

EMC Upgrade Conceptual Design and Implementation Plan

- This presentation is broken into two parts:
 - » Presentation of the conceptual design that we feel will meet the requirements.
 - » Presentation of the implementation and testing plan required to proceed from the conceptual design to a final design and implementation on all three IFOs.

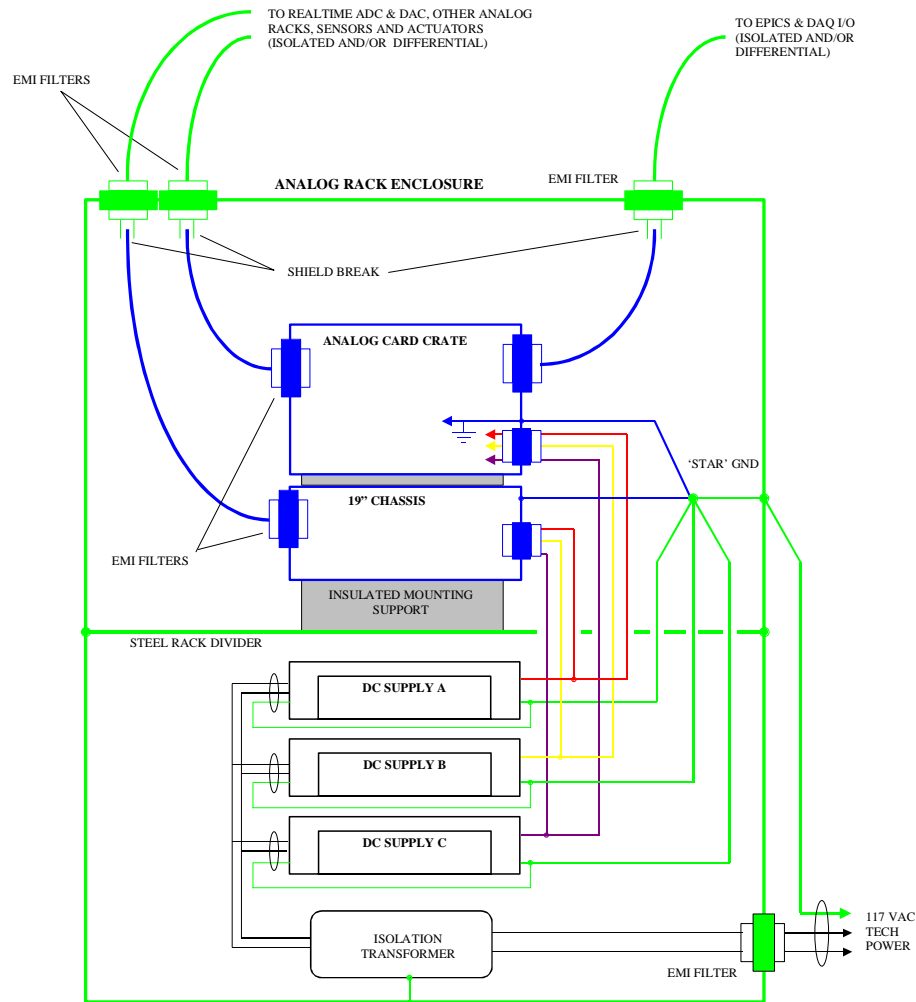
EMC Upgrade Conceptual Design

- The conceptual design for the upgrade can be broken into the following categories:
 - » Power Supply Replacement and Shielding
 - » Separation of Analog and Digital Functions by Rack
 - » Containment of Digital RFI
 - » Analog Circuit Isolation and Shielding
- Each will be discussed in the viewgraphs that follow.

Power Supply Replacement and Shielding

- All switching power supplies used for analog racks and circuits will be replaced with linear power supplies
- Any switching power supplies built into commercial instruments and equipment will be shielded and dealt with on a case by case basis
- Supplies will be separated from analog circuits. Steel racks and conduits will be used to provide shielding.
- A star grounding scheme will be incorporated into the design.

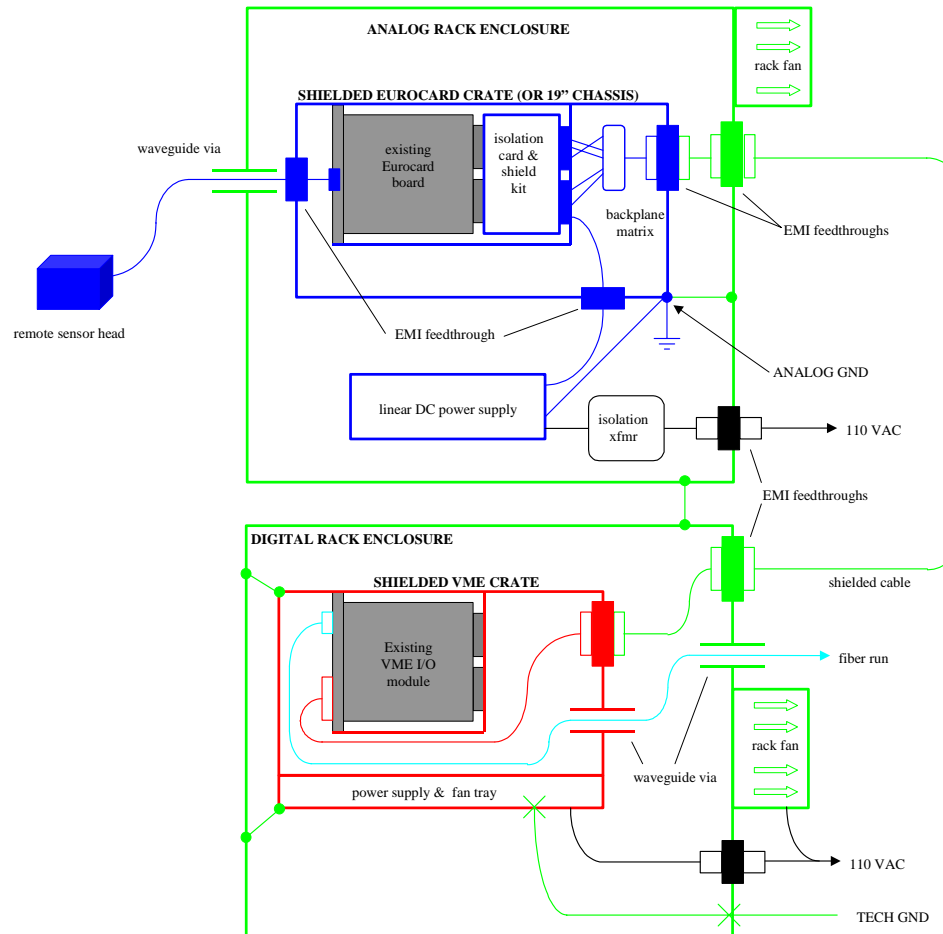
Power Supply Star Grounding Scheme



Separation of Analog and Digital Functions by Rack

- High speed level transitions associated with VMEbus activity and clocks on-board modules present a significant source of noise.
- Separate racks for analog and digital circuits will be used and, if possible, two levels of faraday shielding acting in series will be interposed.
- Connections between the racks will be via twisted, shielded differential pairs (analog) and optically isolated (binary).

Separation of Analog and Digital Functions by Rack cont'd



Containment of Digital RFI

- Shielded VME crates will be utilized
 - » Features include: conductive blank front panels, finger stock and gaskets, fully enclosed wiring, RFI feedthroughs for cable penetrations
 - » Manufactures include: Elma Engineering, Tracewell and others
 - » Crates meet TEMPEST and MIL-STD-461

Custom System



Containment of Digital RFI cont'd

- Shielded Racks will be utilized for digital equipment
 - » RFI rated racks and enclosures will be specified and obtained.
 - » Vendors include Equipto Electronics Corp., AMCO Engineering Co. and MFB
 - » Meet Mil Spec 285 and TEMPEST standards
 - » 80-120dB attenuation for E-fields (10KHz<freq<100MHz)
 - » >20dB attenuation for H-fields (10KHz<freq<1MHz)



Analog Circuit Isolation and Shielding

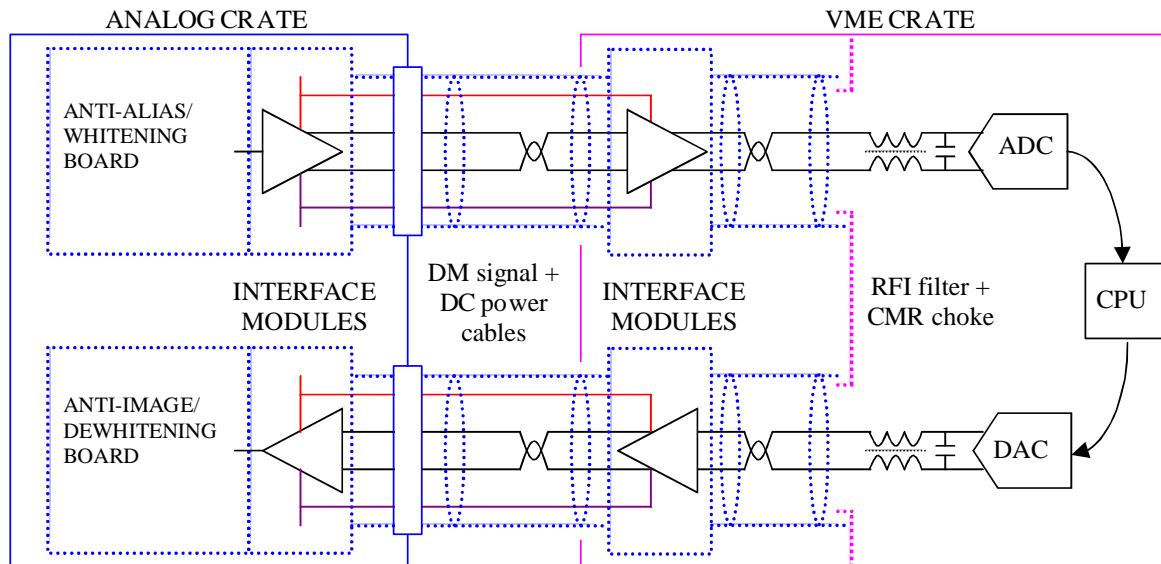
- Shielded racks similar to those used for digital systems will be used.
- Remote Sensor/actuator grounding and umbilicals
 - » All power, ground and signals to/from remote modules such as PDs will be routed through interface modules. There will be no other connections.
 - » All cable connections will be bundled and routed together. All cabling will be shielded.
 - » RF signals will be routed on coax, lower frequency signals will be routed on twisted, shielded differential pairs.

Analog Circuit Isolation and Shielding cont'd

- ADC and DAC Signal Isolation
 - » All signals between analog circuitry and VME based ADCs and DACs will be differential pairs. The differential driver or receiver located in the VME crate will be powered from the analog power supplies. All circuitry will be enclosed in a faraday shield and isolated from VME grounds. All inputs/outputs will incorporate EMI feedthroughs and passive filtering sections. Common mode cores around cables and/or signal bundles may be used to augment filtering.
 - » Second generation ADCs and DACs might have the “analog” portion of the module in the analog rack and the digital portion of the module in the digital rack with galvanically isolated optical or RF signaling in between.

Analog Circuit Isolation and Shielding cont'd

- ADC and DAC Signal Isolation using LIGO interface modules



Analog Circuit Isolation and Shielding cont'd

- Analog Crate Shielding

- » There are currently two options for shielded analog crates:

- Shielded eurocard crates with extender/interface card mounted to P1 and P2 connectors. The specs for these crates would be similar to those of the VME crates
- VXI type crates and modules with LIGO custom backplane

- » Features and Specs of either would include:

- Hinged front panel with fully enclosed internal wiring. External wiring will be fully shielded and enter enclosure through RFI feedthroughs.
- Filters and traps incorporated into all signal and power lines.
- Options for ducting and cooling.
- Conductive filler panels.
- Options for isolating chassis from rack
- DC power will be grounded in star configuration and will be distributed directly from power supplies to crates, i.e. no longer through cross connects.

Analog Circuit Isolation and Shielding cont'd

- Analog Card Shielding

- » Multi-layer circuit boards with signal lines sandwiched between ground planes.
- » Board mounted RF cans for local shielding
- » To as great an extent as possible, on-board voltage regulators will be incorporated into module designs.
- » VXI form factor already would provide external shielding for boards. Eurocard form factor would require board mounted cans and sandwiched signal lines.

Analog Circuit Isolation and Shielding cont'd

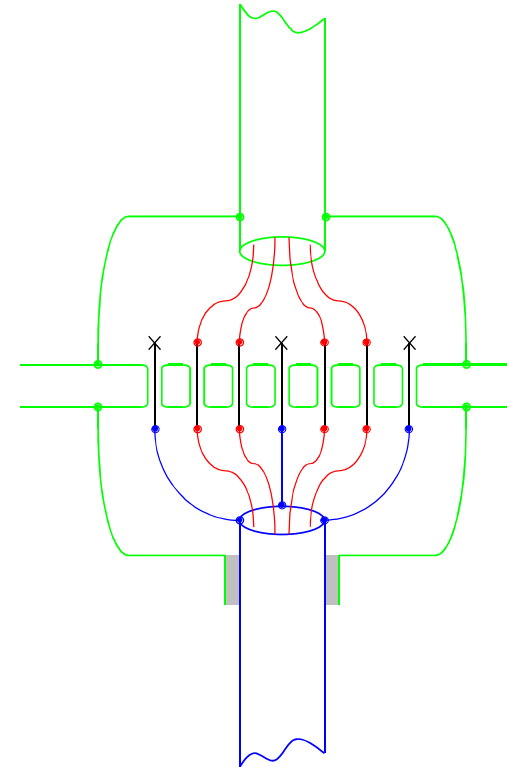
- Analog Chassis Adaptations
 - » Analog chassis mounted in racks will be adapted/redesigned to meet the requirements
 - » Features will be similar to analog crates and cards
 - RFI filters on all signal lines
 - Options to float chassis from rack
 - Contiguous faraday shielding
 - Differential signals, optical isolation
 - Star ground scheme
 - Etc.

Analog Circuit Isolation and Shielding cont'd

- Shielding/Elimination of exposed cross connects
 - » The current method provides a significant cross section for noise to couple into the system
 - » Ways to eliminate these cross connects or significantly reduce their cross section are being investigated. These include:
 - Dedicated backplanes
 - Custom interface boards
 - Any solution of this type needs to be carefully evaluated for flexibility, maintainability, and practicality by site personnel.
 - » Current cross connects could be improved
 - Shielded twisted pairs for interconnect wiring
 - Shield/Enclose entire cross connect area.

Hybrid Grounding

- Intentionally floated signals, grounds and chassis connected at RF modulation frequencies
- One method uses unconnected pins of RFI feedthroughs



EMC Test Equipment and Tests

- Sites will be equipped to carry out isolated product testing and in-situ audits
- Testing will support verification of compliance with LIGO-E020986 and sections of MIL-STD-461E
- Equipment will include:
 - » Outdoor test range platform with ground plane and DC power provisions
 - » AC power conditioning and isolation transformers
 - » Portable RF spectrum analyzer
 - » Low-noise broadband RF preamplifier
 - » Portable audio and RF signal generators
 - » RF power amplifier and matching network
 - » Audio power amplifier

Installation and Testing

- The retrofit must be integrated without causing unacceptable loss of observing or commissioning time. We will adhere to the following general rules:
 - » No upgrade step will be undertaken without prototype qualification and extensive bench testing of the underlying methods, as well as “dry run” installation practice.
 - » All upgrade steps will be integrated in a reversible way wherever feasible, to permit backtracking.
 - » For each category of improvement (crate, cable, module) there will be a limited trial integration of one or a few instantiations, made on *one* interferometer. Expanding integration to other instances and to other interferometers will only be approved after this trial integration has proven successful
 - » Upon qualification of an upgrade step, production and completion of the retrofit to each interferometer will be scheduled in accordance with commissioning and observing timetables.
 - » The Detector Technical Review Board will be used for review of intermediate results, pre-installation readiness, and approval of major procurements.

Installation and Testing

- The list of tasks to be accomplished during the retrofit can be broken into two categories:
 - » Tasks to be accomplished immediately (pre- to post-S2)
 - These tasks are not necessarily the highest priority, but are tasks that represent good engineering practice and/or are easy to implement
 - » Tasks that require design, development, and testing
 - These are tasks that require much more in the way of design and development. Some of these tasks will be implemented or partially implemented prior to S3.
 - To date these types of tasks have been implemented, tested and refined on portions of the LLO IFO and then propagated to the rest of LLO and LHO. In an effort to maintain consistency and concentrate the EMI team, this practice will probably be maintained in the future.

Pre- to Post-S2 Tasks

- Switching power supply replacement and separation of power supplies from analog racks
 - » Has been partially implemented at LLO and anecdotal evidence shows that it has improved the noise situation. Quantitative measurements were hard because the upgrade was implemented as part of the DSC installation.
 - » There is an effort underway to complete the change at LLO by S2. More quantitative measurements will be possible.

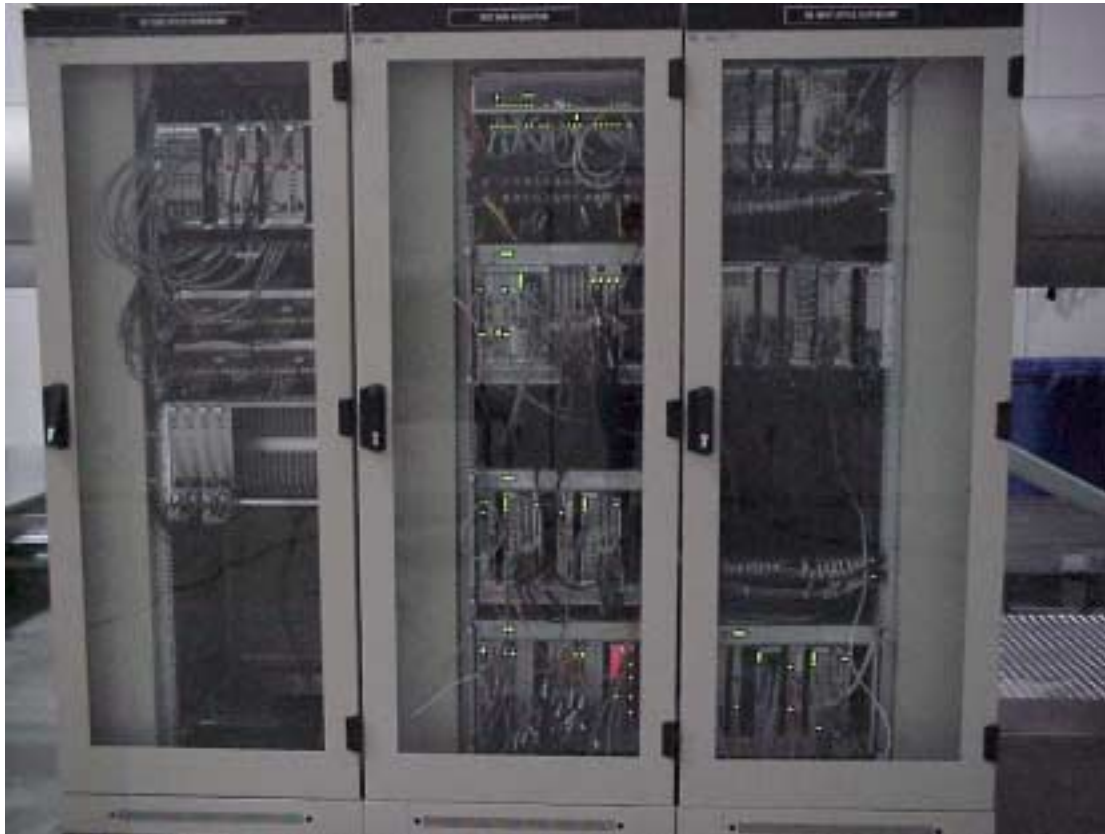


Pre- to Post-S2 Tasks cont'd

- Separation of Analog and Digital Functions by Rack
 - » This process has already been started on the LHO 2K and LLO 4K with the installation of the DSC. VME crates and eurocard cages were moved to separate racks. Where possible the connections between the two use differential pair signaling. The full up solution using optical isolation, differential signaling, faraday shielding has not been completed. Hopefully we will be able to complete this by S2.
 - » Anecdotal evidence shows that even this “modest” separation of equipment has improved performance. As more of the fixes are installed we will be able to make more quantitative before and after measurements.

Pre- to Post-S2 Tasks cont'd

- Separation of Analog and Digital Functions by Rack



Pre- to Post-S2 Tasks cont'd

- Replacement of all cabling internal to racks with shielded, twisted pair cables
 - » Has already been done at LLO, with the exception of individual cross connect wires
 - » Direct before and after measurements of IFO noise show that it helps significantly.
 - » The replacement takes on the order of 2 days per rack “bay”. Multiple rack bays can be upgraded in parallel given enough manpower.

Pre- to Post-S2 Tasks cont'd

- Analog Circuit Isolation and Shielding
 - » All recent designs have used sandwiched circuitry, differential transmission, EMI filters, voltage regulators, faraday shields, etc. Get picture of new AI board. Show cross section of layers.
 - » Differential drivers/receivers have been developed to interface DACs and ADCs to analog circuitry- these use differential transmission, EMI filters, twisted-shielded pairs, common mode chokes and faraday shields.

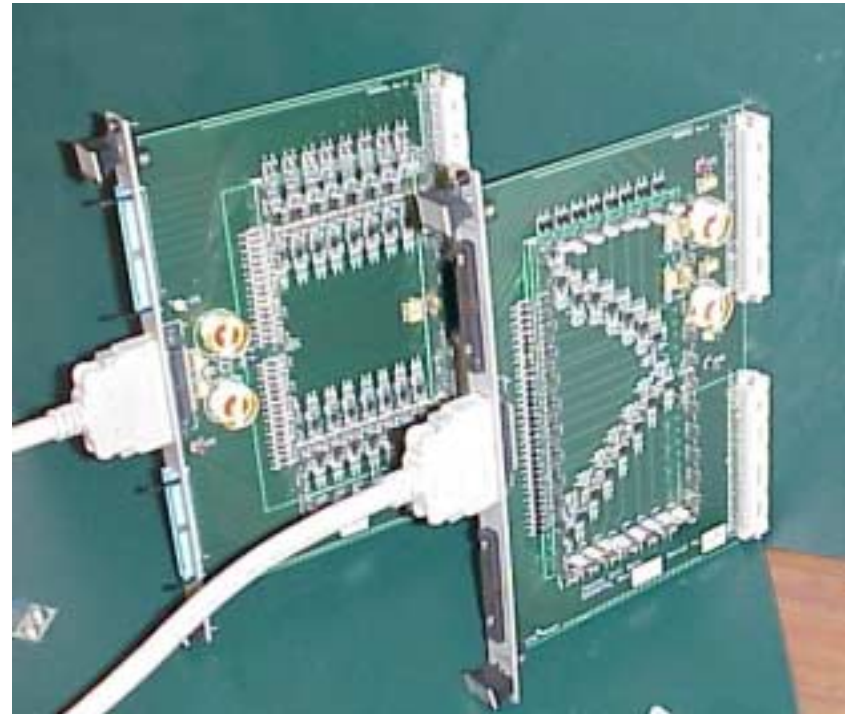
Pre- to Post-S2 Tasks cont'd

- Analog Circuit Isolation and Shielding
 - » LIGO Anti-Image Board (Rev C)
 - Sandwiched signal lines
 - Faraday shield
 - EMI filters
 - Voltage regulators
 - Chokes
 - Differential Input and output



Pre- to Post-S2 Tasks cont'd

- Analog Circuit Isolation and Shielding
 - » LIGO Differential Driver/Receiver Pair
 - Differential inputs and output
 - EMI filters
 - Faraday shield (removed for picture)
 - Chokes, Common mode filters
 - Powered from analog crate side
 - Connected via twisted shielded pair



Tasks Requiring Design, Development and Testing

- Shielded VME Crates

- » Specs and requirements will be developed and quotations obtained. Units will be procured and installed.
- » Before and after surveys and IFO noise measurements will be conducted.
- » This will probably be done just after S2.
- » It is felt that commercial EMI rated units can be used. The only adaptation that will be necessary will be the back panel RFI feedthroughs for cables.

Tasks Requiring Design, Development and Testing cont'd

- **Shielded Analog and Digital Equipment Racks**
 - » Specs and requirements will be developed and quotations obtained. Units will be procured and installed.
 - » Before and after surveys and IFO noise measurements will be conducted. Initial testing will probably be done at an End Station. All types of signals, systems, etc. are represented at the ends, but on a more manageable scale. The only components missing from the ends are those used for RF modulation and demodulation. It may also be possible to conduct testing on the LVEA racks used for ASC, LSC and DSC, but this is a much bigger job.
 - » This will probably be done just after S2.

Tasks Requiring Design, Development and Testing cont'd

- ADC and DAC Signal Isolation

- » We will continue using in-house developed adapters, etc. through S2 until more appropriate DACs and ADCs are available.
- » Low noise DACs with galvanic isolation are being developed and will be tested. The first prototype is due in early Dec. Following prototype tests and approval of design, production quantity boards will be manufactured. These will not be available until mid-March or April 2003. Testing in LIGO IFOs will require code changes to DSC and will need to be coordinated with commissioning.
- » Specifications for ADCs are partially developed. These will be completed and a development cycle started. Using the DAC development as a model, these modules would not be available for test in IFOs for ~9 months after requirements are finalized.

Tasks Requiring Design, Development and Testing cont'd

- Analog Card Shielding
 - » A set of test criteria needs to be developed
 - » Enclosed eurocard and VXI methods will be tested
 - » A prototype of a VXI extender/adaptor board and VXI hardware has been developed. It appears as though these items can be used to used to convert almost all existing designs to VXI format with a minimum of effort. (picture of module)
 - » It is most likely that the VXI system can be implemented relatively easily, so the additional shielding, board space etc. may push for this solution. The only problems may arise in the loss of slots. Each VXI crate has 13 slots as opposed to 21. This could be a problem in some systems, but removal of the power supplies and separation of analog and digital has freed up some rack space.
 - » 19" analog chassis will be redesigned and retrofitted as needed.

Tasks Requiring Design, Development and Testing cont'd

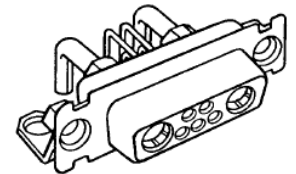
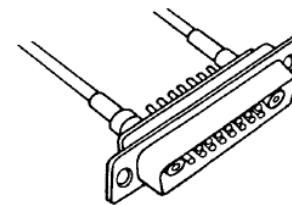
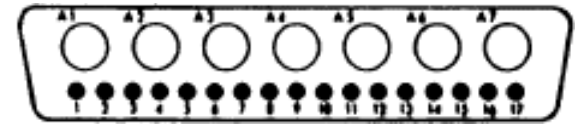
- Analog Card Shielding

- » LIGO LSC Whitening Module converted to VXI form factor using adapter card and module kit



Tasks Requiring Design, Development and Testing cont'd

- Remote Sensors/actuator Grounding, Power and Shielding
 - » All remote sensors and actuators will be evaluated for compliance with this new plan.
 - » Cabling will be rerouted, bundled and shielded. Products such as zippertube can be used for retrofit. Connectors such as Sun RGB connectors can be used for mixed twisted pair and coax.
 - » In some cases redesign may be needed.



Tasks Requiring Design, Development and Testing cont'd

- Cross Connect Substitute
 - » A wide discussion of proposals will be started.
 - » Any solution will need to be evaluated, and tested thoroughly prior to full-scale implementation.
 - » Several alternatives have been discussed to date, but none have been fully fleshed out. Most would limit the flexibility provided by the current method. These limits to flexibility need to be evaluated in light of operations and commissioning requirements.

Proposed Sequencing Summary

- Pre-S2
 - » Complete testing of linear power supplies installed at LLO.
 - » Spec and procure initial EMC test equipment for lab and observatory trial.
 - » Conduct baseline EMC surveys of existing equipment & installations
 - » Procure linear supplies & support hardware for remaining installations
 - » Complete remaining wiring diagrams and equipment layouts for digital/analog rack division
 - » Build up shielded VME crate/digital rack prototype in lab; test & iterate offline

Proposed Sequencing Summary cont'd

- Between S2 and S3
 - » Install linear power supplies on all interferometers (one station at a time)
 - » Integrate single instance of shielded digital rack & associated new wiring; test
 - » Procure shielded crates, racks, feedthroughs and cabling for remaining instances.
 - » Install digital electronics shielded crate/rack/feedthrough packaging systems (one station at a time)
 - » Swap analog racks for shielded versions (reinstall existing analog systems unmodified)
 - » Conduct update EMC surveys of revised equipment & installations
 - » Design and build offline prototype for analog shielding and isolation solution

Proposed Sequencing Summary cont'd

- Post S3

- » Install prototype analog shielding and isolation system & test in situ
- » Review and procure hardware for remaining instances
- » Install all interferometers/all stations (one station at a time)
- » Revisit EMC survey and address remaining issues