L Jones & D. Coyne
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Linear Voice Coil Actuator Design Requirements
Advanced LIGO Seismic Isolation System

Two models are required.

General Requirements for Both Models:

- Configuration is rectangular, to reduce undesired torques when the coil is shifted laterally from the nominal position. BEI/Kimco's Model LA15-65-000A exhibits a rectangular configuration that fits the force vector orientation requirement for the large actuator (although of a different size).
- Operating environment will be ultrahigh vacuum, 10^{-8} torr
- Minimum Lateral Clearance, X & Y: +/- 0.040"
- Minimum Stroke, Z: +/- 0.040"
- Winding direction(s) and magnet placement designed to cancel external dipole moments; the design shall include two counterwound coils
- Bobbin to be aluminum, with anodized areas limited to where required for electrical insulation
- Bobbin to be machined on all surfaces, then given to Caltech for precleaning prior to winding; clean room gloves to be used for subsequent bobbin handling and winding/curing of adhesive
- Actuator frame, screws and magnets to be given to Caltech for precleaning prior to assembly; clean room gloves to be used for subsequent assembly, as well as any handling done prior to assembly
- None of the actuator parts shall have blind holes; if it's impractical to use a through hole, a vent hole shall be added to vent the volume trapped by assembly (this is for both thoroughness in cleaning and to aid vacuum pumpdown)
- All tapped holes shall be tapped with a 0.005" oversize tap to reduce the risk of galling in the ultraclean condition
- All screws used shall be silver plated stainless steel, to reduce the risk of galling in the ultraclean condition
- Wire insulation to be Polyimide-ML, or -HML
- Wire adhesive to be Cytec's Cycom 3001 (polyimide), if needed
- Magnet material to be SmCo, baked at 350C for 96 hr and then Ni plated to seal surface voids from contamination
- Magnets to be secured mechanically, with no epoxy
- Potting material to be selected on the basis of minimum outgassing while meeting performance requirements, with LIGO testing for qualification. (Note: it is likely that potting materials will need to be polyimides in order to meet our outgassing requirements, which are much more stringent than NASA requirements. The LIGO Project will make a qualification decision within 2 weeks of receipt of a candidate material.)

- In production, required actuator testing is limited to high-pot testing of coil and limited functional and performance testing
- First article acceptance testing consists of functional and performance testing (centered and at X & Y maximum offsets), QA for interface dimensions and workmanship inspection
- Customer acceptance testing includes vacuum compatibility testing. All testing and liability with regard to compatibility with the LIGO vacuum system is the customer's responsibility. The Manufacturer is only required to adhere to approved materials and processes
- Actuators will not include proof masses/flexures, encoders/sensors or bearings/bushings
- (stated as a preference, not a requirement) Preferred voltage range is +/- 25 V, preferred current range is +/- 10 A

- The voice coil assembly shall be capable of being vacuum baked (by the customer) at 200C (non-operating) for indefinite duration (~48 hr.)
- The allowable temperature range of the coil should be at least from 15C to 200C (operating)
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- For reference only (not a requirement): The nominal operating conditions are in-vacuum at ~23C ± 5C for the large actuator (and ~25C ± 5C for the small actuator) and dissipating < 25 mW rms. Conduction dominates over radiation at these conditions. Operation at the maximum continuous force will be for periods of time considerably shorter than the thermal time constant. If operated continuously at the maximum allowable continuous force, radiation effects would reduce the interface resistances stated below.

Requirements for Small Actuator:

- Maximum Continuous Force: 10 lb_f
- Input Power at Maximum Continuous Force: 40 W
- The Force Vector is perpendicular to actuator mounting plane
- Nominal envelope dimensions: 3.6” L x 1.8” W x 3.3” H
- Mounting interface dimensions: 2.8” L x 1.8” W for frame, 3.6” L x 0.8” W for bobbin
- The maximum, steady-state, temperature difference between any point on the coil surface and the coil mounting interface should, by design, be minimized on a best efforts basis, with a goal of < 0.6 C/W assuming either a four point connection to the bobbin or a two point connection, along with two copper heat straps to the other end of the bobbin
- The thermal resistance of the coil interface (with attachment of 0.75 in^2) is ≤ 3.5 C/W
- The thermal resistance of the magnet frame interface is ≤ 7 C/W
- The thermal time constant of the coil interface is ≥ 100 hrs.
- The thermal time constant of the magnet frame interface is ≥ 100 hrs.

Requirements for Large Actuator:

- Maximum Continuous Force: 50 lb_f
- Input Power at Maximum Continuous Force: 100 W
- The Force Vector is perpendicular to actuator mounting plane
- Envelope dimensions: 8.2” L x 4.3” W x 4.1” H
- Mounting interface dimensions: 7.1” L x 4.3” W for frame, 8.2” L x 2.0” W for bobbin
- The maximum, steady-state, temperature difference between any point on the coil surface and the coil mounting interface should, by design, be minimized on a best efforts basis, with a goal of < 0.3 C/W assuming either a four point connection to the bobbin or a two point connection, along with two copper heat straps to the other end of the bobbin
- The thermal resistance of the coil interface (with attachment of 3.87 in^2) is ≤ 1.5 C/W
- The thermal resistance of the magnet frame interface is ≤ 3.5 C/W
- The thermal time constant of the coil interface is ≥ 30 hrs.
- The thermal time constant of the magnet frame interface is ≥ 100 hrs.