A SOLID STATE CONTROL AND LOGIC SYSTEM FOR BEAM HANDLING AND ION OPTICS EXTERNAL TO THE NRL ISOCHRONOUS CYCLOTRON

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Summary

As the capability of isochronous cyclotrons increases, and the requirements of the experimentalist become more sophisticated, the problems of beam handling and transport become more complex and demanding. At the NRL Isochronous Cyclotron Facility, these problems have been solved by using solid state OR, AND, NOR, and NAND logic wherever possible. Initial beam path selection is through a select-safe circuit which allows only one of 15 beam paths to be energized. After selection, it cannot be accidentally shut down. Diode, diode-transistor, and transistor-resistor logic have been used for all beam handling and transport devices, and for light and readout switching. These circuits use diode matrices to control voltage, resistor matrices to mix currents, and transistors as switches. Defective lamps are determined by a circuit which allows all lights in the control room to be tested simultaneously by pushing one button. Plug in boards and relays, quick change indicators, 90-pin connectors, and miniature terminal strips are used to facilitate trouble shooting and programming. A portable mock-up of the control console was produced for circuit test purposes, for on site operation of a beam handling device, and as a training device for new operators.

Introduction

When fully operational, the NRL Cyclotron Facility will have provision for eleven full beam paths which will service three experimental areas, plus four partial paths which will be available in the cyclotron vault. The multiplicity of ion optics and beam handling apparatus along these fifteen beam paths requires some type of switching and selecting control system so that duplication in the number of power supplies, monitoring systems, and remote controls can be reduced.

Figure 1 shows a simplified block diagram of the control and switching system used at NRL.

Beam Path Selection

Beam path selection is made by means of a group of fifteen indicator switches located on the beam path display panel. These switches can only be operated singly, and are interlocked with a safety switch located on the operator's console so that only one beam path can be activated at a time, and it cannot be accidentally shut down. Choosing a particular beam path automatically transfers all controls to the elements along that beam path.

The paths shown in their positions relative to the cyclotron, vault, experimental rooms, and magnets in Fig. 2.

There are eight stations along each beam path which are numbered according to their physical location. There are four beam path stations in the A (or red) section. There are two in each of the three B (or blue) sections, and there are two in each of the eleven C (or green) sections; i.e., equipment closest to the cyclotron will be in station 1; those items near the analyzing magnet will be in either stations 4 or 5, depending on which side of the magnet they are located; and those elements closest to the experimental areas will be in one of the stations numbered 8. Altogether, the eleven paths have 32 stations; i.e., four A's, six B's, and 22 C's.

Figure 3 shows the basic details of the select-safe circuit for the fifteen possible paths.

Figure 4 shows the way in which the path-select buttons are capable of energizing only the proper three path sections involved in any path selection.

Control and Control Display

The beam transport control system consists primarily of two parts. One part is the set of indicator lights, controls, and switches found in the right-hand section of the operator's console. The other part is a large beam path display panel located a few feet behind the console. The beam path display affords immediate graphic information on the conditions of the cyclotron and beam paths, as well as the location and condition of all elements along the beam path.

The problems encountered in the design of control circuits for the numerous beam transport system elements are solved by considering each element in terms of its separate components, such as motor, solenoid, relay, microswitch, illuminated indicators, and indicator switches. The sub circuits, which are created to accomplish a specific task, are then combined to produce a total circuit which will still satisfy the original design criteria. Several constraints, such as a limit of four switches on the operating indicators, and the use of a minimum number of relays and control wires, lead to the substitution of diodes and transistors for relays wherever possible.

Circuit design divides itself naturally into three main phases. The first phase is the design of the actual control circuits. The second phase is the design of indicator light display, which shows the operator the exact condition of each element; and the third phase is any necessary interlocking or bailing of several elements or controls.

All circuits are controlled with the switches which are available on the operating indicators and relays. It is always found possible to provide the necessary bailing circuits and display indicator lights by using the remaining switches and holding coils on the operating indicators and relays, plus inexpensive diodes to provide proper electrical isolation.

In some cases of a particularly complicated control requirement, such as the beam collimator, it is necessary to mix different light colors. For instance, a red or green light is practically invisible when mixed with a white light; thus, switching off the white light also gives the effect of switching on a red or green light.

In the course of circuit development, a special bailing circuit was developed which used only half the usual number of switches per operating indicator. Since two are normally used on each operating indicator, saving one of them effectively increased by 50 percent the number of switches available for other important applications.

Figure 5 shows this dc bailing circuit along with a transistorized bailing circuit.

Figure 6 shows the circuits associated with the collimator controls.

Monitoring and Digital Readout

The status of each controlled device are monitored and the positions of collimator jaws and quadrupoles are measured and read out on digital voltmeters. A DVM is used for each collimator jaw to read both jaw positions simul*taneously, jaw center line* (℄) *and width* (W) can also be read. To read center line and width simultaneously, an automatic control circuit sequentially switches the power supplies, DVM's and collimator jaws. To read jaw width, 40 V dc is supplied to the linear potentiometers of each jaw and the difference is read. To read jaw center line, one of the jaw voltages has to be inverted and both voltages are reduced to 20 V dc. Figure 7 shows the circuit for programming the digital voltmeters and power supplies.

Light failure in the control room will be a constant problem. In order to identify faulty lamps we devised a light testing circuit which will allow all red, green, and amber lamps to be tested in the control console and display panel. This circuit is shown as part of Fig. 3.

Portable Local Operation Control Console

A portable mock-up of the complete control system has been made for test and simulation of all operation and malfunction modes. This step is necessary because many circuit designs which look good on paper are found deficient in some respects, and additional desirable operating features can be discovered only by actually operating the prototype beam path elements. Improvements in the mechanical and electrical design of the beam-element prototypes are also made possible by use of the portable control mock-up. It is expected that the mock-up will be used later in the cyclotron vault and the three experimental rooms to provide in situ operation for testing and adjusting any beam path element.

The portable mock-up contains the major functions found in both the beam path display and the operator's console.

Figure 8 shows a photograph of the portable console along with a typical vertical collimator box.

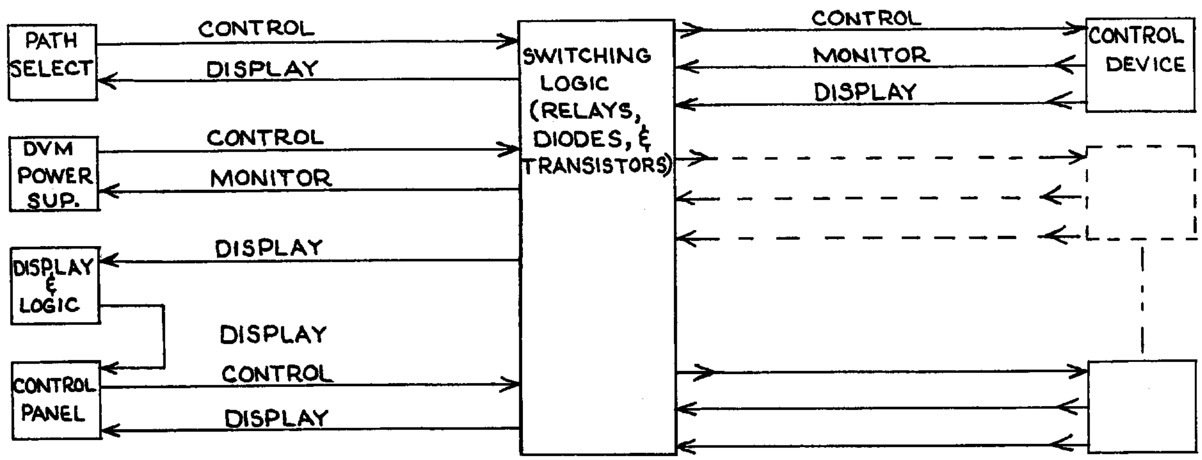

Figure 1 - Block Diagram of Control and Monitor Systems

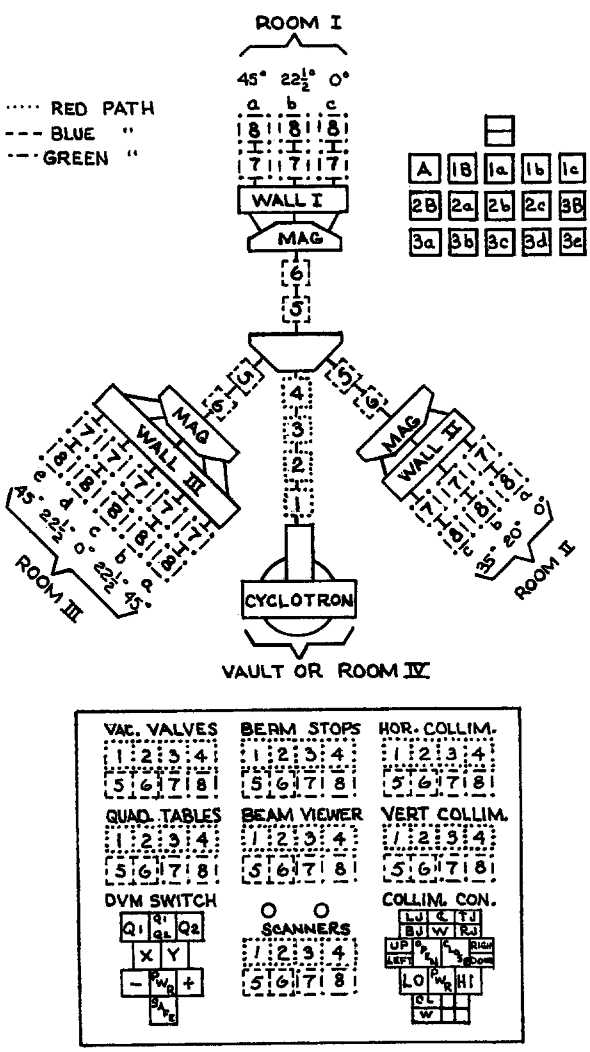

Figure 2 - The Path Display and Control Panel

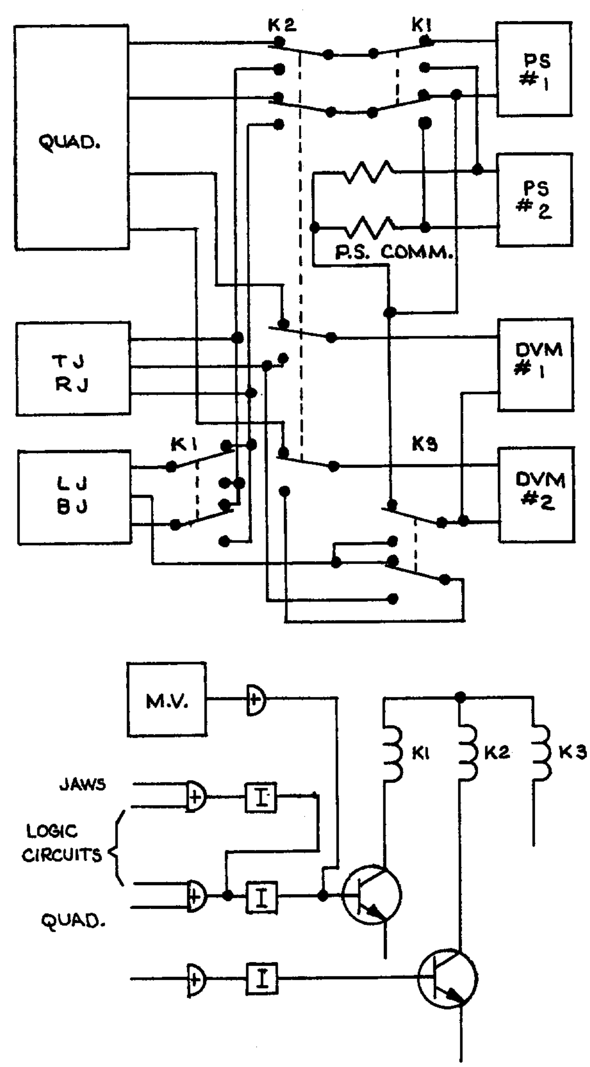

Figure 7 - The Voltmeter and Power Supply Programming Circuit

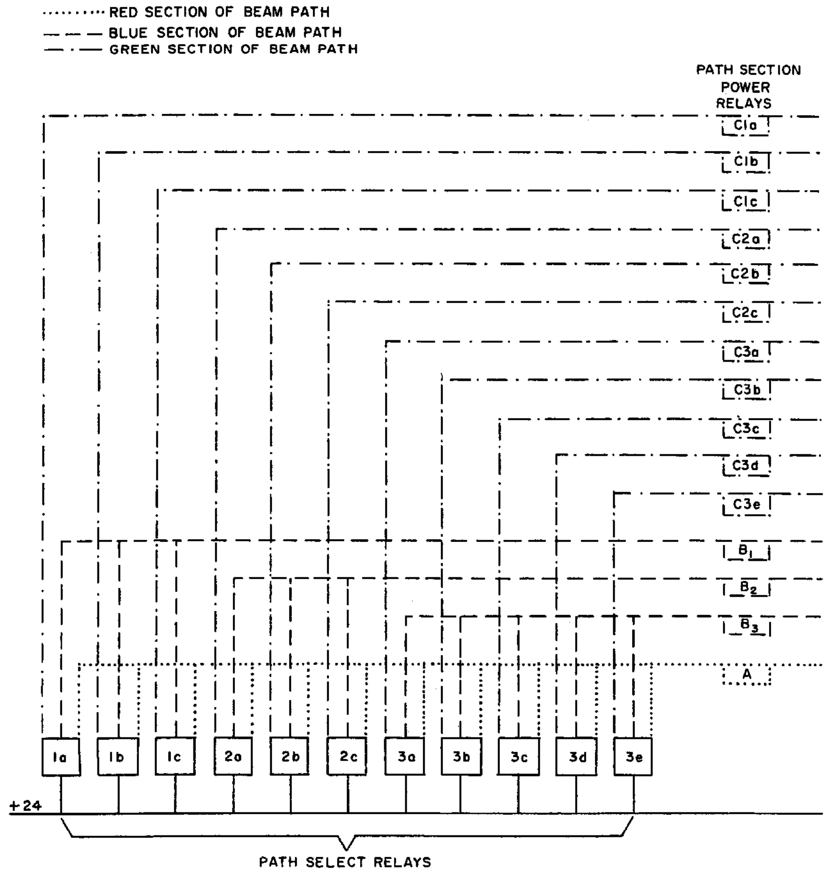

Figure 4 - The Path Relay Matrix

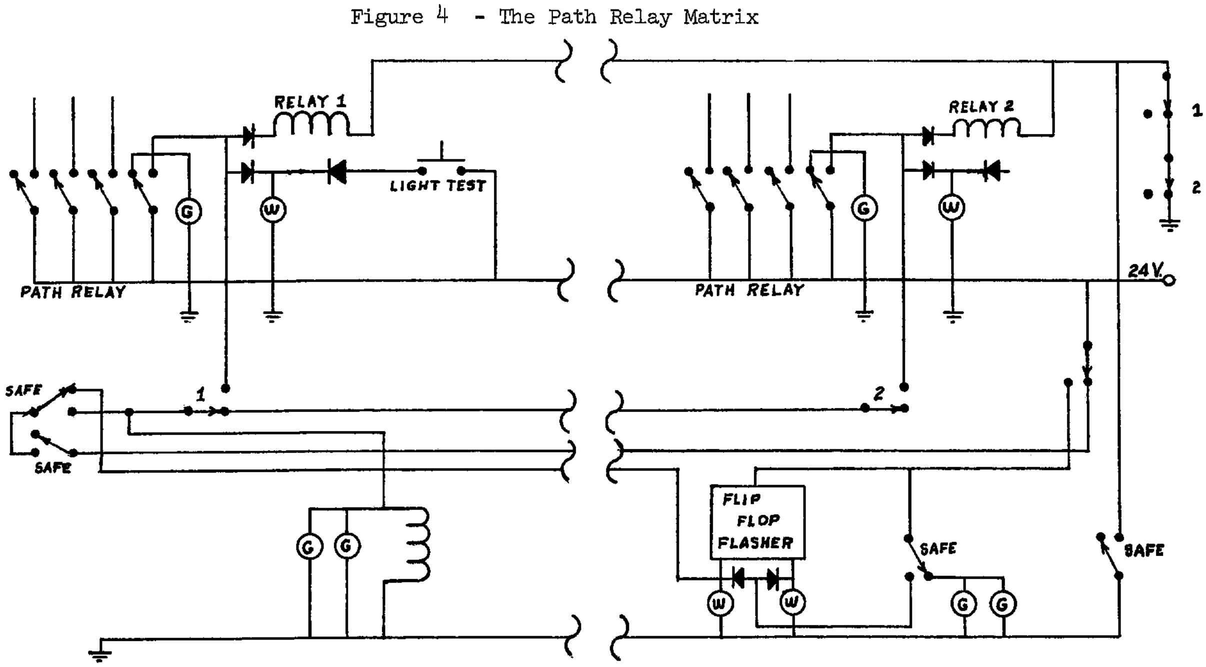

Figure 3 - The Path Selection Circuit

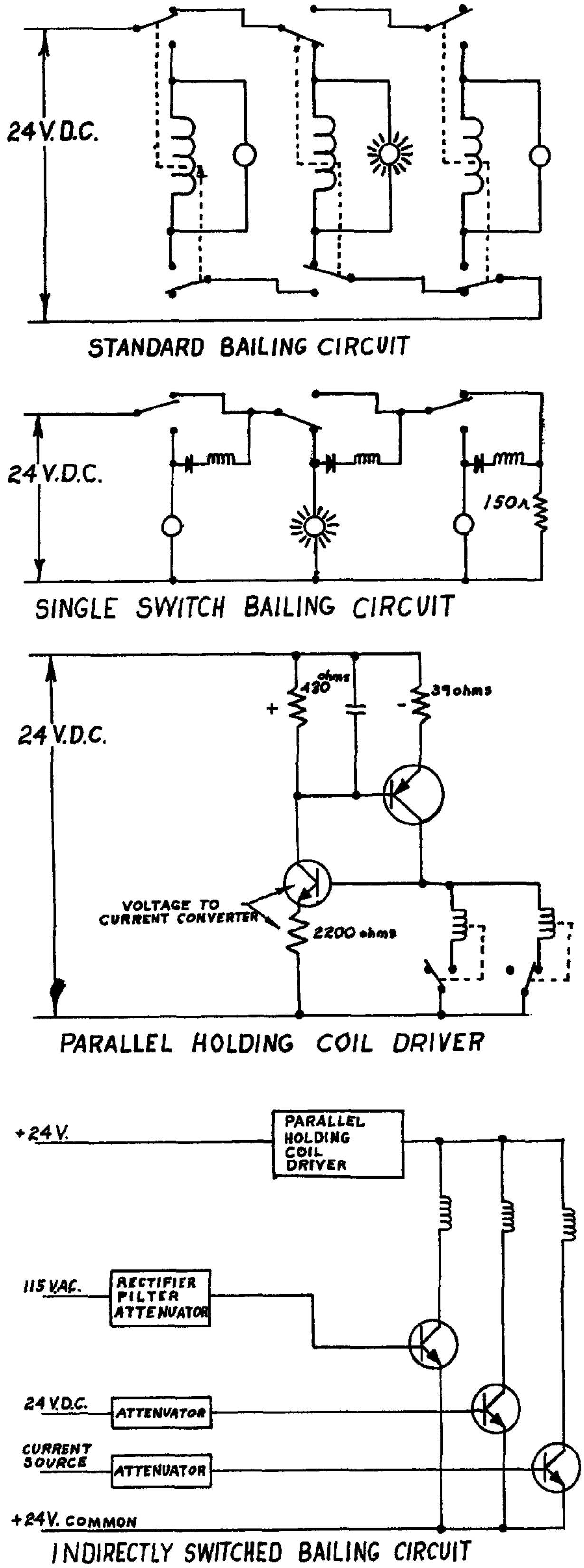

Figure 5 - The Switch Bailing Circuits

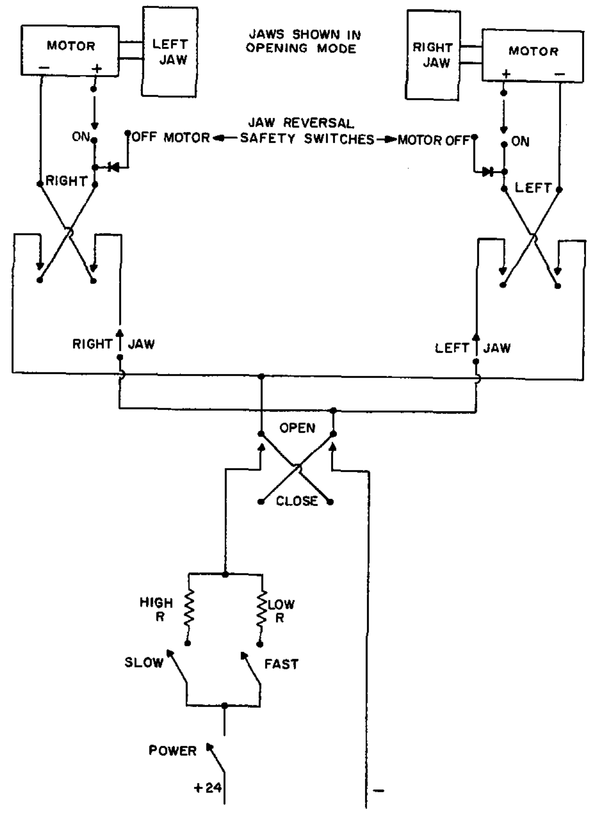

Figure 6 - The Collimator Control Circuit

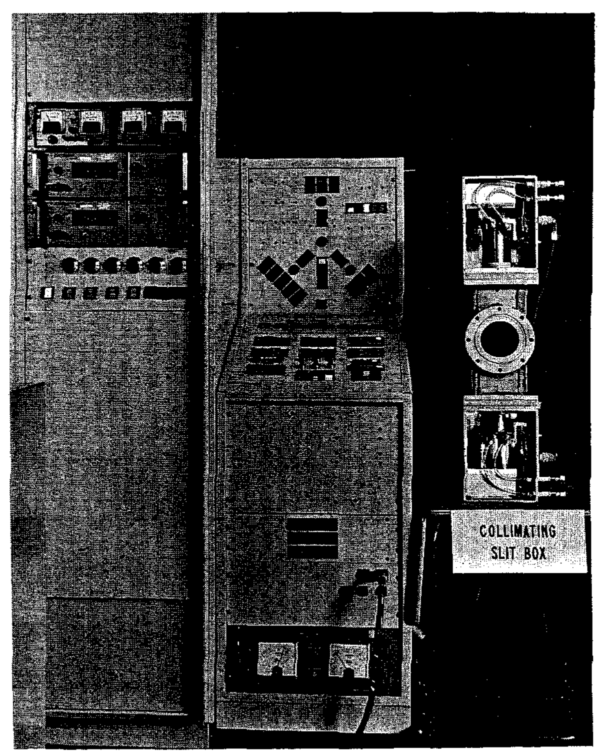

Figure 8 - Close up of Portable Console