APPLICATION OF CROSSBAR RELAYS TO THE CONTROL OF A BUNCHER RING*

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Summary

The high-current beam research at Livermore requires the capability of bunching the 700-A, 6-MeV electron beam of the Astron electron accelerator. The mass of the particles in the beam are modulated by an RF cavity and then transported around a 30-ft-diam. ring to produce bunching. The ring uses a set of eight bending magnets, a set of eight focusing magnets, and eight defocusing magnets. Each set of magnets is series connected and excited from a single power supply. To provide the necessary field trimming, a three-decade set of digitally actuated resistors is connected across each magnet.

Introduction

A buncher was built for the 6-MeV, 700-A electron beam from the LLL Astron accelerator. The beam is momentum modulated by a 120-MHz RF cavity and then circulated around a ring 30 ft in diam. The trajectories followed by the heavier particles have a larger circumference than the trajectories of the lighter particles, thus a spatial modulation of the beam intensity is provided. The beam transport consists of eight focusing magnets, eight defocusing magnets, and eight bending magnets (Fig. 1). Each type of magnet operates at essentially the same current, but each type requires individual trimming within a 5% range. To minimize costs, a single power supply is used for each magnet type. Individual magnet tuning is provided by a resistive-shunt network connected across the magnet and arranged in a 1, 2, 2, 4 code. Control of the 24 trimming resistors is provided by crossbar switches.[1]

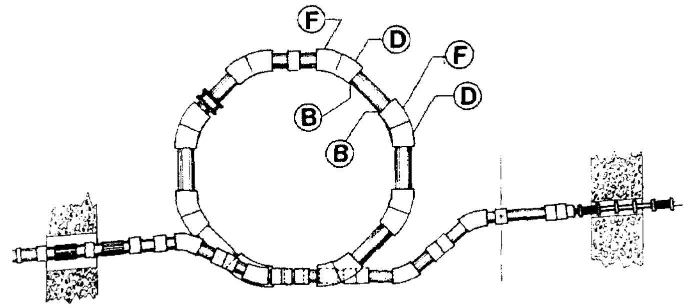

Fig. 1. Buncher ring showing focusing (F), defocusing (D), and bending (B) magnets.

Control System

A block diagram of the control system is shown in Fig. 2. The system consists of a 100-V, 750-A regulated power supply, a manual data-entry panel, two crossbar switches, and latching relay and resistor contactor panels.

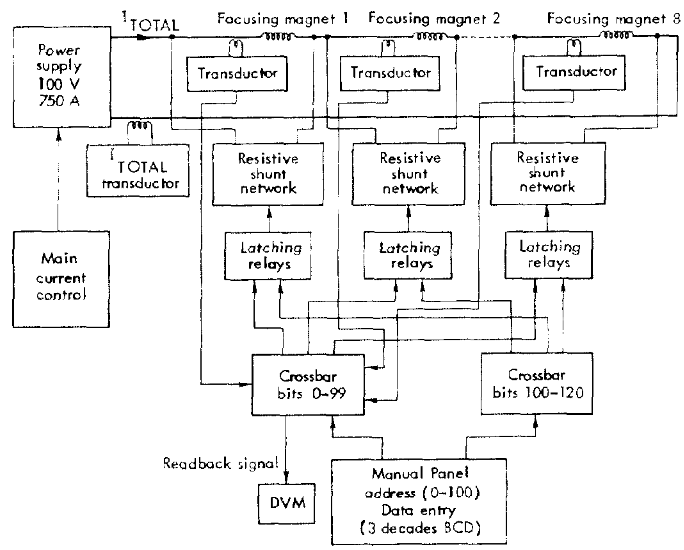

Fig. 2. Control system block diagram.

Magnet Power Supply

The magnet power supply (Fig. 3) is a standard current-regulated supply, which uses a transductor for the current feedback signal and a very stable regulator amplifier and reference. The power supply is controlled to 0.01%. The mean current in the magnet is selected by adjusting the reference; individual magnet tuning is accomplished through the crossbar relay system.

Manual Data Entry Panel

The layout and electrical schematic of the data-entry panel are shown in Fig. 4. There are two decades of address and three decades of data-entry switches. With this combination, 100 magnets can be adjusted and read out; the three decades of data entry allow adjustment of the current ±5% to an accuracy of 0.01%.

For data entry, the diode matrices convert the decimal keyboard to binary logic. To tune a selected magnet the tune pushbutton is activated. This permits the operator to use the data-entry switches to adjust the current. Once the desired current is selected, the lock pushbutton is activated. The next magnet may then be tuned.

Crossbar

Telephone crossbar switches are ideal for applications involving a large number of data channels. Because of the many parallel paths to each latching relay panel, it was necessary to parallel two crossbars.

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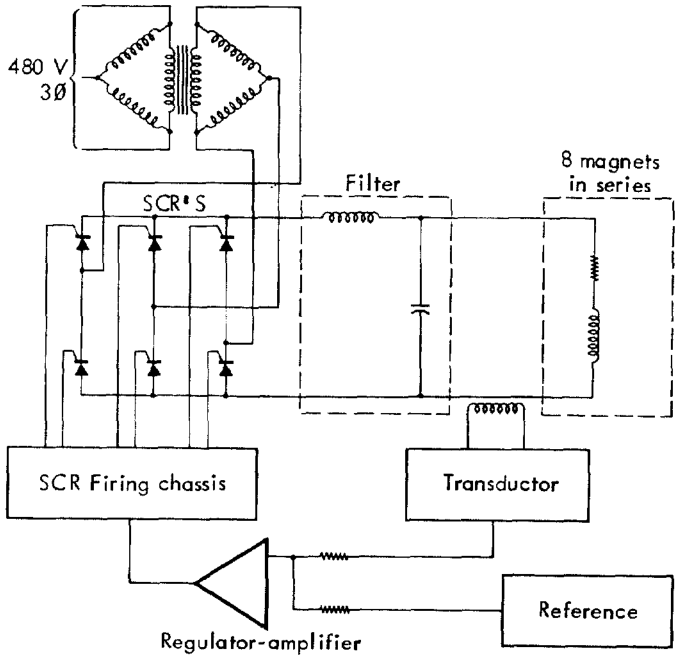

Fig. 3. Typical SCR-regulated power supply.

The addressing of one of a possible 100 cross-points in the crossbar is effected by choosing one of ten select (vertical) magnets and one of ten hold (horizontal) magnets. For proper operation, the select magnets must be energized before the hold magnets. The control circuit to ensure correct sequence of operation is shown in Fig. 5.

In the address keyboard, the tens go to the select magnet and the units go to the hold magnet; however, one would like to be able to choose any magnet without concern as to which digit must be punched in first. When the hold magnets are activated, power is applied to the 50-Ω pull-in coil and the diode prevents the relay from dropping out as its contacts (HN-1) remove power from the pull-in coil but power remains on the holding coil. When the select magnets are activated, their normally open contacts (SN-1) apply power through the RC network to RE-1. This relay is activated for the time constant of the 250-μF and 510-Ω resistor or about 100 ms. As RE-1 opens, the hold magnet drops out for 100 ms, allowing the select magnets to settle to their steady-state position regardless of which magnet, hold or select, is activated first.

Latching Relay and BCD Resistor Panel

For the data entry section, the crossbar acts as a 10-pole 100-position switch and transfers the data directly from the data entry panel to the latching relay

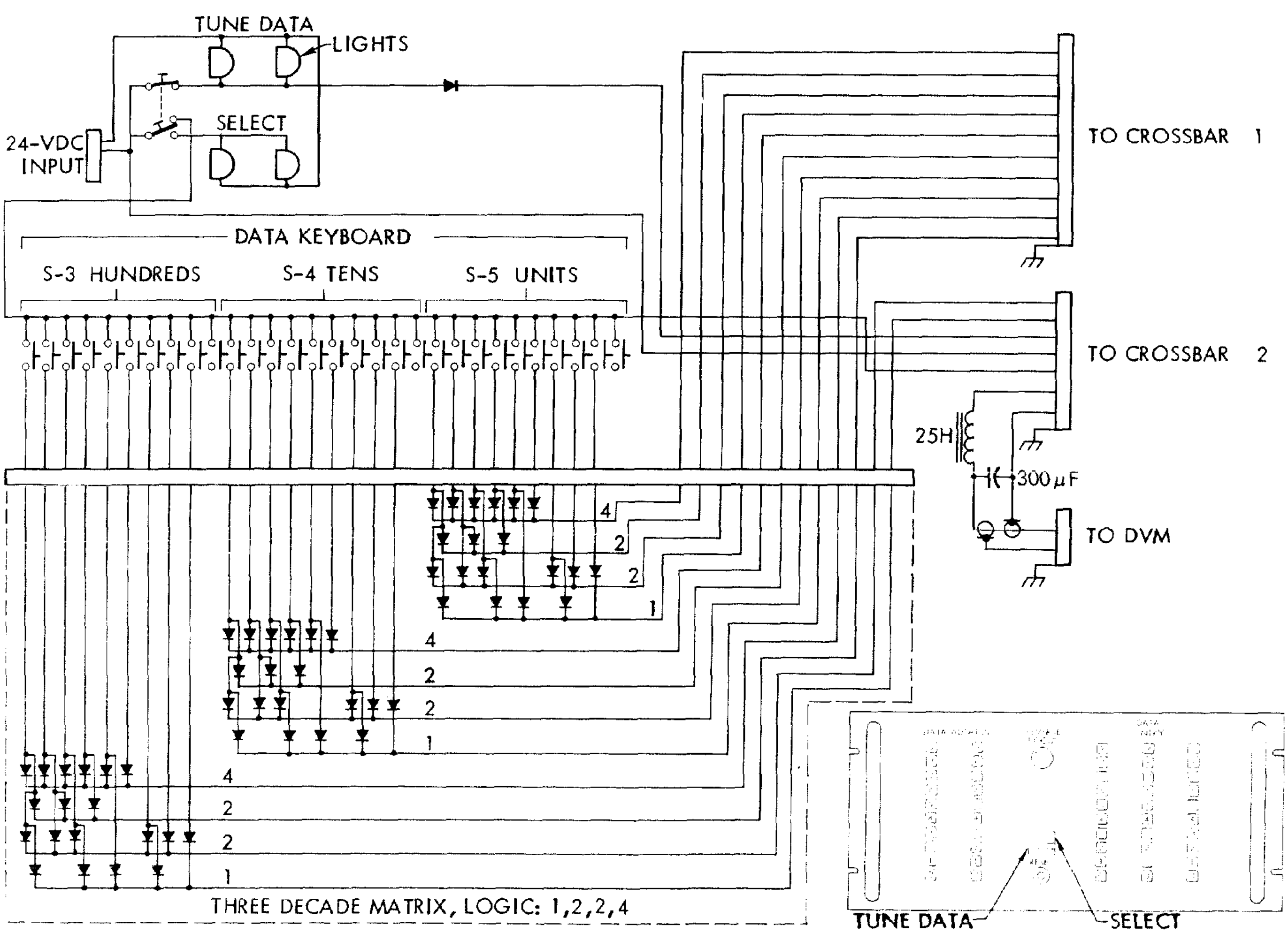

Fig. 4. Address and data-entry panel schematic.

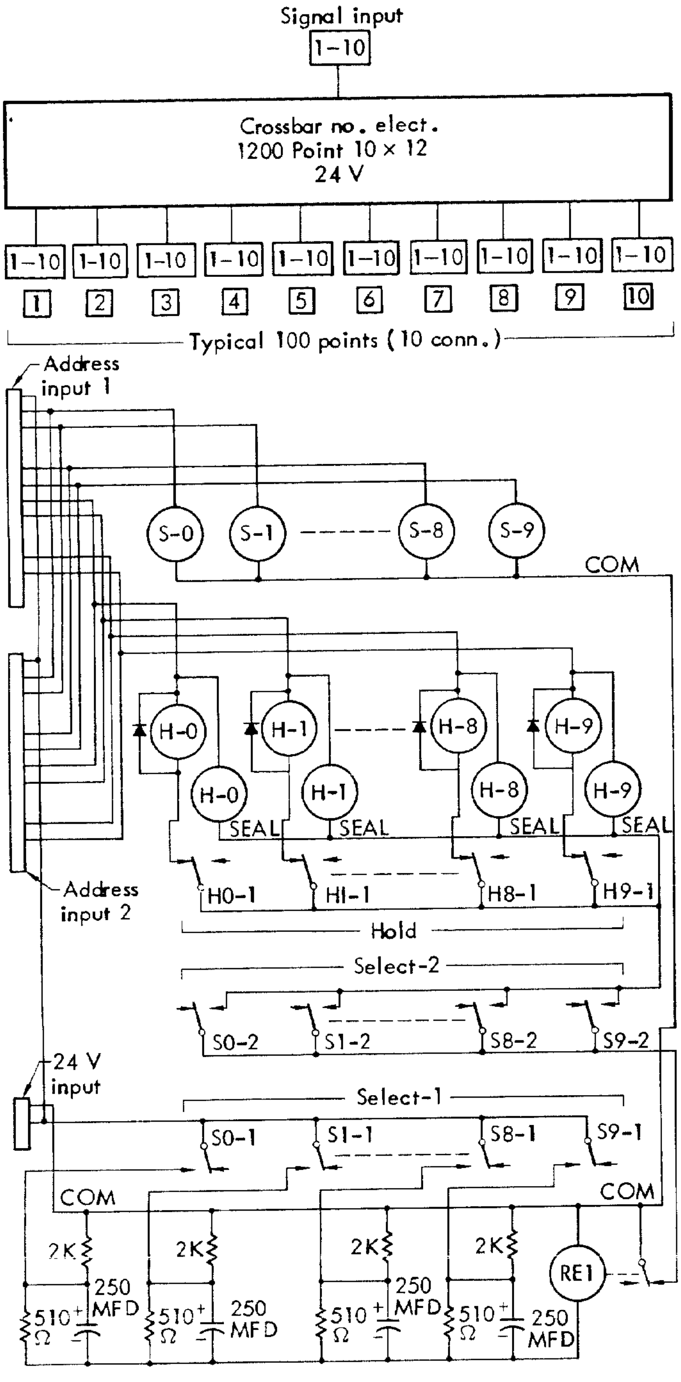

Fig. 5. Crossbar control system.

panel. Each 10-bit data entry pushbutton decade is converted into four bits of binary coded decimal by the three encoding diode matrices. With the data entry switch in the tune position, the current in any one magnet can be adjusted by shunting it with three decades of BCD resistors.

In the tune position, K13 is activated and latching does not occur. When the tuning process is completed and the select pushbutton is activated, K13 drops out, momentarily applying power to K14 through K13-2 and the 250-μF capacitor. As K14 pulls in for about 100 ms, power is applied to the tune bus and those relays that are activated by the data entry pushbuttons latch-in through K13-1 contacts. The latching relays drive aircraft starter motor contactors that switch the trimming resistors in or out.

The trimming resistors were all adjusted to 0.1% accuracy in the more significant digits, because it is possible when going from 9 to 10 to switch 3% resistors to a higher rather than a lower current in the magnet. The adjustment was made by using a digital ohmmeter for calibrating the 3% resistors with the appropriate high-value low-wattage trimming resistor.

Conclusion

For beam transport systems with many magnets operating at essentially the same current, a significant cost reduction can be realized by using a large power supply with a low cost per kilowatt and by using trimming resistors to provide individual current adjustment. Commercial water-cooled resistors used in a BCD configuration and switched by aircraft starter-motor contactors have been economical and reliable. Standard telephone crossbar switches have proven to be a satisfactory method of control. These components are produced in large quantities for industries requiring a high degree of reliability. They are beautifully built and inexpensive.

We use both keyboard and normal helipot control of standard magnet power supplies, therefore a direct comparison is made automatically. Our operators report that both methods are equally convenient. The keyboard has the advantage of being easily adapted to a small computer. An additional advantage of a relay system is the high degree of isolation the relays provide between the controls and the sensitive low-level signal circuitry of the power supply.

Reference

1. J. W. Davis, W. L. Dexter, B. H. Smith, "Application of Telephone Crossbar Relays to Computer Control of a Particle Accelerator," I. E. E. E. Trans on Nuclear Science, Part 1, vol. NS-16, pp. 894-897, 1969.