General specifications of the NuevoMR shim driver current source

2022-12-01

The NuevoMR active shim design is highly matrixed, requiring 32 independently adjustable currents to produce the harmonic homogeneity correction fields. The design emphasizes minimal use of gap space inside the magnet, at the cost of complexity in the electronics outside the magnet.

At NuevoMR, we have successfully used a simple prototype multichannel current source for more than 5 years. Although this design has a number of shortcomings rendering it unsuitable for commercialization, it does provide data to support the following current source specification:

Number of independent channels: 32

Maximum current per channel: ± 0.5 A

Current output supply rail voltage: ± 2.5 V (for typical shim sets)

Total supply rail current: 3A each (in some rare cases, this is too low)

Notes:

* The NuevoMR active shim design usually results in individual current traces with a resistance below 1 Ω and negligible inductance. We anticipate that the shim “wires” for the ETH magnet will have a resistance of roughly 0.5 Ω. The cabling for these shims will contribute to the resistance seen by the current sources.
* The NuevoMR current controller uses a pass-bank built on pairs of NPN and PNP transistors each capable of controlling 3A. The currents are sensed with 1 Ω precision power resistors. (Note that the sense resistance is NOT low with respect to the resistance of the shims themselves.) The power dissipated in the pass-bank can be minimized by dropping the supply rail voltages.
* Power dissipated in the shims wires themselves is quite small and typically does not cause unmanageable difficulties with field drift, even in Neodymium-based magnets.
* We anticipate that the raw magnet will be rather homogeneous and the currents required to shim the magnet may be a fair bit lower than the specifications listed above.
* The outputs of the current sources are not filtered in a manner that limits their response time. In fact, we usually set up our active shim systems without filters at all: no shields on the ribbon cables, no common mode filters, no pass-through filtering at the magnet. We do observe some 60 Hz noise, so some filtering may be helpful for the ETH system. The 60 Hz sidebands do not undermine the work we do at NuevoMR, but they would be a problem for spectroscopy.
* The NuevoMR shim driver senses the current on the high side, rather than in the return path to ground. In principle, this allows all the shim current returns to be via one common conductor. We lay out the shim PCBs with independent returns, which means that low-side current sensing will work, too.
* We have had trouble with the shim drivers latching up while they power up. The probable cause for this is the higher power current supplies coming to voltage before the lower-power control circuitry has stabilized.
* Driving these matrix shims will require some sort of digital control to implement the matrix. We have used digital control based on an Arduino Due talking to a set of DACs via the SPI bus. Communications with the computer is via a USB/serial port. The computer-side code implements the matrix and requests the Due to produce specified currents on each of the wires.