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POWER-SUPPLY REGULATION BY MICROPROCESSOR*

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Abstract

Many small-magnet power supplies are regulated by using a microprocessor system to generate control voltages to continuously servoregulate each power supply. The power supplies are of very simple design since all regulation and feedback hardware are parts of the microprocessor system. Most of the supplies are bipolar transistor followers, powered by a common unregulated D.C. power supply and are used to power trim steering magnets on the three NSLS synchrotron rings. Twelve-bit accuracy is obtained using commercially available microprocessor P.C. cards.

Introduction

Many accelerators are using computers and microprocessors for maintaining data bases, setting and monitoring control parameters. Typical is the control of a multitude of magnet power supplies to steer and focus the beam.

The computer system, in most cases, is used only to generate the analog setpoint and read back the status of the power supply. The system described below uses a microprocessor system as part of the power supply dynamic feedback system to control and regulate the current out of the supply.

The National Synchrotron Light Source uses about 300 power supplies to drive magnets in the linear accelerator, booster ring, and the two storage rings. Over 200 of these supplies are controlled using a microprocessor in the active feedback loop of each supply. About 24 power supplies are fed by each processor. All of the processors are connected to a central computer system via high speed serial RS-422 links[1].

System Description

A typical system uses a commercial multiplexer and analog to digital converter to scan and digitize the voltage from current monitoring shunts on 24 magnet power supplies. The microprocessor then calculates the difference between the measured current and the value stored in the microprocessor data base system, and generates an error signal dependent on the sign of the result. This one bit TTL error level then controls a simple integrator which generates a slowly ramping control voltage used as the reference to the power supply. Each supply has its own error bit and integrator. The reference voltage to a typical supply will continue to increase until the system measures a current setting greater than or equal to the setpoint, which then reverses the sign of the error bit. The system will then oscillate around the current value which the data base is calling for. With a slow integrator ramping rate, the current does not average at the setpoint, but oscillates around the boundary between the setpoint and one A.D.C. bit lower. With a low noise 12 bit converter, better than 14 bit stability can be achieved.

The stability of each power supply system depends on the ability of the microprocessor to measure and calculate magnet current errors at a rate greater than the normal drift and disturbances, and before the integrator overshoots the exact reference value by a large amount. The integration rate should be limited to a rate such that the current does not change by more than the LSB of the analog to digital converter in one measurement interval. For a 12 bit ADC this limits the slew rate to one part in 4096 of full scale per reading, but in practice a rate about 5 times slower is used to minimize the excursions around the setpoint.

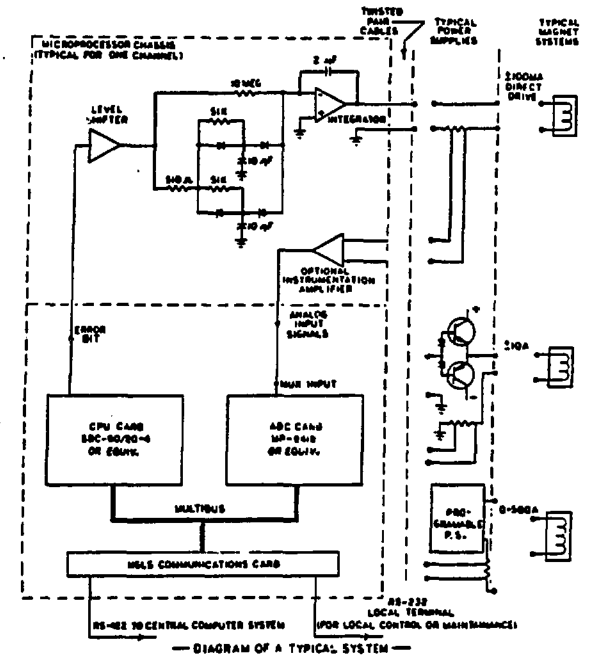

Fig. 1. Simplified diagram of a typical system.

Speed of Response

The ADC system used is capable of scanning and converting at a rate of greater than 20,000 conversions per second, but at this rate little time is left for the microprocessor to perform other functions. Practical limitations lead to a conversion rate of 6000 per second with a 32 channel system or about 200 samples per second for each channel.

Because it is desirable to keep the oscillation around the setpoint as small as possible, any ripple measured on the magnet current shunt causes an error in the digitized readings and causes the supply to hunt with an error equal to the peak to peak ripple. By driving the software scan routine with an interrupt driven trigger from the power line frequency, it is possible to always read on the same point of the ripple waveform and eliminate this hunting effect. This is true whether the source of ripple is from current variations or typical noise on the instrumentation lines. This synchronization lowers the scanning speed to 60 Hz.

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The choice of an integration rate of about 1/20,000 of full scale, per 60 Hz scan, leads to a ramping rate of 5 minutes to cover the full current range. This is unacceptable from a point of tactile control of the accelerator. A simple passive network on the input of the integrator is used to sense whether the error signal is alternating in polarity or not. If the signal polarity does not change after about 0.4 seconds the integration time constant is increased by a factor of 200. The occasion of a single reversal in error signal reverts the time constant to the lower rate. This gives full scale acquisition times of about 2 seconds. Fig.2 & 3 show system response to a command to change magnet current.

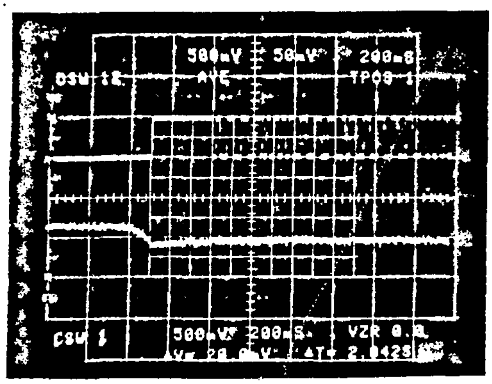

Fig. 2.

Response to a change in computer commanded setpoint. The upper trace shows the error bit input to the integrator. The toggling stops when the new command is received. After about 0.4 seconds the output of the integrator (lower trace) is seen to increase from the slower rate to the fast acquistion rate. After a small overshoot because of the faster slew rate, the reversal of the error bit alternates to hold the integrator output at the correct value. For power supplies with small time constants, the output current waveform of the supply is approximately the same as the integrator output. For large inductive loads the relationship of bit error, integrator error, and output current becomes more difficult to interpret.

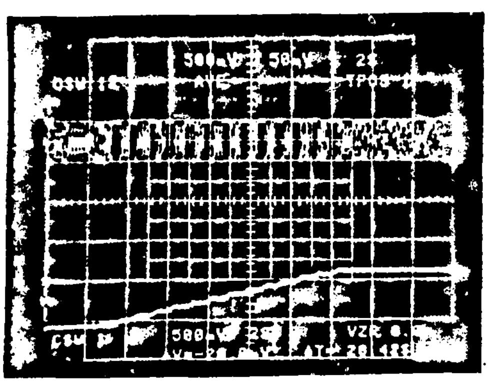

Fig. 3.

Response for a set of consecutive increments of current commands showing response time.

Economic Advantages

The individual power supplies, controlled in this system, need not contain any precision components since the accuracy of the system is controlled only by the ADC and an array of precision current monitors. This allows simple commercial power supplies, operated in either open loop mode or in closed loop voltage control mode, to be used. The problems of internally modifying supplies to run as stable current control regulators driving inductive loads is avoided.

At NSLS the majority of the supplies used are simple bipolar complimentry symmetry darlington followers, powered by large unregulated D.C. sources supplying over 200 small trim steering magnets.

It is possible to intermix different types of supplies, on any system, with the software database keeping track of shunt calibration and logical function.

Hardware

The system is packaged in IEEE 796 (MULTIBUS (TM Intel Corp.)) format in a single chassis with all power and interface circuits. The unit is divided into two system busses, which allows separation of digital and analog signal returns, for low noise aquisition of the analog current readings. A minimum system consists of 4 printed circuit cards. The CPU and ADC cards are commercially available from many manufacturers in several similiar configuations. The third card is a custom high speed serial interface used in all NSLS micro-systems. The fourth card contains the analog integrators and instrumentation amplifiers to operate up to 8 power supplies.

Typical systems have multiple ADC and integrator boards to allow more power supplies to be controlled, with the practical limit being the amount of space on the chassis available for interface connectors. The CPU card is an Intel SBC-80/20-4 or National Semiconductor BLC-80/204 board. The Mux/ADC card is a Burr-Brown MP-8418 card. Both reliability and analog stability have exceeded initial goals.

Microprocessor Software

The software in the microprocessor is written in assembly language and is comprised of a control monitor nucleus, common to all microprocessors in the control system, and application subroutines that contain the code unique to the particular function performed by a specific microprocessor. Each power supply, controlled by an integrating microprocessor, has four parameters associated with it. They are setpoint, tolerance and an upper and lower limit. When the microprocessor is powered on, the setpoints are set to zero and the three other parameters are set to default values stored in ROM. These parameters can be changed from the control room, if adjustments are required, and saved values can be automatically restored from disk files on the main control computer. The limits guard against accidentally driving a magnet beyond it's current capability. If a setpoint is received that exceeds either limit, the micro sets the supply to the applicable limit and sets a status bit indicating that a limit was exceeded. When a setpoint is received, the supply goes into an in-process status for a predetermined amount of time. While in-process, the difference between setpoint and actual readin[illegible] ignored, to allow the supply to slew to the new [illegible]ting. The in-process mode is terminated when the [illegible]ply settles at the new setpoint or when a time ou[illegible] occurs indicating that the supply failed to attain the correct output within the allowed slew time. The latter condition produces a slew error. The interrupt routine that monitors and controls the supplies is driven by an external 60Hz clock. Each supply is controlled by one bit of a parallel output port with a typical configuration using three ports to control twenty four supplies. A background routine monitors the difference between the supply output and the setpoint value approximately once per second. This difference is compared with the tolerance assigned to the supply. To provide some immunity to impulse noise on the sense line, two consecutive differences, that exceed the tolerance, are commonly required before flagging the supply with an error. The detection of an error also transmits a message back to the main control computer where it is logged and placed on a CRT display . The operator is thereby made aware of the problem without having to look directly at the control page containing the supply in question. Because of the dynamic nature of this control system, failures in either the external interrupt signal or the microprocessor hardware must be guarded against to prevent power supply runaway. To accomplish this two counters in a 8253 IC are used. The first counter is part of a heartbeat circuit that controls primary power to all of the controlled supplies. The second counter is used to produce an interrupt at a 17.6 ms rate. Both counters are updated by the interrupt driven service routine that controls the supplies. If this code fails to execute, the first counter will count down to zero and primary power will be dropped before the supplies can drift to any significant extent. The second counter produces an interrupt if the external, power line synchronized, timing signal fails. In such an event, the internally generated interrupt maintains control of the power supplies with no serious loss of regulation. The micro sends a warning message to the main control computer if it shifts to the backup timing mode.

References

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