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Current-Mode Programming for the Prototype-TPC Magnet Power Supply

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Abstract

A circuit was built to interface the DAC output of the Sunset Laboratory Advanced Interfacing Board (AIB-PCt) to the current-mode programming input of a Sorensen DCR 7-300B 2700-W power supply. The design of the circuit and the control of the power supply's output are discussed.

1 Introduction

This note describes the control of the supply current for the Princeton warm-bore superconducting magnet [1], which will produce a 3-T drift magnetic field for the prototype of the low-pressure TPC designed for the Muon Collider Collaboration's ionization-cooling experiment [2]. Section 2 summarizes the current-supply requirements of the magnet. Section 3 outlines the characteristics and operation of the power supply. Section 4 describes the PC board and the C program which control the power supply's current output. Section 5 presents the details of the circuit built for converting the analog voltage output of the PC board into a floating programming signal for the power supply. Section 6 describes the performance of the current control.

2 Requirements for Energizing the Magnet

The maximum current which will be supplied to the magnet is 65 A(dc). Since the inductance of the magnet is approximately 20 H [1], the supply current should be stable, with a ramp rate of the order of 0.1 A/s, to avoid generating high voltages across the coil.

3 The Power Supply

The current source for the magnet is a Sorensen DCR Model 7-300B 2700-W power supply, which takes an input voltage of 208 V(ac) [3]. The two available modes of operation are voltage mode, which keeps the output voltage constant while varying the output current, and current mode, which keeps the output current constant while varying the output voltage. The maximum voltage that the device can supply is 7 V(dc), and the maximum current is 300 A(dc) at 40°C. A crossover feature protects the power supply by forcing a switch from current to voltage mode if the output-voltage requirement exceeds the maximum voltage, and from voltage to current mode if the output-current requirement exceeds the maximum current. This feature limits the maximum ramp rate to 0.35 A/s when the power supply current output is fed into the magnet.

In both current mode and voltage mode, the output of the power supply can be controlled by a programming voltage signal. To source current into the magnet, the power supply is run in current mode, with the value of the output current programmed by a voltage applied to terminal 8 and returned to terminal 9 of the control barrier at the back of the unit. For proper operation, the programming signal must be a floating voltage, with a maximum range of 400 mV, capable of sinking approximately 1.0 mA of current. The ratio of programming voltage to output current was measured to be 0.33 mV/A, as shown in Fig. 1.

The constant-current ripple of the power supply at 300 A is 2.8 A(rms).

4 Current Control

The programming voltage signal for the power supply is produced using the Sunset Laboratory Advanced Interfacing Board for IBM™ and Compatible MS-DOS™ Computers (AIB-PCt) [4]. The AIB-PCt board consists of one 12-bit ADC, two 12-bit DAC's, and three 16-bit timers capable of functioning in various modes. The I/O lines included are 8 analog inputs, 2 analog outputs, and 16 digital I/O lines which can be used as 16 inputs, 16 outputs, or 8 inputs and 8 outputs. To operate the board, Vernier Software's Multipurpose Lab Interface (MPLI) Program for Windows™ [5] is used.

A C program called "icontrol.c" makes use of the relationship between the programming voltage and the output current of the power supply to produce a voltage corresponding to the desired current on one of the analog voltage outputs of the AIB-PCt board. The program enables the user to set the output of the power supply to a

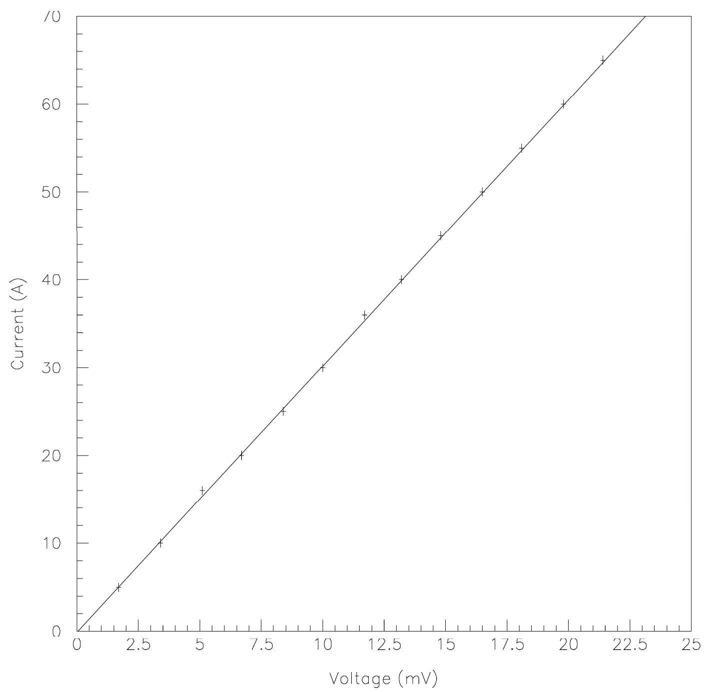

Figure 1: The current output of the power supply as a function of the programming voltage. The data points are fit to the function V = $-0.33 \times$ I. An initial DC offset of 0.36 V was canceled by adjusting potentiometer R53 at the back of the power supply.

given current, or to ramp up to a given current at a given rate. The output current range allowed is between 0 A and 65 A, and the minimum and maximum ramp rates are 0.01 A/s and 0.35 A/s, respectively. The power supply output must be zero before the user may exit the program.

5 The Circuit

Since the AIB-PCt's 12-bit DAC covers the range -5 V to $+5$ V, the resolution of the analog outputs is limited to 2.44 mV/(DAC count). If the output of the DAC were applied directly to the programming pins of the power supply, the output current would increase in steps of (2.44 mV/count)/(0.33 mV/A) = 7.4 A/count, producing high voltages in the superconducting coil of the magnet.

The circuit shown in Fig. 2 resolves this problem by attenuating the output of the DAC by a factor of 100 and outputting a floating voltage which can be used as the programming signal of the power supply. The result is that the programming signal increases in steps of 0.0244 mV/count, and the output current in steps of 74 mA/count.

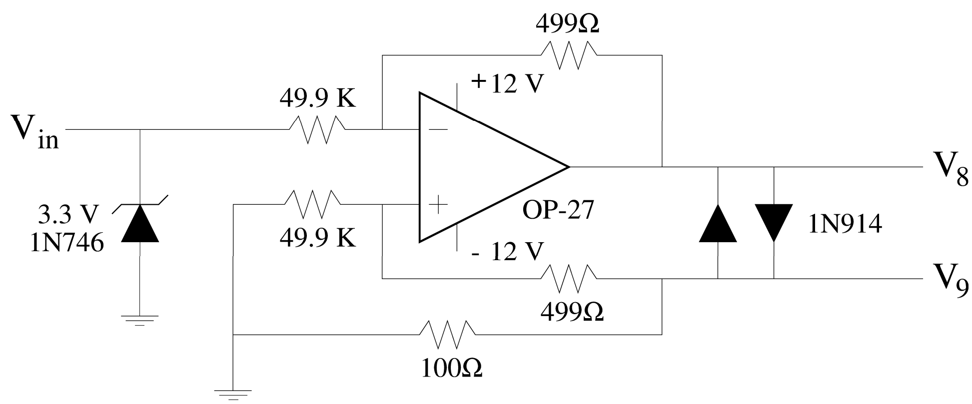

Figure 2: The circuit converts the analog output of the AIB-PCt into a floating programming signal for the power supply. V_{in} is the output of the AIB-PCt board's DAC, while V_8 and V_9 are the voltages to be connected to pins 8 and 9, respectively, of the power supply. The output of the circuit is given by $V_8 - V_9 = -V_{in}/100$.

In the circuit, the 100-Ω resistor serves to sink the 1-mA current from pins 8 and 9 of the power supply. The Zener diode ensures that the input of the Analog Devices [6] OP-27 op-amp remains between 0 V and −3.3 V. The output of the circuit is not filtered, as it was found that placing a 0.1 μF filter capacitor between V_8 and V_9 decreases the output by approximately 3 mV when V_9 is grounded.

The circuit was built into Vernier Software's Multipurpose Lab Interface Box [5], which distributes the voltages from the AIB-PCt, providing a convenient way of interfacing the board to outside devices. To minimize the noise introduced into the programming signal, the circuit is located close to the power supply and connected to pins 8 and 9 by a set of twisted wires 8 inches in length.

6 Performance

It was observed that when the power supply is first turned on, if the programming voltage is set for a nonzero current, the output current does not react for the first few seconds. To ensure the stability of the current, the power supply should be turned on with the program "icontrol.c" started and the current set to zero. A "warm-up" period for the power supply of about 30 minutes should be allowed before setting or ramping the current to a nonzero value.

The power supply should be turned off before disconnecting the programming input.

A further application of the AIB-PCt board would be to use one of the ADC inputs to monitor the output voltage of the power supply.

References

[1] E. Prebys, "Princeton Warm-Bore Magnet," Princeton/$\mu\mu$/**98-9** (1998)

[2] C. Lu, K. T. McDonald and E. J. Prebys, "A Detector Scenario for the Muon Cooling Experiment," Princeton/$\mu\mu$/**97-8** (1997).

[3] *Instruction Manual for DCR-B Series 2700-Watt Power Supplies*, Sorensen (46 River Rd., Hudson, NH 03051), Document Number 165042 Rev F(4/87).

[4] R. A. Cary and D. H. Bax. *Advanced Interfacing Board for IBM^{TM} and Compatible MS-DOS^{TM} Computers*. Sunset Laboratory (2017 19th Ave., Forest Grove, OR 97116), 1992.

[5] *Multipurpose Lab Interface Program for Windows^{TM}*. Vernier Software (8565 S.W. Beaverton-Hillsdale Hwy, Portland, OR 97225-2429), 1994.

[6] Analog Devices, http://www.analog.com.