphone (2 each)	TBD	2048
Broadband RFI Antenna/ Receiver (1 each x 1 ch.)	TBD	2048
Temperature Sensors (5 each)	4-20 mA or 0-1V (-20 to +75 C)	1
Humidity Sensors (5 each)	4-20 mA or 0-1V (3 to 95% RH)	1

The PEM cart also provides various excitation systems, namely:

- Seismic excitation system
- Acoustic noise generator
- Magnetic field generator
- RF generation

Requirements on the PEM DAS to control/acquire data from these excitation systems is TBD.

3.2. PEM Cart Operating Modes

The PEM DAS must allow the PEM cart to be operated stand-alone, with self-contained data acquisition capabilities and as a part of the LIGO data acquisition system, with sensor information being acquired in real-time by the LIGO data acquisition system.

3.2.1. Stand alone Operation

For independent operation, the PEM cart would be equipped with a PC with the following configuration:

- A commercial data acquisition software package (TBD).
- Balzers RGA controller software package
- Commercial "virtual instrument" software to control standard test equipment
- Two, 16 channel ADC modules
- GPS receiver module (to accurately clock/timestamp data)
- Ethernet port
- 4-8 GByte disk drive
- 128 MByte memory
- 17" monitor

With this arrangement, the PEM cart would be capable of independently collecting, storing, analyzing and displaying data. Data files collected by this system could then be downloaded via CDS networks for more permanent archival and/or extraction of data for placement into standard LIGO frame structures used by the LIGO data acquisition system.

Connection of the PC to the CDS network will also allow a user at the PC to view data being collected by the LIGO control & monitoring systems and the LIGO data acquisition system.

3.2.2. Integrated Operation with the LIGO Data Acquisition System

There will be times where the PEM cart equipment will be moved to a fixed location for a period of time and information from its sensors must be collected in real-time and integrated into the data frames being acquired by the LIGO data acquisition system. In the conceptual design document, a stand alone VME crate, with the same design as the LIGO data acquisition system Data Collection Units (DCU), was proposed, with appropriate direct network links into the system. However, this is a high cost solution, given the low channel count of the PEM cart. Given that the PEM cart and its sensors would be located relatively near permanently installed LIGO DCU, when signals from PEM cart sensors are to be acquired in a real-time mode, they will be connected to reserved "spare" ADC channels in the nearest DCU.

4 PEM DAS SUPERVISORY CONTROL AND INFRA-STRUCTURE

4.1. System Architecture

LIGO drawing D970532-00-C (attached in Appendix A) shows the preliminary layout of the PEM DAS. The PEM DAS itself is designed as an integral part of the LIGO data acquisition system, which is descibed in the LIGO Data Acquisition System Preliminary Design LIGO-T970136-00-C.

4.1.1. Corner Station Layout

At the corner station, as shown in sheet 1 of the PEM DAS drawing, there are two racks designated for PEM DAS equipment. One rack will be located at position 1X10. This rack provides for all of the interface connections to corner station PEM sensors (along with beam tube PEM devices within 1000 m on the X1 arm). Other than this rack is dedicated to PEM sensors/devices, this is one DCU of the LIGO data acquisition system, running all of the software and utilizing the networking facitilies as defined in LIGO-T970136-00-C. The only unique item is the addition of the MVME-162 processor to interface serial devices into the system. This is described in section 4.2.

A second rack is to be located in the Mass Storage Room (MSR) area of the OSB. This rack will contain the broadband receivers and its RMS convertors and the weather station. The RMS convertors will provide line drive capabilities allow cabling from the OSB, through the OSB to LVEA conduits, and into rack 1X10. There will also be an additional MVME-162 processor to communicate serial information to/from the receivers, dust monitors and weather station. This processor will be located in a TBD VME crate in the vacinity of the PEM rack. It will only make use of power from this VME crate ie not use the VME bus itself. All communications will be through the serial ports to the devices and a network connection onto the CDS networks to the data acquisition system.

4.1.2. Mid and End Stations

A typical layout for mid and end stations is shown on sheet 2 of D970532-00-C. At these locations, the PEM sensors/devices are directly tied into the existing LIGO data acquisition system ie other LIGO system signals are input to these units as well as PEM information. The only unique part for PEM again is the addition of the MVME-162 processor to interface the serial devices into the system.

4.1.3. Outdoor Devices

Certain PEM devices will be mounted outside of buildings, on roof tops and exterior walls. This includes weather station devices, radio receiver antennas and temperature sensors. Therefore, separate cable routing schemes are required.

For the mid and end stations, the design will be to mount a conduit on the side of building, which connects to the manhole outside of each building. Sensor cables from rooftop devices will be run across the roof and enter the top of this conduit at the roof line. Once pulled into the manhole, the cables will be routed through another conduit, which is embedded in the building foundation, to a data acquisition system rack location in the VEA.

In the case of the corner station, a similar conduit will be attached to the side of the LVEA nearest the OSB. The bottom of this conduit will penetrate the OSB at a TBD location such that cables from the roof can be run into the subfloor area of the FCR and then further routed to their appropriate final terminations.

4.2. Communications

4.2.1. Connection of Fixed Serial and Parallel Bus Devices in Buildings

The PEM DAS system requires connection of RS232 and RS485 instruments. The standard CDS systems to be used for the LIGO data acquisition system will not support these buses directly. Therefore, RS232 and RS485 communications will be handled using an MVME162 VME processor with RS232 and RS485 mounted as daughter cards (Industry Packs). The MVME 162 will be located in the VME crate used for PEM DAS and act as a secondary processor, sending data directly over the VME bus to the primary data acquisition processor. In effect, this processor is employed as an intelligent I/O VME module.

4.2.2. Connection of Devices in BTE

The temperature and humidity sensors and magnetometers located in the BTE will be connected to the PEM DAS system in the corner and mid station buildings using 4-20mA current loops. The cables for power and signals will be routed inside the BTE along the beam tube. The method for securing the cabling is TBD. Typical connections of these devices are shown in section 2 of this document. It is currently planned that spare cabling for 4-20 mA loops will be included in the initial cable installation.

4.2.3. Network Connections

For the purposes of connecting the PEM cart PC and various other workstations which require connection to the CDS backbone, ethernet ports will be provided at various locations within the LIGO VEA. The detailed layout of these network ports will be part of the CDS control and monitoring system infrastructure design.

APPENDIX 1 DRAWINGS