High-Stability, Low-Noise Current Driver

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Customized Z201 Series Bulk Metal® Foil resistors from VPG Foil Resistors are used to meet the demanding target specifications of a precision 16 A current driver — required to drive current through magnetic coils — to produce and study Bose Einstein Condensates (BECs).

Industry/Application Area: Precision instruments for scientific research

Products used:
- Z-201 Series Bulk Metal Foil resistors
- custom-build shunt resistor from Powertron, also a VPG brand

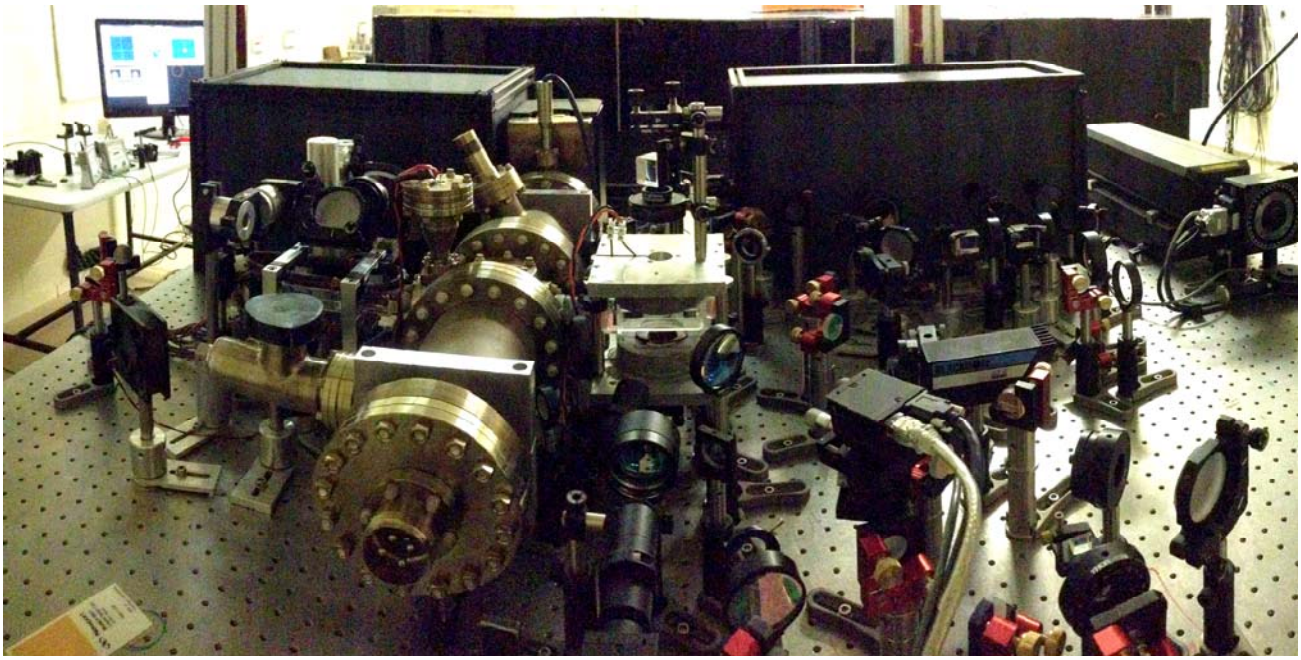

Figure 1: Part of the experimental equipment used to create Bose Einstein Condensates.

The Challenge

Physics research often makes extraordinary demands upon technology. For the Research School of Physical Sciences at Australian National University, the challenge was to produce a 16 A current driver stable to within 1 ppm on all timescales from microseconds up to tens of hours. A require-

ment of 1 ppm/K would have been challenging already, but absolute stability of 1 ppm was required independent of changes in room temperature, putting extraordinary demands upon the resistors used in the circuit. In addition, low noise was needed — less than one part in 10 million — as well as good high-frequency response. Meeting all of these requirements simultaneously was difficult.

Figure 2: View of the 16 A precision current driver. The massive heatsink removes heat from the shunt resistor, via the Peltier modules, as well as from the linear series-pass regulator MOSFETs.

The Solution

A massive 0.1 Ω shunt resistor (380 mm by 110 mm), custom built by VPG Foil Resistors' Powertron brand, was mounted on a Peltier cooled heatsink, temperature controlled to within 0.1 °C. In addition, the feedback amplifier circuits required smaller resistors mounted on the printed circuit board, which also needed to be stable to within 1 ppm. The design philosophy adopted for the project was to use the best resistors available, with the lowest temperature coefficient of resistivity (TCR). With its published TCR of 0.05 ppm/K, VPG Foil Resistors' Z201 Series was selected. The main PCB was mounted in a temperature-controlled enclosure to further stabilize the resistors and operational amplifiers.

The User Explains

Unfortunately, in addition to a DC stability of 1 ppm, our requirements also called for exceptionally low noise of less than one part in 10 million. Bulk Metal Foil resistors such as the Z201 Series have intrinsically low noise, limited by thermal Johnson noise, which increases with increasing resistance. To reduce Johnson noise enough for our needs, without cryogenic cooling, we needed to use low resistance values in the operational amplifier circuits — no more than 500 Ω at the 10 V signal level. This in turn increased the self-heating of the

Figure 3: A cooling fan cannot be used, as the rotating stray magnetic field would inject noise into the sensitive circuitry.

resistors (P=V^2/R), which led to changes in resistance and drift in the value of the all-important controlled current. Placing the PCB in a temperature-controlled enclosure does nothing to reduce this self-heating-induced change in resistance.

Based on the deep understanding of this issue by the experts at VPG Foil Resistors, datasheets for Bulk Metal Foil resistors feature values for the power coefficient of resistivity (PCR), relating change in resistance with dissipated power. Z201 Series devices have an exceptionally low PCR, allowing us to meet our 1 ppm target specification, even in the presence of inevitable and significant self-heating of the resistors. In demanding high-end applications such as this, the modest extra cost of ultra-high-grade resistors such as the Z201 Series removes design headaches, and allows specifications to be met that could not otherwise be achieved.

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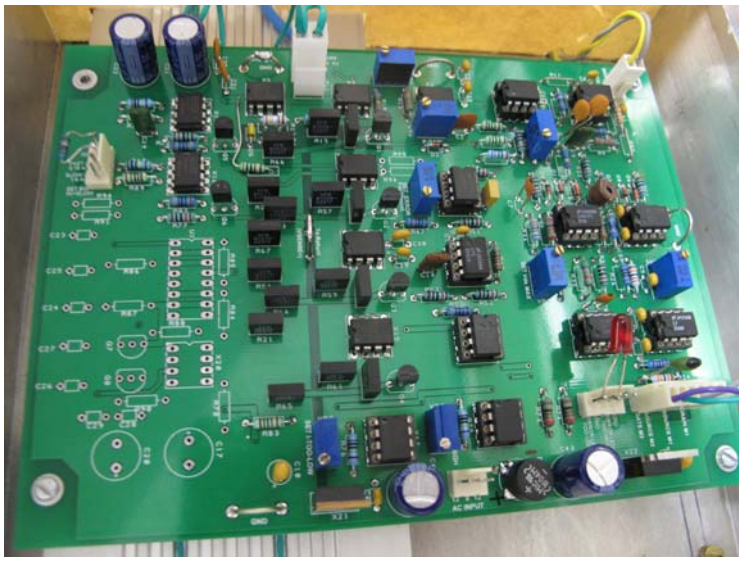

Figure 4: View of the main printed circuit board.
The 16 Bulk Metal Foil Z201 Series resistors (the upright-standing rectangular blocks) are clearly visible, R65, R21, etc.

Acknowledgement: Australian National University’s Department of Quantum Science spans the spectrum of research, from fundamental investigations into quantum mechanics and gravity through to commercialization of advanced technology. We host a node of the ARC Centre of Excellence for Quantum Computation and Communication Technology, and the Centre for Gravitational Physics,

which is pioneering gravitational wave astronomy within the international LIGO consortium. For the study of the formation process of BECs, the University recently became one of only four groups in the world to develop a novel laser cooling apparatus capable of creating BECs using excited helium atoms rather than atoms in the ground state.

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