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ABSOLUTE CALIBRATION of the BOOSTER GAUSS CLOCK

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1. Introduction

The Booster Gauss Clock is described in reference 1. Its relation to the Booster Gauss Line generator has been described in references 2 and 3. The Gauss Clock is fundamentally sensitive to the rate of change of the Booster main dipole magnetic field. The instantaneous absolute value of the magnetic field is derived by integrating the output of the Gauss Clock in an up/down counter. Two properties of differential measuring devices such as the Gauss Clock are:

(1) The value must be initialized.

(2) The value is subject to cumulative errors.

To accommodate the former and correct the latter, an absolute measurement of the field intensity is required. The value of such a measurement could be transferred to the field register as a "jam transfer" but, as will be discussed below, this implies difficult synchronization problems or a period when the Gauss Clock is insensitive to field changes, possibly introducing the cumulative errors which it is desired to correct. A technique to avoid these problems is desirable.

2. Calibration Function

Absolute calibration of the dipole magnetic field requires use of a sensor which detects the field directly. Suitable techniques include hall effect sensors, rotating coils and nuclear magnetic resonance probes. In addition to the ability to measure field with adequate accuracy, we must consider the time sensitivity of the measurement to allow for a field which may have some overall time dependence and certainly has ripple components in its magnitude. The Gauss Clock attempts to provide an instantaneous value of the field intensity to the limit of its resolution. Therefore, to calibrate it we must measure its value at a known time or averaged over some known period. After this we must transfer the calibration to the field register without significant change in the field between measurement and reset of the register. Restriction of the measurement to times when the field is not deliberately varied is required to make this possible but the result is still subject to ripple variations and to unintended changes such as drift. Additionally, a practical system will require a finite measuring time, probably of order 1/60 s, and the value derived will not correspond to the instantaneous field at any particular time.

3. Proposed Calibration Scheme

A method to avoid the limitations described above can be derived by recognising that it is sufficient to measure the discrepancy between the gauss register and the absolute calibration measuring device output at some time or averaged over some period. The latter is preferable to allow for a slow measuring device such as an integrating voltmeter. If we measure the average value of the field between known times and take the same average of the field register values between the same times, we can derive the "error" of the gauss register at the end of the measuring interval. The problem is then to "correct" the field register without accumulating errors during the correction time. This can be accomplished by sending additional up or down counts on the Gauss Clock lines interspersed between the normal outputs of the Gauss Clock. By phasing these to be 180° displaced from the 1 MHz clock of the Gauss Clock, the maximum frequency of counts becomes 2 MHz which is well within range of the counting circuits. This scheme is well adapted to correct the slow accumulation of errors to which the differential measuring technique is prone but will also allow initialization of the field register from some arbitrary value at start-up such as zero. It may also be noted that there is no requirement for a constant field with this method although it would appear conservative to select times at which the field is nominally constant. If the correction is performed under control of "intelligent" hardware, additional averaging of the measured discrepancies and detection of abnormal conditions can be provided.

4. Suggested Parameters

A practical system might employ a temperature regulated hall probe sensor if we acknowledge that consistency is more significant than absolute accuracy. An integrating voltmeter could measure the output of the probe when externally triggered and with an integration time of 1/60s to eliminate line frequency ripple errors. The field register value would be averaged over the same time as the linear average of many readings, at least 48 to average the highest ripple frequency, for a rate of 2880 Hz or one reading per 347μS. This rate might be handled under programmed I/O by a device controller. Higher rates would require DMA or an adder to perform the averaging. An RMS ripple or a frequency spectrum of the ripple might be derived as a side benefit.

The close inter-relation between the Gauss Clock absolute calibration and the Gauss Line Generator suggests that they might be located together and even operated by the same device controller. The Gauss Line Generator might be the only device concerned with absolute field calibration, all other devices using gauss events to provide field markers.

Acknowledgement

I would like to thank J. Geller for useful discussions.

References

(1) J. Geller, Booster Technical Note #175

(2) B. Culwick, Memorandum: The Booster Gauss Clock 12/8/89

(3) B. Culwick, Memorandum: Booster Gauss Line Generator 12/27/89