BEAM CURRENT MONITOR CALIBRATOR FOR THE SPALLATION NEUTRON SOURCE*

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Abstract

The Beam Current Monitor (BCM) system for the Spallation Neutron Source (SNS) to be installed at Oak Ridge National Laboratory (ORNL) requires an on-line calibrator to assure the system is appropriately scaling current. The calibration system must be able to handle the current range expected in the MEBT, Linac, HEBT, Ring and RTBT. This covers a dynamic range of 35ma to 50 amps. A 10-turn calibration winding has been included in all current transformers. This calibrator must provide adequate flexibility to assure the current transformers are not damaged by failures in the calibrator drive amplifier, and provide better than 1% accuracy with a capability to provide calibrated currents covering the dynamic range. This paper will address the design considerations and resulting design of a suitable calibrator for this system.

1 INTRODUCTION

The BCM system is designed as a network attached PC based instrument. The current sensor is a Bergoz® FCT [1]. It has been specially customized for this application and includes a 10-turn calibration winding. This allows the calibrating current to be 1/10 that of the beam.

A calibration signal generator is included to permit the measurement of a known current prior to each beam cycle. This is necessary to insure that the scale and transformer droop are known accurately enough to maintain the 1% system accuracy.

A large dynamic range is required for the accumulator Ring and RTBT where beam currents can reach 50 Amps. The MEBT, Linac and HEBT will only have 50ma peak beams. To satisfy the MEBT, Linac and HEBT requirement, a low current calibrator will be provided. In the Ring and RTBT the same low current calibrator will be installed but will be connected to a high current driver with two additional current ranges. This approach then, uses the low current calibrator to drive a high current driver housed in the drive bay space in the PC for the systems being used for the Ring and RTBT.

2 TECHNIQUE

To meet the demand of an adjustable current source, capable of high accuracy and stability, a current output DAC2902 has been selected as the basic element. This provides a well-controlled dual current source suitable for the two channels included in the PC chassis. The DAC is to be preceded by a memory that can be loaded from the higher-level application program and so act as a function generator that can provide a wide selection of calibration waveforms. The DAC2902 can deliver up to 20ma into a 50 Ohm load. For most applications as a calibrator, however, it is intended to run a 5ma, 400 usec pulse. This is equivalent to a 50ma beam current due to the 10-turn calibration winding in the SNS transformers.

2.1 Special Considerations

A number of design features have been included to assure flexibility and safe operation:

- Ground isolated calibration output.
- Current limiting and fuse protection to assure there can be no damage to the transformer in the event of DAC/driver failure.
- Transmission line AC source termination to avoid reflections due to mismatch at the transformer end and high impedance current source end.
- Opto-isolated digital interface and isolated power supplies to maintain galvanic isolation.
- Memory driven waveform to provide flexibility.
- DC fused protection to protect the transformer winding against catastrophic driver failures.
- Careful attention to cabling and shielding to avoid ground loops and shield against pick-up on the calibration winding cabling.

2.2 Prototype efforts

To test the concepts described above, an evaluation board was obtained from Texas Instruments for the DAC2902. Space available for additional components was used to create a simple clocking system to enter a fixed digital value followed by a zero value, thus creating a pulse. This was accomplished using a 555 timer IC. All digital triggering and power was isolated from ground to avoid ground loops. The DC capability was implemented by inhibiting the clock that would return the DAC to zero. The output current was measured by an Agilent 3458A 8-1/2 digit Digital Multi-meter. In this way a 5ma current was easily set digitally.

The pulse obtained from the DAC2902 was isolated from the transformer by a 50 Ohm protection resistor, and AC terminated at the source (0.1µF and 82 Ohm) to match a 78 Ohm Twinax cable (Belden 9463). The cable was 500 feet long to simulate estimated wiring and measurements performed on the transformer output. By adjusting the pulse width to 400 µs, adequate pulse time was available to permit transients, due to the AC coupled termination, to settle and computation of transformer droop time constant and gain to be performed. The

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transformer droop is compensated by a special compensation filter described in reference [2]. This is necessary for proper calibration since the FCT has a droop near 0.1%/µs.

The original prototype housed the calibrator in the main section of the PC chassis, where space permitted. The final version is expected to devote one drive bay for this calibrator.

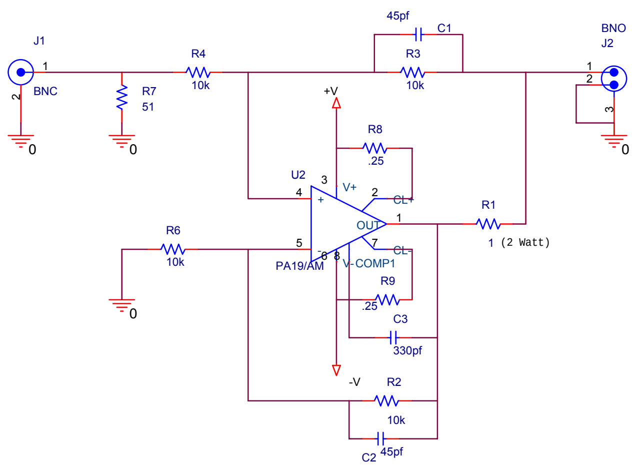

Figure 1: Breadboard of the Improved Howland Current Pump.

3 DRIVER

The prototype described above provides adequate current for the MEBT, Linac and HEBT transformers. To achieve the currents required to calibrate the Ring and RTBT transformers, where actual beam currents will accumulate up to 50 Amps, a current amplifier/driver will be provided.

A circuit has been designed using an APEX PA19A Video Power Operational Amplifier configured in an “Improved Howland Current Pump”[3] as in figure 1. This circuit has been breadboarded and is undergoing tests. So far it appears to offer the rise time, stability and the ability to drive the cable lengths required. Several issues remain however. First the circuit as shown produces an output offset current of around 5 ma. Such a DC offset current in the transformer core has been shown to produce slight errors in the droop measurements and so may need to be carefully zeroed. This might be adequately accomplished with a pot on the board but then over time there is no way to know if the adjustment drifts. It could also be zeroed using the DAC but some additional means of measuring the offset would need to be provided since it does not pass through the transformer. Another possibility being considered is to provide an auto zero feedback in the design to correct for long term drift in this current.

Second, the driver in many cases needs to drive the current pulse along a Twinax cable up to 100 meters long. The single ended driver shown in Figure 1 is perfectly adequate on the bench, but a single ended drive does not take advantage of all the noise immunity provided by a balanced line. Noise pickup in the calibrate cable, as yet unknown, could cause significant problems in the measurement of the currents due to the fact that it is effectively multiplied by ten (the turns ratio) in the transformer output circuit. As a result consideration is being given to a differential output version of the current pump circuit of Figure 1.

4 SUMMARY

A calibrator for the SNS BCM system is in the development phase. A prototype low current calibrator has been built and tested. It provides a DC capability for calibration of the calibrator, and utilizes a current output dual 12 bit DAC2902. A driver amplifier design is underway to use the output of the DAC as an input and develop a current of the order of an amp. For the final product, a board will be laid out that contains the function generator, the DAC2902, timing and control interface logic and the necessary ground isolation.

5 REFERENCES

[1] http://www.bergoz.com/

[2] Martin Kesselman, “Spallation Neutron Source Beam Current Monitor Electronics”, PAC2001, June 18-22, 2001, Chicago, IL.

[3] “Voltage to Current Conversion”, APEX Application Note 13. Available at; http://www.apexmicrotech.com/pdf/app_notes/apnote13.pdf