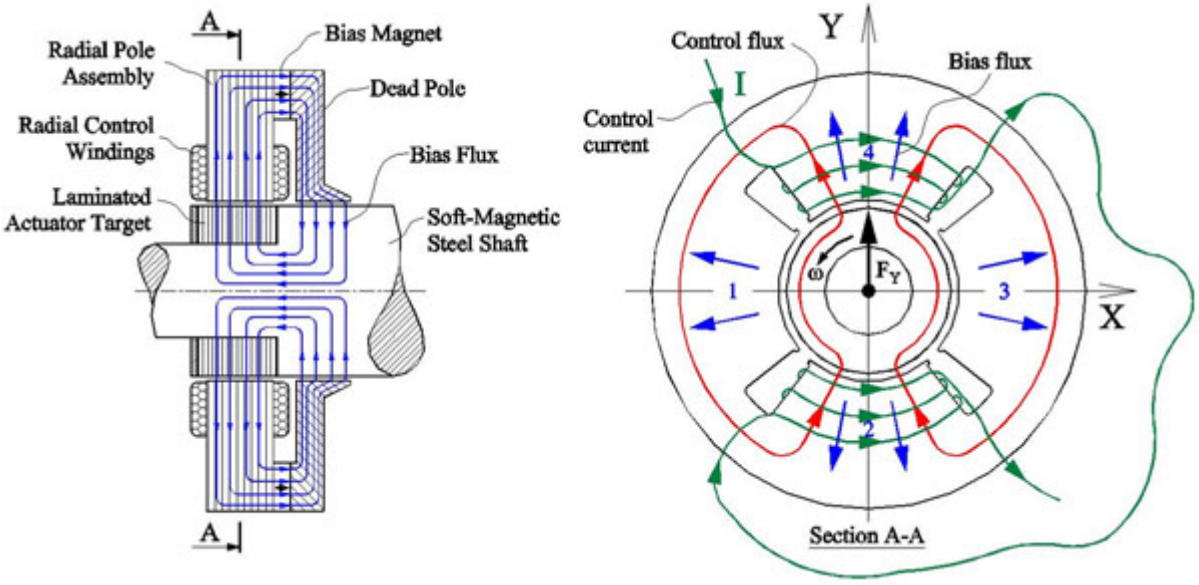
Powerflux™ Active Magnetic Bearings

Calnetix Technologies specializes in high-speed rotating machinery supported by patented active permanent magnet bias homopolar bearings. We offer Powerflux™ Magnetic Bearings in radial and side by side combination configuration. These are the most advanced active magnetic bearings in the market. The very unique advantages of Calnetix's magnetic bearings include the following:

Permanent Magnet (PM) Bias

In active magnetic bearings, approximately a half of the total magnetic field is a steady, uncontrolled bias field. In Calnetix magnetic bearings, the bias is generated by permanent magnets rather than currents in electrical coils (electromagnets). In contrast to coils with currents, permanent magnets produce a magnetic field without generating heat or using electrical power.



Using permanent magnets to generate the steady portion of the magnetic field (bias magnetic field) results in less variation of the force exerted on the rotor when it deviates from the nominal position than when an electrical coil is used for the same purpose. This results in an improved magnetic bearing dynamics and larger load capacity when the rotor is offset from the central position. There are additional packaging and layout benefits as well. The size of a modern rare-earth magnet needed to produce the bias magnetic field is a small fraction of the size of an electromagnetic coil needed to produce the same field. This can be understood given that an electromagnetic coil needs a certain number of Ampere-turns to generate a particular magnetic field. If the size of a given coil is reduced, the Ampere-turns must remain constant, which

inevitably leads to an increase in total resistive power dissipation in the coil, and even more to an increase in resistive power dissipation in a unit volume of the coil. Thus, the lower limit on bias coil size is driven by the heat dissipation available to prevent coil burn out. The smaller size of permanent magnets compared to current-carrying coils result in smaller overall size of a magnetic bearing, leading to a more compact machine design and improved rotordynamic performance.

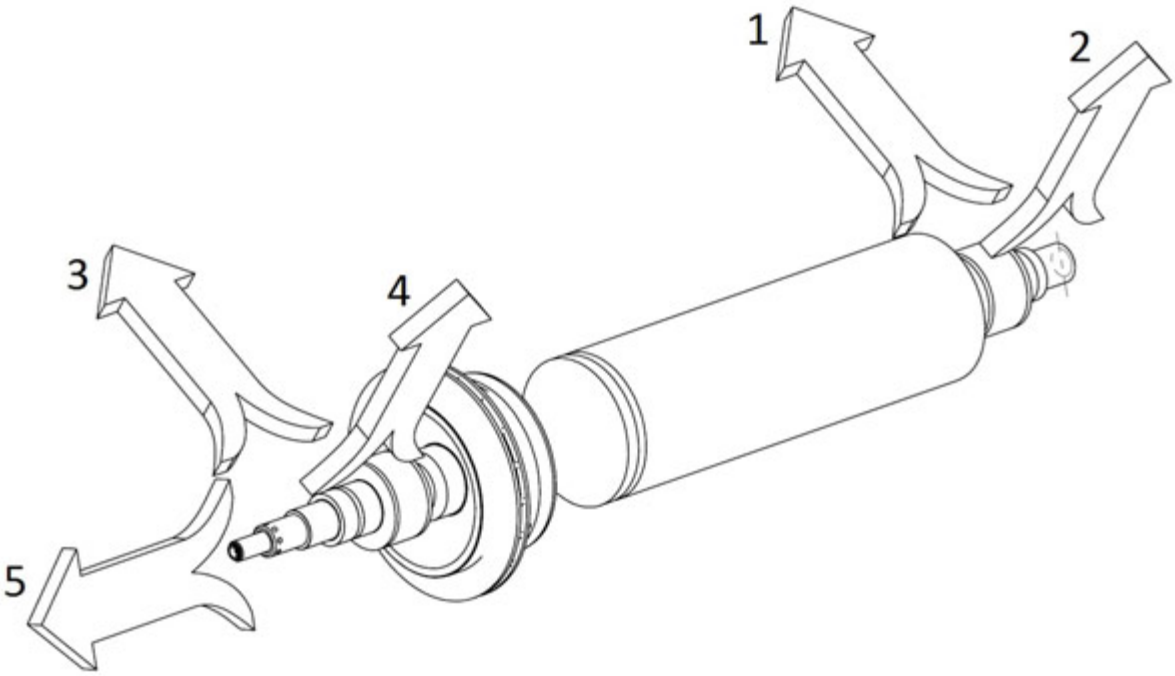
Homopolar Design

There are some inherent losses within Active Magnetic Bearings (AMBs). The radial magnetic force exerted on a rotor by an AMB becomes weaker when the rotor spins at a sufficiently high speed. This is because the rotor, typically made of conductive soft-magnetic material, has induced eddy currents when spinning in the non-uniform magnetic field needed to induce a radial force. In order to reduce the eddy-currents in the rotor, and, subsequently, the loss of some radial force capacity, a portion of the rotor is normally made of electrically insulated steel laminations. Thinner laminations have reduced eddy currents and thus smaller force loss at a given rotational speed. There is a practical limit on how thin an electrical steel lamination can be made. The smallest "off-the-shelf" electrical steel lamination thickness is 0.006" (150µm), and the thinner lamination gets the more expensive it becomes. The loss of the radial force also depends on the frequency of the magnetic field that a rotor sees when spinning, or for a given spin speed, on a spatial frequency of the field distribution around the rotor. For example, a magnetic bearing with a magnetic field distribution having four cyclic changes around the rotor will have lower load capacity at a given speed than a similar magnetic bearing with a magnetic field distribution having only one cyclic change. While other magnetic bearing companies use heteropolar magnetic bearings, where magnetic field distribution around the rotor has at least four cyclic changes, Calnetix utilizes homopolar technology where the field distribution has only one cyclic change around the rotor and only when the rotor is subjected to radial loading. Therefore, Calnetix bearings either have smaller force loss with speed compared to competition, or can be made less expensive by using thicker laminations on the rotor. Another advantage of the reduced eddy current losses of the Calnetix homopolar magnetic bearing technology is a significantly lower heat generation in a spinning rotor compared to heteropolar technology. In fact, homopolar magnetic bearings will have almost no heat generated in the rotor at speed in an absence of a radial loading because the magnetic field will be almost uniformly distributed around the rotor, thus having no significant eddy currents generated. On the contrary, heteropolar magnetic bearings generate heat in a spinning rotor even in the absence of radial loading. Low heat generation in both stationary and rotating parts of homopolar PM-biased magnetic bearings make them very energy efficient and well suited for applications where heat extraction mechanisms are limited, such as in a vacuum.

Combining Radial and Axial Bearing Functions in One Device

Supporting a spinning object in a magnetic field requires constraining its five degrees of freedom with the sixth degree - a spin about an axis - being left unconstrained. A typical magnetic bearing

system configuration for a rotating machine involves one radial bearing constraining two radial degrees of freedom (X and Y) of one end of the rotor, another radial bearing constraining two radial degrees of freedom (X and Y) of the other end of the rotor, and one axial bearing for the axial rotor degree of freedom (Z). Other magnetic bearing system designs use two independent radial and one axial magnetic bearing. Calnetix offers a unique proprietary solution that combines the functions of one radial and the axial bearing in one device – a magnetic combo bearing. The benefits include lower cost and reduction in system size, leading to a rotordynamic advantage and a superior machine design.



Proprietary Position Sensors

Position sensors are critical components of any AMB system. The position sensors continuously provide the MBC (Magnetic Bearing Controller) with accurate and up-to-date information about the rotor position unaffected by external factors, such as speed, temperature, dust, working fluids, external magnetic, electrical fields, etc. While conventional magnetic reluctance sensors, seen in competing designs, work very well for measuring radial displacements, measurement of the axial displacements is often much more challenging. To address those challenges, Calnetix developed a unique constant-flux edge sensor with clear performance advantages, including:

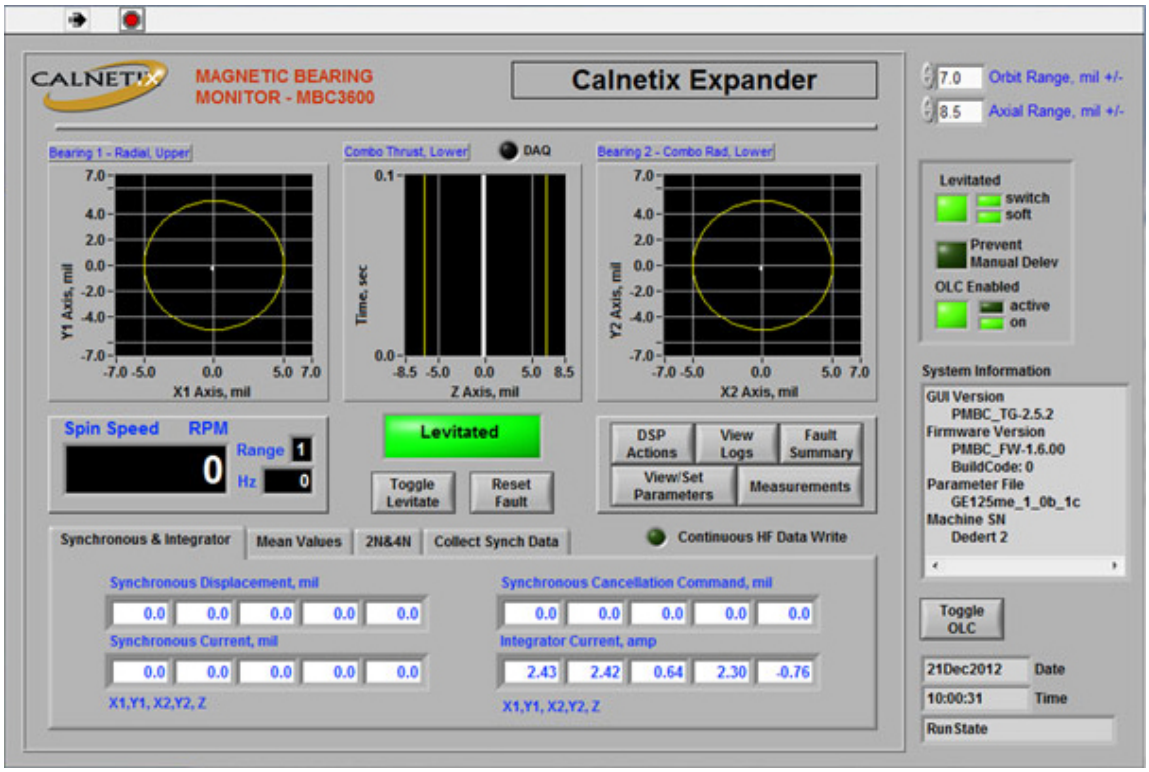
- Immunity to external magnetic fields and radial displacements
- Excellent temperature stability
- Total measurement range in excess of 0.2" (5mm) with a linear sub-range with less than 15% non-linearity in excess of 0.08" (2mm)
- Pass-through rotor assembly
- High raw gain in order of 100V/in (4V/mm)

State-of-the-art Approach to Integrated Machine Design

In most cases, Calnetix utilizes broad multidisciplinary in-house expertise to work with a customer in order to design an entire machine on magnetic bearings rather than simply supplying magnetic bearing components. This achieves optimal performance of the machine as an integrated system and fully realizes the magnetic bearing system potential. This approach is made possible thanks to a wide range of Calnetix in-house areas of expertise including mechanical, electromagnetic, rotordynamic, thermal and electronic design and analysis. Over the course of numerous machine development programs, Calnetix has refined its proprietary design and optimization codes to allow quick generation of optimized magnetic bearing geometries. These proprietary tools use a combination of analytical solutions and both in-house and third-party FEA modules. Such codes greatly facilitate development with faster and fewer iterations at the machine level leading to the optimal design of a machine as a whole.

Advanced Graphical User Interface

Calnetix developed a novel Graphical User Interface (GUI) to give both users and specialists an intuitive way to work with the inherent benefits of a magnetic bearing system. Over the span of many years this GUI has been continuously refined and upgraded based on feedback from both internal and external customers. The GUI provides insight into all aspects of magnetic bearing and machine performance. It is the platform for system setup, monitoring and diagnostics:



- Monitoring made easy with live vibration monitoring
- Commissioning made simpler with built in transfer function tools
- Data and fault logging that may be customized by the user
- Easy offset of the rotor position for operation or testing needs
- Optional data acquisition connections to provide higher quality data
- Calnetix's superior customer support means the GUI is regularly being upgraded