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MANIPULATION PAD--PRELIMINARY REPORT ON A STUDENT-COMPUTER INTERFACE DEVICE FOR PROGRAMMED INSTRUCTION.

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AN INVESTIGATION WAS MADE OF SOME ENTIRELY NEW INPUT-OUTPUT DEVICES DESIGNED TO SOLVE SOME FUNCTIONAL AND ECONOMIC PROBLEMS THAT ARE PRESENT IN EXISTING COMPUTER-CONTROLLED INSTRUCTION EQUIPMENT. THREE FORMS OF MANIPULATION PAD WERE STUDIED. INFORMATION ABOUT SPECIALLY PREPARED OBJECTS PLACED ON THE FLAT SURFACE OF THE PAD WAS SUPPLIED TO A COMPUTER PERMITTING THE DETERMINATION OF THE NUMBER, SIZE, SHAPE, AND ORIENTATION OF THE OBJECTS WHICH CAN BE FREELY MANIPULATED BY A STUDENT. THE CONSTRUCTION OF A DEMONSTRATION MODEL OF THE FERROMAGNETIC OBJECT RECOGNITION MATRIX (FORM) MANIPULATION PAD WAS REPORTED IN DETAIL. PRELIMINARY RESULTS INDICATED THAT A SATISFACTORY MANIPULATION PAD FOR PROGRAMMED INSTRUCTION HAD BEEN ACHIEVED WITH THE WORKING MODEL OF FORM. (AL)

MANIPULATION PADS

PRELIMINARY REPORT ON A STUDENT-COMPUTER INTERFACE DEVICE FOR PROGRAMMED INSTRUCTION

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ELECTRICAL SYSTEMS AND POWER CONDITIONING R&D

MANIPULATION PAD

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MANIPULATION PAD

Preliminary Report on A Student-Computer Interface Device for Programmed Instruction

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ABSTRACT

The Manipulation Pad is a device for transferring information to a computer about the area covered by specially prepared blocks which are manipulated on a tablet by a student. Investigation of several devices proposed as manipulation pads for programmed instruction is reported. The construction of a feasibility model of the FORM (Ferromagnetic Object Recognition Matrix) manipulation pad is described in detail. A working system of 16 by 16 point resolution complete with all necessary electronics is available for demonstration. Progress on a 64 by 72 array is reported.

INTRODUCTION

General Requirements for Computer-Controlled Classroom Instruction

Computer-controlled classroom instruction requires considerably more man-machine interface equipment than most other computer applications. The lack of interface equipment specifically designed for programmed instruction has necessitated the use of much ill-suited and makeshift interface equipment. This new field has requirements for student station equipment which are largely incompatible with the military and commercial requirements ~~which~~ that have influenced the design of existing equipment. The large number of student stations in a typical installation requires that the interface equipment generate digital signals which the computer may utilize directly, lest the computer capacity be squandered in signal processing and interpretation. As the program material and student responses will generally be different for each station, a quantity of data which could readily overload an inefficient input-output system must be transferred. The same multiplicity of student stations establishes a limit on cost per station which renders much available equipment prohibitively expensive. A further requirement for much programmed instruction is that little or no student training should be necessary for full utilization. This is indispensable for computer-controlled instruction of mentally retarded or very young children. As the existing systems generally do not satisfy the technical requirements without modification, and as they are generally too expensive even in their unmodified form, some better approach is necessary to achieve a solution which is both functionally and economically satisfactory.

The Manipulation Pad - A Device Specifically Suited to Programmed Instruction

Consideration of the unique system requirements of programmed instruction has suggested entirely new input-output devices, accomplishing new functions not readily implimented with available hardware. One such proposed device is the manipulation pad. This is conceived as a flat surface on which are placed various specially prepared objects of assorted plane geometric shapes. The function of the pad is to provide information permitting the computer to determine the number, size, shape and orientation of the objects. The pad should discriminate between the special object and extraneous objects, such as pencils, eraser or parts of a student's body. The considerations mentioned above as to cost and complexity must also be satisfied. It should be possible at any time to add new objects without reprogramming the computer.

INITIAL INVESTIGATION

Two Approaches which were Subsequently Abandoned

Photocell Matrix

The initial attempt to construct a manipulation pad for demonstration purposes used an array of photocells which detected reflected light.

As shown in Figure 1, a block of clear plexiglass was milled to provide an array of isolated pyramids. A piece of Wratten 73 filter was glued to the bottom of each projection, and a Clairex CL904 photocell mounted below each.

The assembly was housed in a cabinet with an incandescent light source beneath. Light was then transmitted via the flat spaces between the pyramids through the face of the assembly. Any object placed on the face which reflected a sufficient amount of light back into any pyramid would alter that photocell's resistance enough to be detected. The color of reflected light necessary to cause recognition of an object depends on the overlap of the spectral responses of the filter and the photocell.

The sensitivity of the photocells was lowered somewhat by the large amount of unwanted light directed on them from internal reflection from the face of the assembly and diffusing in through the sides of the pyramids. Most overhead lighting is flourescent with very little light beyond 5,000 Å and hence was not thought to be a problem since the filter-photocell combination is most sensitive around 6,000 Å .

A greater source of trouble, though, was that the heat generated by the light source directly affected the photocells resistance.

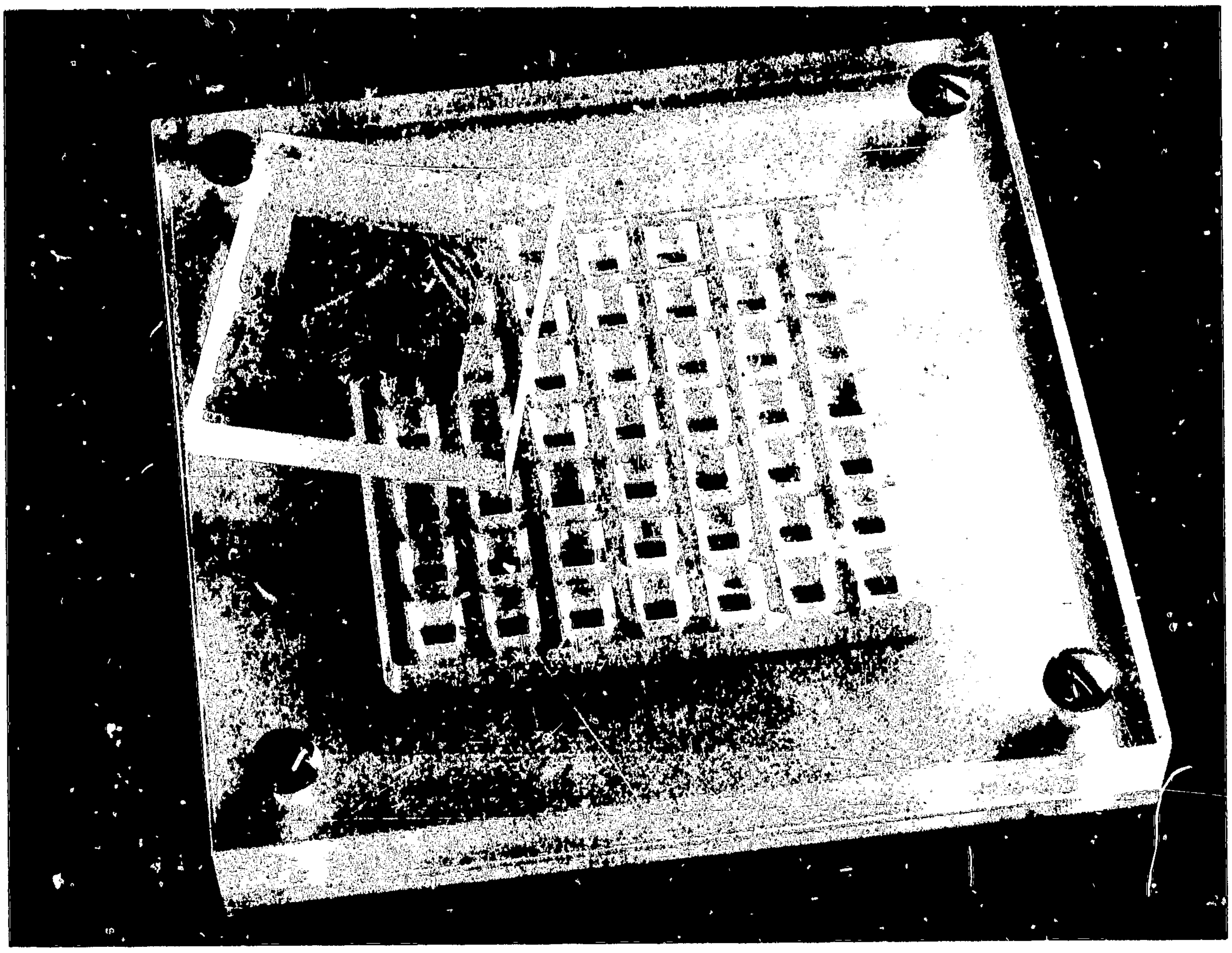


Figure 1
Light Cell Device

RM

With the test setup shown in Figure 2, the following results were obtained on one test:

ACTION	V
Lamp off - normal room light	4.4 V
Lamp on - normal room light	5.6 V
Hand pressed on face	7.4 V
White paper	8.4 V
Filter backed with aluminum	8.4 V
Filter backed with aluminum with cupped shape	10.4 V

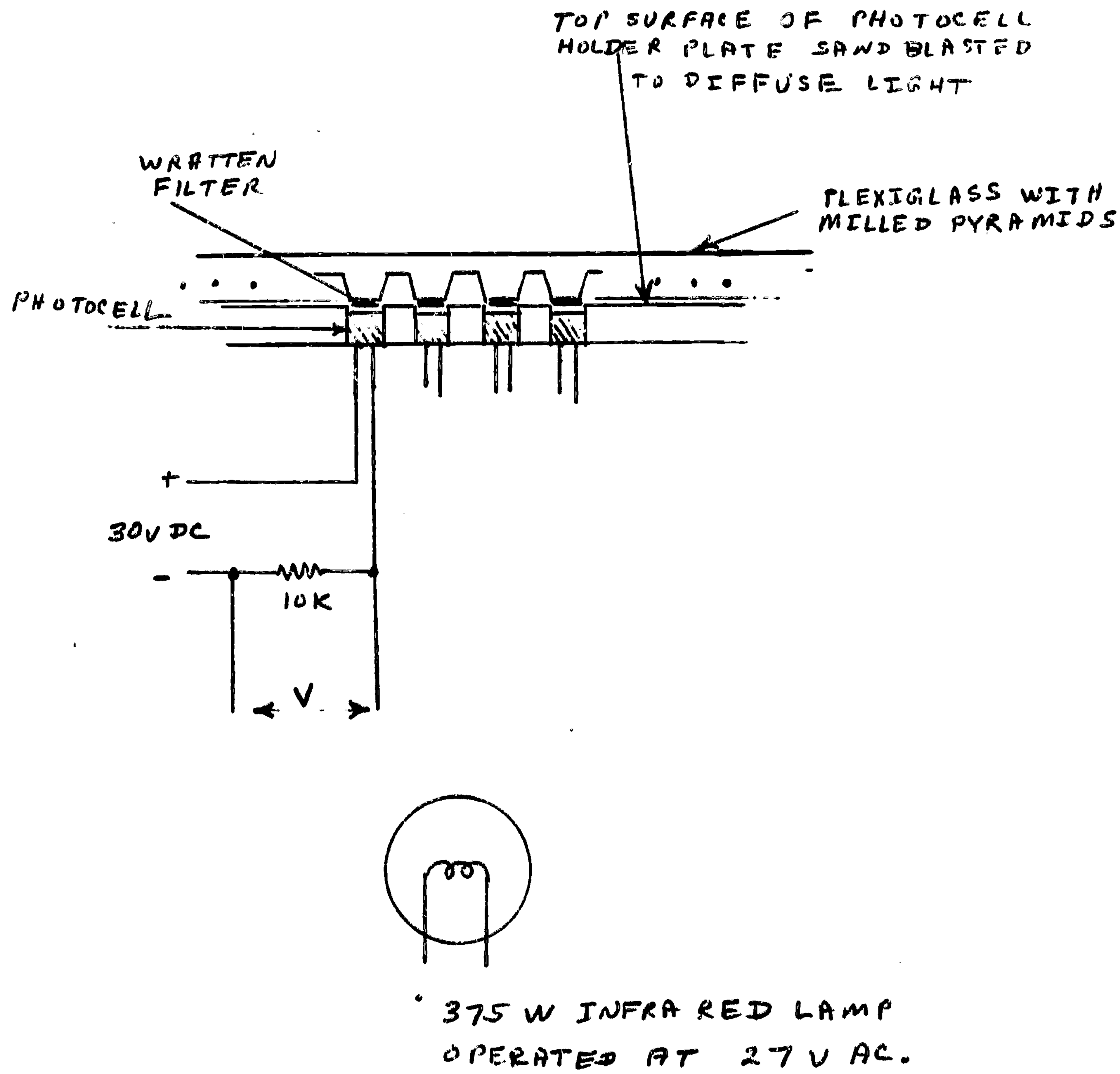
It was concluded that with a suitable thresholding circuit the device could discriminate the hand and normal clothing from an object reflecting light of a wavelength greater than 5,000 Å. Any prepared block with such a reflecting portion on each face could be used with this device.

Capacitor Matrix

The second manipulation pad used a metallic block which capacitively coupled an ac signal from a surrounding grid to individual islands on a flat non-conducting plate.

This device, illustrated in Figure 3, was constructed by gluing the grid and individual islands with attached wires to the bottom of a shallow square mold. The mold was then filled with epoxy. When set, the block was separated from the mold and its surface milled flat. To protect the thin metal pieces, a layer of 1 mil mylar was glued over the surface of the pad.

An ac signal then connected to the grid could be capacitively coupled to the pads by any flat metallic block placed on the surface.



MANIPULATION BOARD TEST
(PHOTOCELL DESIGN)

FIGURE 2

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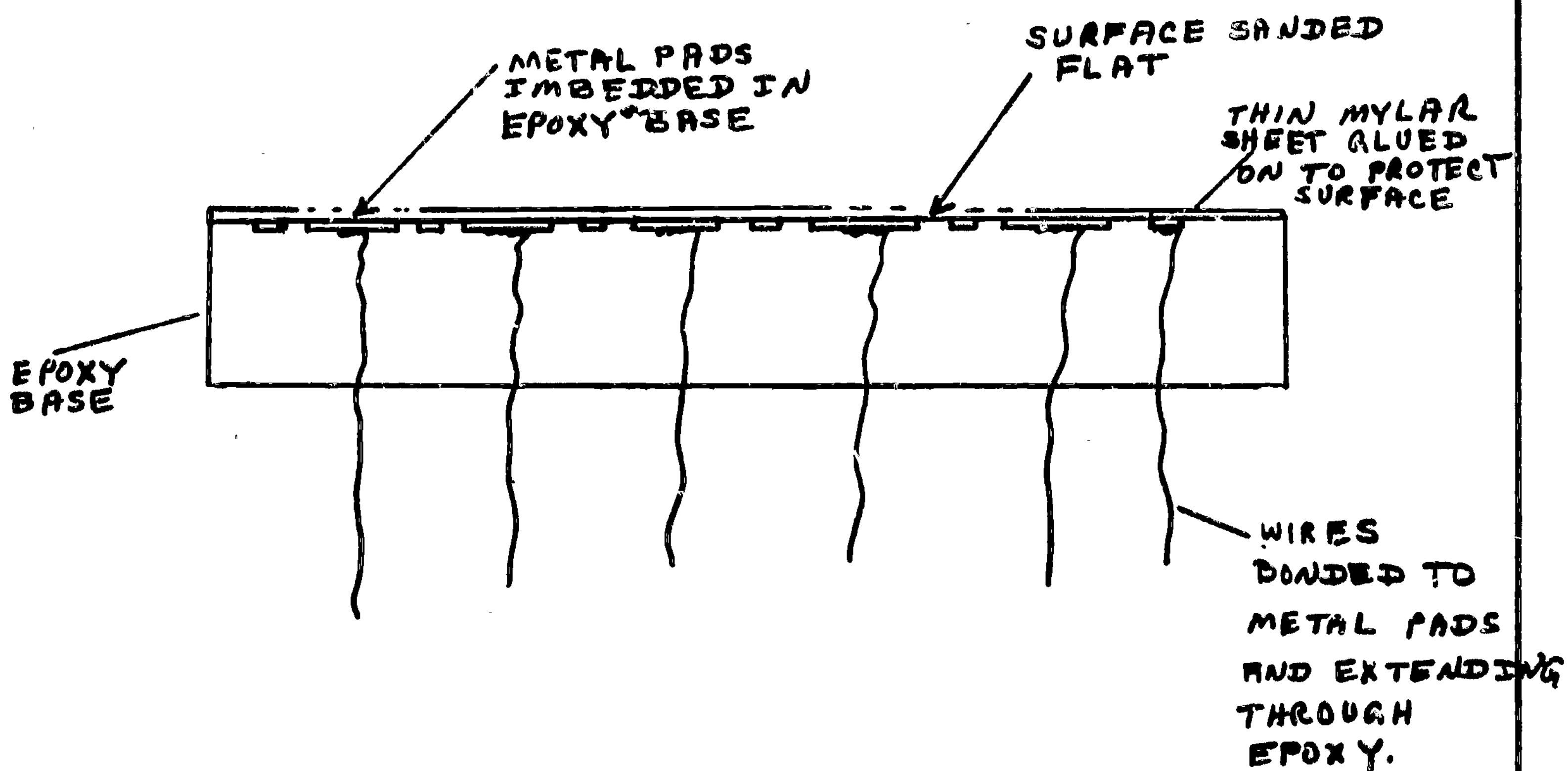


Manipulation Board

Construction Detail

FIGURE 3

J.R. BALL 3/2/66

The problem with this type of device is the extremely small capacitance involved (typically <10 pf) and the resulting high output impedance.

Another slight problem occurred because the output signals from the individual islands were not filtered and 60 cps noise could be coupled into the islands easily by an ungrounded hand. Either grounding oneself directly with a ground wire or sitting on a grounded metal stool seemed to solve this problem.

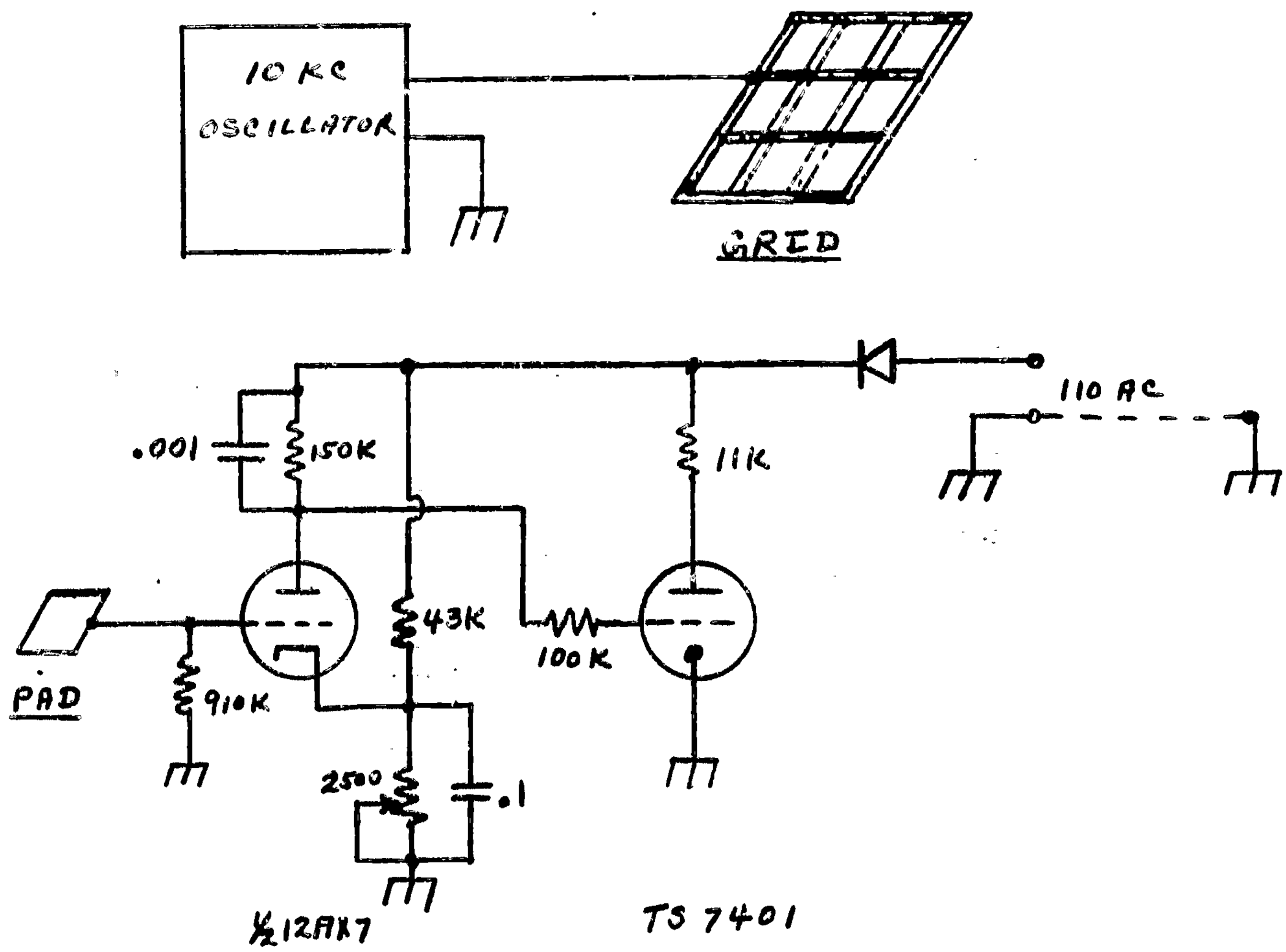
Since the device actually constructed was to be used for demonstrations only, each island was connected to its own indicator. No attempt was made to reduce the number of indicators by scanning techniques. The circuit used is shown in Figure 4.

The 12AX7 tube was used primarily to provide sufficient voltage output to fire the chosen indicator device, a Tung Sol 7401 tube. With a different indicator semiconductor circuitry could be used. The 10 kc oscillator frequency was picked as the upper limit for satisfactory operation of the 7401 tubes. The demonstrator using this system, shown in Figure 5, has given satisfactory and stable operation after initial adjustment.

Problems with Initial Manipulation Pads

The difficulties experienced in test of the photocell matrix were principally those caused by stray light and heat from the internal lamp. These could probably be reduced to an acceptable level by a combination of the following:

1. Blacking the sides of the pyramids to prevent light from below from entering the photocells.



MANIPULATION BOARD CIRCUIT
(CAPACITIVE DESIGN)

FIGURE 4

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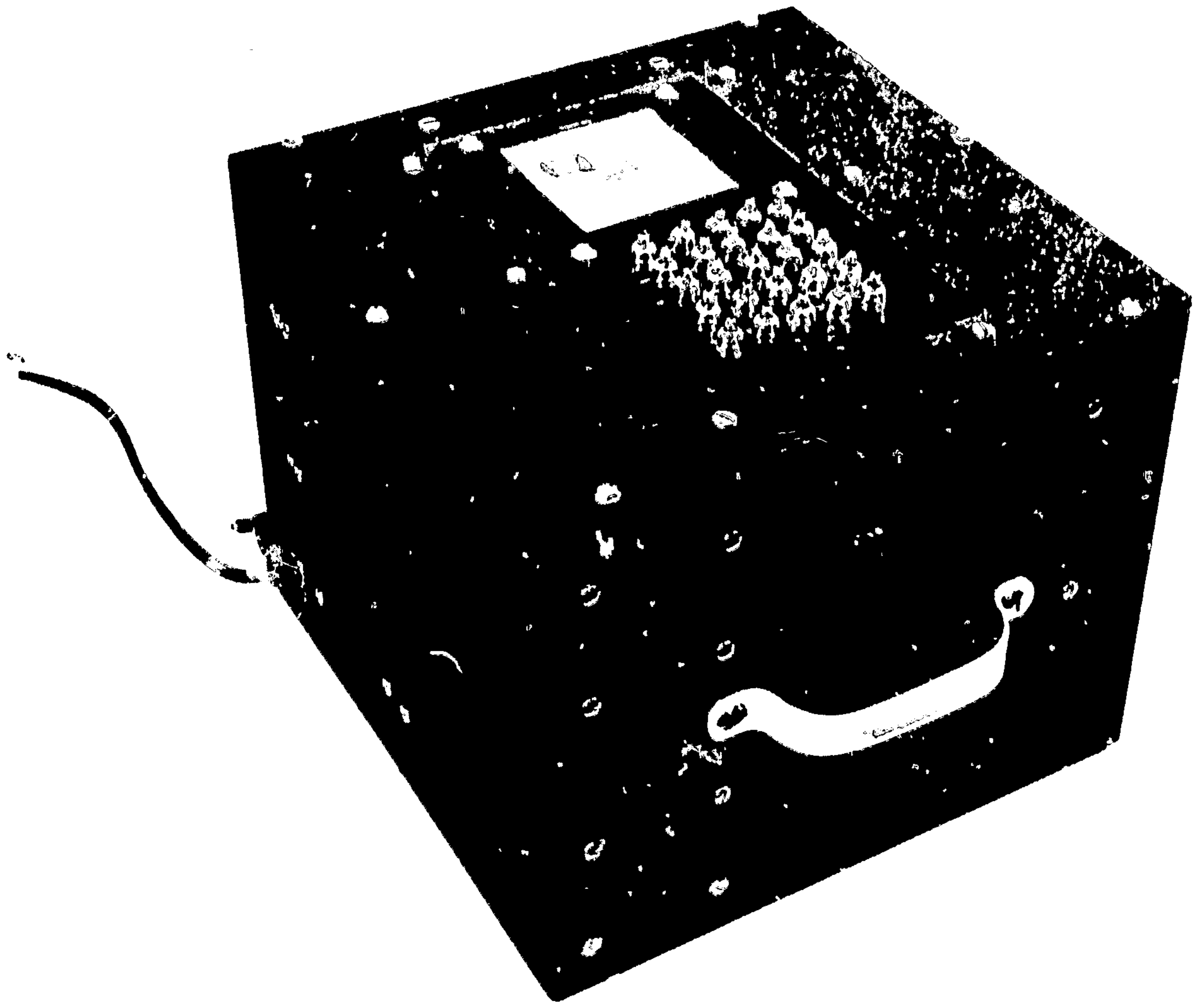

Figure 5
Capacitive Demonstrator

2. Polishing the flats between the pyramids to prevent diffused light from entering at above.

3. Isolating the photocells from heat generated by the light source.

4. Checking whether another color filter would give better discrimination against unwanted objects (the one used here was selected only to match the photocell spectral response).

The feasibility model used approximately nine photocells per square inch. There is no apparent reason that the density could not be improved substantially with smaller photocells.

The major problem is that of systematically developing for a computer digital signals which could efficiently convey the information about the illuminated cells. The voltage levels obtained suggest the use of diode decoding, but variations between cells make this approach less than reliable. Also, decreasing the size of the cells to increase the density decreases the power that may be dissipated per cell and hence limits the applied voltage.

The difficulties with the capacitor matrix system are more severe than with the preceding system. The feeble signal levels obtained prevent any direct sampling of the signals from the islands; each point requires an amplifier to obtain usable signal levels. A detection threshold must be set for each island for noise rejection. The density of points in the demonstrator, nine per square inch, is already close to the limit for separation of signal and noise.

Although feasibility has been demonstrated for both these approaches, it is felt that the superiority of the system described below eclipses these models. Further work on the preceding systems is not contemplated or recommended.

FORM

The Ferromagnetic Object Recognition Matrix

Principle of Operation

The operation of FORM is based on the principle of a transformer with a variable reluctance magnetic path. Two wires are placed in a slot in a block of ferromagnetic material. One wire is the drive line and the second the sense line. When the drive line is pulsed by a current source, a signal is coupled to the sense line. The coupling existing between lines and therefore the magnitude of the signal generated in the sense line is a function of the magnetic circuit reluctance. With no magnetic material covering the slot a large air gap exists in the magnetic circuit. This constitutes a high reluctance magnetic path and little signal is generated in the sense line. When the magnetic path is completed by bridging the slot with a magnetic material a much larger voltage is generated in the sense wire. By using high permeability, high saturation flux density ferrite such as Indiana General's Type H, only objects made from a similar material will complete the magnetic path satisfactorily and cause a high output from the sense line.

The complete object recognition matrix consists of a two dimensional array of individual, slotted blocks wired with drive and sense lines. Each blc constitutes a point in the array. However, an individual drive and sense lin is not provided for each point. An arrangement similar to that of Figure 6 is used.

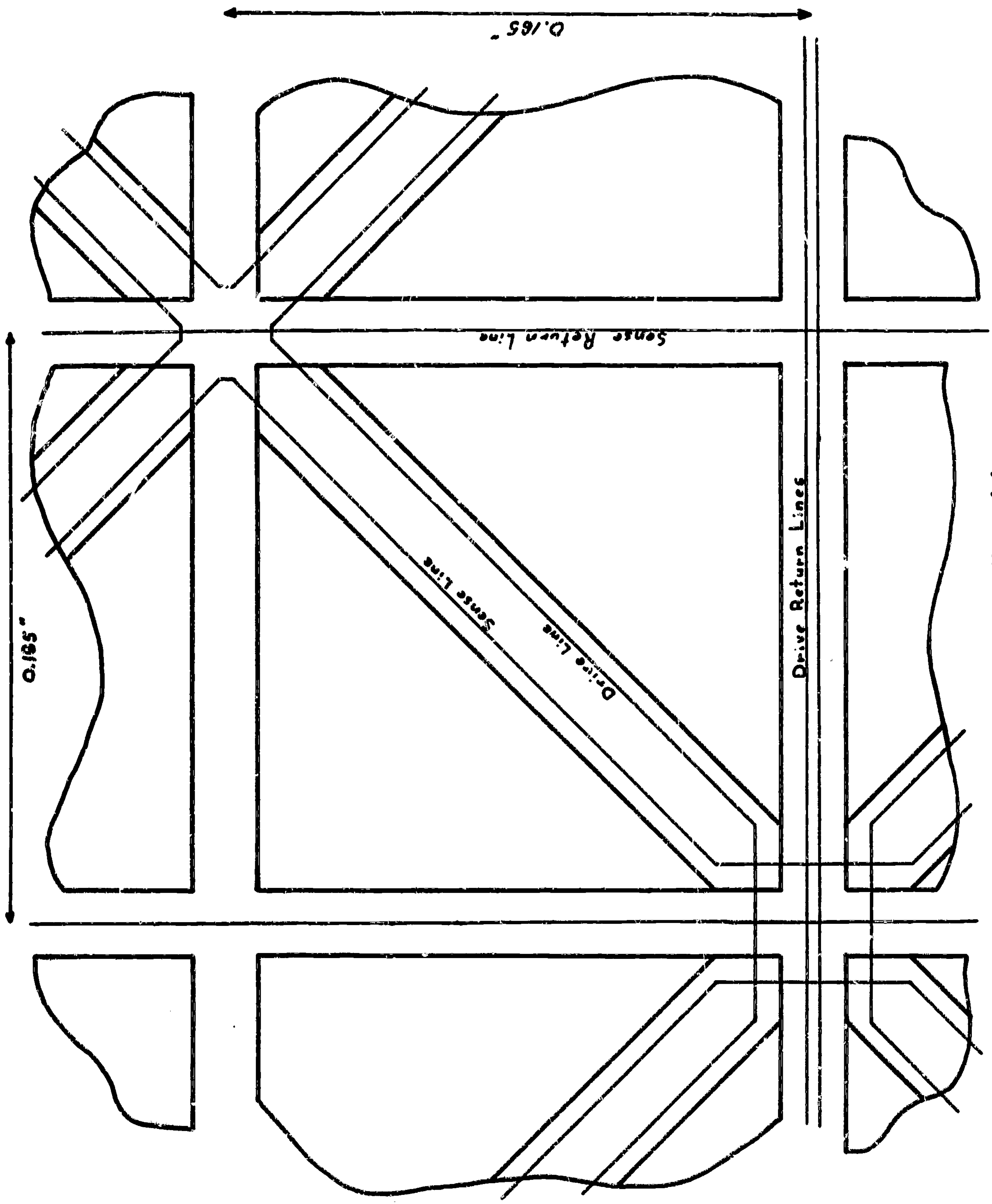

Figure 6—Drive and sense line wiring

Many points are served by each drive line and sense line such that a drive line energizes a number of points equal to the word length of the associated computer, and a number of sense amplifiers equal to the word length is used. A number of drive lines sufficient to give the required number of points is provided. Each time a drive line is energized one word of information is obtained, the drive lines being sequentially operated until the desired area has been explored.

It is convenient to make the number of blocks across the pad in one dimension a multiple of the computer word length. Thus a highly efficient encoding to digital form is accomplished. An example is shown for a seven by seven array and a seven bit computer word length. Each bit specifies the location of a point and whether or not the point is occupied.

	Colm. 1						Colm. 7	
First Word	0	0	0	0	1	0	0	Row 1
Second Word	0	0	0	1	1	0	0	.
.	0	0	1	1	1	1	0	.
.	0	0	1	1	1	1	1	.
.	0	0	0	1	1	1	0	.
.	0	0	0	0	1	0	0	.
Seventh Word	0	0	0	0	0	0	0	Row 7

Arrangement of the digital words in this format makes it evident that each point is specified once and only once. It may be noted that even with this low resolution, the object on the pad may reasonably be deduced as a square of about four points per side, oriented at about 45° and located near the upper right corner of the pad.

Construction of FORM Prototype

A demonstration model of the FORM manipulation pad has been completed and operated satisfactorily. This model is a 16 by 16 point array containing 64 drive lines and 4 sense lines. A larger model is being constructed with a 64 by 72 point array. This model utilizes 256 drive lines and 18 sense lines. The 18 sense lines correspond to the 18 bit input word length of the PDP-7 Computer for which this pad is intended.

The basic raw materials used in the construction of the pad are ferromagnetic bars, glass module plates, a ground flat stock backing plate, and epoxy cement and/or hard wax. Ferramic "H" purchased from Indiana General Corporation, Keasbey, New Jersey, was the ferromagnetic material employed. This material was chosen because of its high permeability (4300) and its high saturation flux density (3400 Gauss). The largest pieces Indiana General Corporation could supply were 1/4" by 1-1/2" by 3-15/16". These slabs of ferrite were then ground, cut, sliced and grooved to produce small 18 by 8 point blocks. The first step in this operation was to grind one of the large flat surfaces of each rectangular block smooth using a surface grinder with an 8 inch diameter diamond grinding wheel.

The blocks were then trimmed to their final dimensions using a diamond cutoff wheel. This produced a ferrite block 2.95 in. by 1.30 in.

The next step was to mount each of these blocks to sheets of 1/16 in. pyrex glass also precut to 2.95 in. by 1.30 in. The ground surface was placed next to the glass. Two different methods were used for bonding the ferramic to the glass. Originally the bond was made using DoAll Mounting Cement, a low melting temperature wax. This performed satisfactorily. However, it was thought that since the wax melted at a relatively low temperature, 170°F, it would be safer to bond the two materials using epoxy cement. Epoxy was used to mount 25 or 30 pieces. Trouble developed during the next operation. Apparently some kind of force occurred between the glass and the ferramic material. When attempts were made to slice the ferramic using a 4 inch diameter .020 in. thick diamond cutoff wheel the glass shattered and the epoxy bond broke. After unsuccessfully trying to cut 10 or 15 pieces it was decided to return to the wax bond. This proved satisfactory except that there were not sufficient blocks remaining in stock if the epoxied blocks were discarded. During the cutting and slotting operations on the wax bonded blocks the epoxy bonded blocks went through some unknown change because they were again tried and were completed satisfactorily. The cutting operation performed on the blocks consisted of first slicing the block parallel to the edges completely through the ferrite and .005 in. to .010 in. into the glass. These cuts were made on 0.165 in. centers and determined the resolution of the completed tablet. The next step was to slot the blocks diagonally. These cuts were made so that each of the 0.165 inch squares created by the first slicing was slotted diagonally from corner to corner. The slots were made such that the bottom of the slot was 0.200 in. from the top of the glass backing. Since the slicing and grooving operations were experimental some blocks were machined in a different order. These were first grooved diagonally and then sliced parallel to both edges. Since the block was initially cut

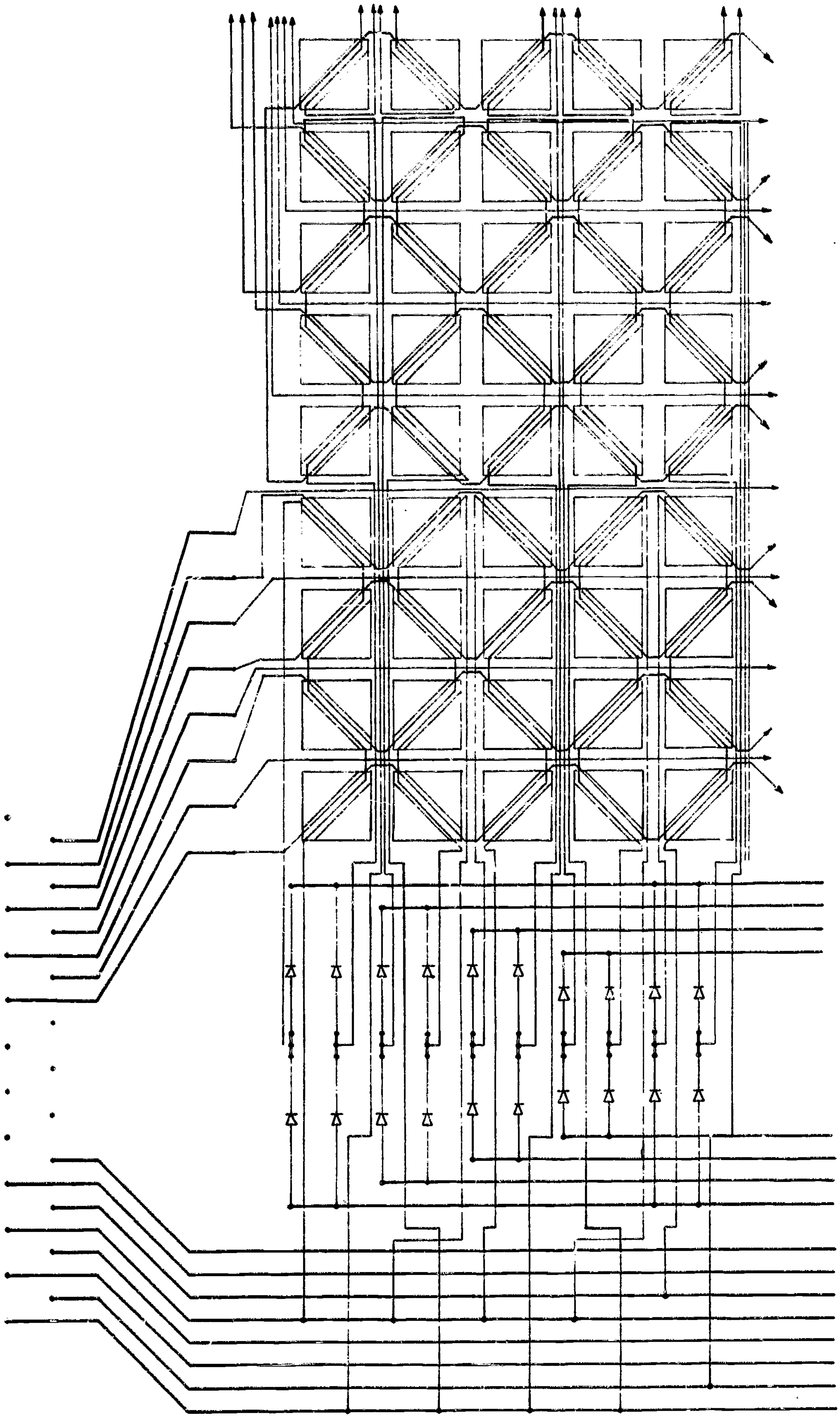

Figure 7—Partial wiring plan for 16 by 16 point array

to size it is an array of 8 x 18 points when slicing and cutting is completed. These blocks are then mounted to a backing plate of steel flat stock to make the complete array. Ground flat stock was chosen because of its flatness and rigidity.

The demonstration tablet was constructed using two of the 8 by 18 point blocks. These blocks were bonded to a backing plate of 1/8 inch ground flat stock using Elmer's epoxy glue. A printed circuit board supporting decoding diodes and termination points for the pad wiring was also fastened to the backing plate. Figure 7 is a partial wiring diagram for the resulting 16 by 16 point array. Two rows of points were neglected from the 16 by 18 point to make a 16 by 16 array. The two rows were omitted because a 16 by 16 array was more conveniently wired.

Wiring the FORM is a major problem in itself. A first prototype 16 by 16 array was wired by hand using No. 30 "polythermaleze" coated solid copper wire. This model was unsatisfactory. The sharp corners created by the cutting and grooving operations on the ferrite cut through the wire insulation. Since the ferrite is not a perfect insulator, low impedance paths developed between the drive and sense lines, making the pad inoperative. The measured leakage resistance was as low as 100 K ohms between some drive and sense windings. Several solutions to this problem were tried. These included: spray coating the blocks with a plastic film, using nylon or teflon coated magnet wire, wrapping the wire with a plastic layer, lining the slots with a plastic layer, and finally using copper wire with very heavy nylon insulation. All these attempts failed except for the last.

The use of a wire with heavy plastic or nylon coating was a fairly obvious solution to the problem. However, the problem encountered was trying to find a source of such wire. Several samples of wire, both solid and stranded, which would fit into the 0.020 inch slots were obtained. No company, however, could or would supply from stock the small quantity which was needed for the 64 by 72 point pad. A satisfactory solution was finally found in the form of copper thermocouple wire manufactured by the Thermoelectric Company, Inc. The small pad was wired using their stock wire No. N-30-DTP. This is number 30 AWG wire with .004 inch nylon insulation. This was successfully employed. However, it was rather difficult to get the wire in the slots and around all the corners because of the large external diameter of the wire (.018"). The large pad will, therefore, be wired using Thermoelectric Wire No. N-3b-DTP. This is the next smallest stock wire and is No. 36 AWG with .004 inch nylon insulation. Tests have shown that a smaller wire size will greatly ease the job of wiring the large pad and still give satisfactory electrical service.

After completion of the wiring, an electrical test of the pad is made. This includes a test of the leakage between drive and sense lines, leakage between drive lines, and leakage between sense lines. A functional check is also conducted to insure that all drive and sense lines are placed in the proper slots. If any error or excessive leakage is found, the offending wires are replaced. This is mandatory since after the next step no change is possible in the wiring. The small tablet was successfully wired and tested.

The interwinding resistance was measured and found to be greater than 10 megohms. At this point in the construction of the small pad, an electrically satisfactory but rather fragile working model existed.

To complete the assembly process the entire ferrite array was vacuum impregnated with an epoxy potting compound. The epoxy holds the wiring in place in the slots and bonds the small blocks into a rigid assembly. The potting is done in a vacuum to eliminate air pockets between the wires and the ferrite. A layer of epoxy is left covering the entire pad preparatory to the final assembly step.

The final step in the assembly is to grind the top surface of the tablet. This removes the excess epoxy and produces a smooth, flat surface which mates well with flat objects placed on the tablet. The final grinding was achieved using the surface grinder with an 8 inch diamond wheel. Because of the large dimensions of the large 64 by 72 point array, a different grinder will have to be used. Such a grinder is not available at the Research Laboratories, so this work will be done outside. This completed the assembly of the small pad except for an aluminum protective cover. This finished FORM is shown in Figure 8.

Alternate Construction of FORM

The procedure described above results in a working model of the FORM tablet. This is an expensive process involving much machine shop time and hand wiring. This does not mean the FORM tablet could not be economically produced in large quantities. Some suggestions and proposals for an inexpensive production model follow.

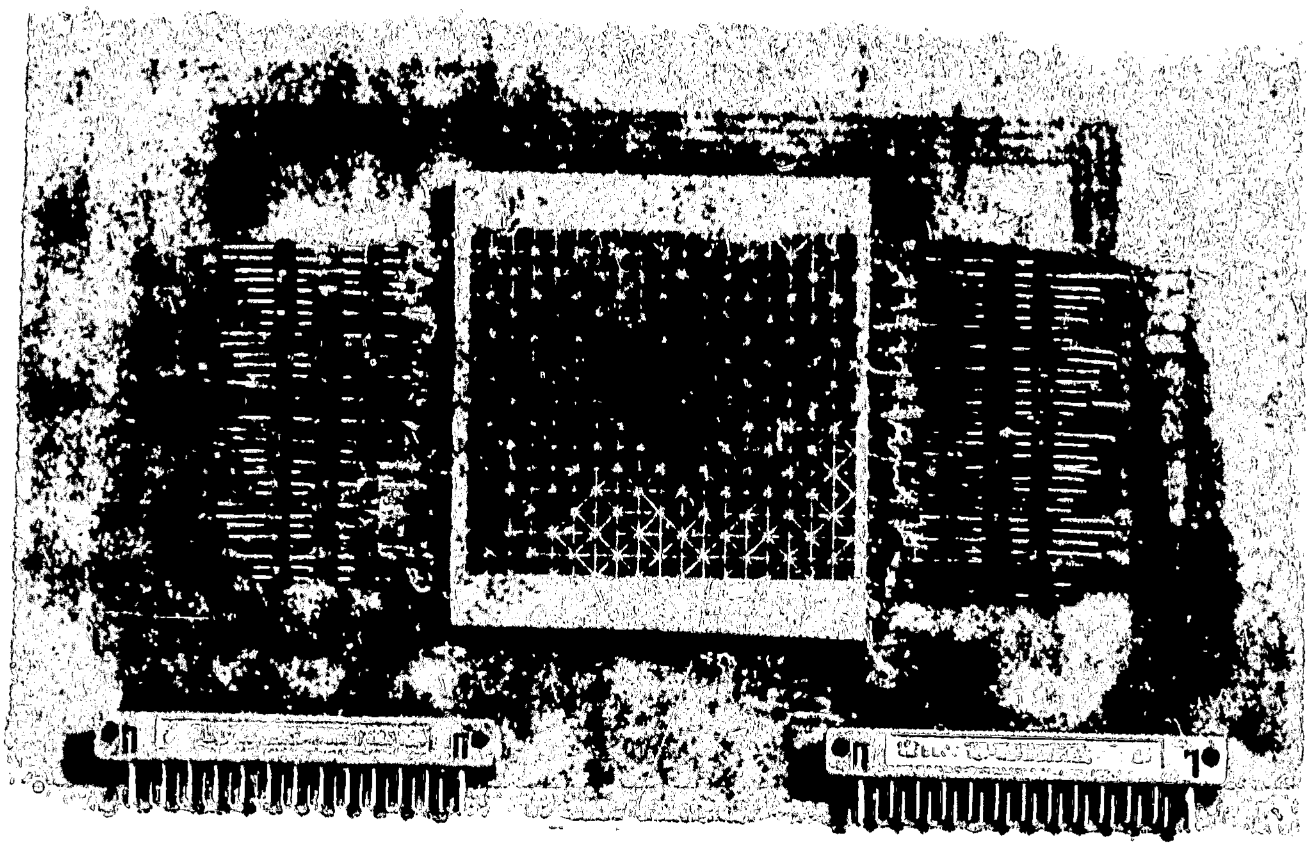

Figure 8
FORM Tablet

The model described above was constructed from large slabs of ferrite material sliced and grooved. This was very expensive and time consuming. It is suggested that the basic building block be the actual point of ferrite produced by the cutting and slicing operations. These could be manufactured, using a molding operation, by the ferrite producer. These could be made in large quantities at low cost. Assembly could be done by using a pre-assembled form with spaces for the required number of points. Any size array could be constructed using this technique.

Additional time and cost could be saved by elimination of the time consuming hand wiring. While this wiring cannot be conveniently eliminated it can be reduced significantly by choosing the proper shape block to have molded. Figure 9 shows four different block geometries which can be used. Figure 9A is the shape used in the present model. Previous figures show that this shape requires the wire to zigzag through the slots. This is the time consuming operation. If the wires could be placed in straight lines, wiring time would be reduced. Figures 9B, C, and D are block shapes which will allow the sense and drive wires to lay in straight lines. The shapes in Figure 9B and 9C also provide another advantage. These permit the return wires to be active also. The original had only one leg of each sense and drive line active. Future models utilizing the molded pieces would have both sides of the drive and sense loops active.

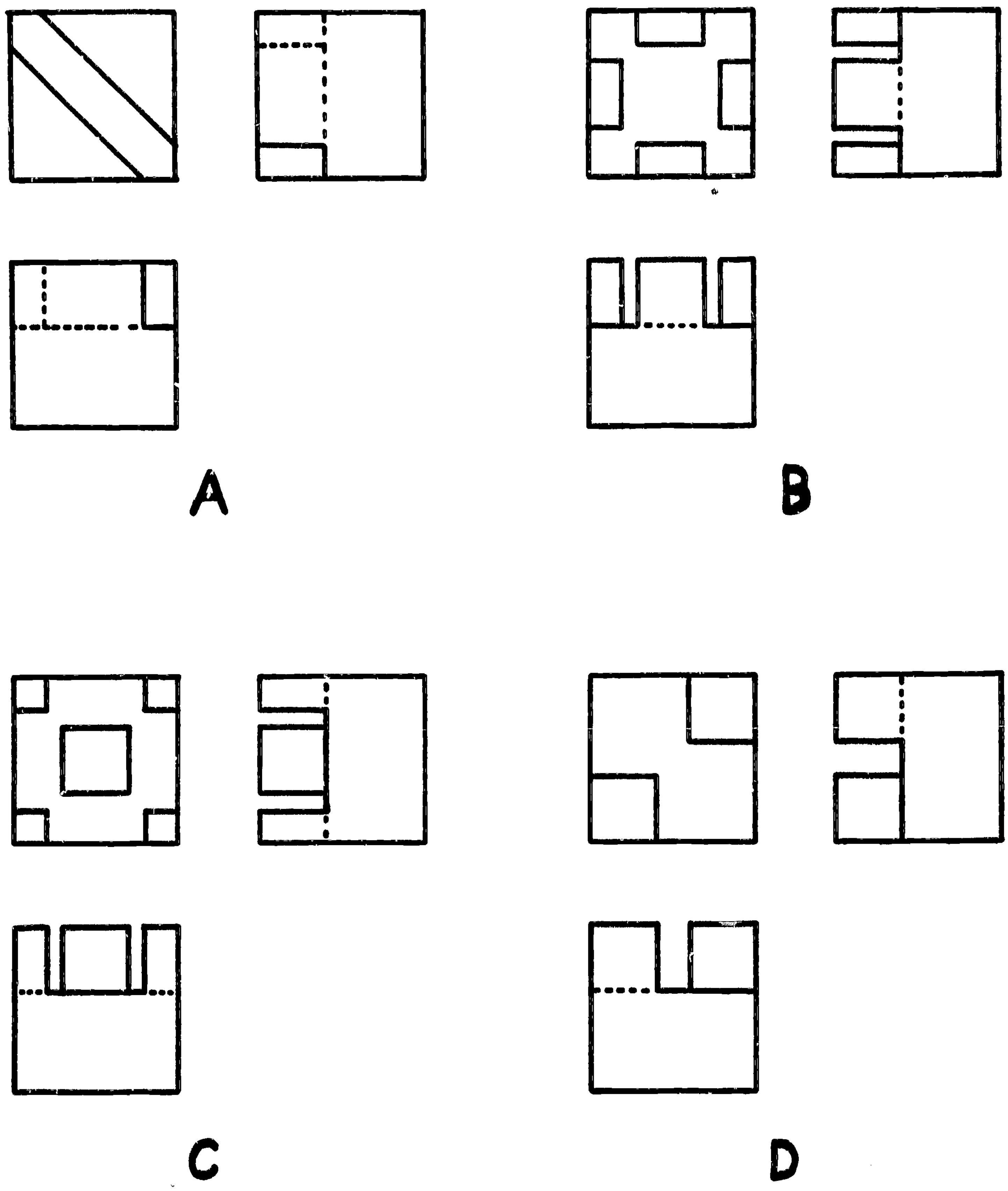

Figure 9—Alternate geometries

FORM ELECTRONICS

The electronic circuitry which accompanies the FORM tablet resembles that used for a word organized computer core memory. The drive pulses are decoded by an 8 by 8 by 4 matrix for the 64 by 72 point tablet and by an 8 by 4 by 2 matrix for the 16 by 16 point tablet. There are 4 sense amplifiers associated with the small array and 18 sense amplifiers associated with the large array. The sense amplifiers are pulse amplifiers with a variable input threshold. The sequencing for the drive circuits is provided by shift registers and decoders utilizing Westinghouse integrated circuits as the logic elements. The electronic circuitry for the small FORM is housed in one standard 19 inch rack panel Elco card cage. This rack contains: one board with sense amplifiers and output drivers; five boards with drive circuits; two boards containing shift registers, decoders and clock; one board with logic level changers; one board with two digital to analog converters and two boards for power supplies. The large FORM electronics will be housed in two 19 inch Elco card racks. At present the cages have been wired for the power supplies, the sense amplifiers and output drivers, the drive circuits and an 18 bit output register indicator. The remainder of the two cages will be used for sequencing circuits, decoders and digital to analog converters. Digital to analog converters are provided in each model for different reasons. There were included in the original small FORM to provide directly an X-Y CRT display of points covered by the test block since the tablet was to be used without a computer for laboratory demonstrations. They were included in the large tablet to provide a means of checking the operation of the pad. If such an automatically sequenced display were not available, each of the 256 18-bit words available as output would have had to have been sequenced manually each time it was desired to check the operation of the tablet.

Only the electronics for the small FORM are described in this report. The large FORM is not complete and a final logic diagram is not yet available. The large FORM circuitry is very similar to that of the small FORM. Therefore, a discussion of the small FORM electronics will suffice.

Drive Circuits

Figure 10 is the simplified wiring diagram with each of the basic circuits in block form. The figures following give details of the contents of each block. There are four basic printed circuit boards used in both models of the electronics. The pulse boards of Figure 11 supply the actual current pulses to the drive lines. The pulses are 600 ma with a duration determined by the pulse transformer. The particular transformer used supplies a maximum pulse of 1 μsec when used in the circuit described. The pad magnetic circuit will only support voltage during 200-300 nsec of this pulse. The pulse from the sense lines is therefore 200-300 nsec.

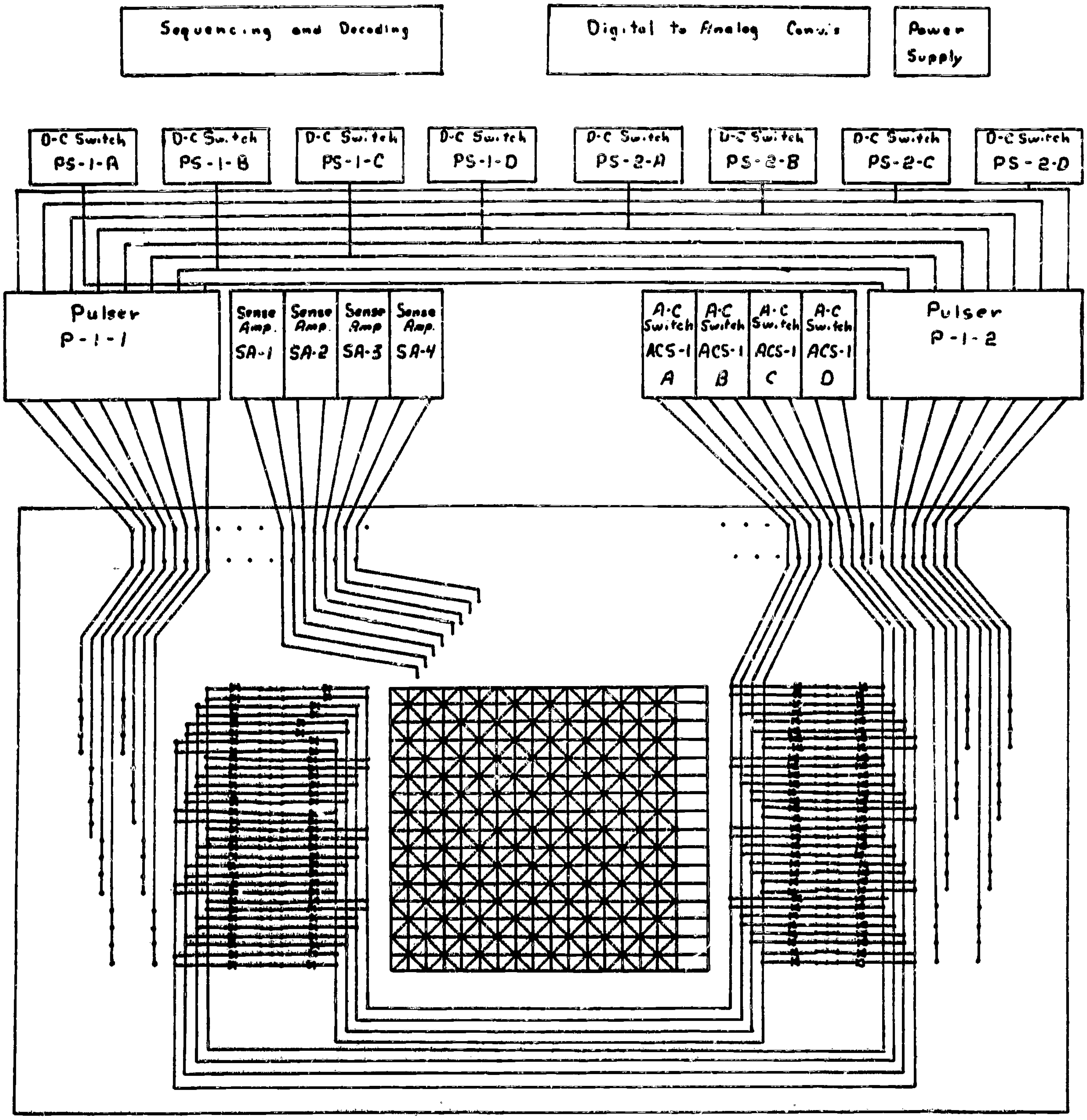

Figure 10—Form diagram

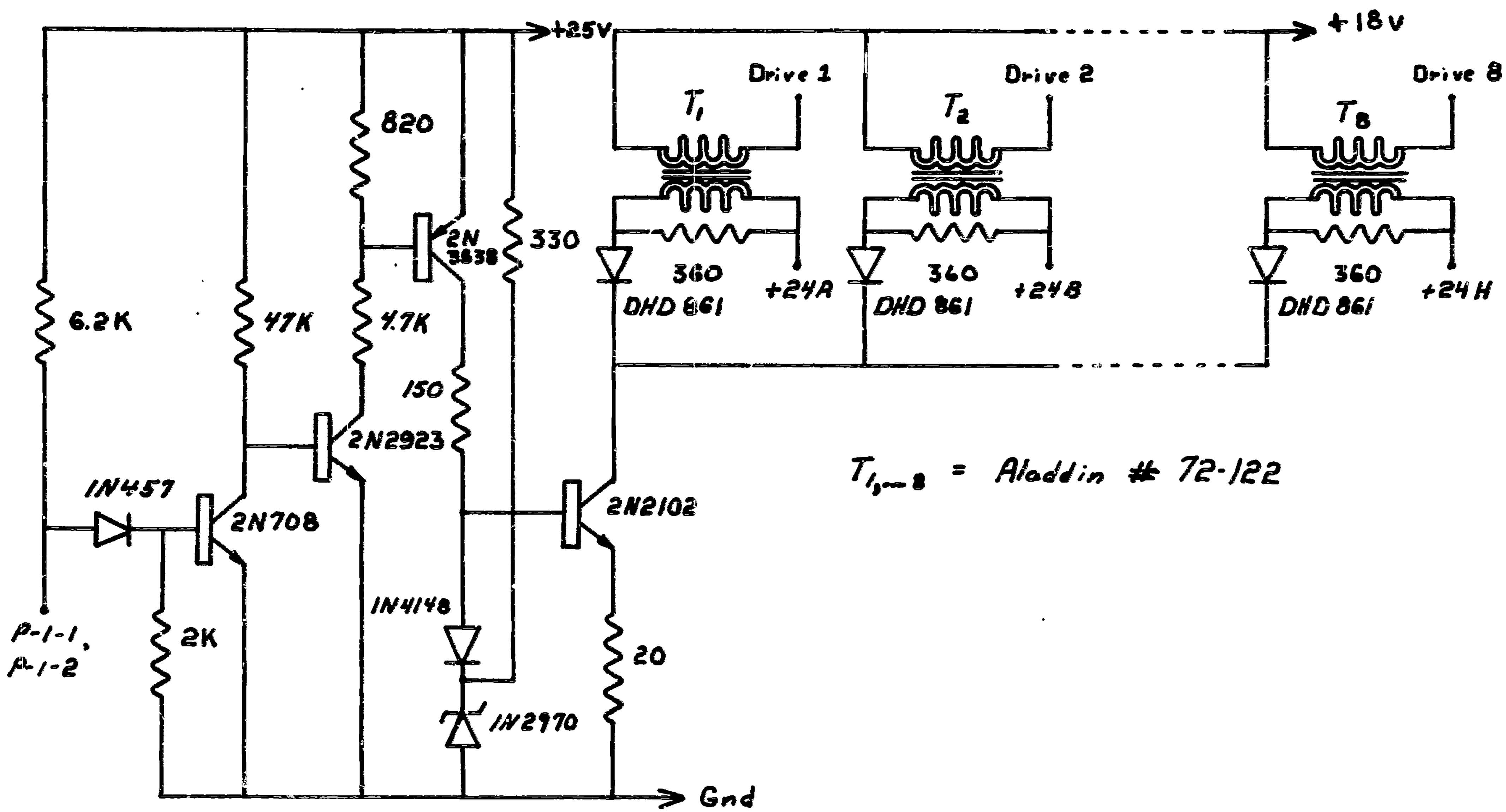

Figure 11—Pulser

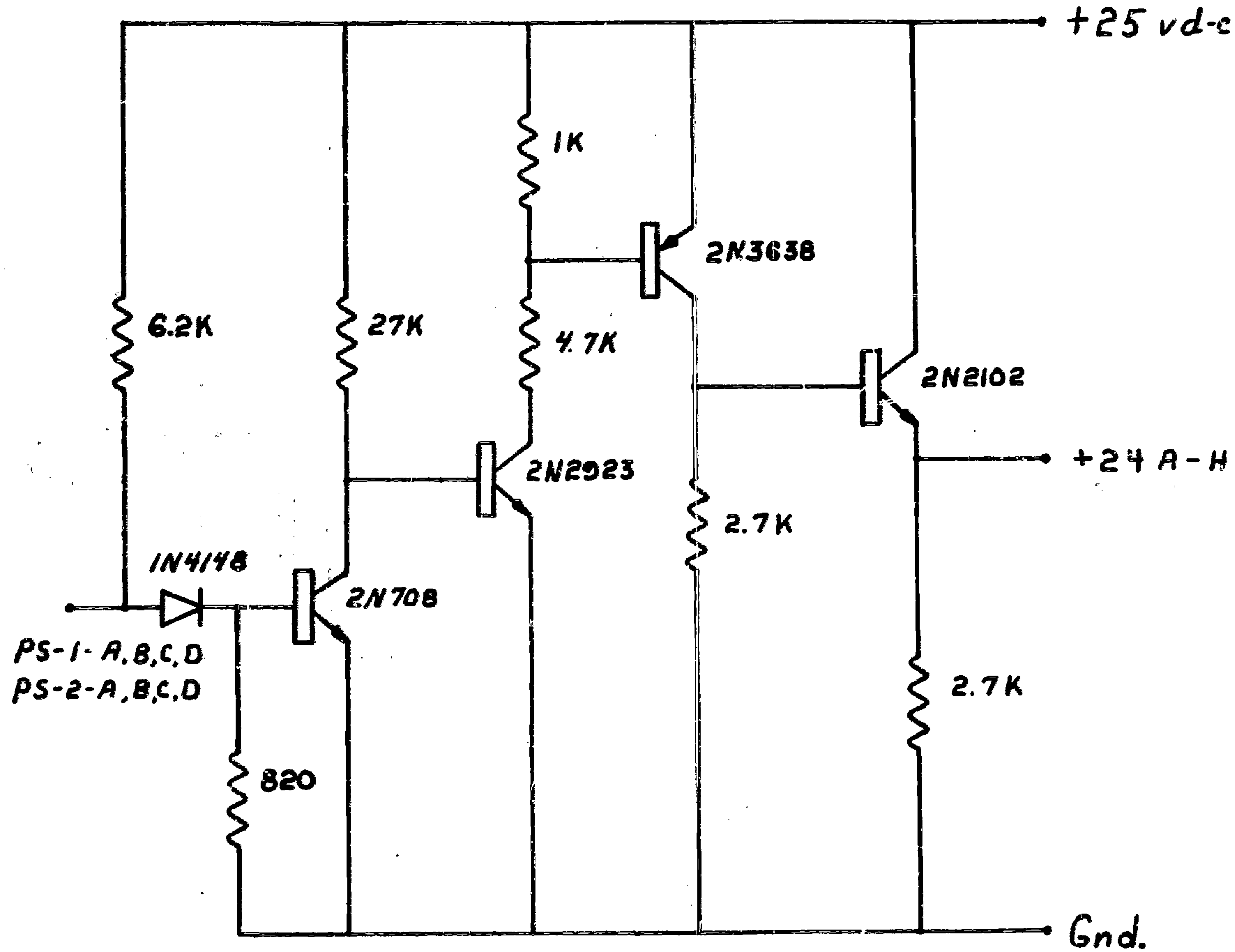

Figure 12—D-C power switch

Two types of power switches are used to select a particular drive line. Eight d-c power switches select which of the eight pulse transformers on each pulser is energized. Each d-c switch energizes two pulse transformers but each is associated with only one pulser. Therefore, we now have an 8 by 2 selection matrix. The four a-c switches then determine in which of four drive lines current is permitted to flow. The net result is the desired 8 x 4 x 2 selection matrix. To select a particular drive line, one pulser, one d-c switch and one a-c switch are activated. Figures 12 & 13 are schematics of the d-c power switches and a-c power switches respectively.

Sense Amplifiers and Output Drivers

There are four sense amplifiers associated with small FORM. These amplifiers trigger a flip-flop output driver which is capable of delivering a zero or -3 v d-c logic level to an output drive line. This level was chosen ao that the outputs could be delivered directly to a PDP-7 computer input register. The small FORM does not, however, operate in conjunction with a computer and therefore another output is provided to furnish the zero and + 6 logic levels appropriate for the Westinghouse integrated circuits used elsewhere in the FORM.

Each sense line is floated on a d-c level at the input to the sense amplifier to which it is connected. The d-c level is variable

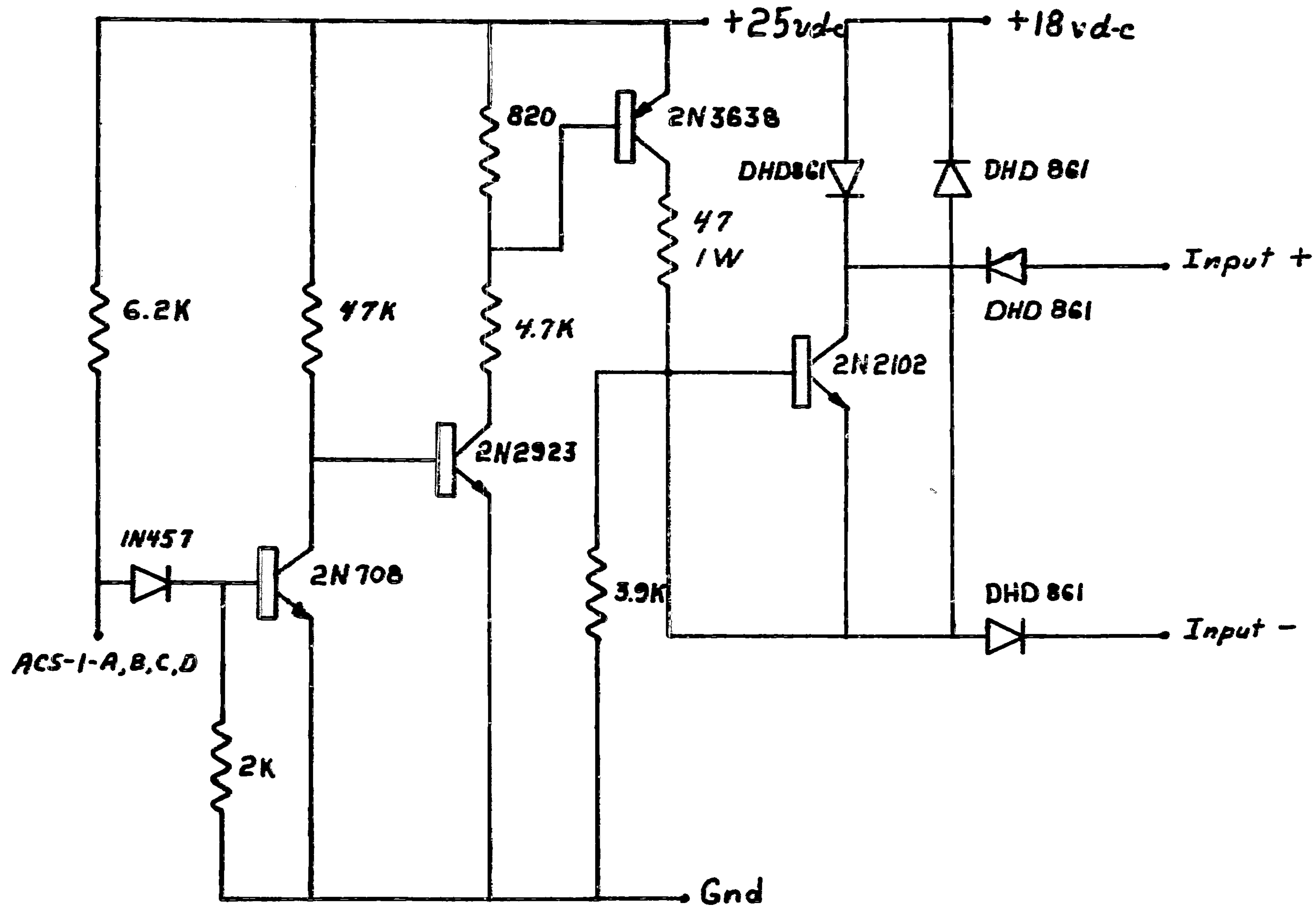

Figure 13—A-C power switch

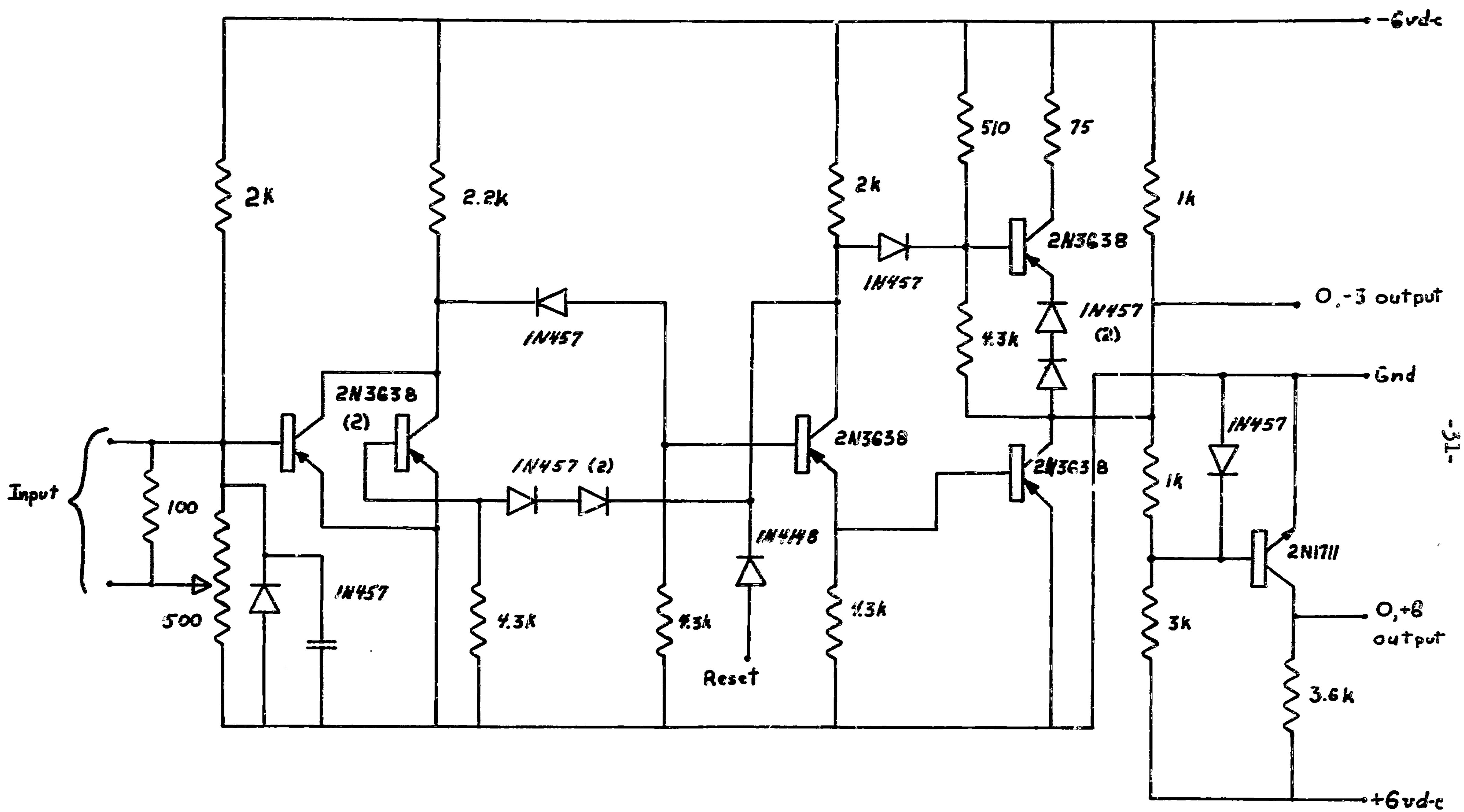

Figure 14—Sense amplifier and level changer

over a range of zero to -0.8 v d-c. This permits a discrimination level to be set for each sense line so that only the signal pulse will trigger the flip-flop and not any noise pulses which are present. Also it enables the silicon PNP transistor used as the amplifier to detect a pulse signal of less than 0.8 volts. Each amplifier d-c level is set individually by means of a trimming potentiometer adjustment.

Figure 14 is a single sense amplifier and flip-flop driver circuit including the level changer on the output.

Sequencing and Decoding

The sequencing and decoding logic necessary for selecting drive lines was embodied using Westinghouse integrated circuits. The types used are the WM210T, WM211T and WM213T. These are packaged in 12 lead TO-5 shape cans. The WM213T is used as a shift register element. The WM211T is a dual four input NAND and the WM210T is a dual three input NAND line driver.

The basic counting circuit used is a shift register counter which gives two counts per stage when properly converted and decoded. This counter connection is shown in Figure 15. The circuit configurations shown are one register of six counts, two registers of four counts each, and two stages of two counts each. The 4 x 4 x 2 x 2 decoding matrix which results from the last four registers determines

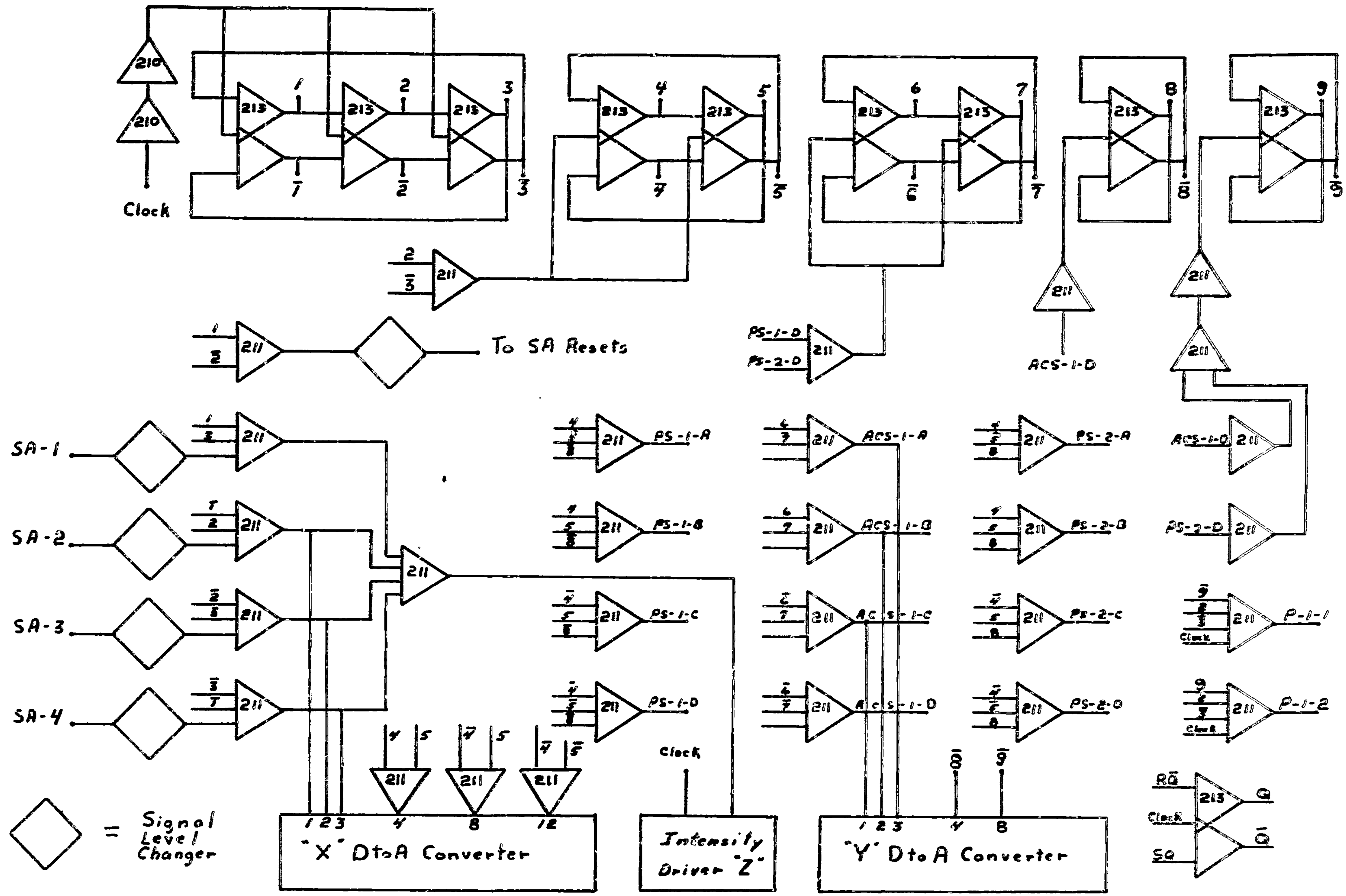

Figure 15—Sequencing and decoding logic

which drive line is selected. The six counts produced by the first three stage counter are used for resetting the output register and for sequencing the D-A converter through the four bit output word to produce a video display. The outputs of counter stages are decoded using WM211T's. The WM211T's then select the various drive circuits. These decoded outputs are also used as the inputs to the D-A converters which generate a video display of the pad surface coverage.

The large FORM sequencing and drive circuit will be very similar except that the number of counts per register will be larger. The small FORM was continuously sequenced by an internal clock but the large model will be sequenced by one of three methods. When used with the computer it will be stepped by pulses from the computer. During testing operations it can be stepped through the 256 available words manually, one at a time, or automatically by an internal clock.

Miscellaneous Circuits

Diagrams of the remainder of the circuitry used in the small FORM appear in Figure 16 through 19. Figure 16 is the power circuitry used. This power supply delivers three voltages: +25 v d-c at 1.25 amp., +6 v d-c at 1.0 amp., and -6 v d-c at 1.25 amp. The high currents are not needed in the small FORM but the same circuit board will be used in the large FORM, which will require these current capabilitie

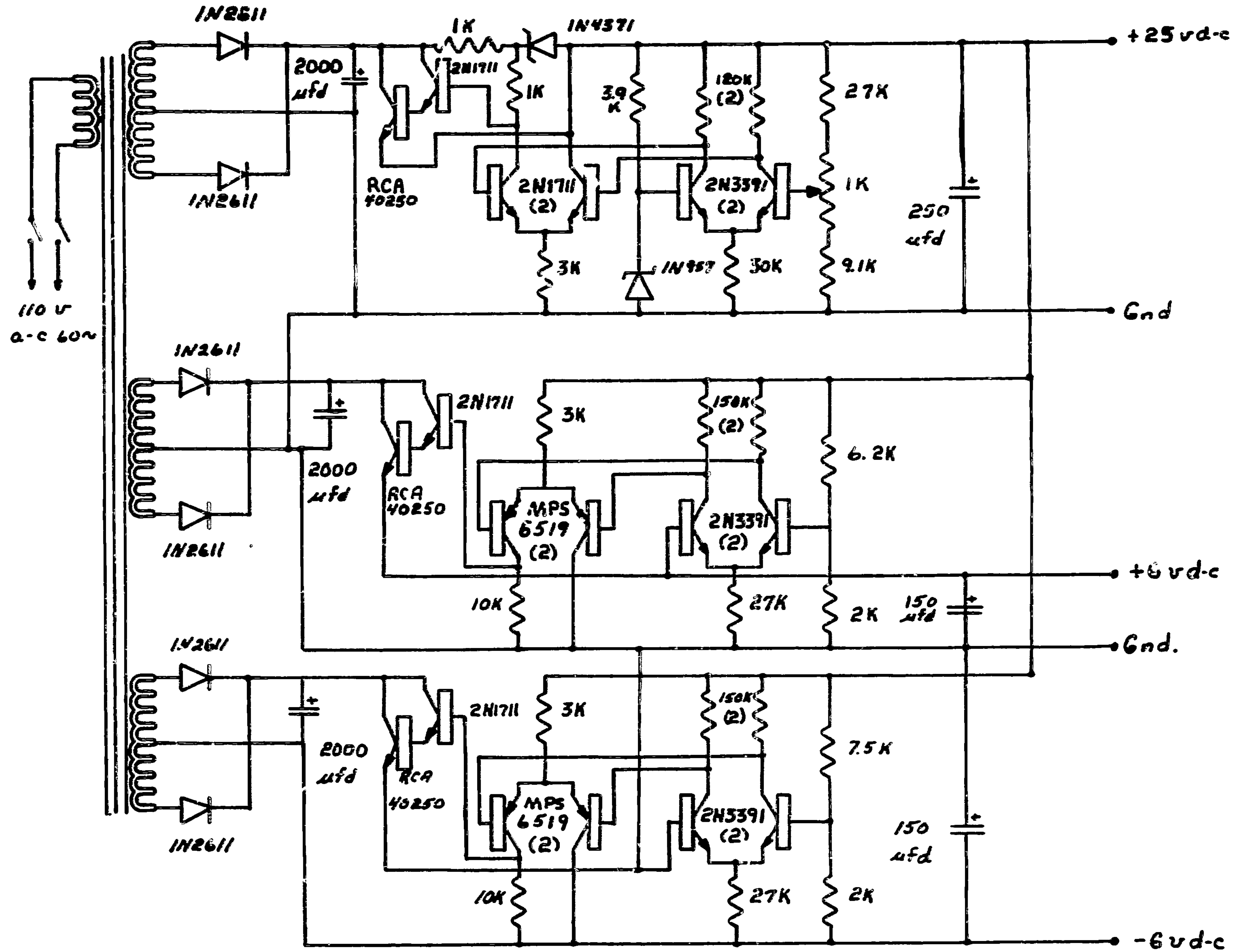

Figure 16—Regulated power supply

Figure 17 is the circuit which resets the output register after each word of output has been used.

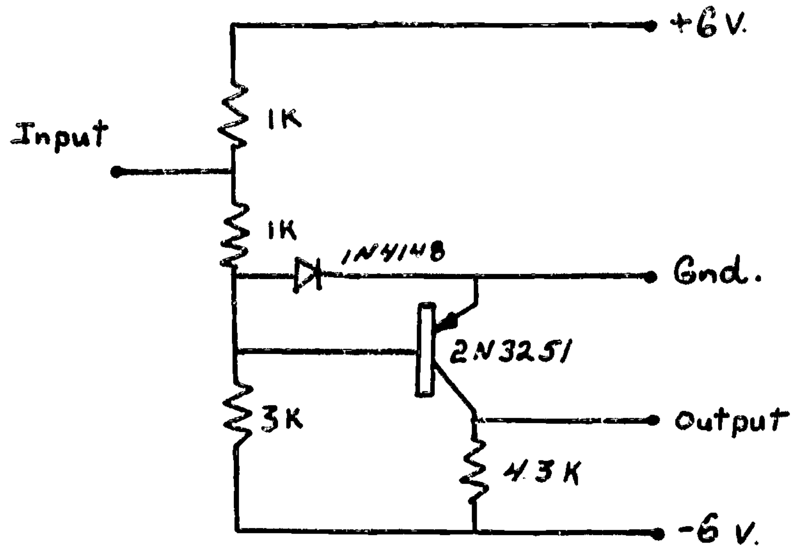

Figure 17

Figure 18 is the clock used. It is a simple astable multivibrator running at 50 kc. The rise and fall times are improved by cascading two WM211T's.

Figure 20 is one of the two D-A converters used to drive an oscilloscope. This, in conjunction with the intensity driver of Figure 19, produces a dot pattern which corresponds to those points which are covered on the FORM pad. Current summing is done at the input to a differential amplifier. The weighted resistors are different for the X and Y converters but the principle is the same. The differential amplifier then drives a single ended amplifier which in turn drives a compound output stage. The output is d-c coupled back to the input so that the five transistors comprise an operational amplifier. The current through the 2.4 kΩ feedback resistor must equal the total input current; therefore, the output voltage is proportional to the input current and the digital count.

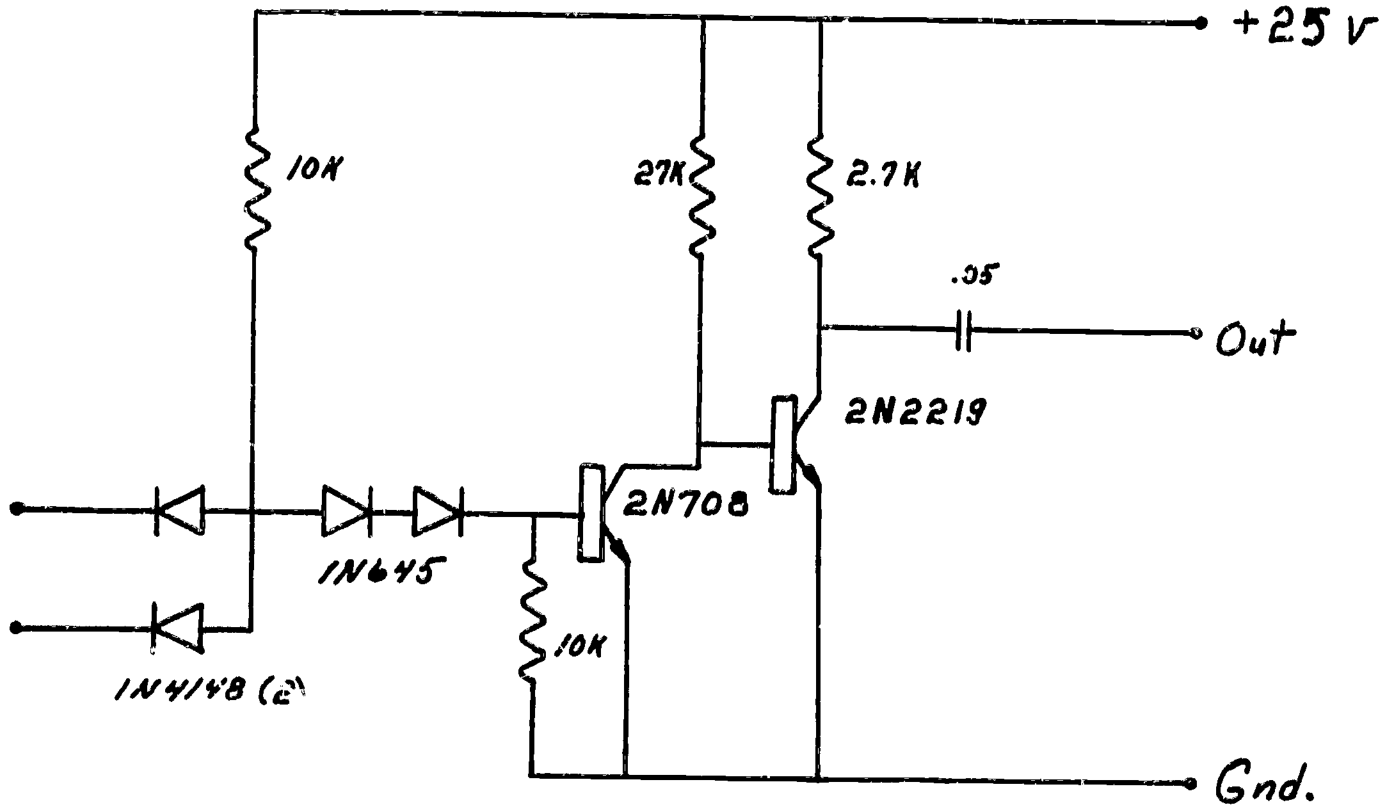

Figure 19—Intensity driver

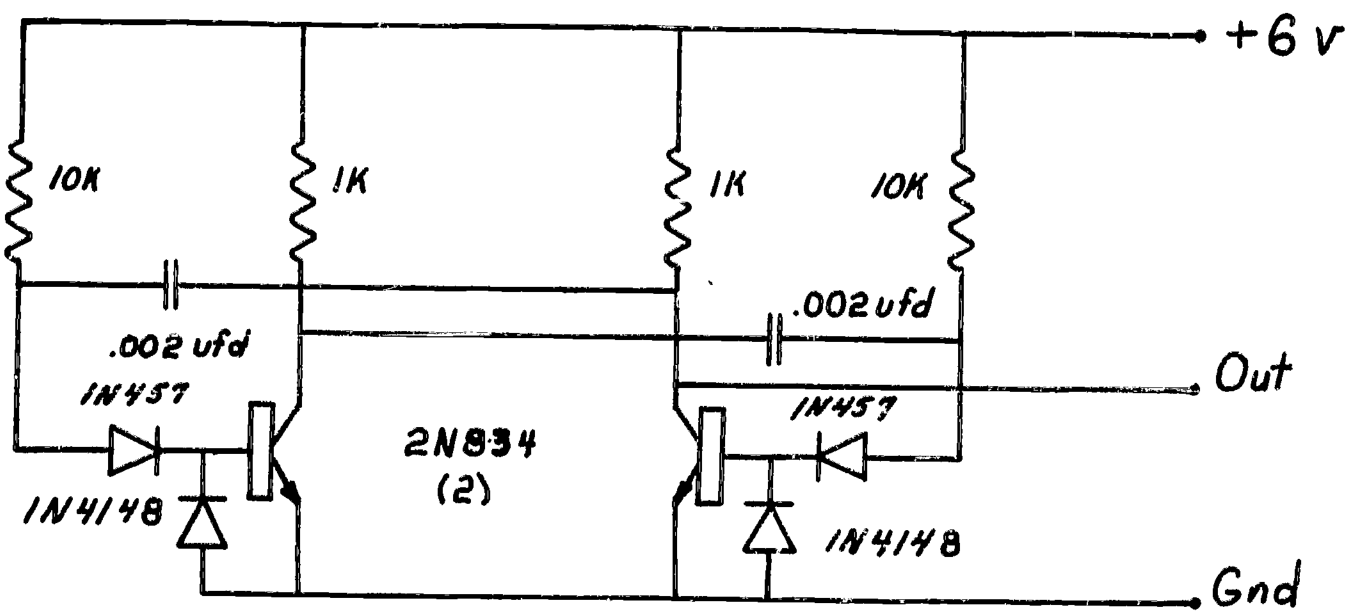

Figure 18—Clock (50 Kc)

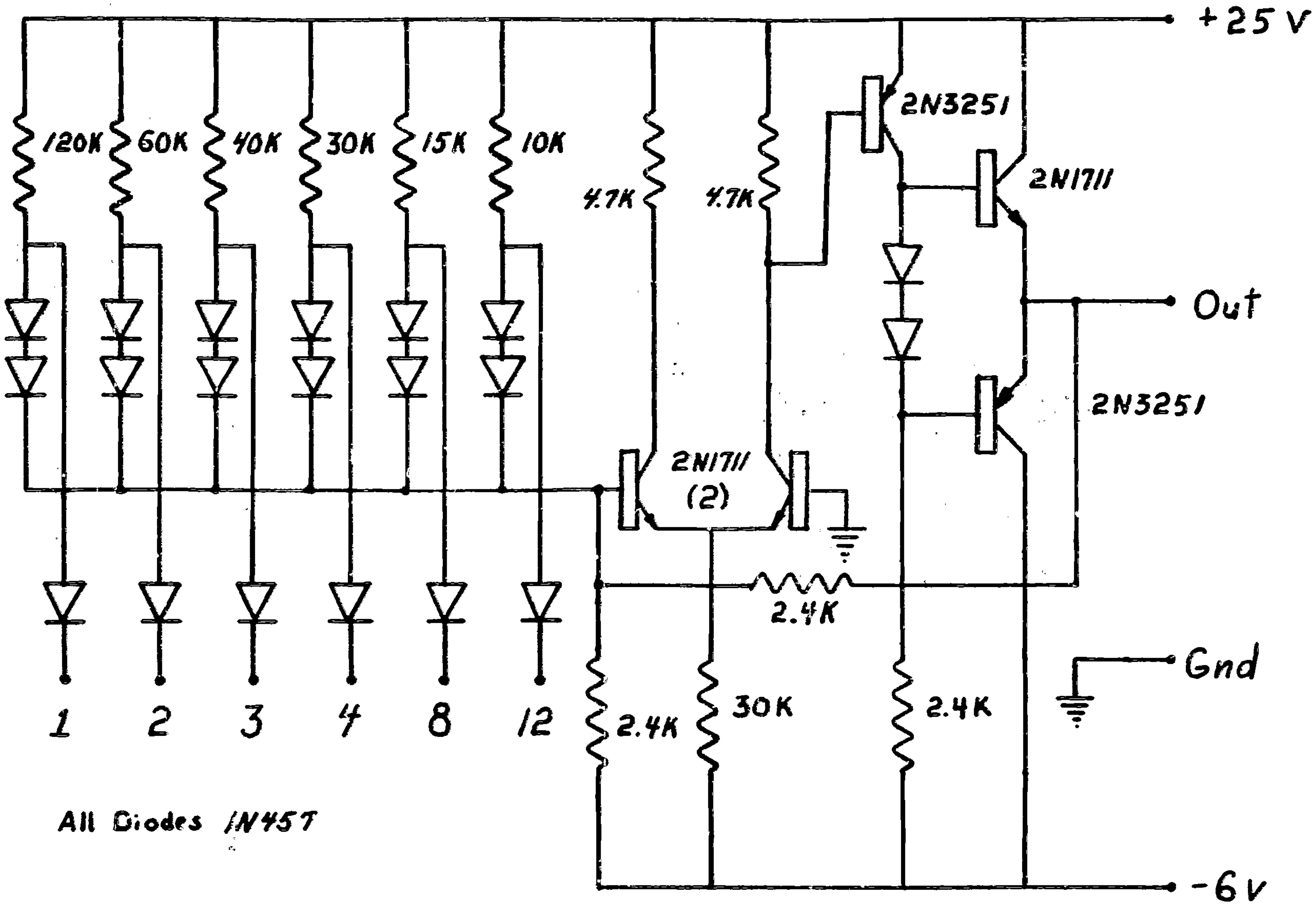

Figure 20—D to A converter

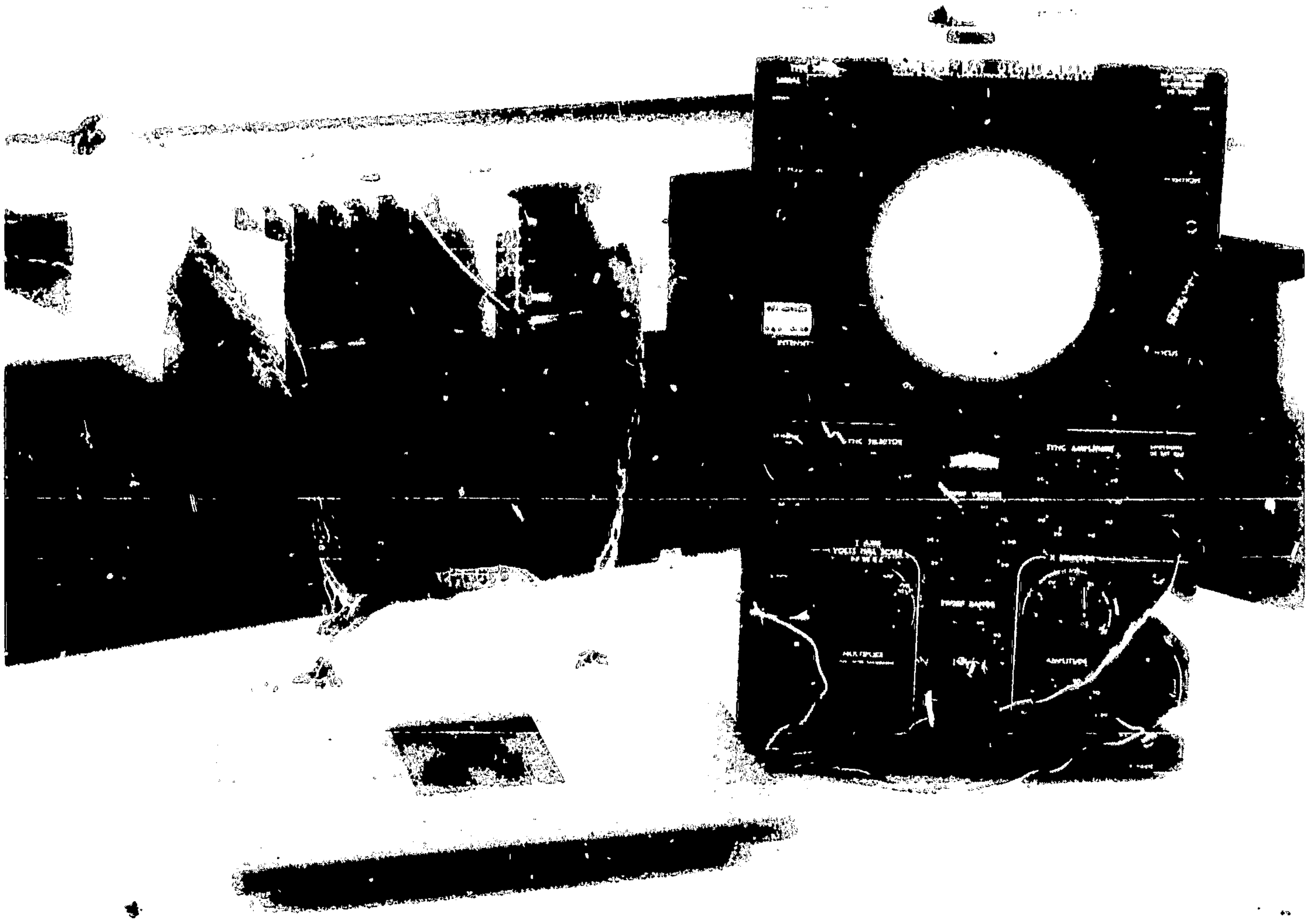

Figure 21
FORM Demonstration

CONCLUSIONS

Results to date indicate that a satisfactory manipulation pad for programmed instruction has been achieved by the development of the FORM (Ferromagnetic Object Recognition Matrix), which is shown in operation in Figure 21. The FORM achieves a simple information format for the computer, permits ample resolution, and can be made in various sizes for specific applications. The demonstration system produces an X-Y array directly on a CRT and has not been tied to a computer. The larger array will supply information to the computer on demand; the display will be controlled by the computer. Only one of the alternate proposals appears feasible and it appears that it cannot be made economically competitive with FORM.