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A COMPACT PROGRAMMABLE CONTROL PANEL for COMPUTER CONTROL SYSTEMS*

by

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SUMMARY

The Card Programmable Function Button Panel is basically a manual data entry device used for computer program assignment and binary control. However, it has the ability to be reassigned in over one thousand different configurations by changing a computer-read program card which also provides labeling of the panel's control buttons and indicator lights. The multiple assignment capability is accomplished by an optically-read ten-bit binary code on the program card. The panel is packaged in a 3-wide 8 3/4 inch high AEC Standard Nuclear Instrument Module (NIM). The front panel contains 30 control-button/indicator-light pairs which are labeled by the dollar-bill-sized program cards. The cards are made of a thin white plastic with a special writing surface. The recessed indicator-light matrix thus provides separate backlighting through each of the button-adjacent printed partitions of the over-laying program cards. Binary code bit-locations are printed across the bottom edge of the card, and the cards are encoded by punching out the appropriate code using a standard hand punch. The panel contains all the electronics necessary for lamp drivers, lamp test, lamp dimmers, as well as the logic for the registration, validation, reading, and transmission of the card's binary code to the computer. Separate electronics provides for button-switch debouncing, encoding, key-roll-over protection, and indicator-status memory. Electronic and mechanical construction details are reviewed as well as a brief description of the panel's use on the operator's control consoles at the Clinton P. Anderson Meson Physics Facility of the Los Alamos Scientific Laboratory (herein referred to as LAMPF).

INTRODUCTION

For even the simplest of computer control systems there exists a need for a number of dedicated control buttons with corresponding indicator lights to control and monitor vital process and data. On larger computer control systems with various interactive CRT terminals additional function buttons and status indicators are needed for fingertip command/readout of routinely used programs and parameters that might otherwise occupy valuable space on the working CRT displays. Visualize a computer control console operator deeply involved in an interactive data/graphic display, and suddenly needing another simple but undisplayed control program or routine without interrupting his present display. In such an instance it is convenient to have an auxillary hardware panel nearby with such routine programs available. Ideally, this control panel would be configured to suit the immediate task at hand. Unfortunately, once begun, dedicated function panels tend to grow without limit, especially if different operators utilize the console for different routines or systems and, therefore, prefer their own special arrangements. The solution, of course, is to have a small bank of function buttons and status indicators which can be almost instantly configured for different requirements as they occur, without going through additional programming assignments. Ideally, the operator produces his favorite configuration from his own shirt pocket, places it over a blank control panel, and that panel becomes the configuration of the card automatically. Such a system has not only been devised, but there are three such devices on each of the two identical control consoles in the Central Control Room (CCR) at LAMPF.[1] These Card Programmable Function Button Panels have now been in operation for over a year, and are considered to be highly effective in solving the problem of multiple-configured computer control consoles.

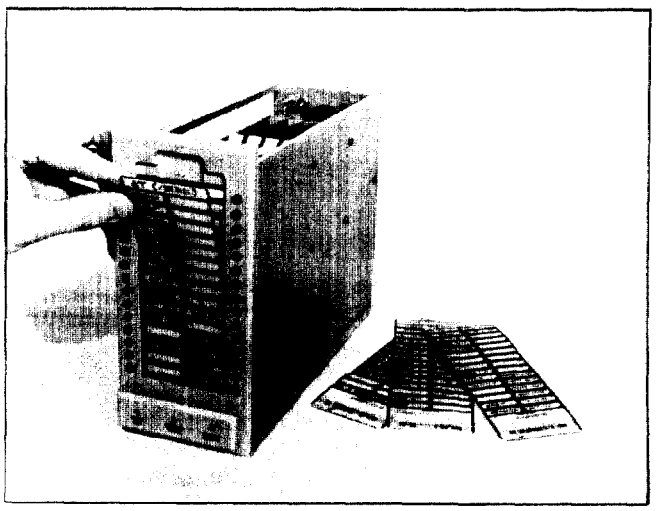


Figure 1. The Card Programmable Function Button Panel is shown with a Program Card being inserted into the panel's card reader slot. The computer-read binary code can be easily seen across the bottom edges of the Program Cards laying on the table. The cards are easily labeled with pencil or ink, and the binary codes are punched with a hand punch. When a Program Card is in use, the indicator matrix backlights the separate partitions of the card with one color for "OFF" and a different color for "ON".

*Work performed under the auspices of the United States Atomic Energy Commission.

USE AT LAMPF

Assume that you are one of many among a large group of variously disciplined scientific staff, having access to the control consoles of a large and complex computer controlled particle accelerator.* The two identical control consoles in the Central Control Room are equipped with various scopes, knobs, indicators, readouts, buttons, and a keyboard. Accelerator beam time is tremendously valuable, your alloted time at the console is limited. Time is of the essence, so you want to take the fullest advantage of a pre-organized experimental routine. Since the control console devices are assigned through program control, they carry only arbitrary reference labels such as knob 1, Readout 5, button 16, storage scope 2, etc. You will want different combinations of these controls in various configurations at different times in your routine to be of most efficient use to you. Although the all powerful interactive-graphics and character scopes could be used to display your program formats, you prefer to dedicate these devices to analytical displays of the experiment as it progresses.

You remove a Program Card from your shirt pocket and insert it in a slot in one of three available Card Programmable Function Button Panels. The panel's indicator matrix turns on, providing background illumination for your labels beside each button. This card will be used for overall program control and status monitoring. You remove two more cards and insert them in the remaining two panels, providing you with your remaining sets of programs, control algorithms, and display configurations necessary for an organized computer interactive system. You now concentrate on your scientific investigation without needless distractions such as tedious keyboard entries and corresponding references to the program directories.

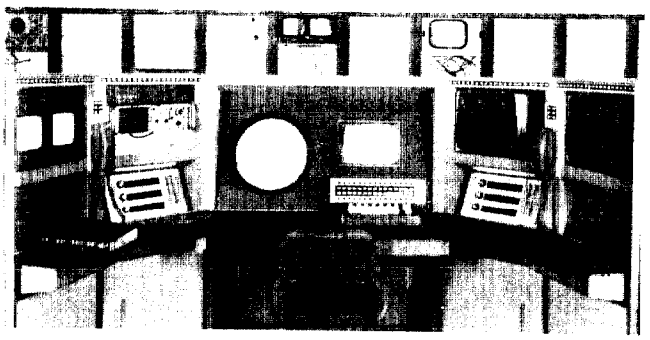


Figure 2. One of the two identical CCR Control Consoles, showing the location of the three Card Programmable Function Button Panels. The long panel in the Console's center section is identical to the panels described in this paper, except for its physical size. The larger panel is intended as an aid in segregating programs and routines used for accelerator operations from those used for research and development.

*The author refers to the LAMPF Accelerator -- an 800 MeV linear proton accelerator built for the USAEC by the Los Alamos Scientific Laboratory of the University of California. It is located in Los Alamos, New Mexico, and achieved its designed full energy potential of 800 MeV in June of 1972.

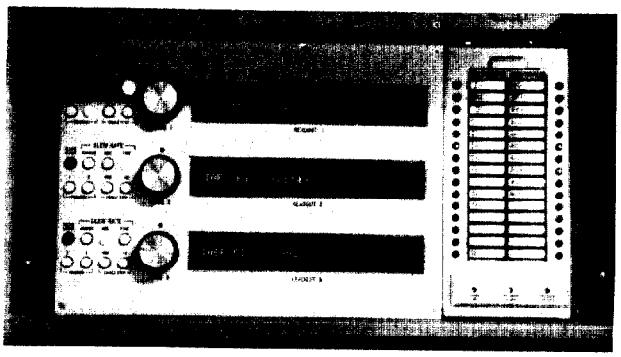


Figure 3. Card Programmable Function Button Panel being used for control of the accelerator's Cockcroft-Walton Injector System; in this instance making use of program assignment to adjacent knobs and readouts.

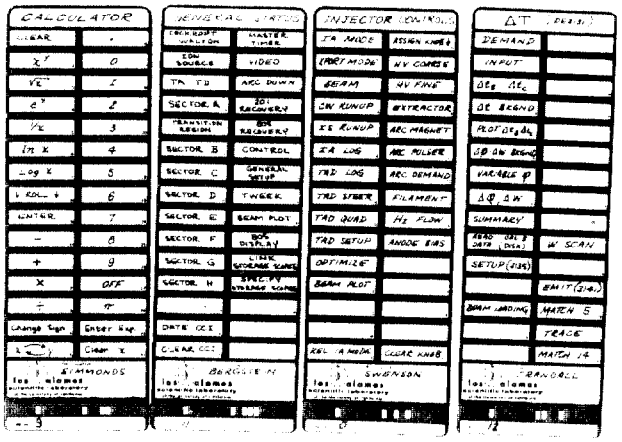


Figure 4A. Typical Program Cards
1. *Calculator card makes panel into a calculator.*
2. *General Status card used for accelerator status monitoring.*
3. *Injector Controls card (shown in use in Figure 3).*
4. *ΔT card used for accelerator control when making critical diagnosis and alignment of proton's time-of-flight.*

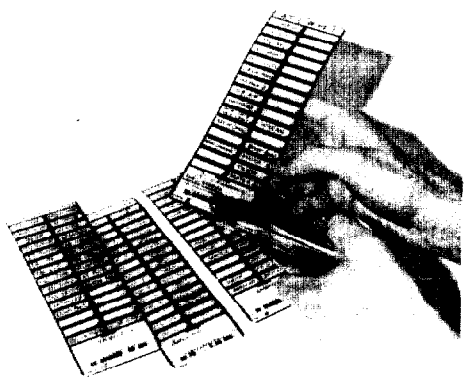


Figure 4B. Preparation of Program Cards.

DESIGN OBJECTIVES

The concept of a programmable control panel is certainly not new, but it was decided early in the LAMPF project that we needed to find such a device which would specifically fulfill the following requirements:

- Panel to be low cost, easy to fabricate, simple to use, easy to maintain.
- Programmable overlays easy to make, handle, reasonable size of matrix yet not unwieldly, not restrained to fixtures or holders when not in use, yet easy to install without misalignment problems in any of several locations.
- Software support to be powerful yet flexible.
- Easy to implement by non-programmer-type users.
- Electronics to provide feedback signals adequate enough to instill confidence in users.

The end result was to be that a user could layout a custom panel configuration with his own particular control algorithm, being efficiently suited to his control requirements. Ideally, this configuration would be on a relatively small card that he could label himself and carry from one location to another to be put into service at the most suitable location. Such a system was to be equally useful for experiments, development, operations, and maintenance.

The extent to which these design objectives have been met by the LAMPF Card Programmable Function Button Panel are discussed in the following sections.

PROGRAM CARD DESIGN

The design and physical realization of the program card is critical to the success of any card programmable control panel. Therefore, with the above design objectives in mind, the program cards for the LAMPF Card Programmable Function Button Panel have been designed with the following features:

- Pocket size (2 1/2" x 7") with thirty locations (2 x 15 matrix).
- Material is a commercial drafting material . . . pliable, 0.008" thick translucent-white polyester, with matte drawing surface for ease of writing and erasing with pencil or ink - yet can be made permanent by acrylic plastic spray. The polyester material is resistant to curl and shrinkage due to heat or humidity, and can be used in office copiers for making duplicate cards or copying specific cards for records and documents or multiple use.
- Card's indicator matrix area is preprinted with numbered partitions and there are spaces for a card title and originator's name. The card material provides excellent lengend contrast and allows even, backlighted illumination.
- Card is square, with no special shapes or cutouts necessary -- easily handmade if desired, economically printed. The ten-bit binary code and four-bit registration/validation code locations are printed across the bottom edge of the card, and any desired code is easily hand-punched.

MECHANICAL DESIGN

General Packaging

The panel's reader assembly, card guide, indicator matrix, function buttons, and status lights are all contained in a front sub-panel and bezel, which are carefully machined to provide accurate and stable alignment. The electronics is contained on four printed circuit cards mounted in a card cage inside the module. The rear panel provides space for all power and input/output connectors, and also the lamp brightness controls.

All components, except the machined front bezel, are off-the-shelf commercial items, and packaging consists of mounting these items inside a standard 8 3/4" high, 3-wide, Nuclear Instruments Module (NIM).

Reader Sub-Assembly

The program card reader assembly consists of standard, commercial, paper-tape (0.1" between hole spacing) source/sensor pairs; mounted in a carefully machined mounting plate type sub-assembly, as shown in Figure 5. Each source/sensor component contains nine bit-locations and two are used side-by-side, giving a total usable capacity of eighteen bits (only fourteen bits are presently used in the LAMPF units). The two halves of the sub-assembly are accurately aligned by virtue of match-machined parts, so that the entire reader sub-assembly can be moved about within the panel as required for alignment with the program card's slot. This arrangement allows rapid and reliable alignment of the panel's card reading system.

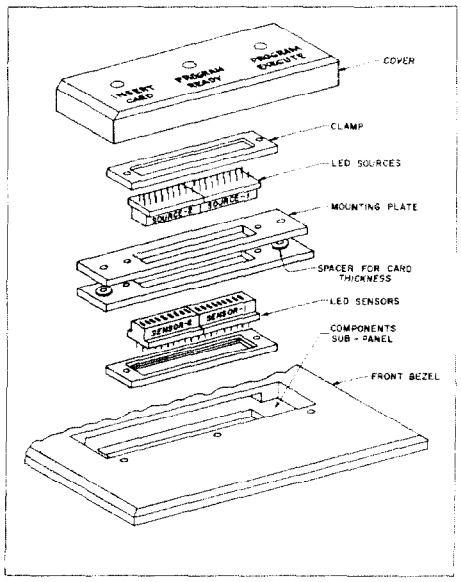


Figure 5. Detail, Sub-Assembly

Indicator Matrix

The indicator matrix is a self-contained assembly, complete with lamps and filters. Each partition contains two aircraft-style (T-1 3/4) lamps, and the lamps and associated filters can be changed from the front without special tools.

Front Sub-Panel & Bezel

The front bezel is machined from 1/4" thick aluminum, and given a clear anodize finish. The indicator matrix is recessed 1/8" in a machined slot in this bezel, which thus provides an accurate program card alignment guide and holder, requiring no further guides, clamps, or covers to maintain the cards in their proper position.

An uncluttered and streamlined appearance for the front bezel is accomplished by mounting all the front panel components on a sub-panel behind the bezel, and the bezel and reader cover being fastened with blind screws into the rear of the bezel.

ELECTRONICS DESIGN

General

A simplified schematic for the electronics contained in the panel is given in Figure 6. This electronics is contained on printed circuit cards as outlined below. (The pushbutton switch debouncing and encoding circuits, and the addressable memory for the indicators were not included in the panel since they already existed elsewhere in the system. By slight repackaging, however, these circuits could easily be incorporated into the panel.)

Reader Logic Card

The program cards are read by the solid-state source/sensor array, and the resultant logic states are deciphered by the reader logic card as one of two possible conditions: 1) a registered and valid card has been inserted, or 2) a card has been withdrawn. The card's registration and validation information is contained in the card bits A, B, C, D, while the ten-bit binary card number is contained in the card bits 0 through 9. The logic shown will respond only to a card which has the code $\overline{A}B \cdot \overline{C}D$ as a valid card. Card registration is automatically checked by the proper sensing of the bits $\overline{A}B$ and $\overline{C}D$, since they are at opposite sides of the card, and any crookedness would result in a loss of validation codes. Thus, a reversed or crooked card will not initiate any action. When a VALID CARD IN condition first occurs, a 1/2 second delay is initiated to allow for the card to settle in the slot. If the VALID CARD IN condition still exists after this delay, the computer is interrupted with a command to enable the panel for the program card number as given by the ten card bits 0 through 9. When a card is removed, the logic senses the code $AB \cdot \overline{C}D$ as a CARD OUT condition, waits 1/2 second, and interrupts the computer with a command to disable the card program previously assigned to that panel. Note that without the delay feature it would be possible to send erroneous interrupt signals to the computer as the bottom edge of the card crossed the sensors. Also, since the sensors are capable of high-frequency oscillation under certain conditions, Schmitt buffers have been added to each sensor's output.

Lamp Controller Card

The Lamp Controller Card contains separate voltage regulators for the ON and OFF lamps to facilitate color brightness balancing as required by various room lighting conditions. Both regulators are controlled by logic, which turns off all lamps when a card is out or when the computer program is not ready, and blinks all lamps and activates a "clacker" when the computer executes the called program. (The clacker is in actuality a large relay mounted on the inside of the module, its only purpose being to produce an audible feedback signal.)

Lamp Driver Cards (2 Required)

The Lamp Driver Cards receive lamp status commands from the computer, via an external addressable memory, and turn on the correct lamps using complimentary transistor drivers. These cards also incorporate a lamp test feature (the test button is located under the top edge of the program card).

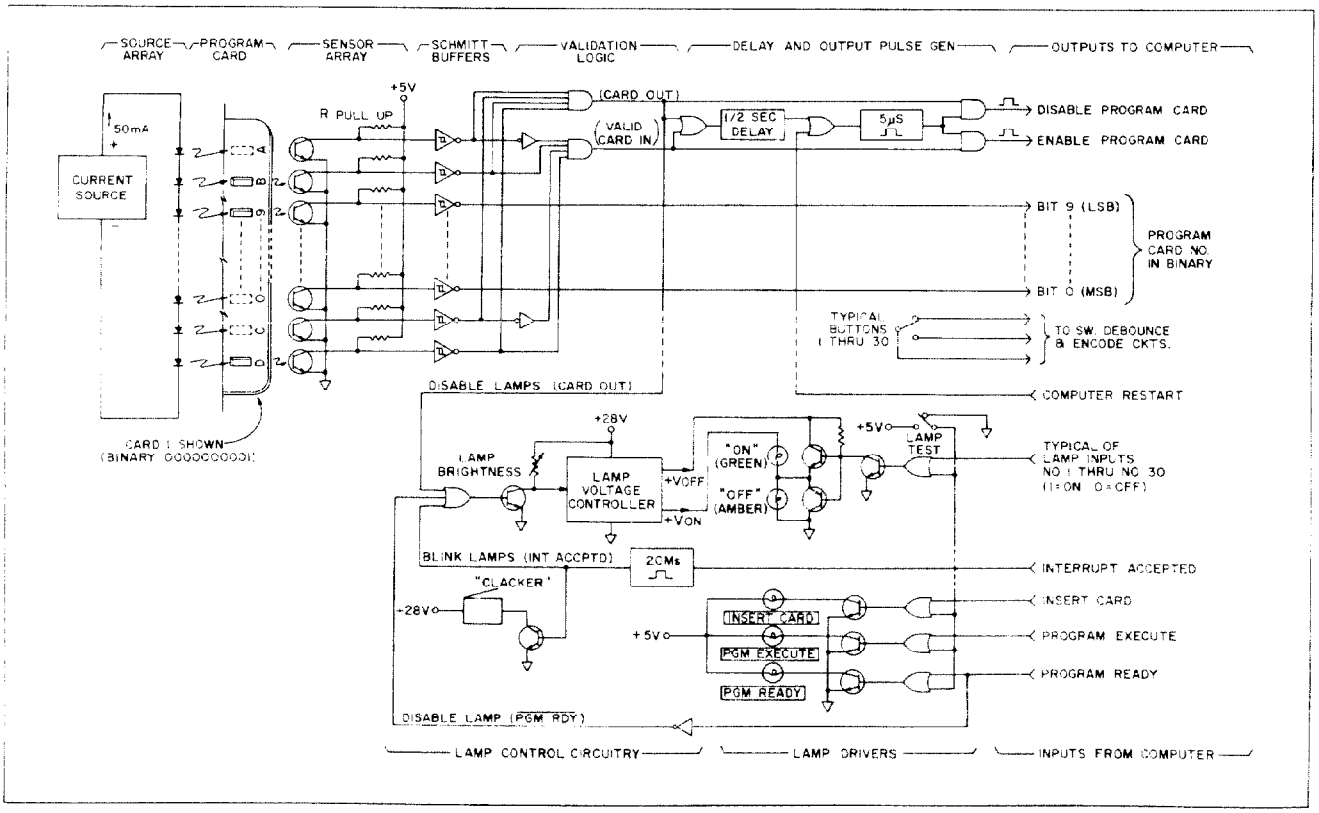


Figure 6. Card-Programmable Function Button Panel - Simplified Schematic Diagram.

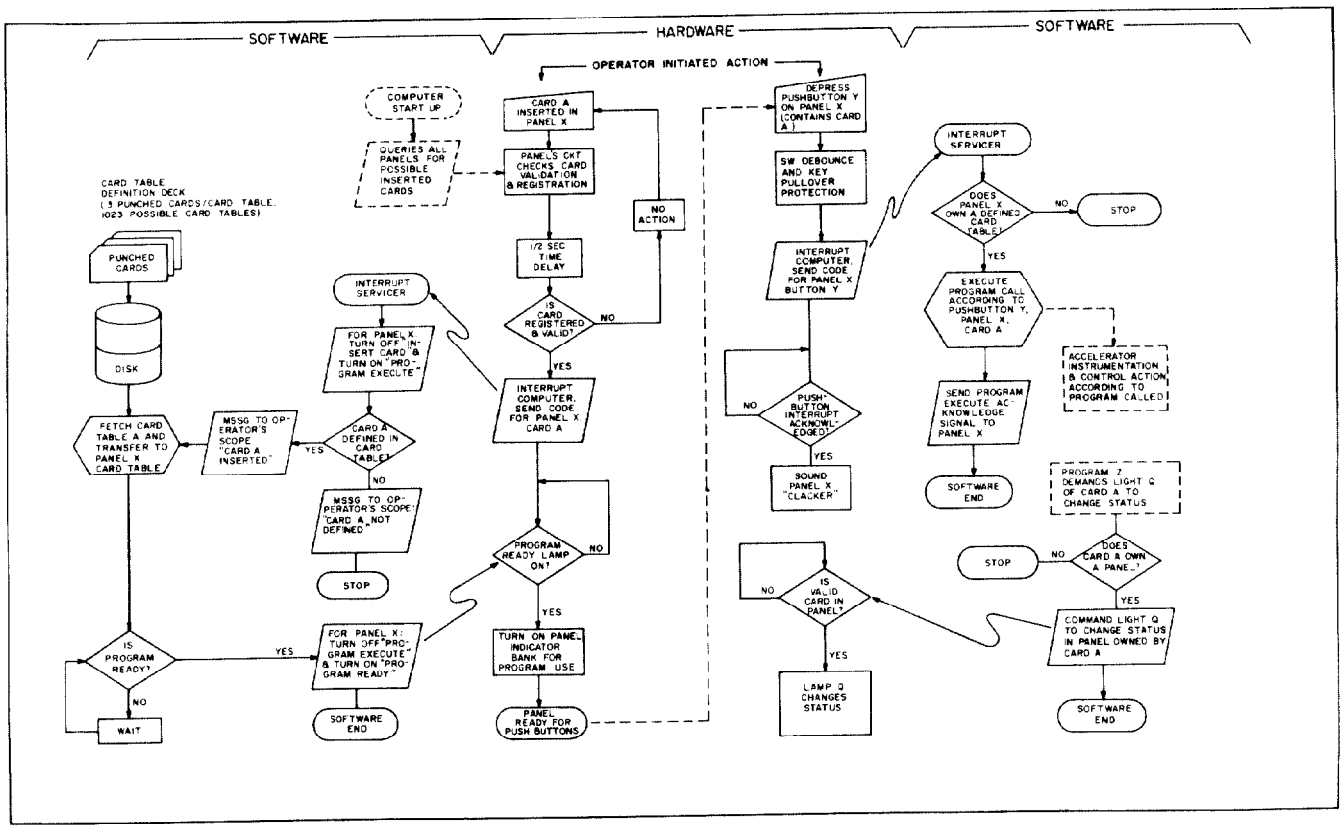


Figure 7. Hardware and Software Flowcharts for Card-Programmable Function Button Panel.

SOFTWARE DESIGN

The software routine used at LAMPF was developed over a period of time, taking good advantage of user feedback. Efforts were made to keep the system subroutines for program card definition and status lamp operations as straightforward as possible. The resultant software routine, along with hardware logic, is shown in Figure 7.

To use a program card the user punches three IBM cards to identify the program card number and the program-calls desired for each of the thirty function buttons. This set of definitions is called a card table. If he wants to use the indicators beside the buttons, he defines their operation through the use of a FORTRAN subroutine called LIGHT. Only two indications are presently used at LAMPF, yellow for OFF and green for ON.

Various forms of software-controlled feedback have been incorporated into the use of the panel in the form of status lights and operator messages. By the use of program reservations, sufficient software control has been added, so that a user will not accidently intrude upon another user's routines. All programs are written in terms of servicing a particular program card number rather than a physical card location. This allows the card's program to be basically independent of various panel locations. However, a card program can be related to physical location (such as knobs, buttons, scopes, etc.) if desired, since the panel's location is given to the computer at the same time the program card number is entered.

Although program card validation is accomplished by the panel's electronics, it could be just as easily done by the software of the system in the form of additional hardware of software reservations or conditions. Note that Figure 7 makes no mention of action when a card is removed, since this action is merely the reverse of the sequence shown (e.g. clearing reservations instead of making them, turning lights off instead of on, etc.)

CONCLUDING REMARKS

It is becoming increasingly common for apparatus of science to be embraced by the control of a computer. Each new device presents it's own set of algorithms, which requires control and status monitor panels unique to that device. Obviously, interactive computer graphics systems provide an ideal solution in such situations, but equally versatile hardware is found to be lacking. The author feels that the Card Programmable Function Button Panel described in this paper should make a significant step towards reducing this man-machine interface gap.

ACKNOWLEDGMENTS

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1. B. L. Hartway, C. M. Plopper, J. Bergstein, "The Central Control Room Man-Machine Interface at the Clinton P. Anderson Meson Physics (LAMPF) Facility," 1973 Particle Accelerator Conference, San Francisco, March 5-7, 1973.