LINAC CONTROL SYSTEM AC TURN ON FOR 200 MEV LINAC*

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ABSTRACT

The general machine philosophy is presented and detailed for the AC turn on, monitoring and control of the 200 MeV Linac. Three major control points are set up to run the linac. The Injector Control Room (ICR) for overall linac control; the Local Control Stations (LCS) for module control; the Sub-Module Control Points for turning on individual equipment. Personnel safety interlocking is provided.

Solid state logic and printed circuit card construction is utilized. Summary status information is displayed at control points so that a minimum number of control wires may be utilized.

General Control System Philosophy

There are three major operational control points in the 200 MeV Linac. The Injector Control Room (ICR); the Local Control Stations (LCS); and Sub-Module Control Points.

Figure 1 shows the layout of the upper equipment bay. M10 is the Injector Control Room from which the entire machine may be controlled. Monitoring and setting of reference levels controlling the beam dynamics is accomplished from here. Modules M1-M9 are all identical rf Drive Systems with Local Control Stations comprised of Control Racks A9-A27. These Local Control Stations control the electrical and mechanical subsystems associated with each of the nine cavities. Each LCS has control of an entire module as well as On-Off operation and monitoring of each sub-module in that particular module. There are additional LCS's throughout the machine to control the pre-injector, pump room, vacuum system, etc. Sub-modules may not 'talk' to each other directly, but must speak through the LCS's. Operation of each sub-module is performed at the equipment level for check out purposes. For personnel and equipment safety, anyone working on a piece of equipment must be able to gain unique control of it. The control point used to turn off a system locks it off. The system must be unlocked from that same point before it can be turned on anywhere.

All systems are modular in construction. Control chassis, Fig. 2, are steel enclosures which were chosen for economy and convenience. They are capable of being RFI gasketed. Inputs and outputs may be RFI filtered if needed. Printed circuit card construction with taper pin interconnections is used. Each control chassis has its own integral power supply. The internal construction is shown in Fig. 3. Power is dis-

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tributed within an enclosure on low inductance buss bars. Remote sensing of the voltages is done right at the buss bars.

Our control cards were designed functionally which greatly reduced the total number of cards and interconnections needed compared to using standard cards. This allows different types of logic and functions to be mixed on the same card which is rarely done on commercially available ones. The control system is repetitive and thus the quantities of each card needed warranted their design. We estimate that it would have required approximately three times the number of cards, at twice the cost, to implement our control system with standard cards. Where quantity or cost warranted it, standard cards have been used. Test points have been incorporated into all cards. There is a fault isolation connector on each control bucket front panel. When it is eventually connected to the appropriate test points it will be possible from the front panel to isolate faults within the bucket to the least replaceable unit (LRU), usually a p.c. card or power supply. The philosophy of using plug-in circuits and devices insures a minimum of down time in the operation of the linac.

The philosophy to insure safe operation (systems must fail "off" rather than "on") is; a '1' is used for a go condition and a '0' is used for turn-off or inhibit. This must be maintained in the case of a shorted or opened wire. The TTL integrated logic used for transmission of signals and performing control functions within a control bucket is "current sinking logic". Thus, current sinking is necessary to maintain a '0' at an input. Normally a broken connection to a TTL input will cause a '0' to look like a '1'. This is not allowed in the control system where it could turn on a piece of equipment or defeat some interlock or other personnel or equipment safety device. Figure 4 shows the evolution of the input biasing used on the inputs to "control cards". To insure a '0' the maximum resistance to ground that can be used is about 500 or 600 ohms. This limits the drive capability of the preceding stage to only one load. The resistor may be increased to 10 K ohms if it is returned to a negative supply of -15 volts. The preceding stage now is capable of driving three loads which is a more reasonable number. A diode was added to clamp the input negatively. Discrete circuits are also utilized where TTL equivalents were not available or adequate.

To allow operation in the expected high noise environment, digital signals are transmitted differentially from and to control chassis. A digital differential driver and digital differential receiver card was designed for this purpose. Signal levels are shown in Fig. 5 along with the truth table for the transmitter-receiver pair. Even though both signals are 0-10 V the effective differential (on to off) voltage is 20 V. There is only one true state out of the four possibilities. Twisted pair shielded control cable is used in most cases with the shield grounded only at the transmitting end to avoid ground loops. The receiver is capable of operating in the presence of a plus or minus 40 volt common mode signal level.

Analog signals are also received differentially with a card designed for that purpose. The characteristics of the analog receiver are 800 KHz bandwidth, over 50 db common mode rejection ratio, approximate unity gain for signals from minus 3 volts to plus 10 volts. Analog signals are also grounded at the transmitting end to avoid ground loops.

AC Control and Monitoring

Figure 6 shows the standard pushbutton array which is used universally in the Linac. The lights indicate the status of the system of which it has on-off control. The linac standard for colors of lights is red for on, green for off, white for malfunction and blue for special functions.

At the equipment, the heart of the control system is a general purpose equipment card. Figure 7 is a block diagram of this card. The usual inputs and outputs are labeled on the diagram. There are various levels of interlocking and shutdown provided. The card is used in most major pieces of rf equipment. Typically $\overline{M}$ indicates no malfunctions, "F" turn on filaments and "AC" cycle complete or turn on high voltage. The inputs are on the left side of the diagram. For the three outputs generally used, $\overline{M}$, "F" and "AC" all to be '1', all inputs must be '1' with the exception of under voltage malfunction which must be '0'. An undervoltage malfunction is annunciated but does not inhibit or turn off "F" or "AC". Inputs normally fed to Gate 1 are vital services such as air and water. Loss of any of these, inhibits or shuts off both filaments and high voltage and indicates a malfunction. The signal to the top input on G1 is derived from a powerstat or inductrol lower limit switch. This input must be satisfied for any turn on sequence to be initiated. The on and off switches at the equipment level are shown connected to the equipment card. They are part of the standard pushbutton array mentioned earlier. The off switch is alternate action; each time it is pressed it changes the sense of the off signal to the differential receiver. This is used to implement the philosophy that the off switch locally locks off a system making it impossible to turn on remotely. The on switch is momentary, it presents s signal to the equipment card while it is pressed. Normally after the filament sequence is completed the auxiliary contacts on a contactor or its equivalent are used to seal the on signal and powerstat input. The seal signal verifies that the command to turn on the filaments has been executed and the on button may be released. The powerstat input must be sealed because once the powerstat receives its command from "F" it moves off its lower limit switch and would otherwise shut the system down. The filament signal initiates a time delay which when completed satisfies the lower input on Gate 3 allowing the high voltage or next higher level system to be turned on. The method of bypassing door switch interlock signals, to the equipment card, to allow working on the equipment, with the filaments on but high voltage turn on inhibited, is shown.

The status card is shown in Fig. 8. It is used to logically interpret the outputs of the equipment card and drive the lights in the On-Off pushbutton array.

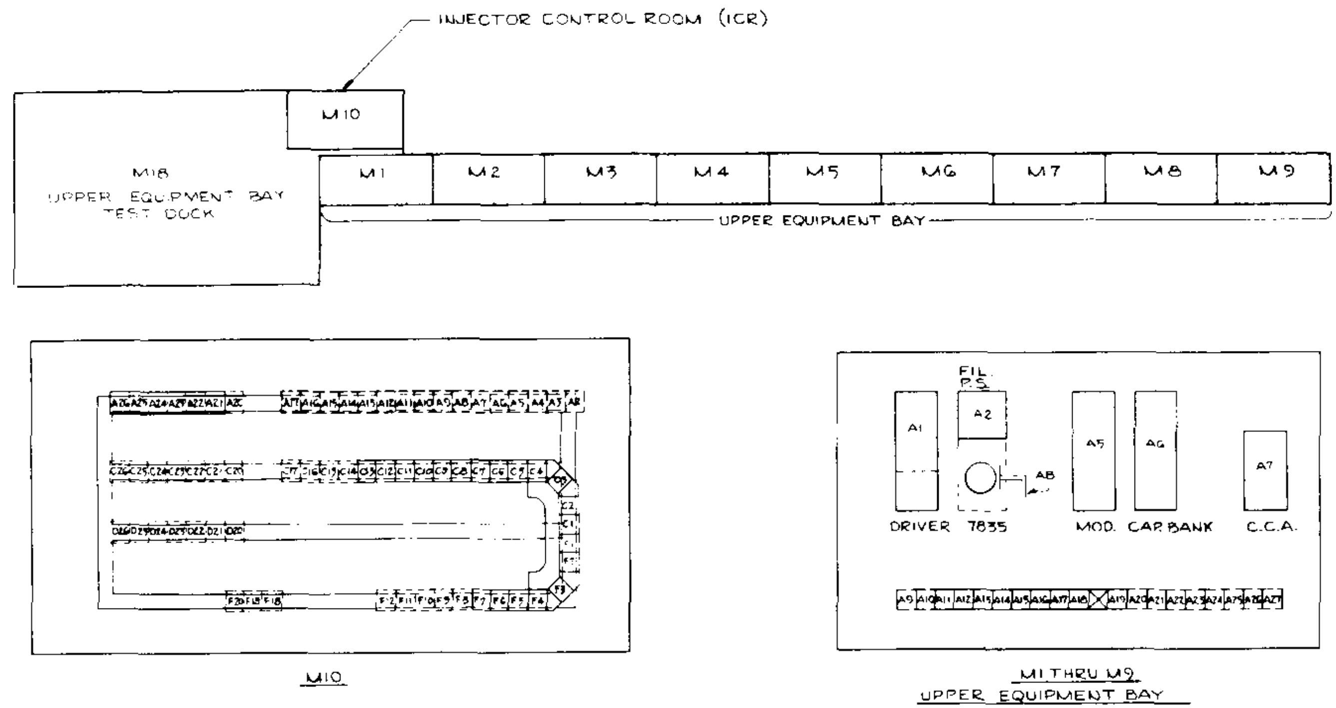
In the linac, control points may be as far as 500 feet from each other. Each signal usually requires a driver and receiver, with their associated power and hardware. To minimize the cost of the control system it was desirable to minimize the number of signals transmitted to the major control points.

The complete On-Off and status circuit is shown in Fig. 9. At the sub-module (equipment level) individual system status and malfucntions are annunciated. At all other control points only summary status information is displayed. The four inputs of each piece of equipment to the Status Card are sent to the LCS where the Status Card is repeated for each and displayed on the regular pushbutton array. The like Status Card inputs are also "anded" and displayed through a master module Status Card at the LCS. The four inputs to the master Status Card are sent to the ICR where the master module Status Card is repeated as an ICR submaster. The like Status Card inputs again are "anded" and displayed through a master ICR Status Card which indicates the status of the whole machine for that particular function (filament, high voltage, etc.). For remote control turn on and off, contacts from relays driven by the master Status Cards and the switches in the pushbutton arrays in the ICR and LCS's are wired as shown. All ON switches are momentary. Pressing any one transmits an ON signal to the equipment card. All OFF switches are alternate action with the local lock off feature. To turn on, the OFF buttons must be unlocked. The master turn on switches are enabled by the relay driver in the master Status Card only if there are no malfunctions or lock signals to it. Master switches are used to turn on multiple functions. They can be used only if all functions they control are operative. If, for instance, module number one has a malfunction in a piece of equipment, then the ICR master switch would show a malfunction, and would not be able to turn any module on. The sub-master switches, however, could still be used to turn on the other eight modules.

The Modulator AC Logic Bucket, Fig. 10, was the first to be implemented with control cards, Fig. 11. It was one of the more complicated ones which could be modified to be used with the other pieces of rf equipment. The additional logic necessary to cover the largest number of cases was put on a general purpose logic card. Lamp and relay drivers, latchable lamp drivers and comparators, were also designed. A total of fifteen cards are used to monitor and control the Modulator. The interconnection to the Modulator itself is also shown in the Figure.

Summary

The AC turn on philosophy for the 200 MeV Linac has been presented. General purpose printed circuit cards using solid state and integrated circuits have been developed to implement it. The philosophy for the turn on of filaments and high voltage presented for the rf system has been used universally in the Linac. With a few additions the same control cards have been used to implement the fast logic pulsing turn on for the rf system. Figure 12 is a photograph of a portion of an LCS. The center rack houses the Master Filament, High Voltage and Pulsing turn on for one rf module. The control system for cavity one, has run reliably during the 10 MeV experiments. The construction and installation of the remainder of the control systems for the 200 MeV Linac is nearing completion.



NOTES:

1. MODULES M1-M9 ARE ALL BASICALLY IDENTICAL R.F. DRIVE SYSTEMS WITH LOCAL CONTROL STATIONS

Fig. 1. Upper equipment bay layout.

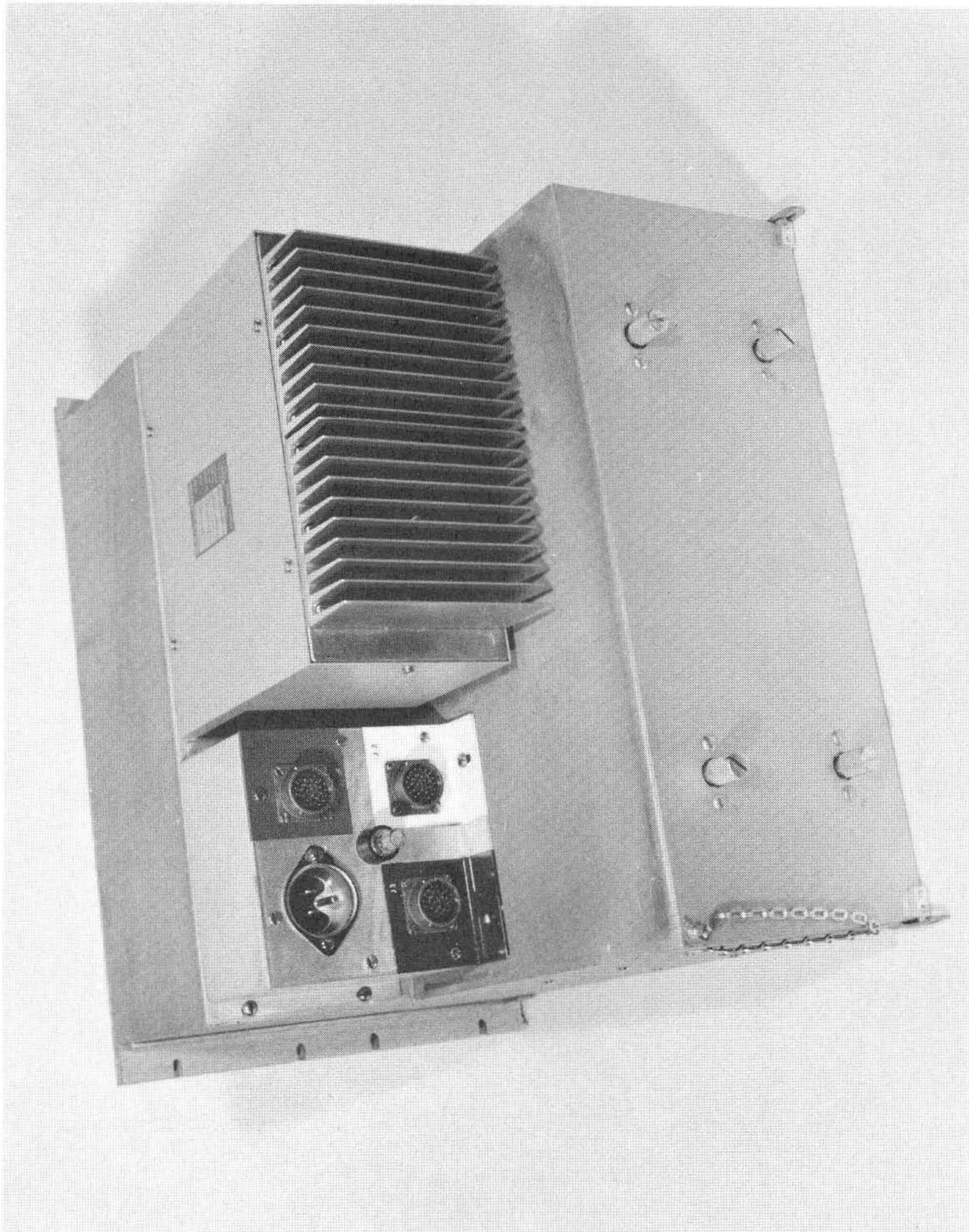


Fig. 2. Control bucket.

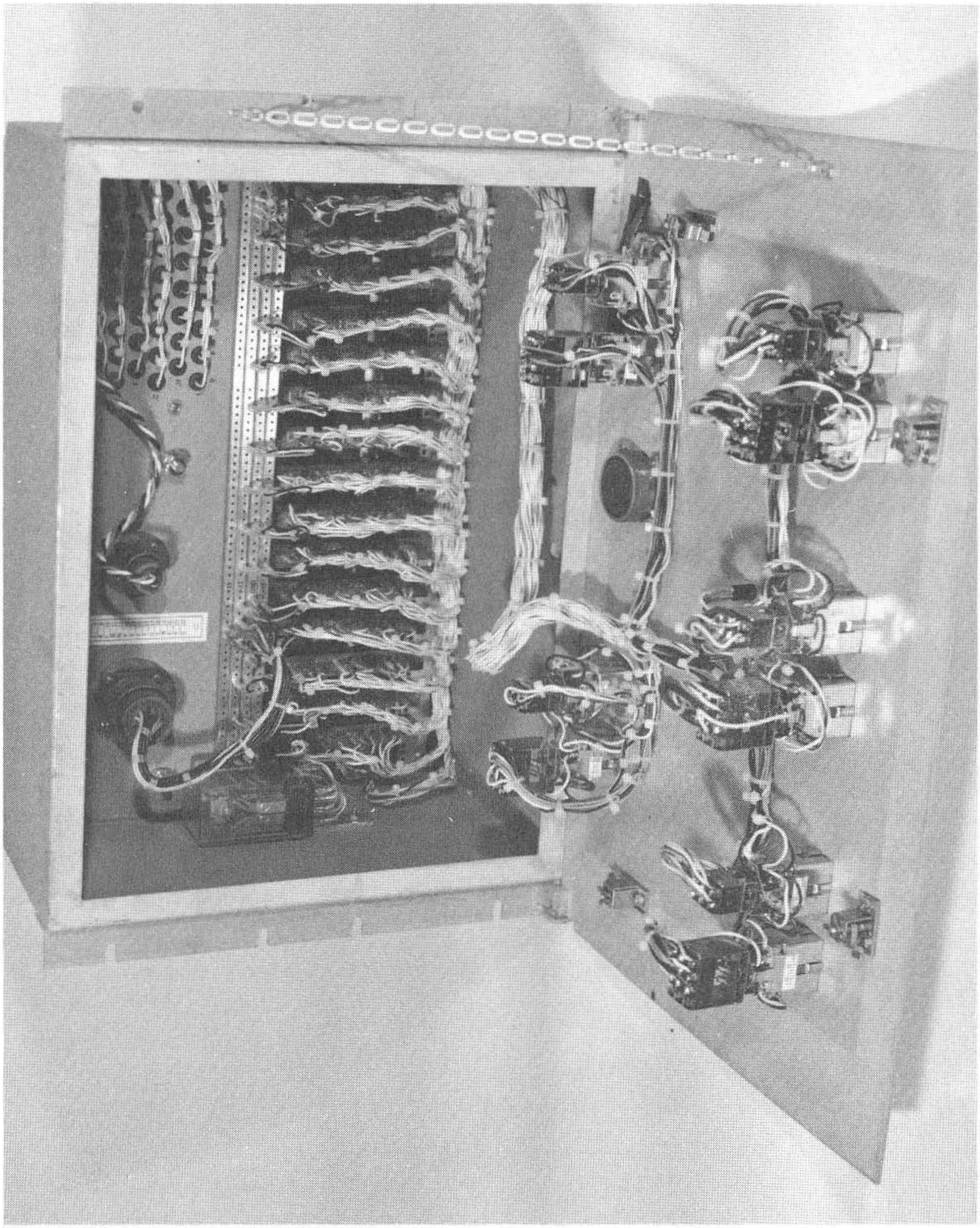


Fig. 3. Internal construction of control bucket.

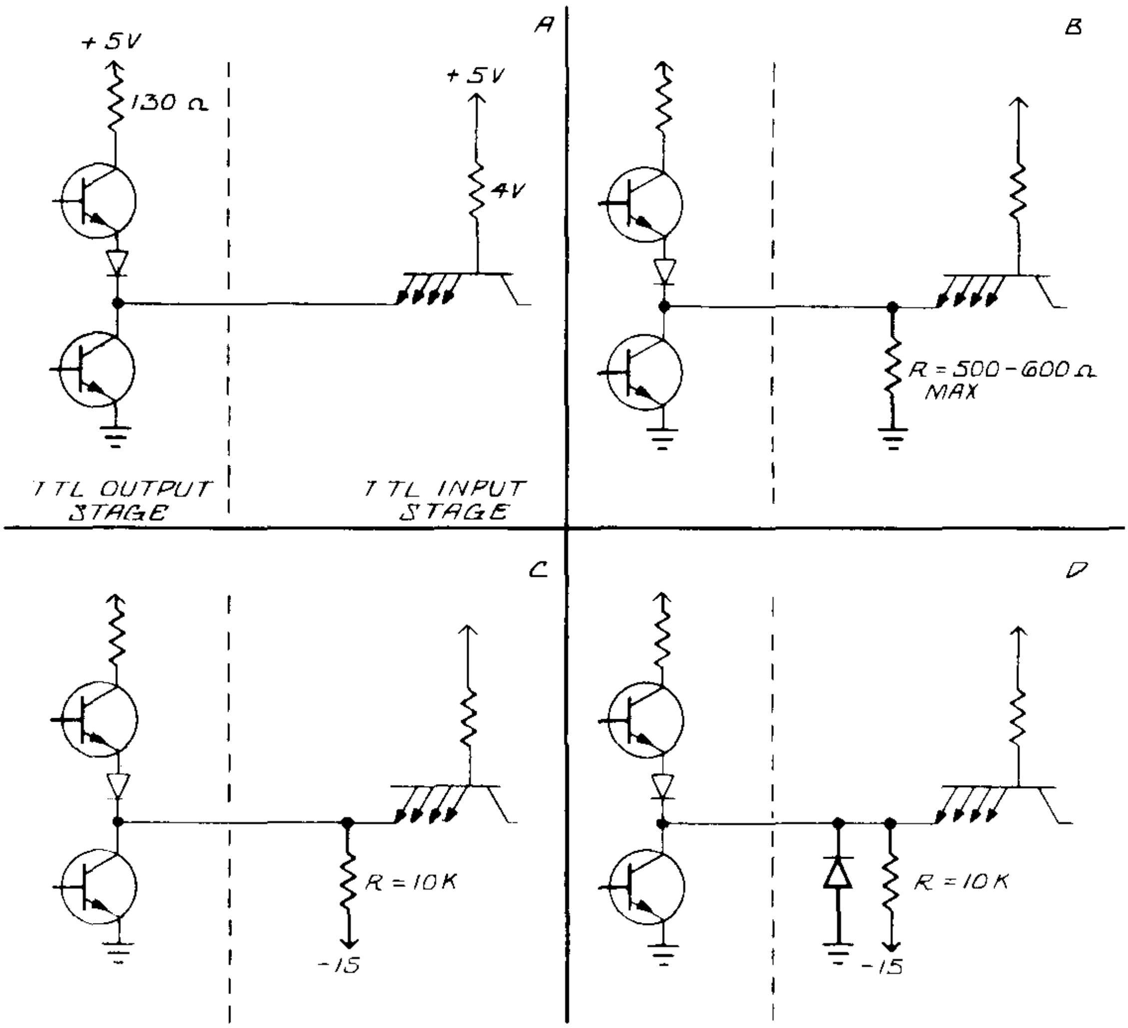
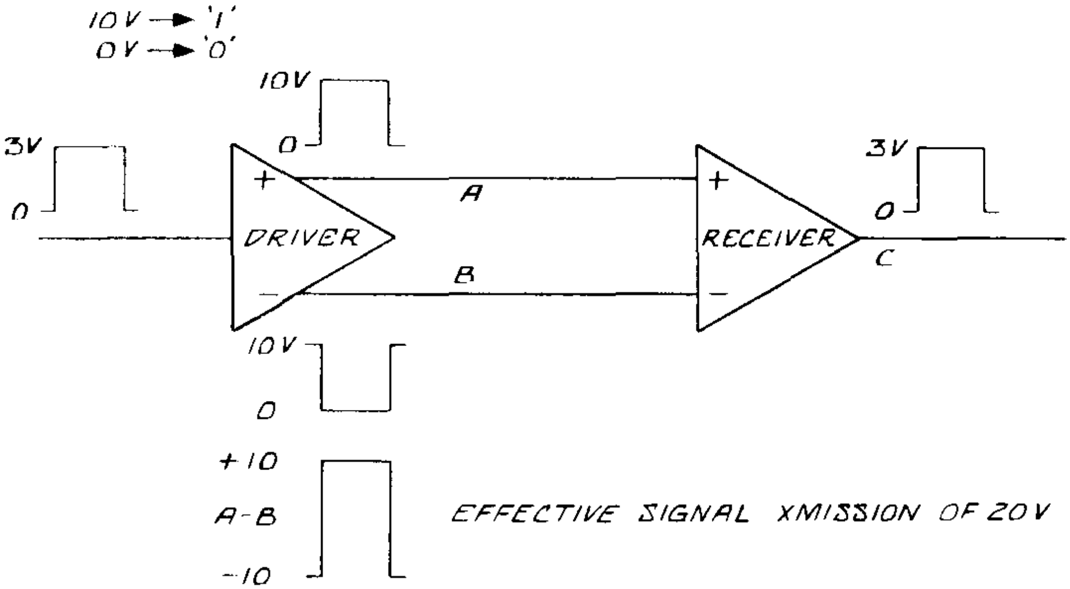


Fig. 4. Input biasing for TTL--current sinking logic.



TRUTH TABLE

A	B	C	
0	0	0	
0	1	0	
1	0	1	TRUE STATE
1	1	0	

Fig. 5. Digital differential driver--receiver block diagram.

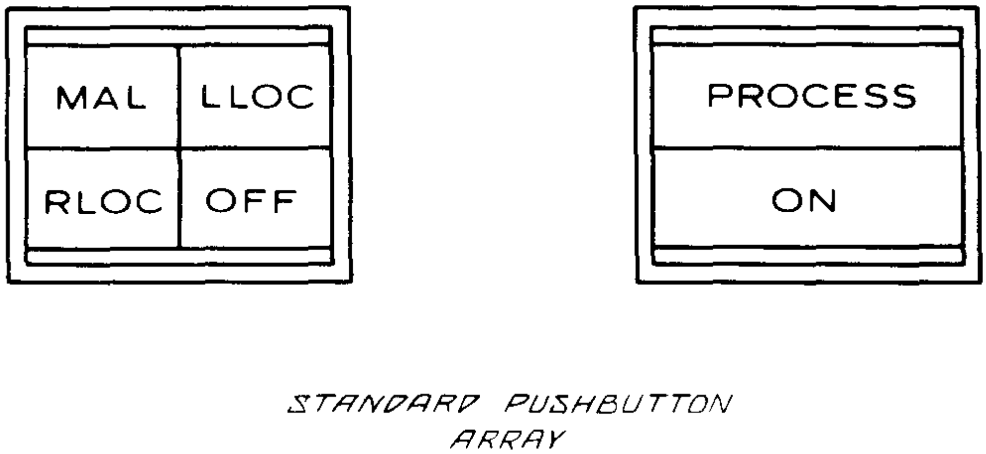


Fig. 6. Standard pushbutton array.

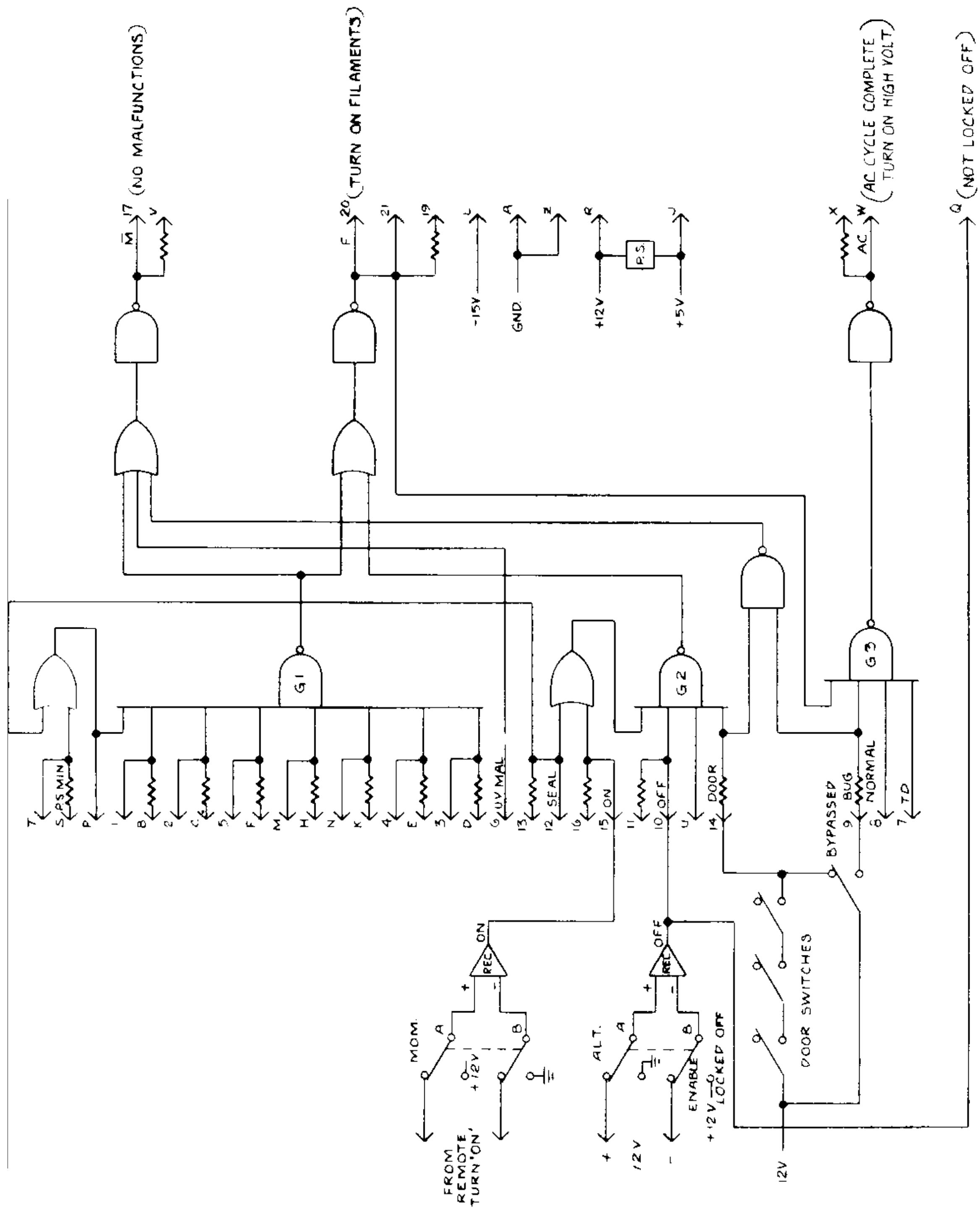


Fig. 7. Equipment card block diagram.

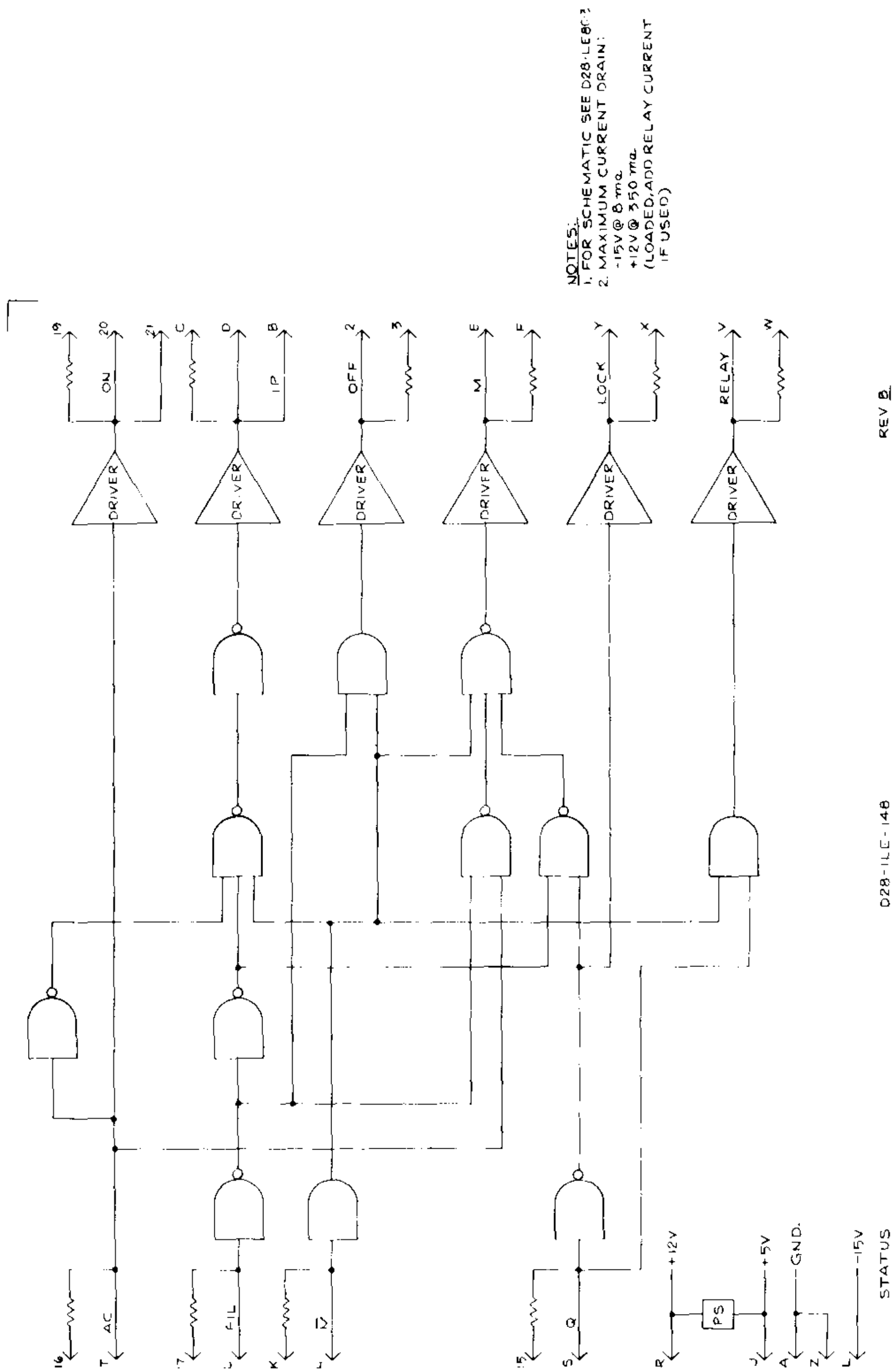


Fig. 8. Status card block diagram.

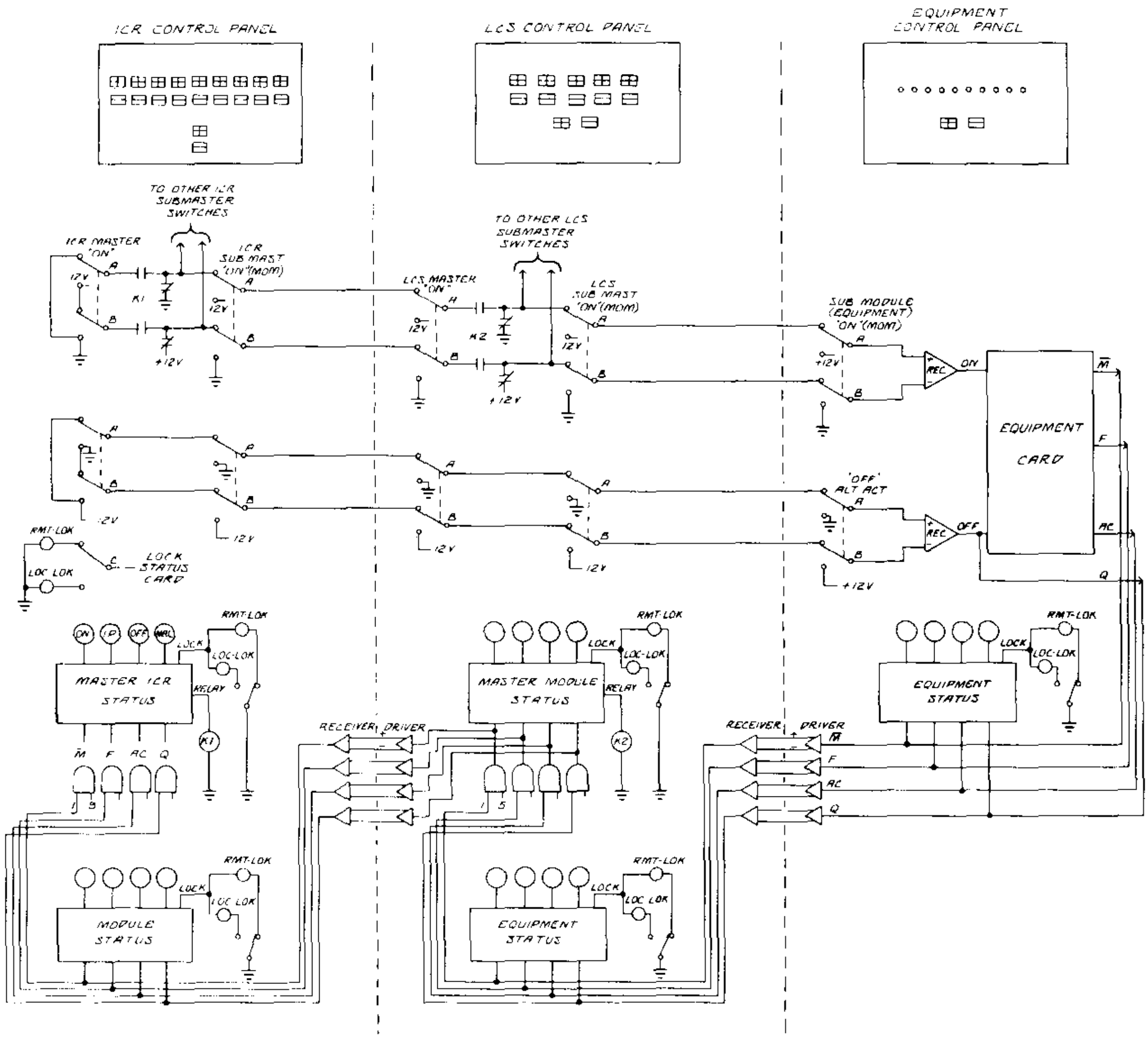


Fig. 9. Complete on-off and status circuit.

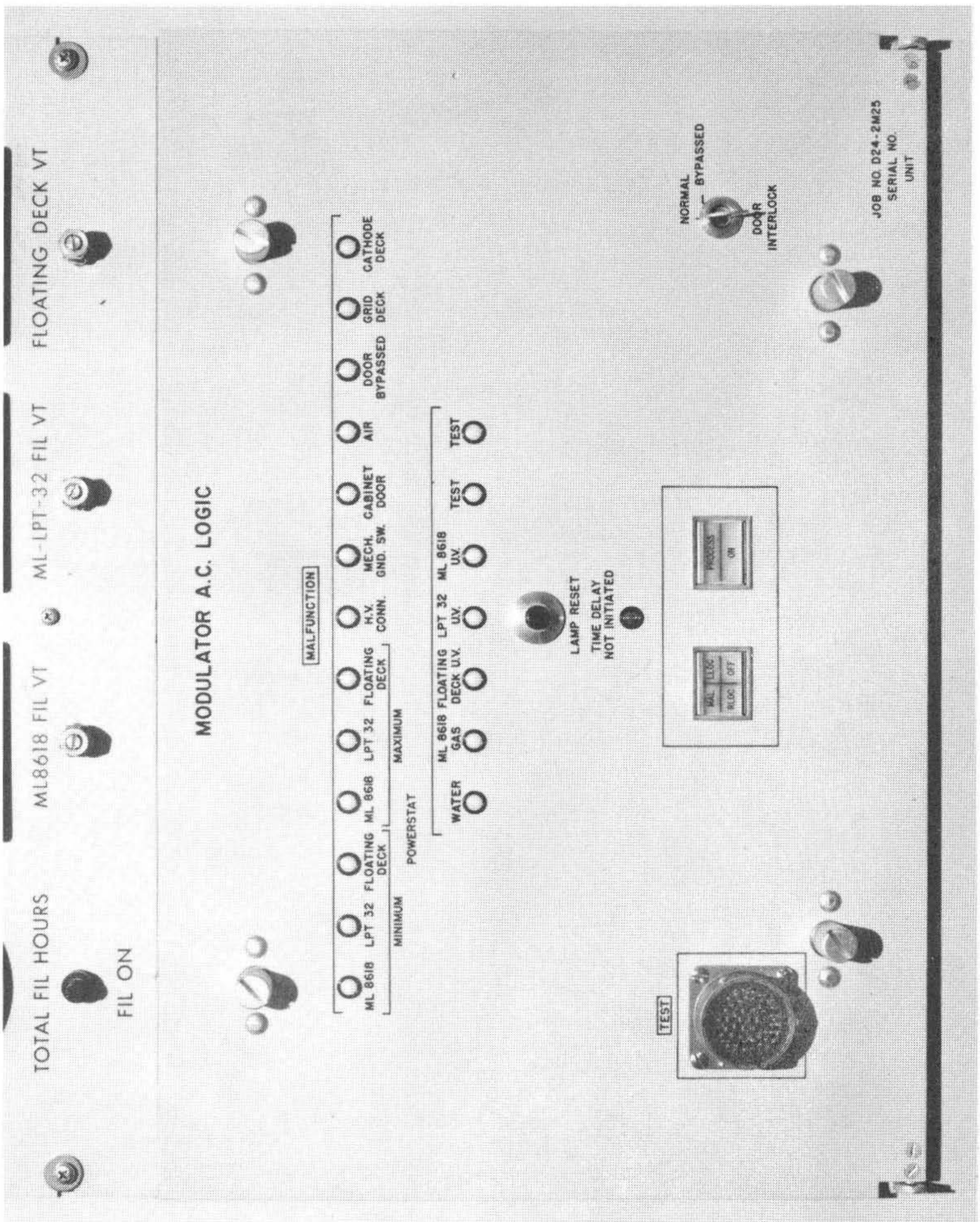


Fig. 10. Modulator ac logic control bucket--front panel.

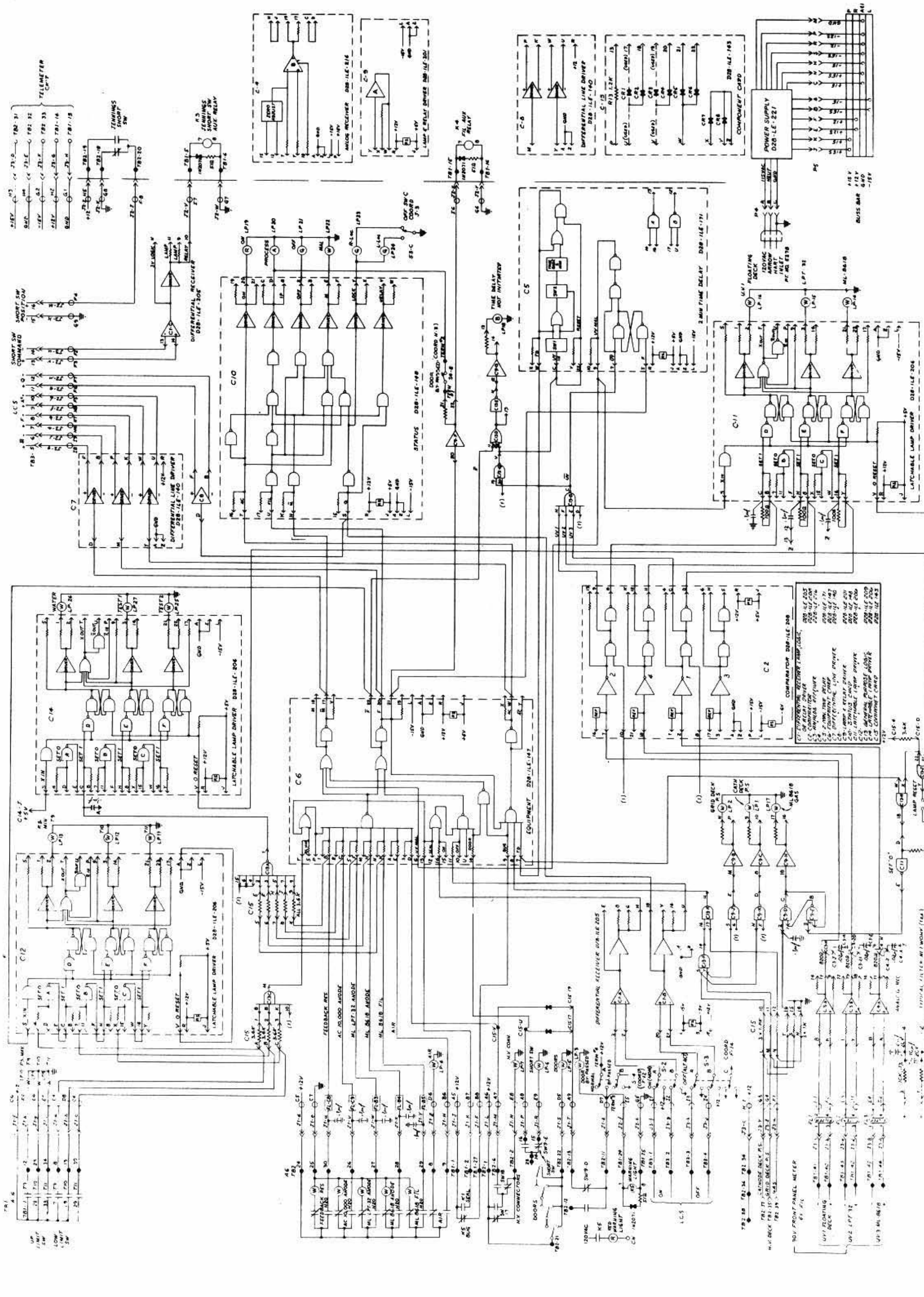


Fig. 11. Modulator ac logic control bucket--schematic.

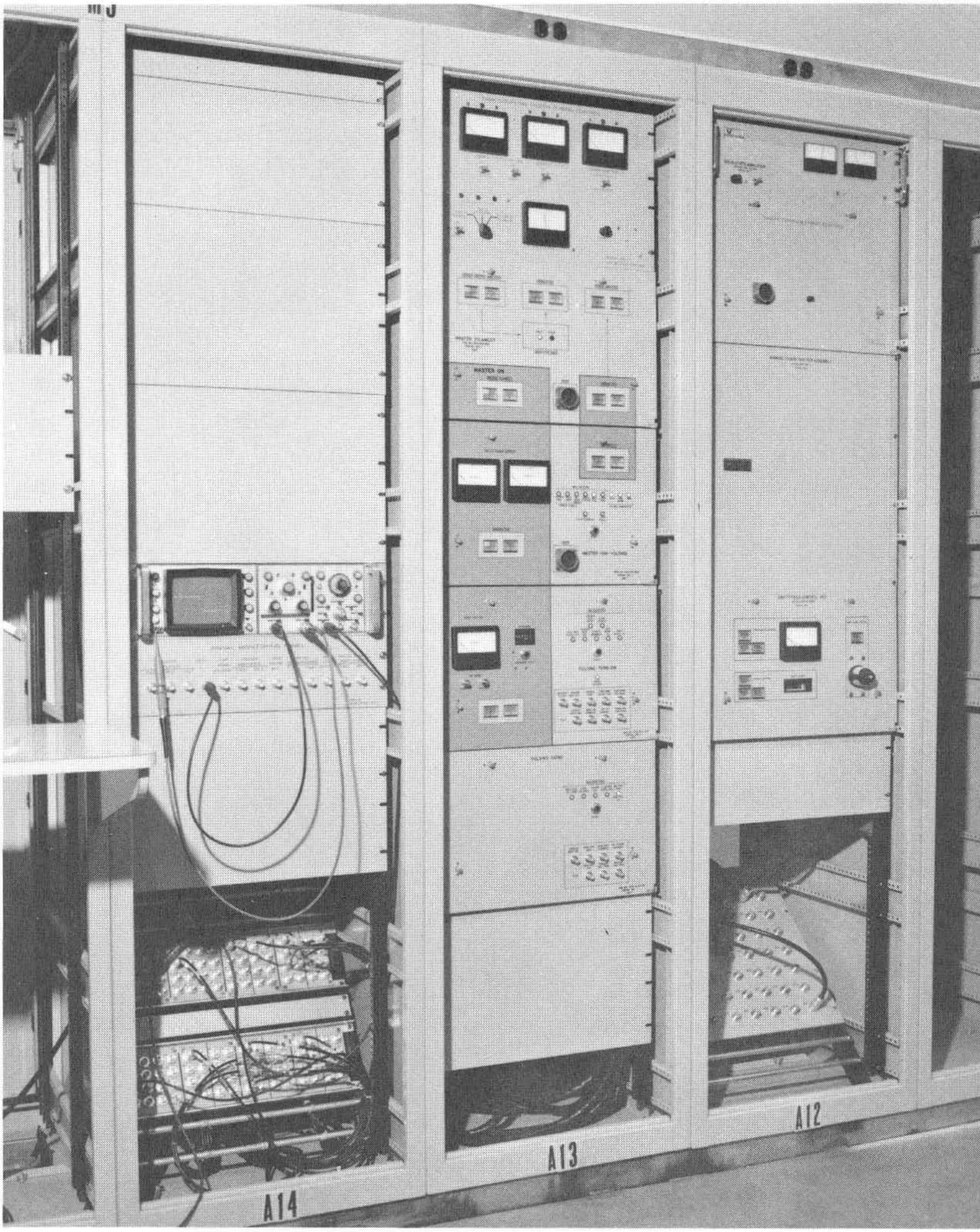


Fig. 12. Local control station.

DISCUSSION

T. M. Putnam (LASL): What sort of resolution do you have on your timing gates? You turn on the rf to fill the tank and then you have a beam pulse following at some later time--what resolution do you provide for this?

D. L. Greenberg (BNL): The timing circuits themselves have about a microsecond risetime, and all our systems are fairly slow. We do have a 400 microsecond pulse, and 200 microseconds are used for the rf.

T. M. Putnam: Are you using a megacycle clock rate?

D. L. Greenberg: We use an 8 megacycle clock rate, and we turn it down to one. The two systems are synchronized then, and in this way we get slight jitter.

D. R. Machen (LASL): Have you found that it is really necessary to shield everything that much?

D. L. Greenberg: In some cases we found it necessary to shield but not very often. We haven't operated all systems together yet.

D. R. Machen: If you look at various accelerators around the country, you see a complete spectrum of shielding.

A. S. Lundy (LASL): I wonder if you have any estimates on the average cost of your control-bin chassis?

D. L. Greenberg: About $1500.

J. E. Leiss (NBS): In your master-timing system have you worried about the possibility, when you are using a very high frequency clock that through some malfunction you might suddenly go to a high repetition rate? We have had this happen to us, and it can be an extremely painful experience. We have put on anode integrators looking at time intervals that can slap us off.

D. L. Greenberg: No. We have monostable triggers that should help this problem.