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Vacuum Feedthrough and Cabling Conceptual Design

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1 INTRODUCTION

1.1. Purpose

The purpose of this document is to outline conceptual designs for the electrical vacuum feedthroughs and cabling to be used within and to penetrate the LIGO vacuum chamber. The conceptual designs will be used to guide the design of individual systems that utilize vacuum feedthroughs and cabling and are a direct outcome of the Vacuum Feedthrough and Cabling Design Requirements Document (LIGO-T950095). Once the design has been completed, the materials and processes developed will be used by other systems and subsystems to provide for their vacuum cabling and feedthrough needs.

1.2. Scope

The conceptual designs described in this document pertain only to the cables, harnesses, mounting devices, vacuum feedthroughs, and vacuum connectors that are used within and to penetrate the LIGO vacuum chamber. The largest user of the devices developed in response to these specifications will be the suspension systems for each of the suspended optics. Other uses for the devices could include modulation signals to Pockels Cells in the Input Optics.

It is the goal of the design process to produce devices, materials and guidelines that will meet imposed requirements in the following areas:

- Vacuum Compatibility and Contamination
- Mechanical/Vibrational Isolation
- Electrical Signal Compatibility including shielding to reduce induced and transmitted interference, current rating, impedance, etc.

1.3. Definitions

Vacuum Connector- connectors that are used inside the LIGO vacuum chamber.

Vacuum Feedthrough- an electrical connector that is used to penetrate the vacuum chamber. It can be a multiple pin or coaxial connector. When installed properly it will not compromise the vacuum chamber integrity.

Vacuum Cabling- cabling that is used to route electrical signals inside the vacuum chamber.

Cable Clamp- a mounting device that is used to securely fasten cables to the seismic stack elements or other components with the vacuum chamber.

1.4. Acronyms

- CDS- Control and Data System
- DRD- Design Requirements Document

1.5. Applicable Documents

1.5.1. LIGO Documents

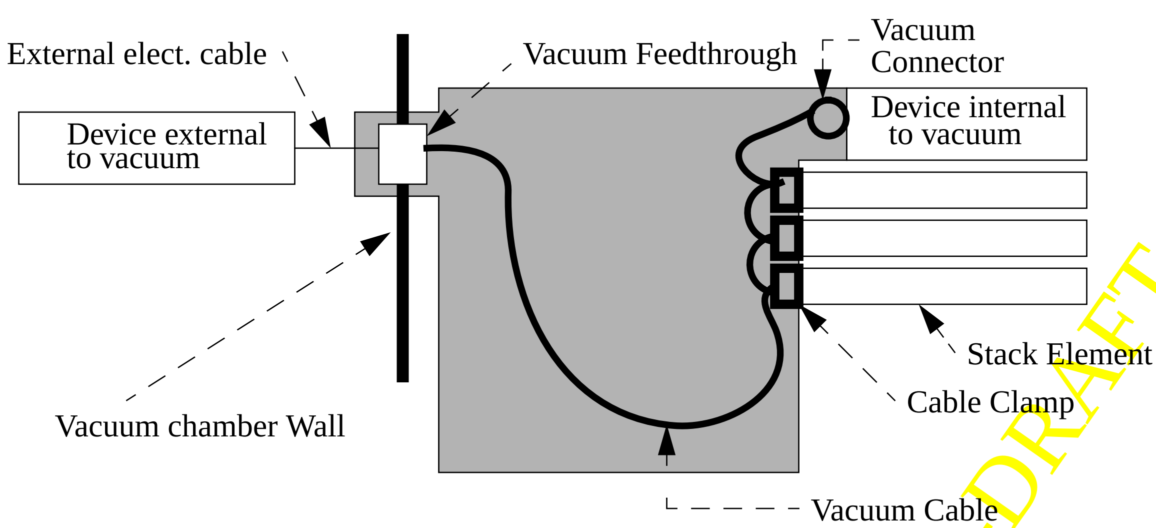
- Vacuum Feedthrough and Cabling Design Requirements Document- LIGO-T950095
- LIGO List of Approved Vacuum Materials- LIGO Document No. TBD
- LIGO Acceptance Process for Vacuum Systems Containing Optics- LIGO working paper (A. Abramovici, April 1993), Document TBD
- LIGO Detector ICD- LIGO Document TBD
- LIGO Detector Naming Convention- LIGO document TBD
- LIGO Detector Implementation Plan- LIGO document TBD
- LIGO Drawing Preparation Standard- LIGO Document TBD
- LIGO Systems ICD- LIGO Document No. TBD
- Seismic Isolation Design Requirements Document- LIGO Document No. TBD

1.5.2. Non-LIGO Documents

N/A

2 SYSTEM OVERVIEW

The materials, techniques and procedures developed for the vacuum cabling and feedthroughs will be used as a component by a variety of detector subsystems. The figure below shows a typical configuration. The pieces that are part of the vacuum cabling and feedthrough subsystem are in the shaded region.



3 VACUUM FEEDTHROUGHS AND CONNECTORS

The various types of vacuum feedthrough can be broken into two categories: multi-conductor and coaxial/triaxial. Each of these is described below.

3.1. Multi-conductor Vacuum Feedthroughs

Multi-conductor vacuum feedthroughs are available from several manufacturers including Ceramaseal and ISI (Insulated Seal Inc.). A this time it is planned that MS style feedthroughs will be used, but other styles are available. Connection to the internal vacuum cabling can be made by either using an internal vacuum connector (available from the manufacturer) or by soldering the internal pins of the single ended connector to a piece of flexible Kapton circuit board (described below).

3.2. Coaxial/Triaxial Vacuum Feedthroughs

Coaxial and Triaxial vacuum feedthroughs are available from several manufacturers including Ceramaseal and ISI. The coaxial connectors include: BNC, SMA, N, and Microdot. These connectors and triaxial connectors can be purchased as single ended connectors (pins on the vacuum side) or double ended (vacuum compatible connector on vacuum side). The choice of single ended or double ended connector configuration will be dictated by the type of cabling that is to be used internal to the vacuum system. If a commercial coaxial or triaxial cables are to used, the double ended configuration will be chosen. If flexible circuit board is to be used the single ended configuration will be chosen. Each of theses cable choices is described below.

4 VACUUM CABLING

The various types of vacuum cables can be broken into two categories: multi-conductor and coaxial/triaxial. Each of these is described below. In addition, each type of cable may require a fastening device.

4.1. Multi-conductor Vacuum Cables

Multi-conductor vacuum cabling will be fabricated using flexible Kapton multi-layer circuit boards. The requirement to provide twisted pair cabling will be handled as shown in the figure below.

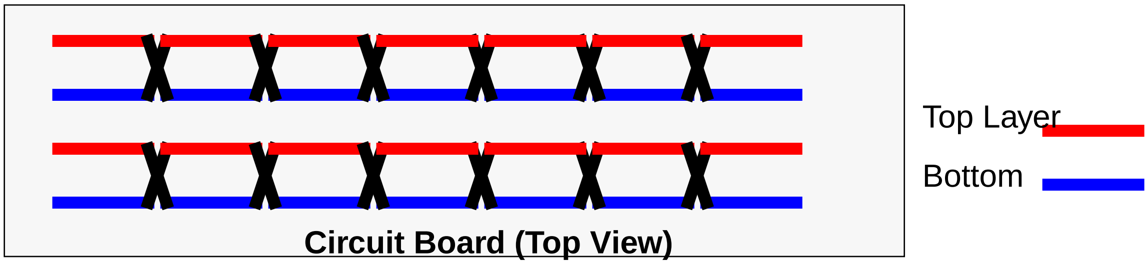


Figure 1: Twisted Pair Configuration

Each signal pair will be “twisted” by dithering the traces laterally on the circuit board and alternating the layers on which the signal and return are routed. Current handling capability will set by the trace width and plating thickness. Voltage standoff will be set by conductor pair spacing, but will typically be greater than 1000 VDC for standard layouts.

The requirement to provide for an overall shield for the cable will handled by using a multi-layer circuit board design with outer layer ground planes. This configuration is shown in the figure below.

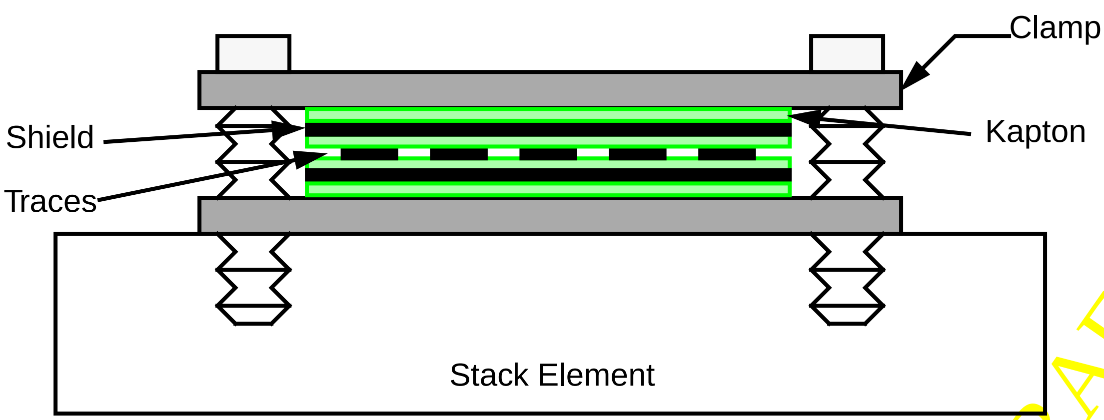


Figure 2: Shielded Cable Configuration Showing Stack Fasteners

There are several manufacturers that can provide the flexible Kapton circuit board that are required. A sample approximately 10 feet in length, 3 inches wide and 0.5 mils thick with 100 traces each 10 mils wide was obtained from Flex-Link Products Inc. and subjected to vacuum outgassing tests at Caltech with acceptable results.

4.2. Coaxial/Triaxial Vacuum Cables

There are two choices for internal coaxial/triaxial vacuum cabling. Commercially obtained Kapton insulated cables with attached connectors or fabricated transmission line Kapton cables.

Prefabricated Kapton cables can be obtained from several manufacturers including ISI. These cables come in various lengths and cable sizes and have vacuum compatible connectors attached. In addition, the cable material and connectors can be purchased separately and manufactured by LIGO. The stiffness of these cables will need to be investigated if these cables are to be used to connect devices located on seismically isolated optics tables.

Matched transmission line cabling can be fabricated using the Kapton circuit board technology described for multi-conductor cables. In this configuration the traces and planes would be adjusted such that 50 ohm transmission lines are created on the circuit board. This configuration is shown in the figure below.

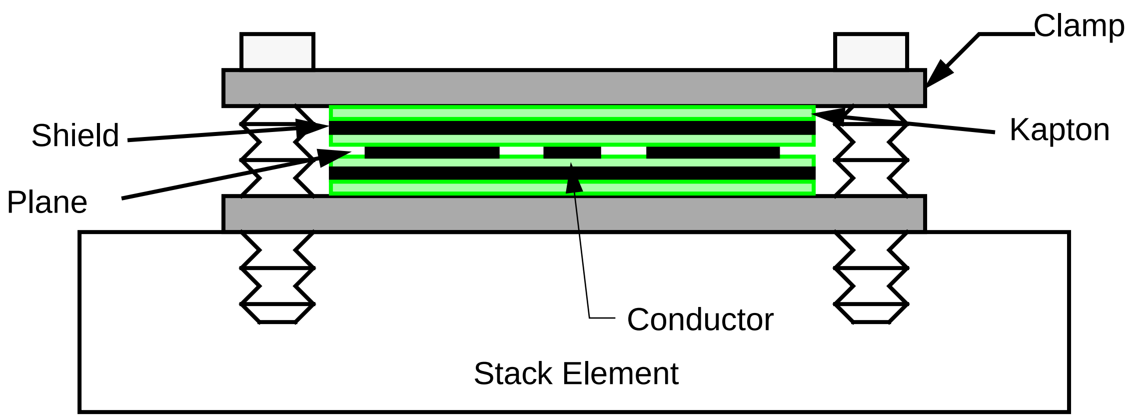


Figure 3: Transmission Line Configuration Showing Stack Fasteners

4.3. Seismic Stack Cable Fasteners

Fastening of cables to the seismic isolation stack to prevent transmission of high frequency vibration will be accomplished by clamping the cables at each stack element as shown in figures 2 and 3. The clamp materials and mechanism for attaching to the stack elements will be determined as part of the preliminary design.