Charge Balancing Fill Rate Monitor

J.L. Rothman and E.B. Blum
National Synchrotron Light Source, Brookhaven National Laboratory, Upton, New York 11973

Abstract

A fill rate monitor has been developed for the NSLS storage rings to allow machine tuning over a very large dynamic range of beam current. Synchrotron light, focused on a photodiode, produces a signal proportional to the beam current. A charge balancing circuit processes the diode current, creating an output signal proportional to the current injected into the ring. The unit operates linearly over a dynamic range of 120dB and can resolve pulses of injected beam as small as 1μA.

I. INTRODUCTION

The fill rate monitor is one of the most frequently used diagnostic tools in the NSLS control room, allowing the operator to optimize injection and reduce the time between fills. Previous fill rate monitors have used signals from pickup electrodes (PUEs) or from a DC current transformer (DCCT). A tuned receiver connected to a PUE can measure very small currents, but tends to saturate with large signals. The DCCT tolerates large signals but is too noisy to resolve small changes in current. The new unit combines the best elements of the other systems, providing both high sensitivity and a wide dynamic range.

II. DESIGN

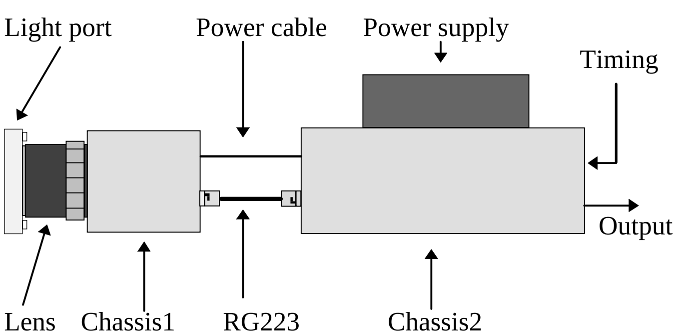

Figure 1: Schematic view of the mechanical design

The mechanical design is shown in figure 1. The lens is a standard video camera lens mounted on the light port via an adapter. It focuses the light into chassis 1 and onto the photodiode. The diode is mounted on a micrometer so the beam spot can be centered. Current from the diode runs through a double shielded cable to the electronics located in chassis 2.

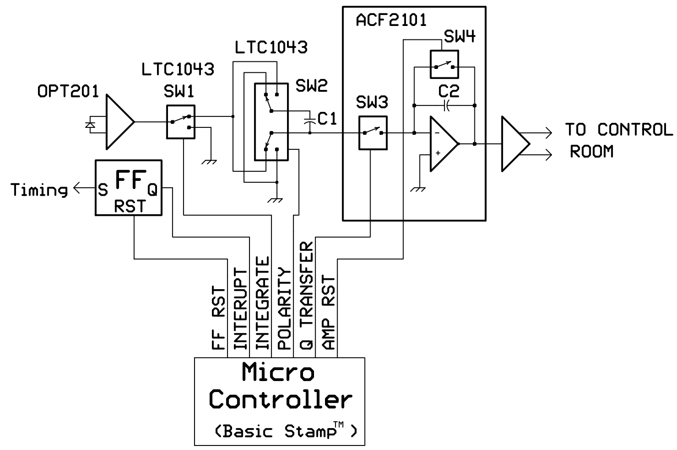

Figure 2: Electronic System diagram

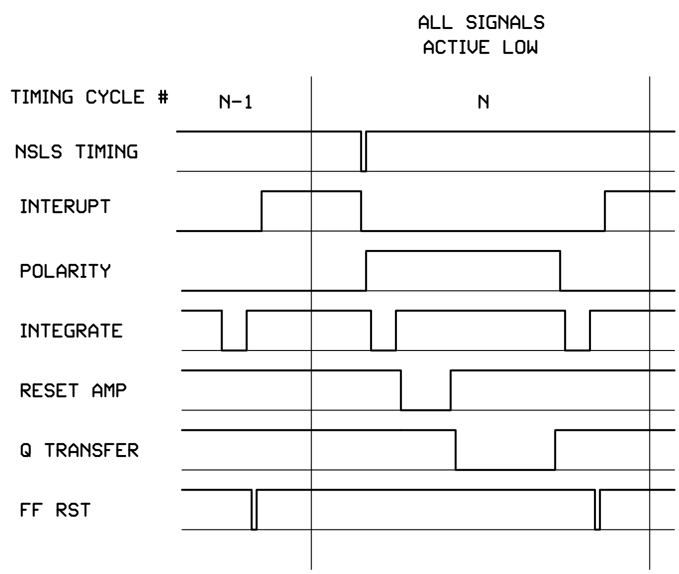

Figure 3: Timing diagram

The electronic system and timing diagrams are shown in figure 2 and figure 3 respectively. At the end of timing cycle N-1, the absolute current in the ring is measured by closing SW1 and integrating the photodiode current on the bottom plate of C1 for 50mS. The interrupt flip flop is then reset in preparation for timing cycle N. A timing pulse sets the flip flop and interrupts the microcontroller 100mS after a shot has been injected into the ring. This allows the beam to damp and

* Work performed under the auspices of the U.S. Department of Energy

prevents fluctuations in the diode current due to beam motion. The microcontroller then reverses the polarity of SW2. SW1 closes again and integrates the photodiode current on the top plate of C1. The charge remaining on C1 is proportional to the current injected into the ring. At this point SW4 closes, resetting the charge sensitive amplifier. After SW4 opens SW3 closes to transfer the charge from C1 to C2, updating the output signal. Since C1 = 10μF and C2 = 4.7 nF the voltage gain = 2100. The output is buffered with a differential driver and transmitted to the control room for display on a digital oscilloscope.

The OPT201[1] is a low noise photodiode and a transimpedance amplifier fabricated on the same chip. In this application it has been configured to provide a current output. SW1 and SW2 are LTC1043 [2] FET switches. C1 is made large to keep the input signals near ground. This makes the switch charge injection less than 1pC, contributing less than 200μV to the output offset voltage. The ACF2101 [1] is a dual analog integrator also with low noise and low charge injection characteristics.

A Basic Stamp™ [3] microcontroller sequences the FET switches. Since the Stamp is programmed in a dialect of the Basic programming language, only 11 executable lines of code are required to produce the needed timing signals. Programs are downloaded from a PC via the parallel port.

Variables can be sent back to the PC at run time for debugging purposes, making an emulator unnecessary. The code is stored in an EEPROM so programs can be updated at any time.

III. PERFORMANCE

The resolution as a function of beam current is shown in figure 4. The noise floor is given by:

$$I_N = 1\mu A * (1 + (I_{BEAM}\ \mu A / 27369))$$

Despite the increase in noise at high currents the monitor can still resolve 37ppm changes in beam current with 850mA in the ring.

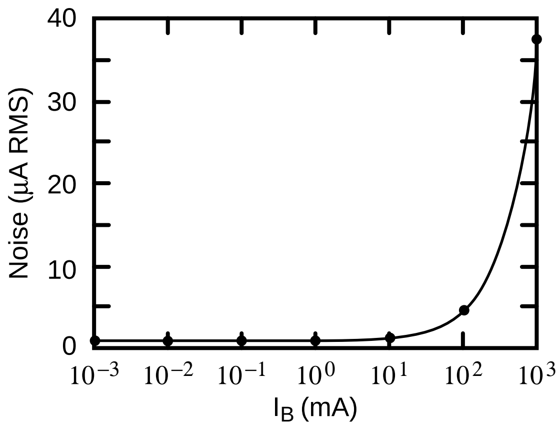

Figure 4: Resolution as a function of beam current

IV. CONCLUSIONS

The charge balancing technique used in this fill rate monitor allows high resolution measurements to be made over a wide range of beam current. The performance can be further enhanced by moving the unit to a beam port that sees less beam motion. Even so, it measures small changes in current much better than previous detectors, opening the possibility of using charge balancing techniques to measure beam lifetime.

VI. REFERENCES

[1] Burr Brown Corporation, Linear Products, P.O. Box 11400 Tucson, AZ 85734-1400

[2] Linear Technology Corporation, 1630 McCarthy Blvd, Milpitas, CA 95035

[3] Parallax, Inc. 3805 Atherton Road, #102, Rocklin, CA 95765

V. ACKNOWLEDGMENTS

Thanks to Henry Link for technical support.