ERRATA

Technical Memorandum 86

Page

iv	Fig. 14 title should read: "...interval timer..."
vi	Fig. 48 title should read: "...of the trial warning circuit."
	Add Fig. A.1: "f(t) for four values of N.....58"
14	Last paragraph, first line should read: "When RY-1 is unenergized,..."
15	Second paragraph, fifth and sixth lines should read: "Also RY-5 must be unenergized."
40	Second paragraph, fifth line should read: "In addition, one counter is assigned to each of the selections..."
43	Fig. 37 title, last line should read: "...a number of independent...
53	Fig. 48 title, last line should read: "...trial warning circuit."
56	Second line should read: "...the LM-11 relay."

THE UNIVERSITY OF MICHIGAN
OFFICE OF RESEARCH ADMINISTRATION
ANN ARBOR

N.P. PSYTAR: NOISE PROGRAMMED PSYCHOPHYSICAL TESTER AND RECORDER

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Cooley Electronics Laboratory
Department of Electrical Engineering

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Approved by: [signature]
A. B. Macnee

A CEL publication is given a memorandum designation due to reservations in one or more of the following respects:

1. The study reported was not exhaustive.
2. The results presented concern one phase of a continuing study.
3. The study reported was judged to have insufficient scope.

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ABSTRACT

A machine for automatically performing psychophysical experiments, known as N. P. Psytar, is described. N. P. Psytar is an electronic system that generates timing controls, makes random selections of signals for presentation to the observers (experimental subjects), and records the observers' answers. The system requirements, logic, block diagram design, and circuits are presented.

N. P. PSYTAR: NOISE PROGRAMMED PSYCHOPHYSICAL TESTER AND RECORDER

1. INTRODUCTION

Prior to 1953, when work was begun on this equipment, W. P. Tanner, Jr. was conducting psychophysical experiments in the Vision Laboratory at the University of Michigan. As a result of Dr. Tanner's experience with the equipment of the Vision Laboratory the need for more flexible programming equipment was recognized and methods for fulfilling it suggested. These suggestions were incorporated in the original design of N. P. Psytar,[1] with further improvements being made from time to time as experience with the equipment indicated their need. Figure 1 shows the present physical appearance of the system.

The most outstanding difference between N. P. Psytar and other psychophysical programming machines is in the generation of random selections. In most of these machines the random selections are conveyed to the machine by a punched paper tape, which has usually been perforated manually using numbers from a random-number table. Any change in the probability of a selection, therefore, requires the preparation of a whole new tape. Random selections in N. P. Psytar, however, are generated internally by electronic random selectors, developed at the request of Dr. Tanner, and the probability of a selection can be changed by merely adjusting a knob on the front panel.

[1] Noise-Programmed Psychophysical Tester and Recorder.

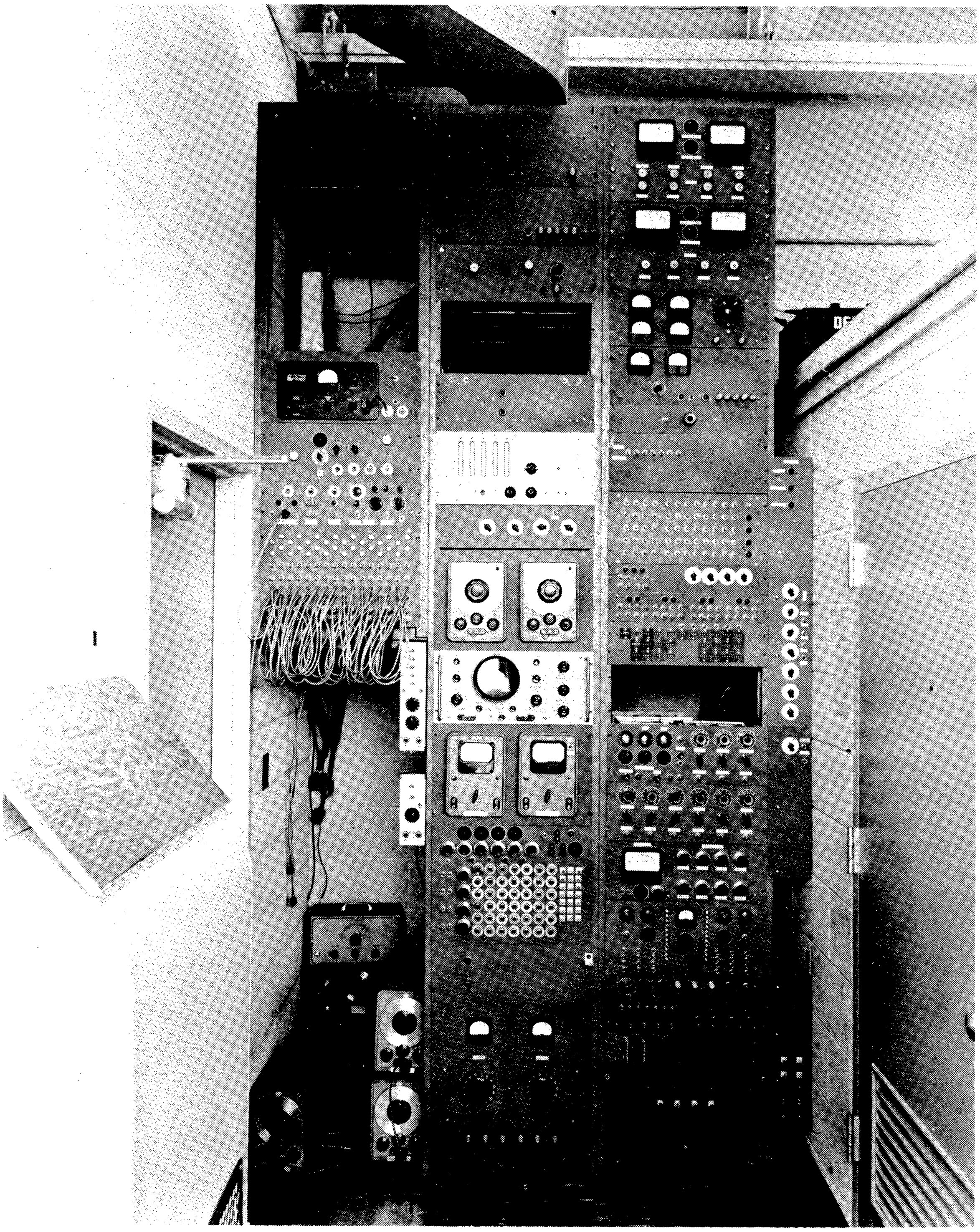


Fig. 1. N. P. Psytar.

2. SYSTEM DESIGN

2.1 The Psychologist's Requirements

The psychologist would like a machine capable of performing any experiment of which he can conceive. This is not feasible, but, to a certain extent, it is desirable to incorporate versatility into the machine. The following requirements result from the design of machines prior to N. P. Psytar, several years of experience with N. P. Psytar, and speculation of future experimental requirements.

Factors relating to observers:

It is necessary that the observers' room be air conditioned and large enough to accommodate four persons (7'9" x 4'9" x 6'9" is the minimum size for auditory experiments). Visual experiments require that it exclude all outside illumination, and auditory experiments need a soundproof room.

Presentation, Warning Information, and Record Answer Equipment:

Each observer must have warning information presented to him to tell him when to do his various tasks in a trial cycle. For auditory experiments lights are to be used. For visual experiments audio warning tones are to be used.

One light is to be used to identify the beginning of a trial cycle. A second light is to be used to identify the possible times that a signal may be presented to the observer. A third light is to be used to tell the observer when he can record his answer.

For visual experiments different tones replace the lights.

The observer is to record his answer (i.e., best estimate of the signal) by operating one push-button from a set.

Push-button actuation force should be around 1 to 2 ounces. Experience has indicated that some observers are fatigued by typical commercial push-buttons that require a force of about 12 ounces.

For ordinary tests two sets of four push-buttons are to be provided for recording answers. Each set is to be used to record one answer from a maximum of four possible choices. For certain tests one set of four and one set of eight push-buttons are to be provided. One of each set is operated, and this 4 x 8 matrix is then capable of handling 32 choices.

It should be possible to feedback to the observers the information that they have made a correct answer, if the experimenter desires.

Factors relating to the programming equipment:

Trial Cycle

The following events must take place during each trial cycle: A random selection or selections must be made; the observer must be warned at the beginning of the trial cycle, at possible signal presentation times, and at record-answer time; observers must record their answers; data must be recorded; the signal must be presented to observers; observers must be given correct answer feedback information; and all circuits must be reset ready for another trial cycle.

The trial cycle should be as versatile as possible. The total period should be adjustable. A number of intervals should be provided in the trial cycle, and the number and duration should be selectable. The duration of the intervals should be adjustable from 0.5 to 5.0 seconds except for the signal presentation intervals which should be adjustable from 0.5 to 50 seconds. For N. P. Psytar a maximum of 9 intervals is provided.

The equipment should be designed so that it presents exactly N trial cycles and then stops. N should range from 1 to 999. It should not be possible to start a new sequence of N trial cycles until a reset button has been operated.

Random Selectors

Three independent random selectors are to be provided. Two are to be equally likely random selectors with the number of selections adjustable from 2 to 10. The third random selector is to be an adjustable probability type with probability adjustment increments of 1 percent and a maximum of 4 selections. A maximum questioning rate of 1 cps is required.

Signal Presentation Equipment

The signal presentation equipment should be easily tied into the programming equipment. It should be as versatile as possible since changes will be made in this equipment most often. The exact nature of this equipment depends on the particular experiment being conducted.

Data Recording

Two types are to be provided:

(1) Electro-mechanical counters are to be provided to count correct answers for each observer. Also counters are to keep track of the random selectors' outputs.

(2) IBM card recording of actual selections by the random selectors and by the observers for each trial cycle is to be provided.

It is very important that the record-answer part of data recording be designed such that an observer can record only his first choice (that is, the first operation of a push-button). All record-answer equipment should be inhibited during all intervals except the record-answer interval.

2.2 System Block Diagram

The overall organization of N. P. Psytar is best described by block diagrams. A very simple diagram is shown in Fig. 2. There is a control segment of the system that tells the other parts when to do specified operations. The parts directly connected with the control are data processing, random selector, signal presentation, warning information, and start. The observers are connected indirectly to the control by these parts. Warning information tells the observer when to perform different tasks in the trial cycle. The random selector determines what signal is to be pre-

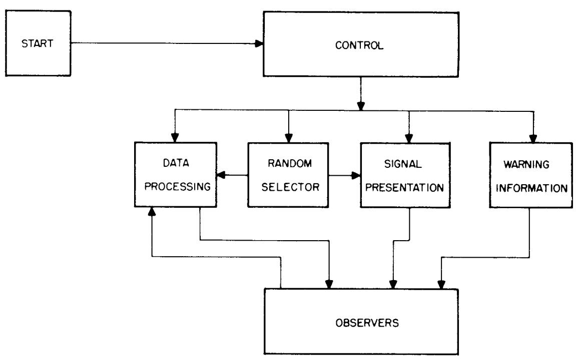


Fig. 2. Simple block diagram of N. P. Psytar.

sented to the observer. This information is also needed in the data processor to check the observers' answers. The signal presentation box is the part of the system that generates and presents the desired signal to the observer. Data processing takes the observers' answers and compares these with the correct answer. Each observer with a correct answer has a "one" added to his correct answer counter. In addition to this, when it is desired, it is possible to record each observer's actual answer, the actual selection made by the random selector, and miscellaneous data on IBM cards. Subsequent to the experiment the cards are processed on an IBM 704 or 650 computer.

A somewhat more detailed block diagram is shown in Fig. 3. Here the control circuit has been separated into the master timing generator and the trial cycle counter. The master timing generator is simply a device with a maximum of nine different intervals, each of adjustable duration. These intervals control the occurrence of the events in a trial cycle. The trial cycle counter circuit controls the number of trial cycles in an experiment, according to preset information. Note that an arrow runs from the start box to the trial cycle counter. To start an experiment the trial cycle counter must be set to zero. Part of the start procedure is to operate a push-button to reset the counter.

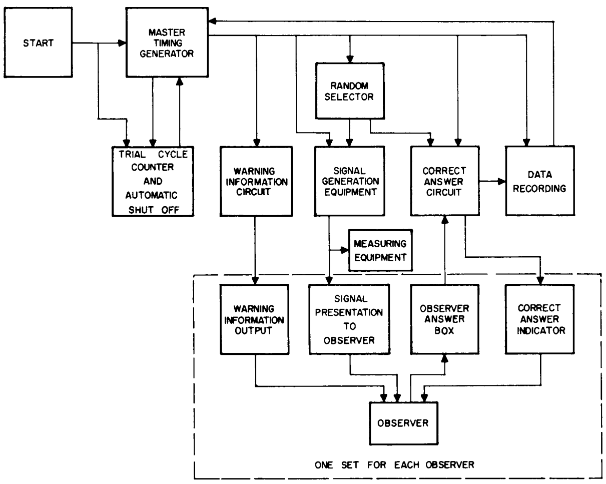


Fig. 3. More detailed block diagram of the system.

Data processing is broken down into the correct answer circuit and data recording. Note that information and control for the correct answer circuit comes from the random selector, the observer, and the master timing generator. When an IBM card punch is used for data recording, then its time cycle becomes part of the master timing generator cycle.

Each observer has four links with N. P. Psytar. Equipment is provided to convey the warning information to the observer. For instance, when the experiment is auditory, lights are used to present the warning information. For a visual experiment, auditory warning information is used. The observer records his choice, or answer, for a trial cycle by pushing the proper buttons on his record-answer box. The correct answer indicator then tells the observer whether his answer is right or wrong. This is very important feedback information because it aids the observer in learning the correct signal cues and rejecting the incorrect ones. This greatly reduces the training period for new observers.

2.3 Sequential Operation

This section is principally concerned with the general design of the N. P. Psytar sequential control.

In designing the control it was necessary to take the psychologist's requirements and determine what operations have to be done at which particular time. The result is the timing chart for trial cycle events, shown in Fig. 4. In order to provide flexibility in setting up an experiment, the decision was made to use nine separate time intervals, each with an independent adjustable duration and each with the possibility of being bypassed.[1]

[1] In an earlier model of N. P. Psytar and in other psychophysical equipments a mechanical cam assembly has been used as the master timing generator. This technique is very inflexible and in the long run is far more expensive than the above electronic master timing generator.

Interval one provides time for the random selectors to make their selections. Interval two is used to present the trial warning tone. In the spatial experiment the signal is presented during interval three, and intervals four, five, and six are bypassed unless needed for some auxiliary purpose. For temporal experiments intervals three, four, five, and six are the possible signal intervals. Interval seven is used to record the observers' answers. Interval eight may be used to give the observers the machine correct answer; interval eight may also be used to record data on IBM cards. Interval nine is used to reset all storage circuits.

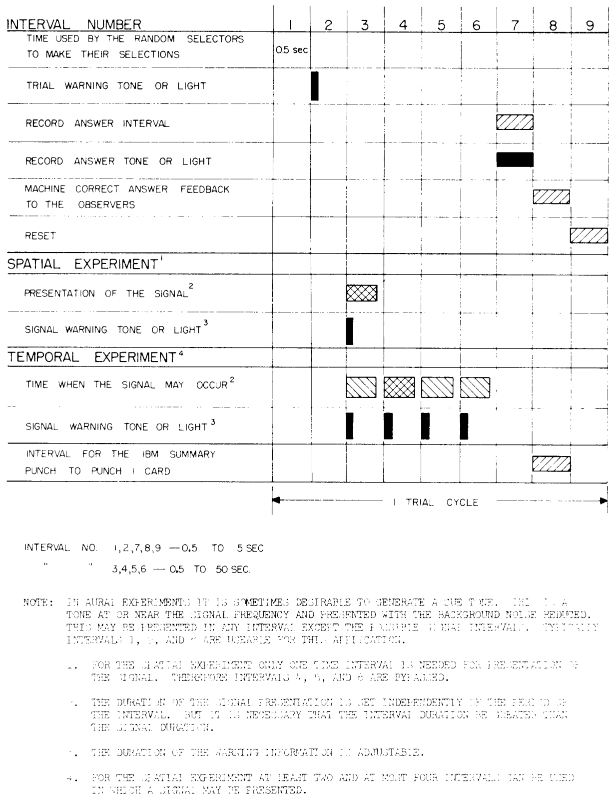


Fig. 4. Timing chart for trial cycle events.

An operations flow chart is shown in Fig. 5. This diagram along with the material that has been previously discussed is essentially self-explanatory.

3. CONTROL

3.1 Block Diagram

The block diagram for the control equipment is shown in Fig. 6. The master timing generator (MTG) consists of nine single-shot multivibrators in sequence. A photograph of the master timing generator is

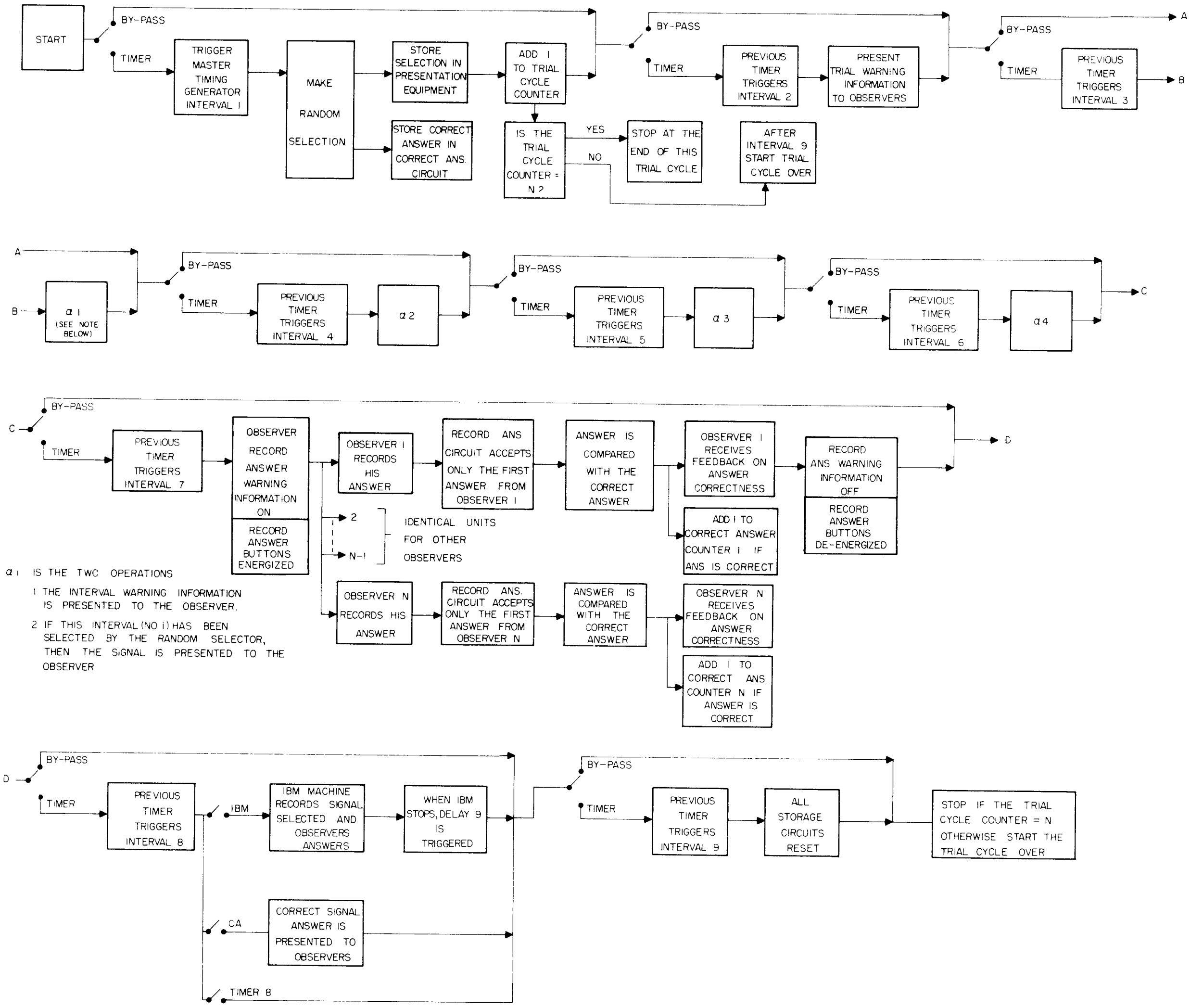


Fig. 5. N. P. Psytar operations flow chart.

shown in Fig. 7. Between intervals 1 and 9 is a run relay. The start, stop, and automatic stop switches control the run relay to start and

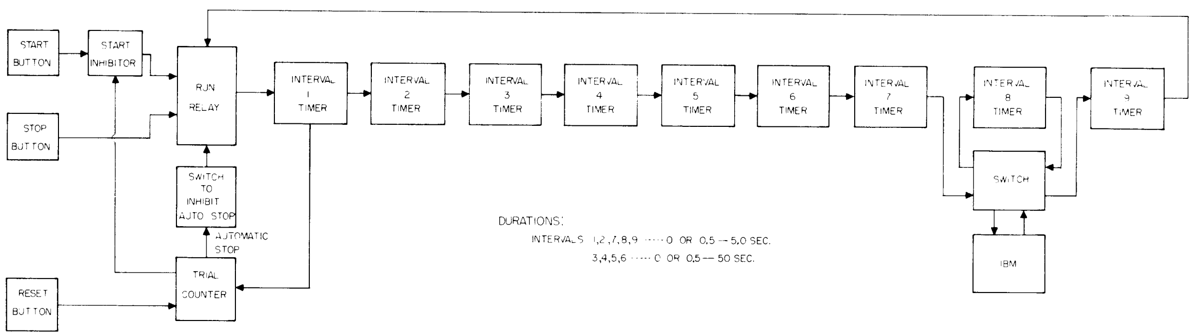


Fig. 6. Block diagram of control equipment.

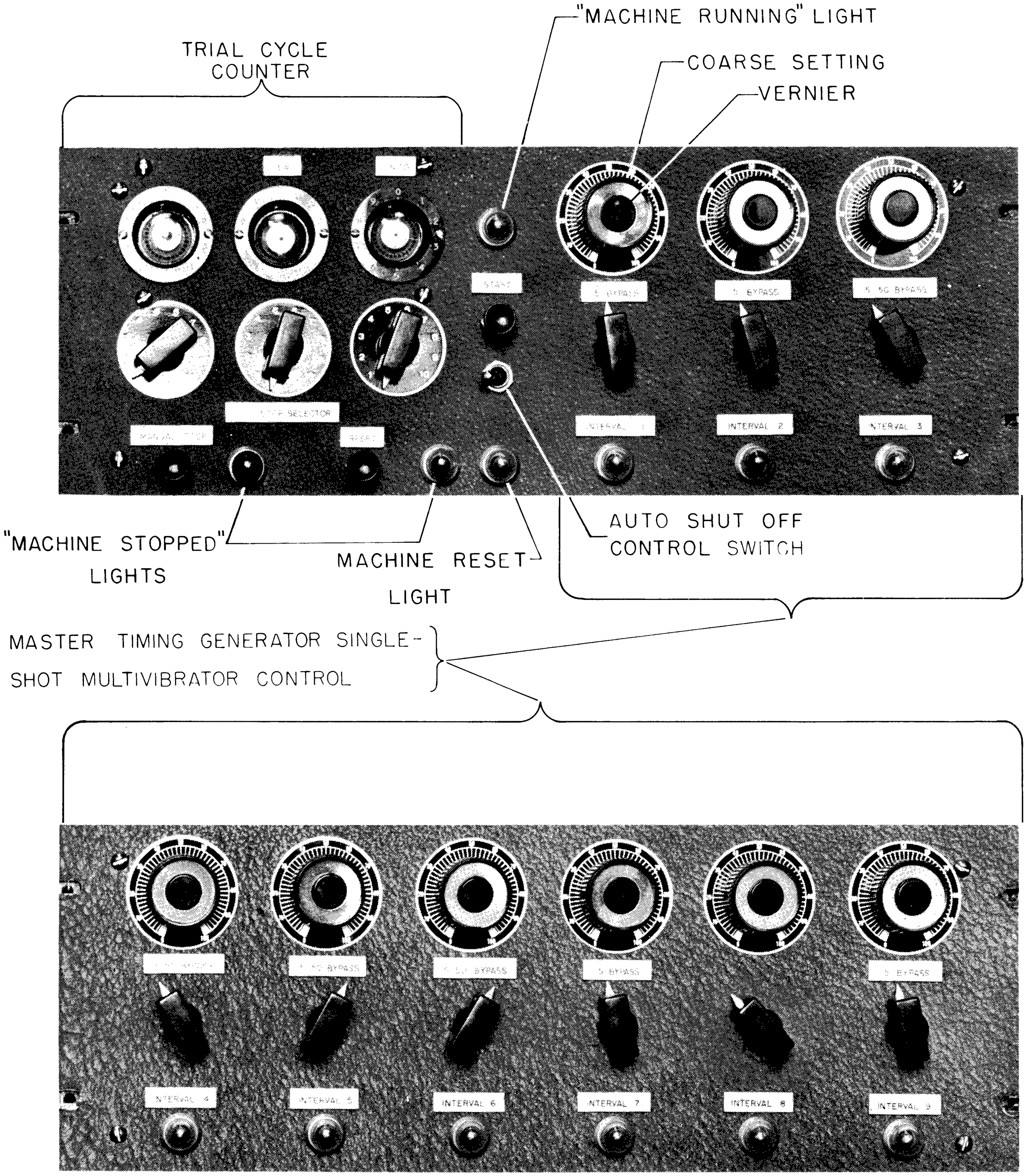


Fig. 7. Master timing generator.

stop an experiment. The interval timers 1, 2, 7, 8, 9 can be bypassed or set for any time duration between 0.5 and 5.0 seconds. Interval 8 has additional switching to allow the use of the IBM machine or to allow the psychologist to present the correct answer to the observer. The interval timers 3, 4, 5, 6 can be bypassed or set for any time duration between 0.5 and 50 seconds. Note that because of the location of the run relay an integral number of trial cycles is generated. In order for the master timing generator to cycle at least two timers must be in an unbypassed position.

The run relay is activated by the start push-button and may be opened by the stop button. If the auto stop circuit is inhibited, then the only way of stopping the generation of trial cycles is by the manual stop button. If the auto stop circuit is not inhibited, then the run relay will be opened when the trial counter gets to a preset count, provided that it has not been previously opened by the manual stop. After the run relay has been opened it is not possible to start an experiment again until the reset circuit has been operated and the trial counter is actually registering 000.

3.2 Inputs and Outputs

There are two types of inputs, control inputs and parameter inputs. The control inputs are start, stop, and reset. The parameter inputs are the trial-cycle automatic-stop selector (range 1 to 999), the automatic stop inhibitor, a duration control on each interval timer, a selector switch for each interval that determines whether the interval is bypassed or not, and, in the case of interval 8, whether or not the IBM machine is used or whether or not the observer is presented the correct answer for the trial cycle.

The outputs of the control timer unit are voltages from the nine timers.[1] Four outputs are provided from each timer output. Output "A" is +180 volts when the timer is OFF, and +10 volts when the timer is ON. The second output "B" is the same as the first except that a 1000-pf capacitor is in series. The third output "C" is 0 volts when the timer is OFF, and +100 volts when the timer is ON. And the fourth output "D" is the same as the third except that a 1000-pf capacitor is connected in series. Photographs of the typical outputs are shown in Fig. 8. For output "A" the rise time for the leading edge of the ON pulse is approximately 100 μsec, and for the fall time for 80 percent of the trailing edge is approximately 200 μsec. For output "D" the rise time for the leading edge is approximately 4 μsec and the fall time for 50 percent of the trailing edge is approximately 50 μsec. These values are essentially unchanged by a change in duration.

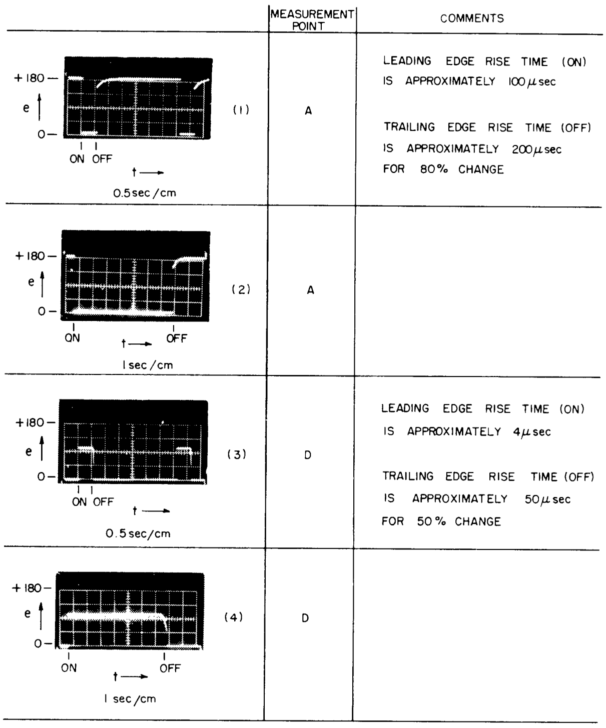


Fig. 8. Typical output waveforms for the master timing generator.

3.3 Control Schematics

The complete schematic for the control equipment is shown in Appendix B. In order that the reader may easily understand the circuit

[1]See Fig. 14.

it has been broken down into a number of simpler parts in Figs. 9 through 19.

A simplified circuit for start and stop control of the master timing generator is shown in Fig. 9, with its logical equivalent shown in Fig. 10. Fundamentally three things must be done. To start a sequence

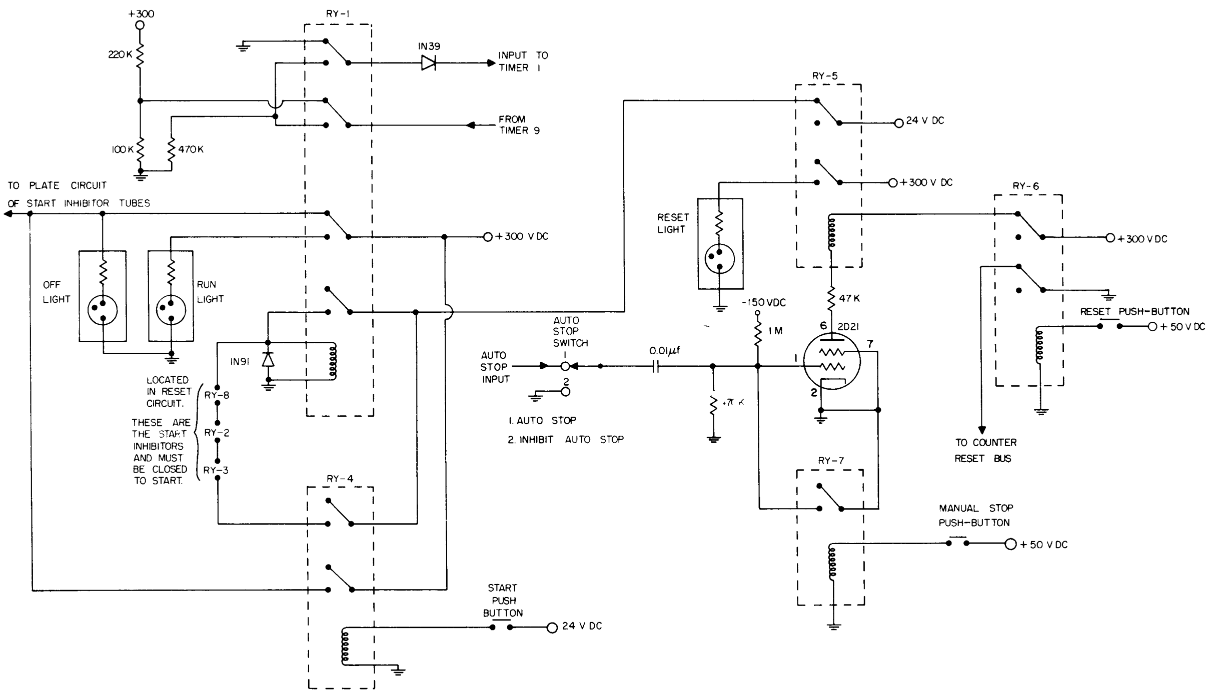


Fig. 9. Simplified circuit for start and stop control of master timing generator.

of trial cycles it is necessary to apply a positive input pulse to timer 1. To continue a sequence, a conducting path must exist between timer 9 and timer 1. To stop a sequence at the end of interval 9 it is necessary to open the path between timer 9 and timer 1.

When RY-1 is de-energized, the input to timer 1 is grounded and the output of timer 9 is connected to +100 volts. The output of 9 has a series capacitor which will charge to a potential of +100 volts. When RY-1 is energized, this 100 volts is applied to the input of timer 1, thus triggering it. As long as RY-1 is closed the output of timer 9 is connected to the input of timer 1 and the master timer will continue to cycle through its sequence. The remainder of the circuit is simply for the control of RY-1.

To start a trial cycle sequence RY-8, RY-2, and RY-3 must be energized. These will be energized only if the trial cycle counter is reading "000". Also RY-5 must not be energized. This will be the case if the 2D21 has been reset. With these conditions met the operation of the start push-button will energize RY-1. RY-1 has a hold contact so that it will remain energized independent of relays RY-8, 2, 3, and 4. The only way to de-energize RY-1 is by energizing RY-5, which opens the 24 vdc supply circuit to RY-1.

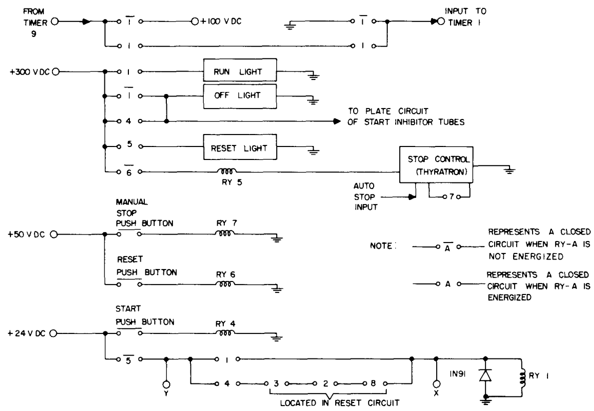


Fig. 10. Simplified logical circuit for start and stop control of master timing generator.

To stop a trial cycle sequence RY-5 must be energized, and this means the 2D21 must be fired, and in turn RY-6 must not be energized. (Note that the stop circuit will not operate when the reset circuit is activated. If the auto stop selector switch is in position 2, then to trigger the 2D21 the manual stop button must be operated momentarily, energizing RY-7. If the auto stop switch is in position 1, then either a positive input pulse to the 2D21 from the auto stop circuit or the operation of RY-7 will energize RY-5.

When RY-5 is energized, the light labeled reset is illuminated.

This tells the operator that in order to start a trial cycle sequence, the circuit must be reset.

To reset the equipment it is only necessary to energize RY-6 by operating the reset push-button. This opens the positive 300 volts supplied to the 2D21, thus resetting it. In addition, the trial cycle counter tubes are reset to 000 by ungrounding the counter reset bus.

When RY-1 is energized, the run light is illuminated. This tells the operator that RY-1 is in the run position. When RY-1 is not energized, the off light is on and the start inhibitor tubes are supplied with B+. This switch is also paralleled by a contact on RY-4 so that B+ will be retained on the start inhibitor tubes until RY-1 becomes completely energized. (Note: in some applications it may be satisfactory to tie the common side of the coils on RY-8, 2, 3 to +300 and to eliminate the lower contact on RY-4, which is in parallel with 1 of the off-light circuit.)

A simplified circuit of the start inhibitor is shown in Fig. 11. The purpose of this circuit is to make it impossible to start a sequence of trial cycles until both RY-5 is unenergized and the trial cycle counter reads "000". When RY-1 is not energized, the series circuit of 5, 4, 3, 2, 8 must be closed to energize RY-1. Once RY-1 is energized, the circuit of 4, 3, 2, 8 is bypassed. The circuit 3, 2, 8 is closed only when

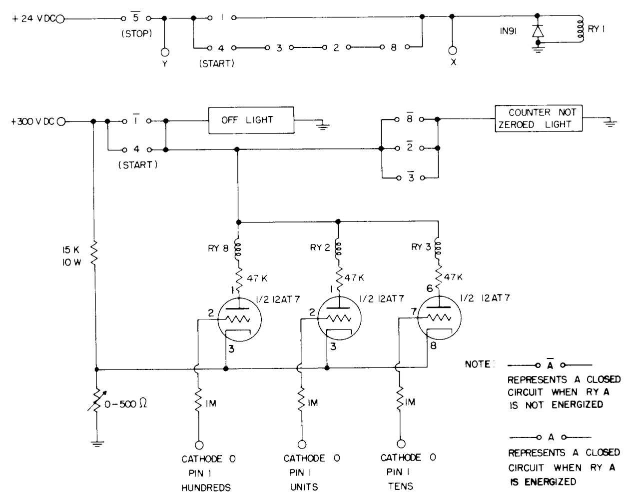


Fig. 11. Simplified start-inhibitor circuit.

the trial counter reads 000. This is accomplished by a positive voltage of about 15 volts minimum being applied to the grid of each of the 12AT7's. If at least one of these voltages is less than 15 volts, then the circuit 3, 2, 8 will be open and prevent the circuit to RY-1 from being closed when the start button closes 4.

A typical decade of the trial-cycle counter is shown in Fig. 12. The counter is a cold-cathode glow transfer type with all cathodes brought out individually.[1] The 12AX7 is a driver tube designed to provide the proper waveforms to the guides, pins 11 and 12. Note that each

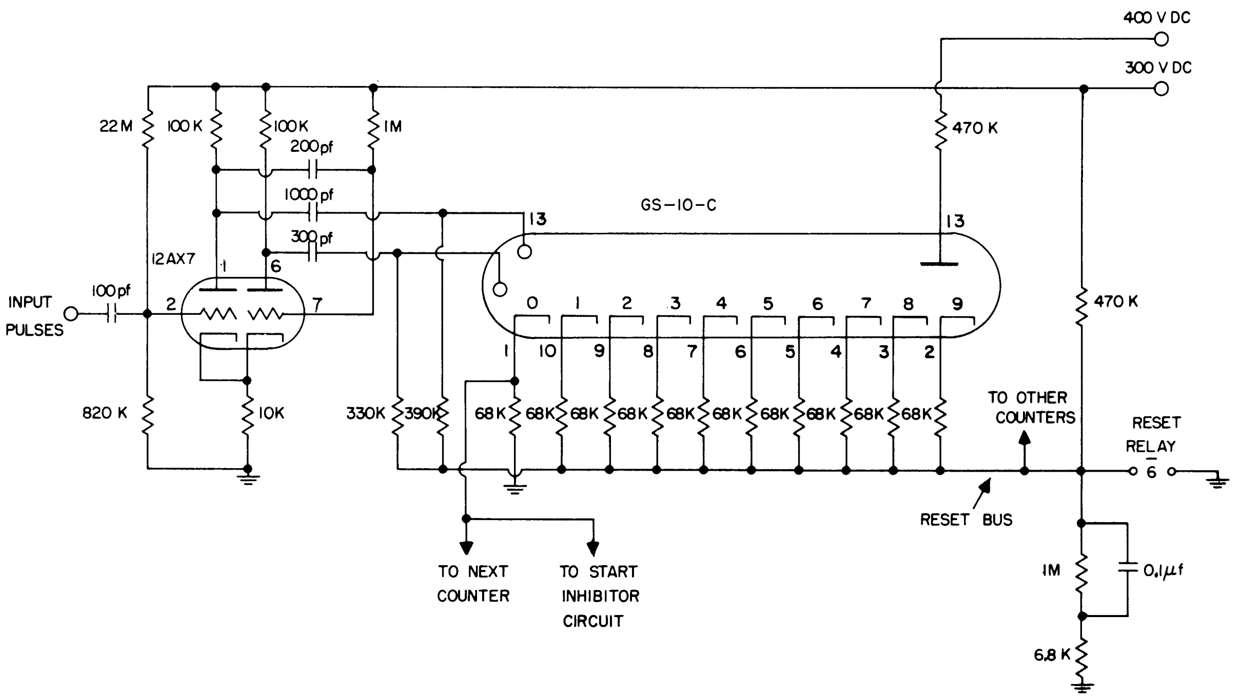


Fig. 12. Typical counter circuit for automatic stop.

cathode has a separate cathode resistor and that the "0" cathode resistor is always connected to ground. In operation, one and only one cathode will have a glow present at any time, and the resulting current lifts this

[1] For a discussion of the operation of this type tube see "Pulse and Digital Circuits," Millman and Taub, pp. 335-339.

cathode to a potential of +20 to +25 volts above ground. Normally the lower end of each cathode resistor is grounded. To reset the counter to cathode "0" all other cathodes are raised to a more positive potential by opening RY-$\overline{6}$.

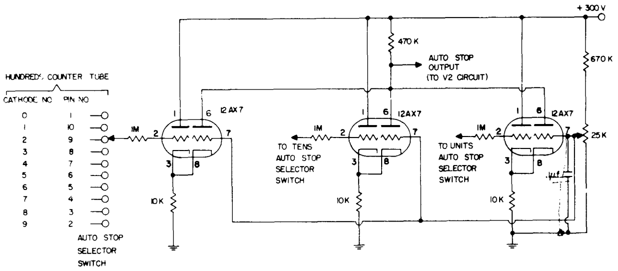


Fig. 13. Simplified circuit for auto stop sensing.

A simplified circuit for automatic stop sensing is shown in Fig. 13. There are three decade switches, one for each counter tube with each position connected to one cathode. The three 12AX7's serve as a coincidence detector and generate a positive output pulse only when all three inputs are positive. This output then triggers the 2D21 in Fig. 9. If it is desired to stop at 100, for instance, the units and tens switches are set at their respective 0 cathodes and the hundreds switch is set at 1. Only when the counter reaches 100 will a positive output pulse be generated.

The circuit for a typical interval timer is shown in Fig. 14. This circuit without modification is used for intervals 1, 2, 7, and 9. Two panel controls, a selector switch and a duration control, are used with each interval timer. The selector switch either bypasses the timer or connects its input to the preceding timer and its output

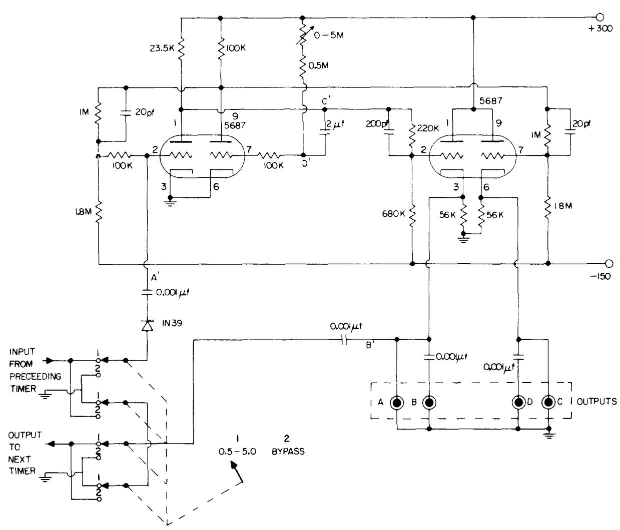


Fig. 14. Typical interval time for master timing generator.

to the following timer. The duration control provides adjustment of the duration from approximately 0.5 to 5.0 seconds. The timer circuit is a single-shot multivibrator triggered on a positive-going input pulse. The positive and negative outputs of the single-shot multivibrator are passed through cathode followers to the output connectors, A, B, C, and D. See Fig. 8 for the output waveforms.

For intervals 3, 4, 5, and 6, it is desired to have a duration range of 0.5 to 50 seconds. This is accomplished by adding to the above timer a second timing range. To do this the switch is modified as shown in Fig. 15. The 2-μf capacitor in Fig. 14 between C' and D' is removed and placed on the switch along with a 20-μf capacitor.

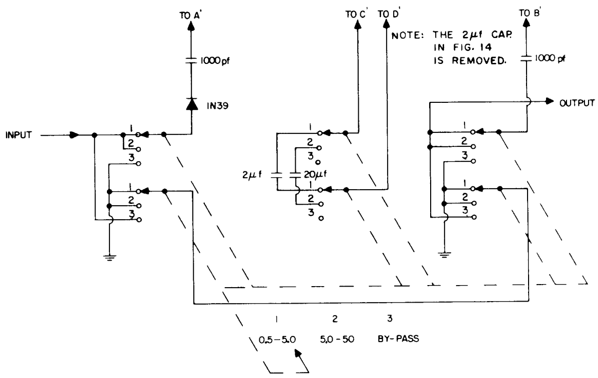


Fig. 15. Switch modification for interval timers 3, 4, 5, and 6.

For interval 8 there is a special switch modification and additional circuitry to control the IBM machine (see Figs. 16 and 17). For switch positions 1 and 2 this timer operates in the same manner as timers 1, 2, 7, 9. In position 3 the timer is triggered by interval 7, but the output is not connected to interval 9. Instead the input pulse is applied to the IBM trigger circuit which closes a relay contact for 150 milliseconds, and in turn starts the IBM summary punch. The summary punch is set up to pro-

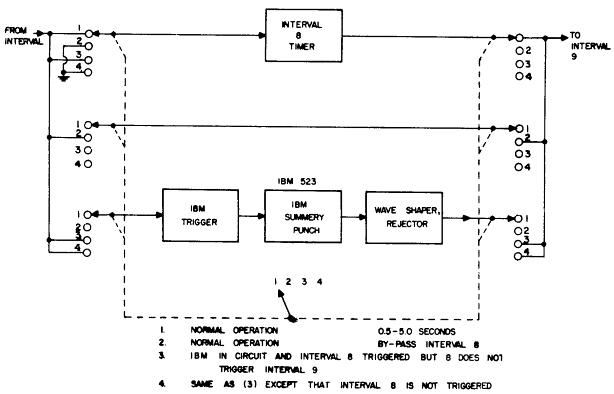


Fig. 16. Special switching for interval 8.

ceed through one punch cycle and stop. At the end of the punch cycle a pulse is generated which triggers the wave shaper and rejector circuit. The output of the rejector then triggers interval 9. In position 4 the operation is the same as 3 except that timer 8 is not triggered.

The IBM summary punch-control circuit is shown in Fig. 17.

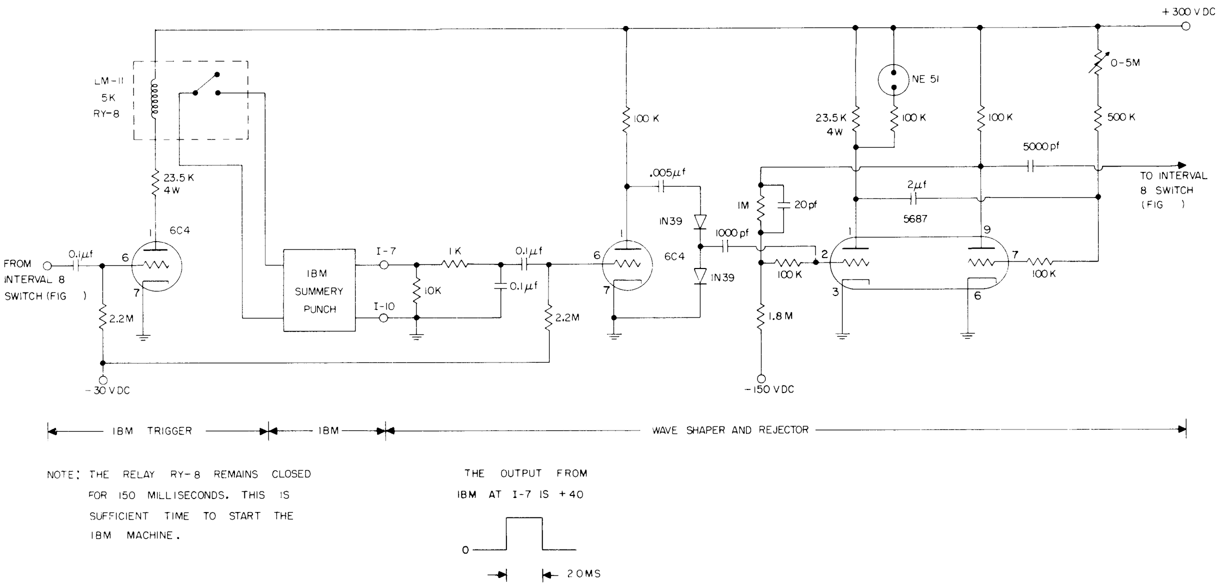


Fig. 17. IBM summary punch-control circuit.

To initiate a punch cycle the IBM machine requires a switch contact to be closed for 150 milliseconds. At the end of the punch cycle the IBM machine puts out a 20-millisecond pulse 40 volts in amplitude. These characteristics must be matched to the characteristics of the timing generator.

The IBM trigger circuit takes any input of at least 40 volts amplitude and 150 milliseconds duration and closes RY-8 for 150 milliseconds. This meets the input requirements. Note that if RY-8 remained closed too long the summary punch would be started on a second punching cycle. The output of the IBM machine is filtered and amplified and this in turn triggers a single-shot multivibrator. The purpose of the filter is to reduce contact hash. The single-shot multivibrator improves the output pulse waveform and also rejects subsequent pulses which the IBM machine produces while coasting to a stop.

3.4 Recommendations for Circuit Improvement

It may be desirable to replace the Baird-Atomic Dekatron counter circuits with Burroughs Beam Switching counters. This, of course, means considerable circuit modification, but it would have the advantage of direct counter readout in digital form and enabling relays to be operated directly for recording the trial number on the IBM card.

If the present type of counter and auto stop sensing circuit are retained and if a maximum count of 100 is desired with only two counter tubes, then a slight modification should make this possible. In the present circuit if the auto stop sensing circuit is set to "000" the master timing generator will count to 10 and stop. This is because for a very short time after the units counter transfers to 0 from 9 the tens counter is still in the 0 stage. Thus the auto stop circuit generates a short pulse. The pulse which occurs under normal auto stop operation is much longer in duration, therefore some low pass filtering at the input of the thyratron should make it possible to reject the narrow pulse.

The single-shot multivibrators should be replaced by a single electronic counter-type timer which is cycled from one output circuit to the next in sequence. As an input, to setup times and switch positions for the different intervals, an IBM card with the desired information punched on it could be used.

4. RANDOM SELECTORS

The random selectors presently being used in N. P. Psytar with some modifications, are described in this section. The modifications that have been made should improve the random selector performance and eliminate the need for critical selection of components. All modifications have been "breadboarded" and perform satisfactorily. The modifications have not yet been incorporated in N. P. Psytar, and therefore some "bugs" might be present in the overall operation of the random selector. There are presently two identical random selectors in N. P. Psytar, labeled RS-1 and RS-2. Random selectors 1 and 2 each have adjustable moduli from 2 to 10 with the selections equally-likely. These random selectors use counters for probability control and a nuclear radiation source for randomness generation.

A third random selector which is to be included in the future, provides from 2 to 4 selections with adjustable probabilities. This unit will also use a counter for the probability control and a nuclear radiation source for randomness generation.

Prior to late 1957 the random selectors used in N. P. Psytar were all adjustable-probability types using samples random noise to obtain the selections. These random selectors had poor probability-setting stability and therefore are being replaced by the counter-type probability controls.[1]

4.1 Block Diagrams

A photograph of RS-1 and RS-2 is shown in Fig. 18. A block diagram of the equally-likely random selector (RS-1, RS-2) is shown in

[1] G. A. Roberts, "The Theory of Electronic Random Selectors," Cooley Electronics Laboratory Technical Report No. 115, The University of Michigan, December 1960, p. 8.

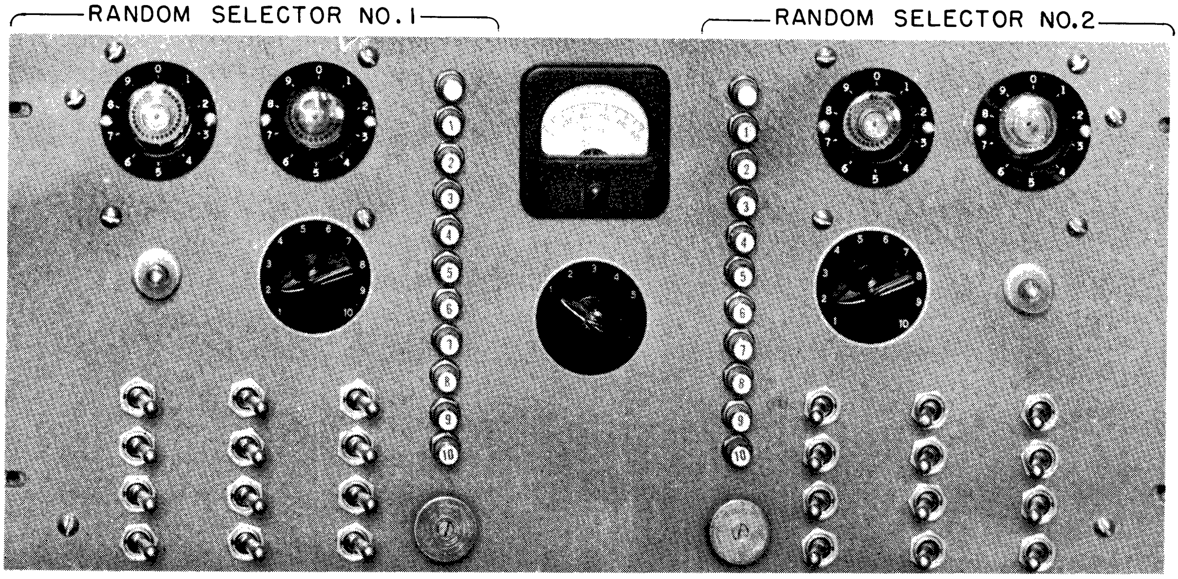


Fig. 18. Random selectors 1 and 2.

Fig. 19. The random selector is divided into three main units (1) randomness generator, (2) the driver unit, which programs each selection, and (3) the probability control, which makes a selection and stores it at the request of the driver unit.

The probability control consists of an oscillator that is gated on for a random period. The oscillator output drives a counter. This counter is a spinning disk and the modulus is adjustable as an input parameter. When the oscillator is turned off another pulse is coupled to the thyratrons that store the selection.

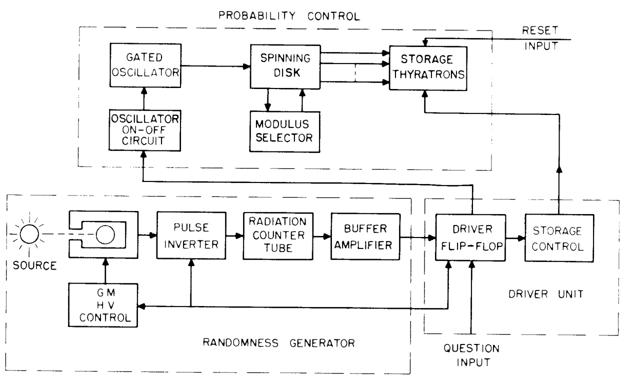


Fig. 19. Block diagram of equally-likely electronic spinning-disk random selector.

The randomness generator is controlled by a Beta radiation source. A Geiger-Müller tube senses the radiation, the G-M tube pulses are inverted and drive a decade counter. The time between pulses from the G-M tube is exponentially distributed (for very short times this is not a correct statement, but will make no difference in the randomness generation). If every tenth pulse is selected from this sequence the time between these tenth pulses has an X^2 distribution (this approximates a normal distribution). See Appendix A for further description.

The driver unit consists of a flip-flop and a storage control. The flip-flop is normally in state 1. An input question pulse transfers the flip-flop to state 2. This causes three actions: the G-M tube has high voltage applied to it; the pulse inverter is turned on; and the gated oscillator is turned on. At a random time, determined by the 10th count from the G-M tube, the driver flip-flop is returned to state 1. This turns off the high voltage to the G-M tube and immediately stops the pulses going into the randomness generator decade counter. The gated oscillator is turned off and the probability control spinning disk is stopped. The spinning disk selection is now stored by the thyratrons until a reset input is received, after which the process can be repeated.

4.2 Inputs and Outputs

The inputs to the random selectors are a question signal and a reset signal. The question signal is a pulse from the D output of the interval-1 timer. The reset signal is a drop of the +100 volts to the thyratron plates from +100 volts to 0 volts during interval 9. Also inputs from intervals 3, 4, 5, and 6 must be fed to the coincidence circuits (not shown on the block diagram of Fig. 19) for temporal readout of the selections.

Spatial and temporal outputs are provided. For spatial output each random selector has three sets of output wires. Output type 1 is identified by one wire of the 10 wires of the set being energized with +100 vdc. This is labeled CA+100. Output type 2 is identified by a corresponding wire of set 2 being energized with +24 vdc. This is labeled CA+24. Output type 3 consists of 20 wires, two of these being connected together to identify the selection. One wire is identified as CA-1 and the other as CA-2. For random selector 3 only four selections are possible. Thus the number of output wires is proportionally reduced (see Fig. 33, page 39). Temporal output is a pulse occurring on a single wire with its time of occurrence randomly selected. Presently in N. P. Psytar this randomization in time is quite restricted. The only times when the pulse can be generated are at the beginnings of intervals 3, 4, 5, and 6. The interval selected is determined by the random selector and the probabilities of selection by the probability settings of the random selector. The reason for the restricted type of temporal randomization is that the experiments being conducted with N. P. Psytar are concerned with signals known exactly. The amplitude of the temporal output pulse is 150 volts. A photograph of this pulse is shown in Fig. 20.

4.3 Schematic Diagrams

The over-all schematic diagram is shown in Appendix B. Simplified schematics are shown in Figs. 21 through 28.

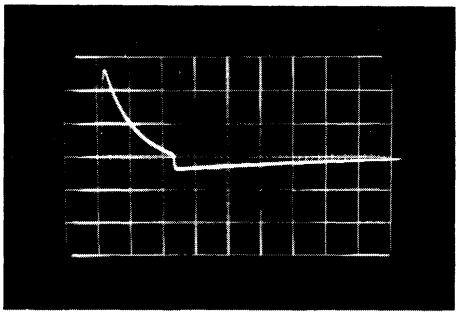


Fig. 20. Temporal output pulse.

The driver flip-flop and

its buffer amplifier are shown in Fig. 21. Following a random selection

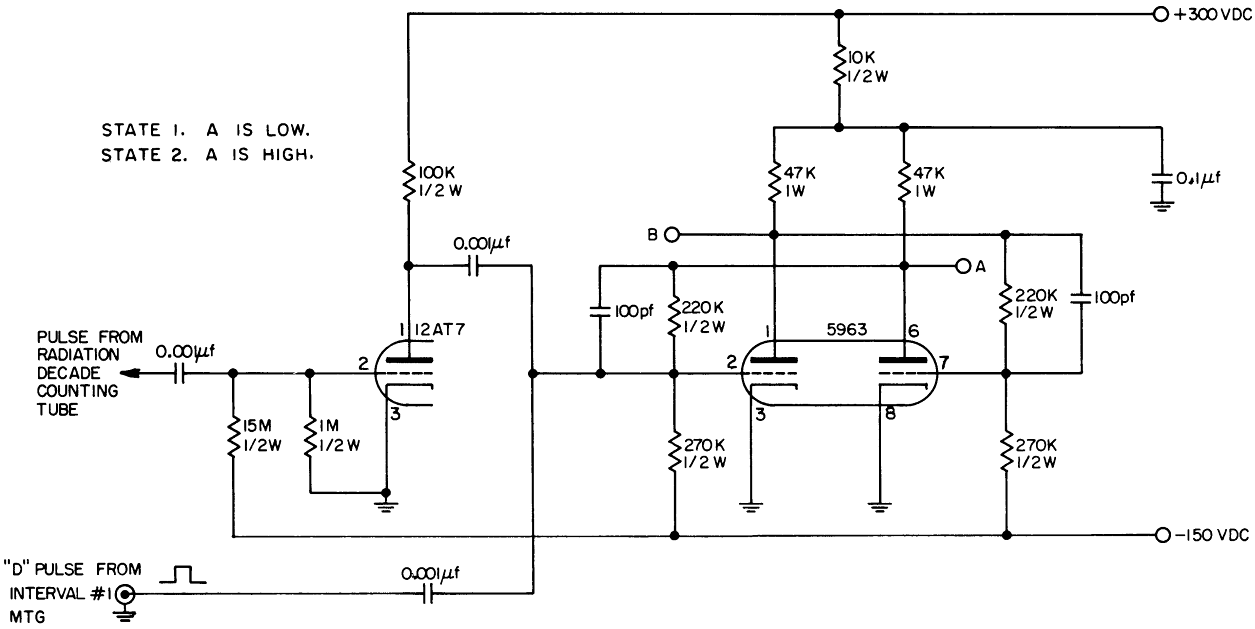


Fig. 21. Simplified circuit of the buffer amplifier and driver flip-flop.

and prior to a new selection the state of the flip-flop (state 1) is plate A low and plate B high. The beginning of interval 1 of the master timing generator (MTG) transfers the flip-flop to its other state (state 2), plate A high and plate B low. The flip-flop remains in state 2 for a random time determined by the randomness generator. A pulse from the radiation decade counting tube is amplified and inverted by the buffer amplifier; this transfers the flip-flop from state 2 to state 1.

A simplified circuit of the radiation detector is shown in Fig. 22. When the driver flip-flop is in state 1 the plate voltage on the 1B85 is low and the 12AT7 inverting amplifier is inoperative. When the driver flip-flop is in state 2 the 1B85 has +920 volts applied to its anode. Beta particles passing through the 1B85 now produce negative pulses of 20 volts amplitude. These pulses are amplified and

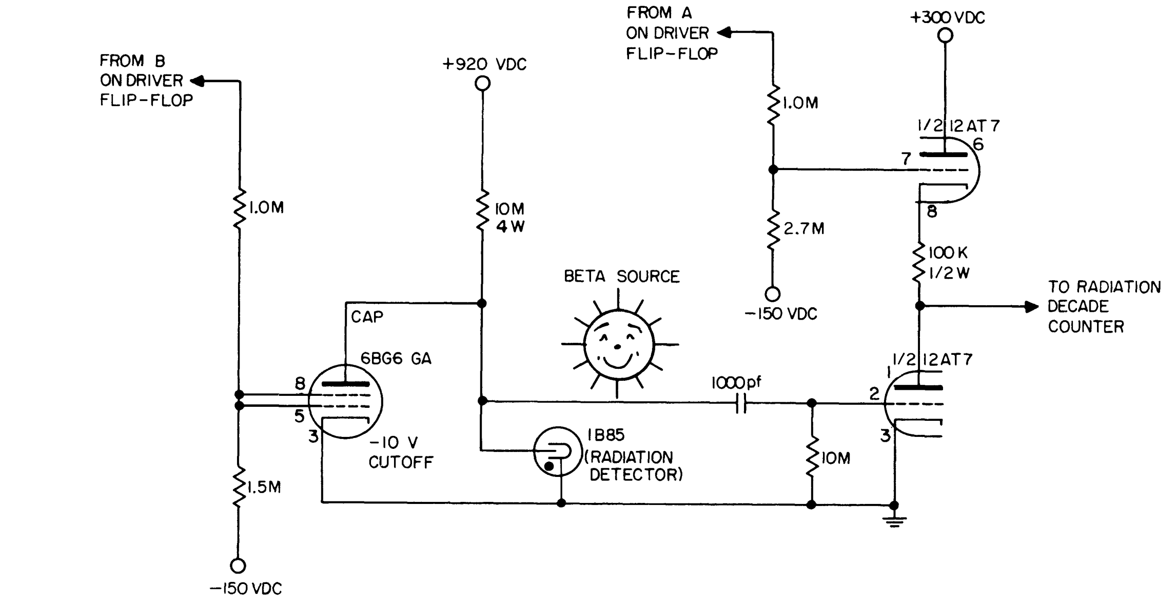


Fig. 22. Simplified circuit of the radiation detector.

inverted. To insure that no pulses are fed to the radiation decade counter after the transition to state 1 the inverting amplifier is gated off by the 12AT7 cathode follower.

Figure 23 is a simplified circuit for the radiation decade

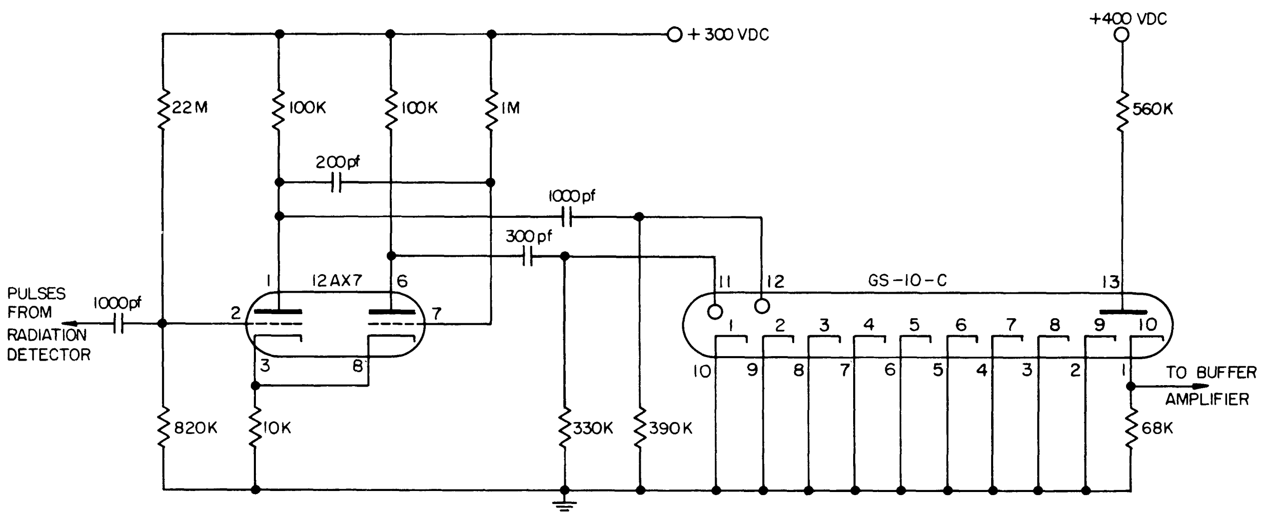


Fig. 23. Simplified circuit for the radiation decade counter.

counter. This is a straightforward glow transfer counting circuit.

The output corresponds to the tenth count from the radiation detector. This output pulse is coupled to the buffer amplifier and returns the flip-flop to state 1.

The preceding circuits constitute 1/2 of the driver unit and the randomness generator. These two units provide all the control necessary to operate the spinning disk for a random period of time, resulting in a random selection.

A simplified circuit of the recurrent pulse generator for the probability control is shown in Fig. 24. This multivibrator oscillator

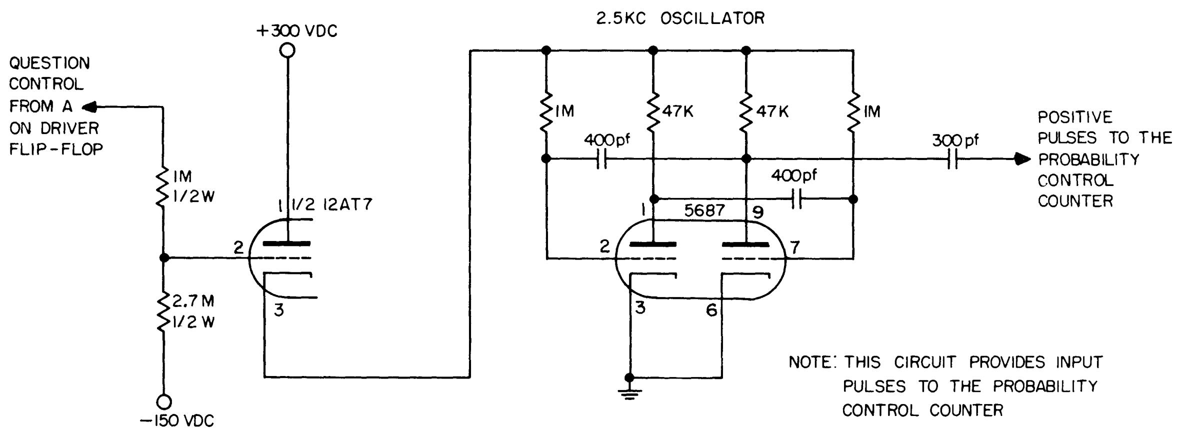


Fig. 24. Recurrent pulse generator for the probability control.

is supplied with plate voltage by the cathode follower which in turn is controlled by the driver flip-flop. When the driver flip-flop is in state 2, the oscillator is generating positive pulses every 0.4 millisecond.

These pulses drive the equally-likely probability control circuit shown in Fig. 25. An adjustable modulus counter using a glow transfer counter tube and a single-stage amplifier reset circuit constitutes the probability control. A large negative pulse to a cathode of the GS-10-C will cause the glow to jump to that cathode. This is the idea

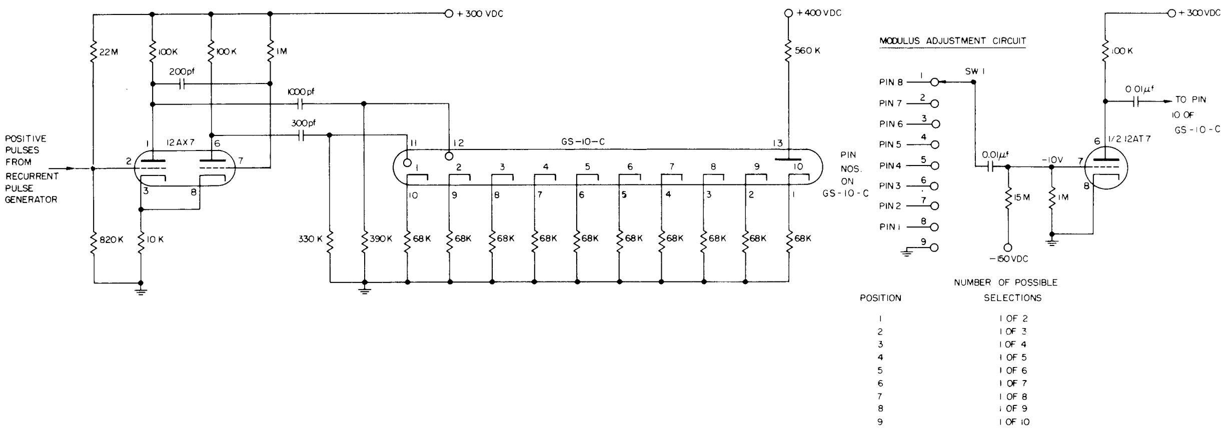


Fig. 25. Simplified circuit of the equally-likely probability control.

used in the reset circuit. The grid of the reset amplifier is connected to the cathode (N+1) following the last cathode (N) in the modulus cycle. The plate circuit is connected to cathode 1. When the GS-10-C glow begins to transfer from cathode N to cathode N+1 a large negative pulse is produced at the output of the reset amplifier, and this pulse forces the glow back to cathode 1. The maximum modulus period is 4 milliseconds. When the recurrent pulse generator is stopped the probability control will stop on one of the N cathodes. This determines the selection.

The selection is stored by a thyratron, Fig. 26. There are ten thyratrons, one connected to each cathode of the GS-10-C. After the thyratrons are reset and prior to a question signal to the random selector the potential on the thyratron cathodes is approximately +40 volts. This potential is maintained until the time that the driver flip-flop goes from state 2 to state 1. Then the spinning disk is stopped and the cathode level of the thyratrons is reduced to approximately +13 volts. This operation triggers the thyratron connected to the GS-10-C cathode with a glow, and the thyratron cathode bus rises to above +60 volts. This state of the output thyratrons will remain

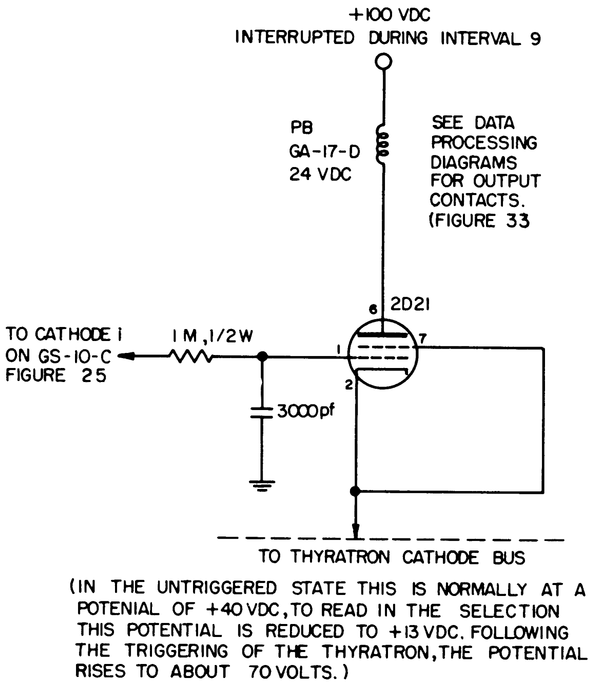


Fig. 26. Simplified circuit for the ith output thyratron.

until the +100-volt supply is interrupted. Then the cycle can be repeated. A simplified circuit of the contact wiring for the output relays is shown in Fig. 33, (page 39).

A simplified circuit for reading-in the random selection to the output thyratrons is shown in Fig. 27. This circuit provides the desired voltages on the thyratron cathode bus at the proper

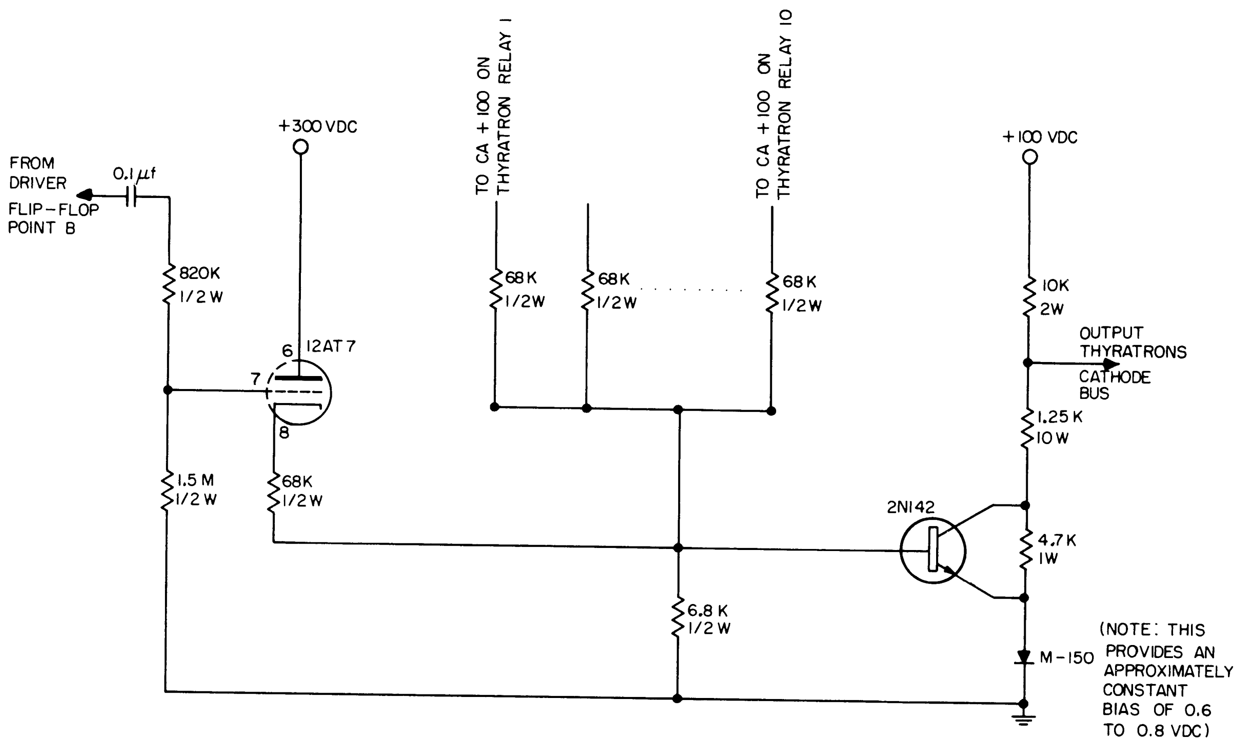


Fig. 27. Simplified circuit for reading-in the random selection to the output thyratron.

time. When all thyratrons are nonconducting and the 2N142 is cutoff, then the resistor divider network places about +40 volts on the cathode bus. At the end of the driver flip-flop's state 2 a pulse of at least 20 milliseconds is applied to the base of the 2N142 from the cathode follower. This pulse causes the 2N142 to short the 4.7K resistor between its collector and emitter, and the thyratron bus voltage momentarily drops to about +13 volts. When a thyratron fires, its cathode current through the 1.25 K resistor raises the cathode bus potential above +60 volts. The 4.7K resistor must remain shorted out after the thyratron is fired. A current is supplied to the 2N142 base from the energized relay to accomplish this function. Upon resetting the thyratrons the 2N142 circuit is also reset.

A simplified circuit for temporal readout of the random selection is shown in Fig. 28. After a selection is made by the random

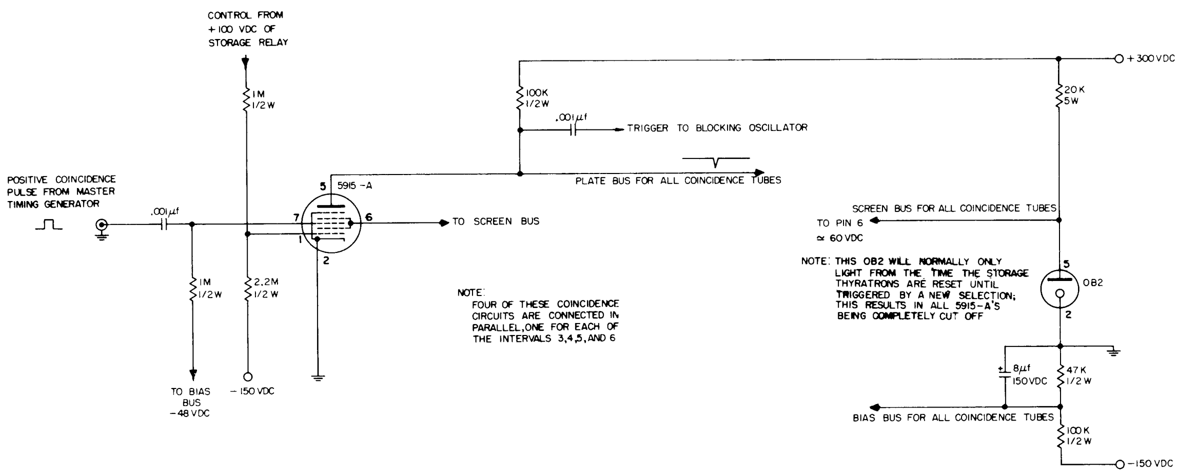


Fig. 28. Simplified circuit for temporal readout of the random selector.

selector, one of the coincidence circuits will have 0 volts on its number 1 grid and all other 5915's will have grid 1 cutoff. The second control grid of each 5915 is fed from the MTG. Coincidence tube 1 from

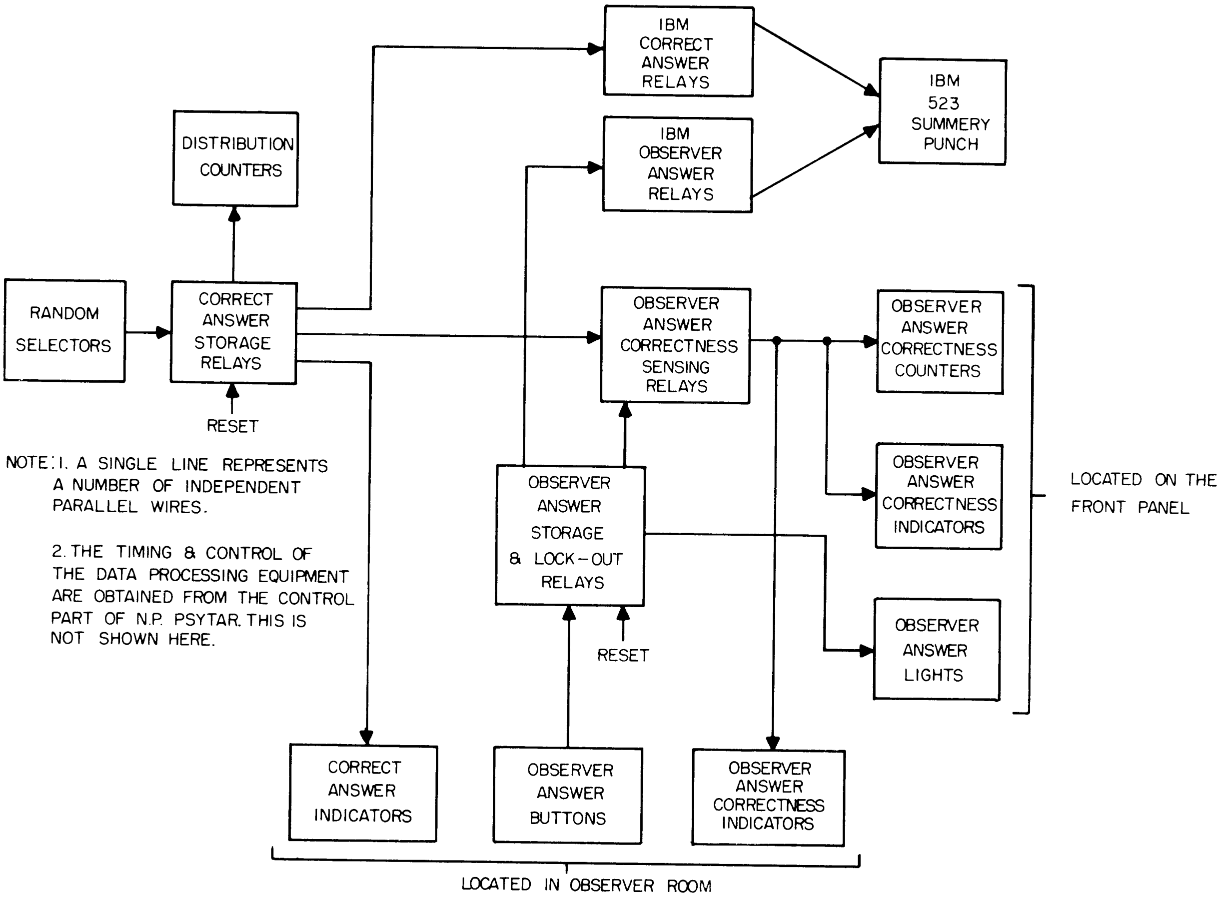


Fig. 29. Block diagram of the data processing equipment.

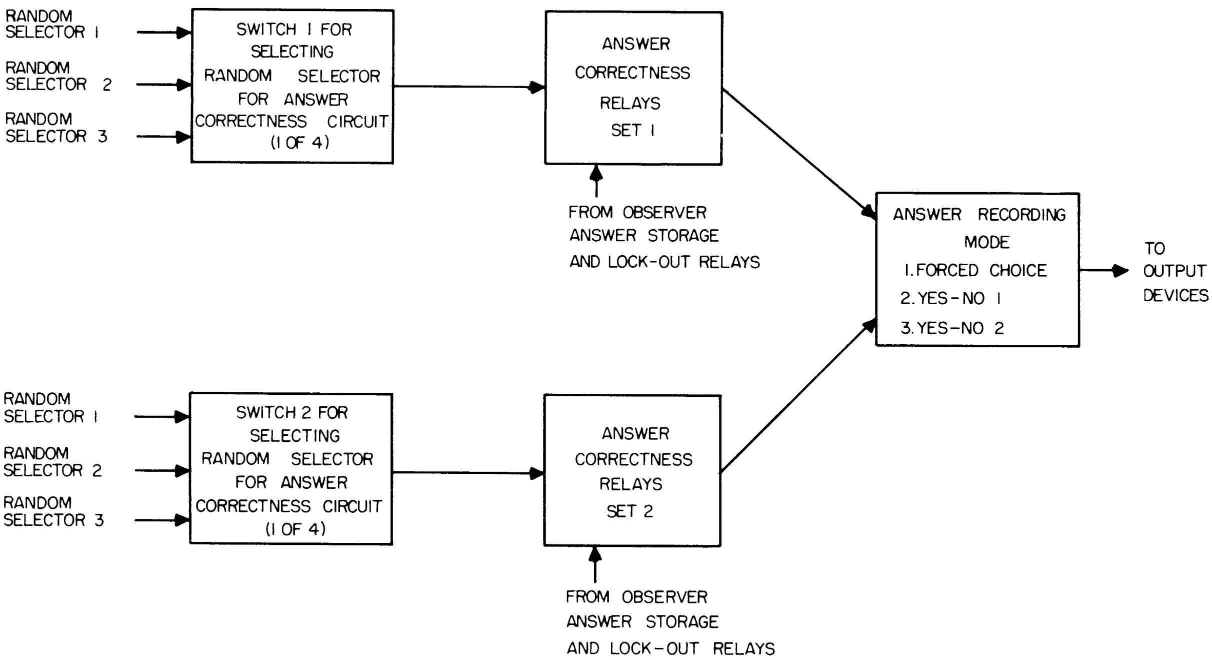


Fig. 30. Block diagram of the block "observer answer-correctness-sensing relays" in Fig. 31.

interval 3, tube 2 from interval 4, tube 3 from interval 5, and tube 4 from interval 6. If the random selector has picked selection 3, then the coincidence circuit will put out a pulse at the beginning of interval 5, and similarly for the other selections.

4.4 General Design Specifications

The maximum rate for requesting random selections is 1 per second. The maximum modulus period for the probability control is 4 milliseconds. The average ON period for the spinning disk is 140 milliseconds and the standard deviation of the ON period is 45 milliseconds. Thus it is easily seen that ϵ for the wrap-around probability density function is extremely small.[1]

5. DATA RECORDING

5.1 Block Diagram

The block diagram for the data processing equipment is shown in Figs. 29 and 30. A wiring block diagram is shown in Fig. 31. Several functions are performed by the equipment. Input data are generated by the random selectors and observers. These data are processed, displayed on neon light bulbs, recorded on electromechanical counters, and when desired, recorded on IBM punched cards.

Selections are made at the beginning of the trial cycle by the random selectors. These data are called the correct answer information, CAI. For use later in the trial cycle this correct answer information is stored by the correct answer storage relays. At the end

[1] G. A. Roberts, "Theory of Electronic Random Selectors," Cooley Electronics Laboratory Technical Report No. 115, The University of Michigan, December 1960.

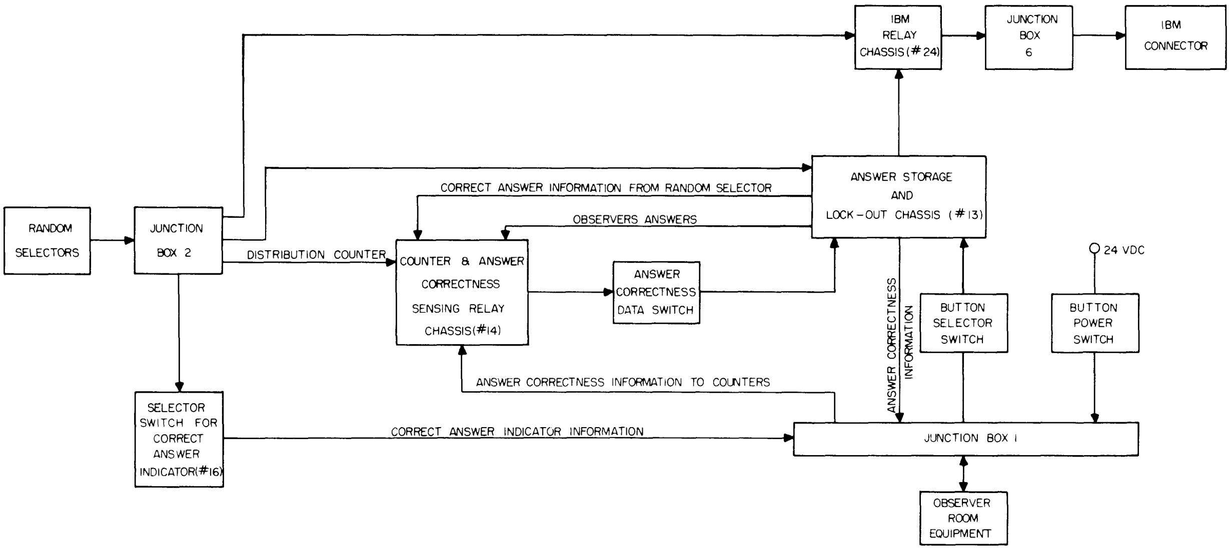


Fig. 31. Block diagram of the chassis and interconnecting cables for data processing.

of the trial cycle the correct answer information is erased by resetting the relays.

The CAI is used in the following ways:

(1) It is accumulated on electromechanical counters so that the experimenter may know the number of each of the possible selections presented to the observer.

(2) It is supplied to the observer-answer-correctness sensing relays. If an observer's answer is the same as the correct answer, then his correct answer counter and lights are operated. Otherwise the correct answer counter and lights are not operated.

(3) When desired the CAI is presented to the observers by means of the correct answer indicators after the observers have recorded their answers.

(4) If the IBM machine is being used to record data, then the CAI is given to the IBM correct answer relays and in turn

to the IBM machine during interval 8.

The observer presents his answer to N. P. Psytar by actuating one of a set of push-buttons. A necessary requirement of the data processing system is that each observer present only one answer per trial cycle. All observers will tend to make mistakes and some observers will try to cheat. For this reason the observer answer storage and lock-out relays are included in the circuit. The circuit accepts as an answer only the first button pushed by the observer. If somehow two buttons or more are operated simultaneously, then the circuit still accepts only one answer. In this case the one answer is more or less randomly selected. The observers can only record answers during interval 7. This set of observer answers is called the observer answer information, OAI.

The OAI is used in three places.

(1) The OAI is presented to the observer answer correctness-sensing relays. Here it is compared with the correct answer. Each observer with a correct answer will have his correct answer counter and light operated.

(2) The OAI is displayed on the front panel of N. P. Psytar by the observer answer lights.

(3) If the IBM machine is used, then the OAI is given to the IBM observer answer relays and in turn to the IBM machine during interval 8.

5.2 Inputs and Outputs

There are two types of inputs, data inputs and parameter inputs. The data inputs are the selections from the random selectors and the observers' answers. From random selectors 1 and 2 there is a maximum of 20 possible selections, 10 for each. From random selector 3 there is a maximum of 4 selections. Three ways exist for the observers to record answers. Each observer has two sets of four push-buttons. These are used for most experiments to record answers. Generally only one set of four push-buttons is used. The two sets of push-buttons are used when the experimenter wants the observer to record a first and second choice answer or where the observer is recording answers for two signal variables (for instance, range and bearing on a PPI scope). For ROMPAR experiments a maximum of 32 different signals can be presented. An efficient way to have the observer record his answer is to give him a matrix that has four possibilities on one side and eight on the other. To record his answer, one signal from 32 possible ones, he operates one of the four push-buttons and one of the eight push-buttons. A photograph of an observer's input equipment is shown in Fig. 32.

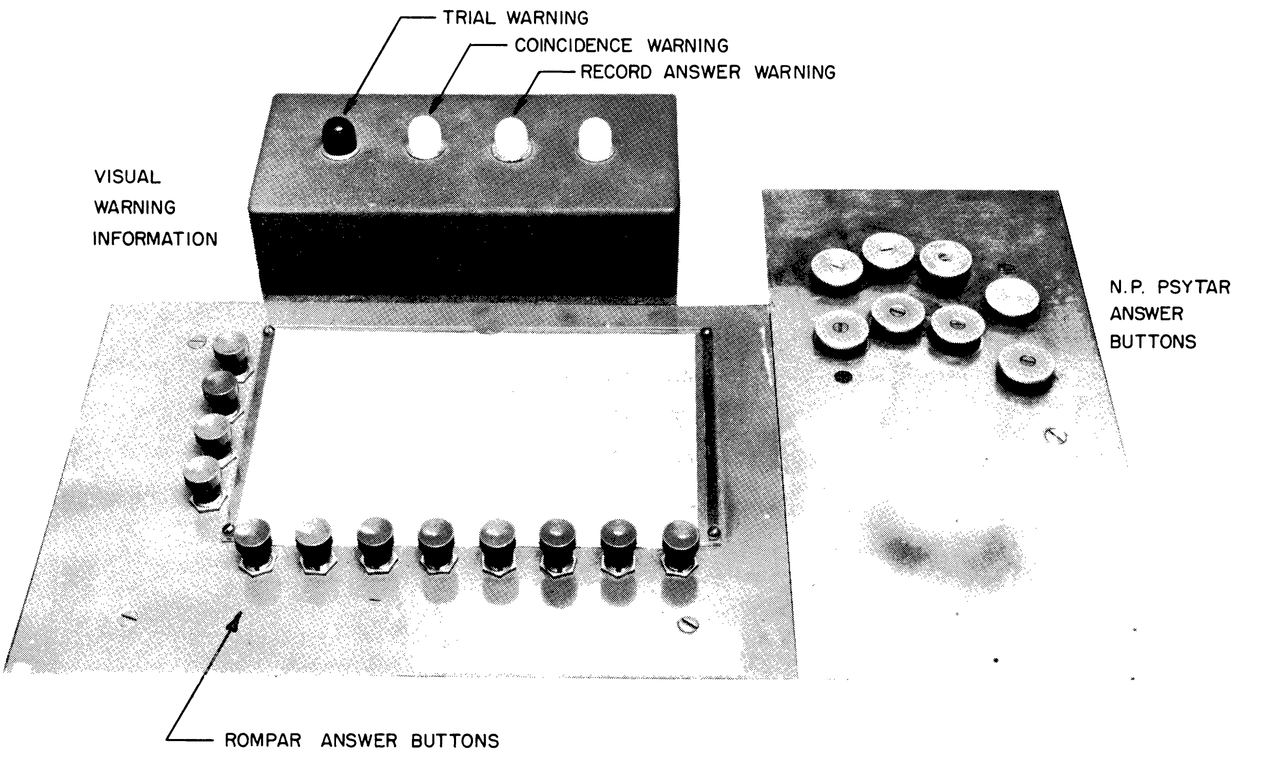


Fig. 32. Record-answer buttons and visual warning information equipment.

The parameter inputs are selector switches for correct answer grounds, selector switches for determining which random selector is used with which correct answer circuit, selector switches for distribution counters, IBM selector switches, selector switches for observer push-buttons, forced choice or yes-no selector switch, switches for activating the various combinations of answer buttons, and a switch to determine whether or not the observers receive correct answer information.

Six different types of output from the data processing equipment are available:

(1) Counters to show the distribution of the random selections. These are the distribution counters.

(2) Indicator lights to tell the observers what the correct answer was for the trial cycle, provided the experimenter desires this information to be presented. This information is presented to the observer after he has recorded his answer. These are the correct answer indicators.

(3) Indicator lights to tell the observers whether their answers were right or wrong. This information is also duplicated on the front panel of N. P. Psytar. These are the observer answer correctness indicators.

(4) Indicator lights that tell the experimenter what answer was made by each observer. These are the observer answer lights.

(5) Counters to accumulate the number of correct answers for each observer. These are the observer correct answer lights.

(6) An IBM 523 or 24 card punch to record all desired information.

The IBM card was designed such that the recorded data could be visually read. Since the card was designed some changes have been made in the machine. For instance, random selectors 1 and 2 now both have the capability of making up to 10 selections. PPI experiments are not now being performed with N. P. Psytar. The use of each of the columns of the IBM card at the present time is listed below:

Column No.	Use	
1 2 3 4 5	Tens digit from the year Units digit from the year Month Tens digit from the day Units digit from the day	Date
6 7 8 9 10 11	Code Number for experiment Experimenter's book number Hundreds digit of page number Tens digit of page number Units digit of page number Item number on page	Experiment Code Number
12	Extra column	
13 14 15	Random selector 1, selection, 1 of 10 Random selector 2, selection, 1 of 10 Random selector 3, selection, 1 of 4	C. A. Information
16 thru 20	Not used now	
21 thru 24	Rompar Selection, 1 hole in a 4 x 8 matrix	
25, 26	Extra columns	
27 thru 32	Not used now	
33 34 35 36 37 38 39 40	Observer 1, Set 1, Answer, 1 of 4 Observer 2, Set 1, Answer, 1 of 4 Observer 3, Set 1, Answer, 1 of 4 Observer 4, Set 1, Answer, 1 of 4 Observer 1, Set 2, Answer, 1 of 4 Observer 2, Set 2, Answer, 1 of 4 Observer 3, Set 2, Answer, 1 of 4 Observer 4, Set 2, Answer, 1 of 4	Observer Answer Information
41 thru 44 45 thru 48 49 thru 52 53 thru 56	Observer 1, 1 hole in a 4 x 8 matrix Observer 2, 1 hole in a 4 x 8 matrix Observer 3, 1 hole in a 4 x 8 matrix Observer 4, 1 hole in a 4 x 8 matrix	Observer Answer Information for Rompar Experiments
57 thru 77	Not used now	
78 79 80	Hundreds digit Tens digit Units digit	Card number

5.3 Schematic Diagrams

The complete schematics and interconnecting wiring diagrams for the control equipment are shown in Appendix B.

An approximate procedure for the description of the circuits is to start at the left of the block diagram of Fig. 30 and work toward the right. Some of the simplified diagrams will show a single possible circuit through several of the blocks.

The correct answer storage relays are physically located in the random selectors. To provide suitable controls for the different devices in N. P. Psytar three types of output are provided for each possible selection. If possibility i has been selected, then there is a wire coming from i with +100 vdc and another with +24 vdc; in addition to these two there is another pair of wires connected together. If possibility i does not correspond to the selection, then the above conditions are replaced by 0 vdc, 0 vdc, and the two wires are not connected together. A simplified circuit for one correct answer relay is shown in Fig. 33.

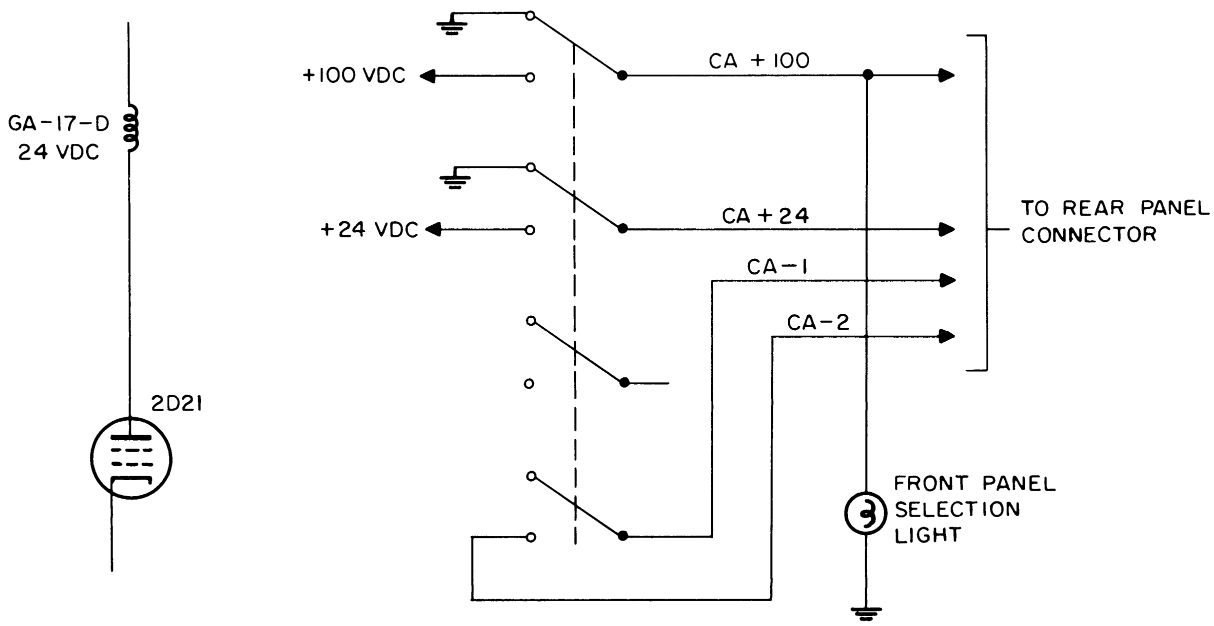


Fig. 33. Simplified circuit for one correct answer storage relay.

There are a total of 24 of these circuits. Ten are associated with random selector 1 and only one of them can be energized at a time. Similarly, for random selectors 2 and 3 except that RS 3 has a maximum of 4 possibilities.

Distribution counters are provided so that the experimenter may check on the random selectors. To economize on the number of counters needed, one counter is used for each of the possible selections (1, 2, 3, 4) on each of the three random selectors. This requires 12 counters. Each of these is assigned to one of the possible selections 5, 6, 7, 8, 9. 10. A switch is included in the circuitry of each counter. This switch allows the experimenter to connect the counter to either random selector 1 or 2. A simplified circuit for the distribution counters is shown in Fig. 34. Note that a 1N39 diode is placed across each counter to reduce undesired transients. The total counter is used to check the automatic reset counter in the control equipment and to provide a total count near the distribution and correct answer counters. A photograph of the counter panel is shown in Fig. 35.

Each observer has a set of four lights, called correct answer indicators. When desired in an experiment these lights tell the observer what the correct answer was after the observer has recorded his answer. All of the information is available from the correct answer storage relays. Thus, it is necessary only to close a relay during interval 8 to present this information to the observers. One important point must be considered. The circuit must be designed so that the neon bulbs in the C. A. indicators do not flash when the correct answer storage relay closes. This is prevented by grounding both sides of the neon bulbs at all times except during interval 8. See Fig. 36 for a simplified circuit. The observer answer buttons are used to record the observers' answers. To

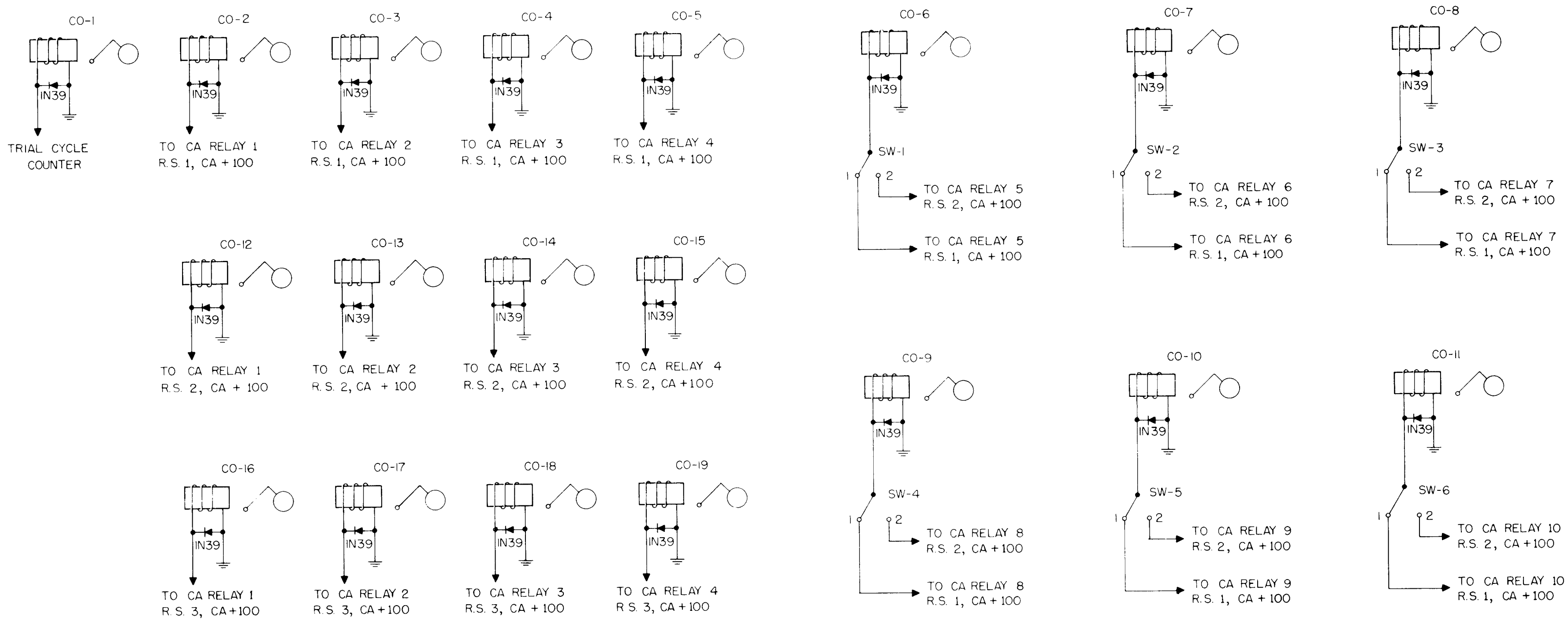


Fig. 34. Circuit of the distribution counters.

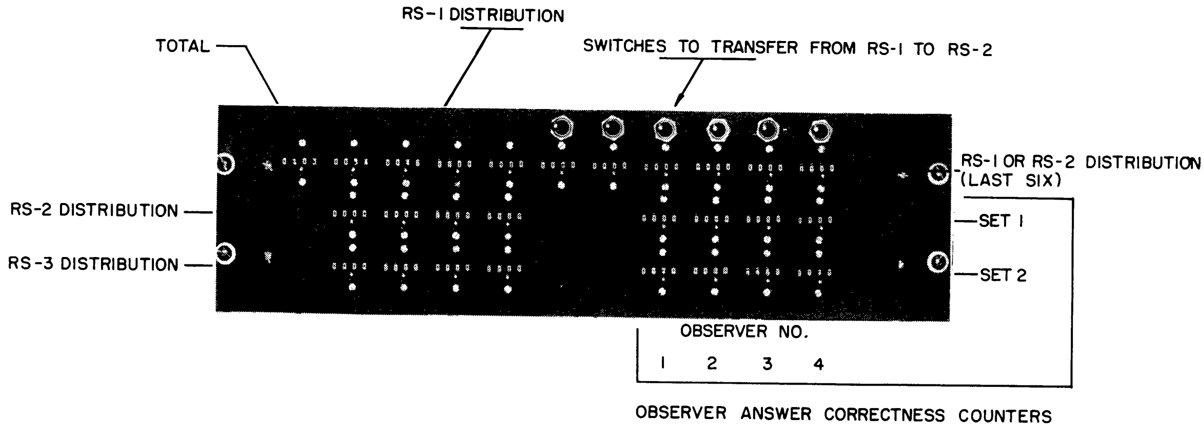


Fig. 35. Counter front panel.

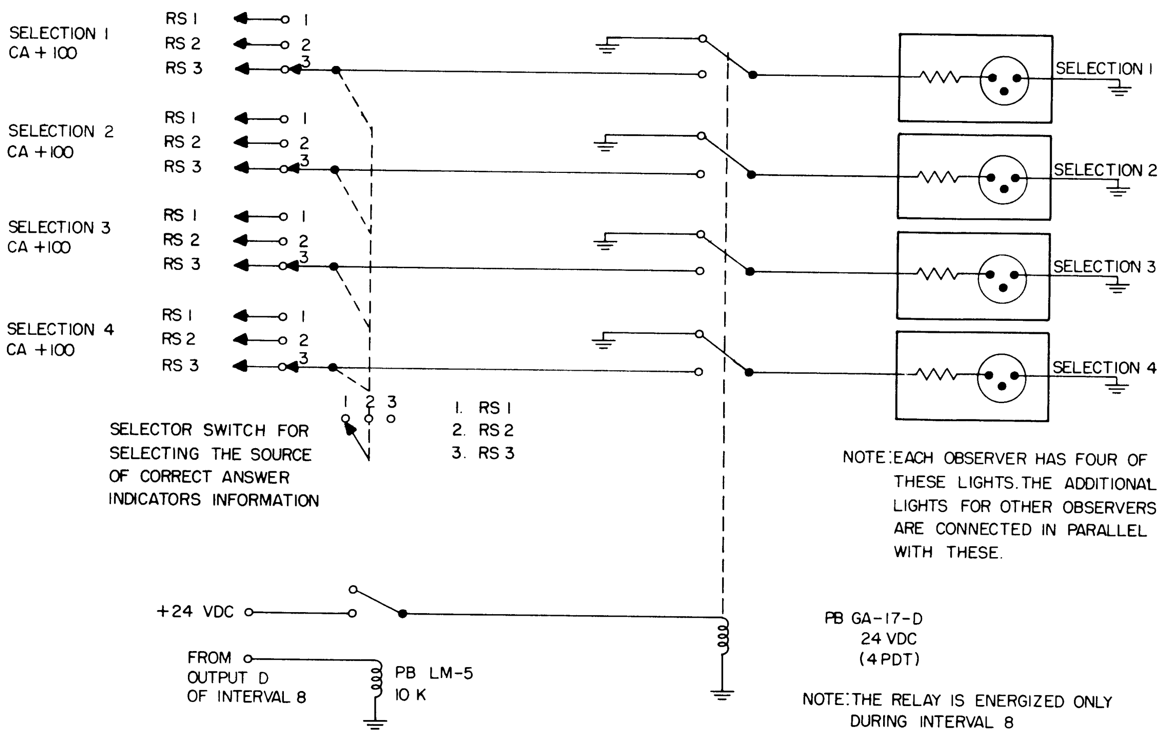


Fig. 36. Simplified circuit for one correct answer indicator set.

provide for flexibility of the equipment, switching is employed so that any one of the 3 sets of 4 push-buttons can be connected to either set of observer answer storage and lock-out relays. Power switches are provided for each of the three sets of 4 push-buttons so that any of the sets may be activated. A block diagram of the correct-answer-button selector circuit is shown in Fig. 37. A simplified circuit diagram for one observer is shown in Fig. 38.

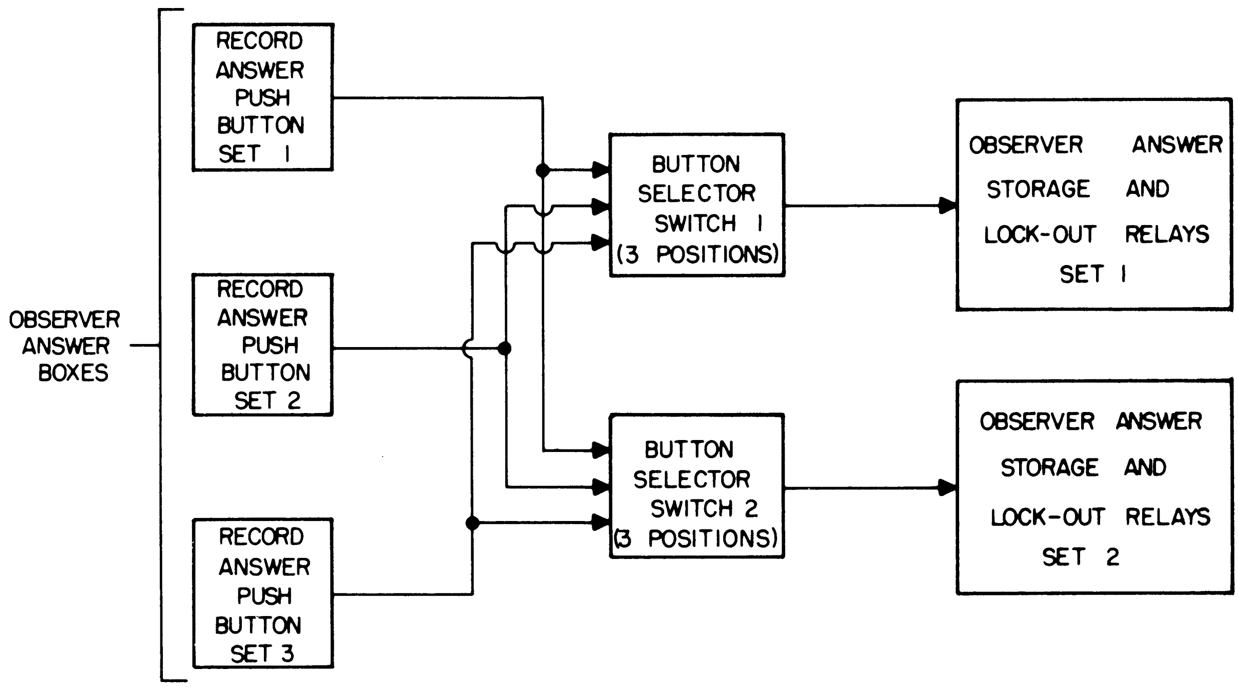


Fig. 37. Block diagram of the observer answer button selector circuit. Note, a single line in this diagram represents a note of independent parallel lines.

The observer answer storage and lock-out circuit performs the function of accepting at most only one answer per observer push-button set and storing these data. Each observer has two storage and lock-out circuits, each designed to store one answer of four possibilities. A photograph of one plug-in unit is shown in Fig. 39. A simplified diagram of one storage and lock-out circuit is shown in Fig. 40. The basic operation of the storage and lock-out circuit follows: Each relay coil, X, has in series with it a normally-open contact activated by X and three normally-closed contacts, one from each of the other relays. In parallel with the normally-open contact is a normally-open push-button. If push-button X is closed then relay X is energized and held closed by its holding contact.

The activation of relay X causes each of the other relay circuits to be opened. Thus, no other relay may be activated. If two or more push-buttons had been operated simultaneously, then it is still possible to activate only one relay.

To reset this lock-out circuit it is necessary only to momentarily open the +24 vdc supply. Outputs are obtained by grounding circuits. For instance, consider point 11. If relay 1 is not energized then, this point remains unconnected. But, if relay 1 is energized then point 11 is grounded. There are three independent grounding circuits for each of the four possible answers.

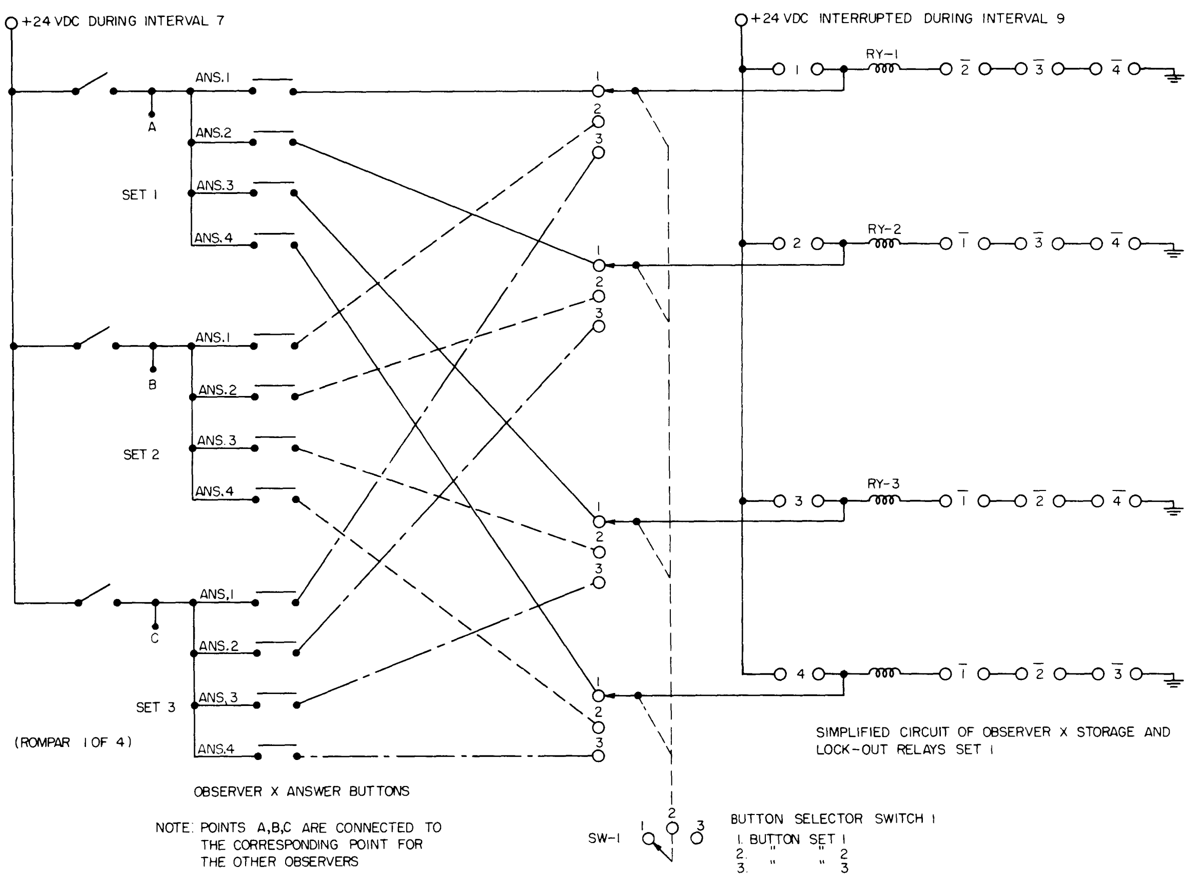


Fig. 38. Simplified diagram of the selector circuit for the observer answer buttons.

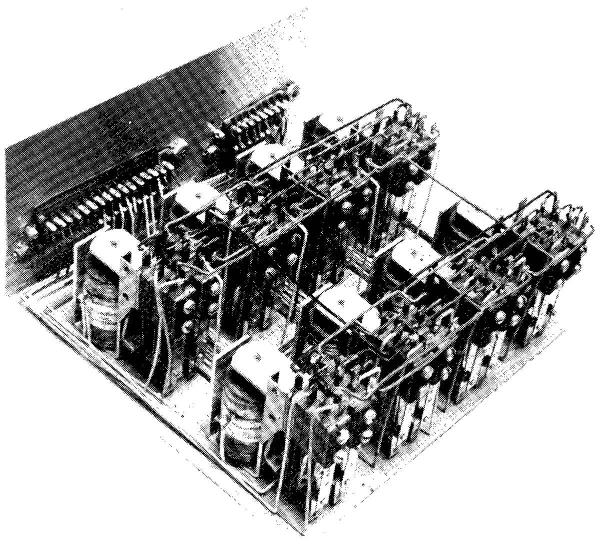


Fig. 39. One answer storage and lock-out plug-in unit.

The observer answer lights are located on the front panel of the N. P. Psytar (see Fig. 41). These provide the experimenter with information about the observers' actual answers during an experiment and are operated by the grounding circuits in the storage and lock-out unit.

The observer answer correctness sensing relays compare each observer's answer with the correct answer. If the answer is correct then the observer's answer correctness counter and answer correctness indicator are operated. There are two sets of answer correctness sensing relays for each observer; one is connected to each of the two storage and

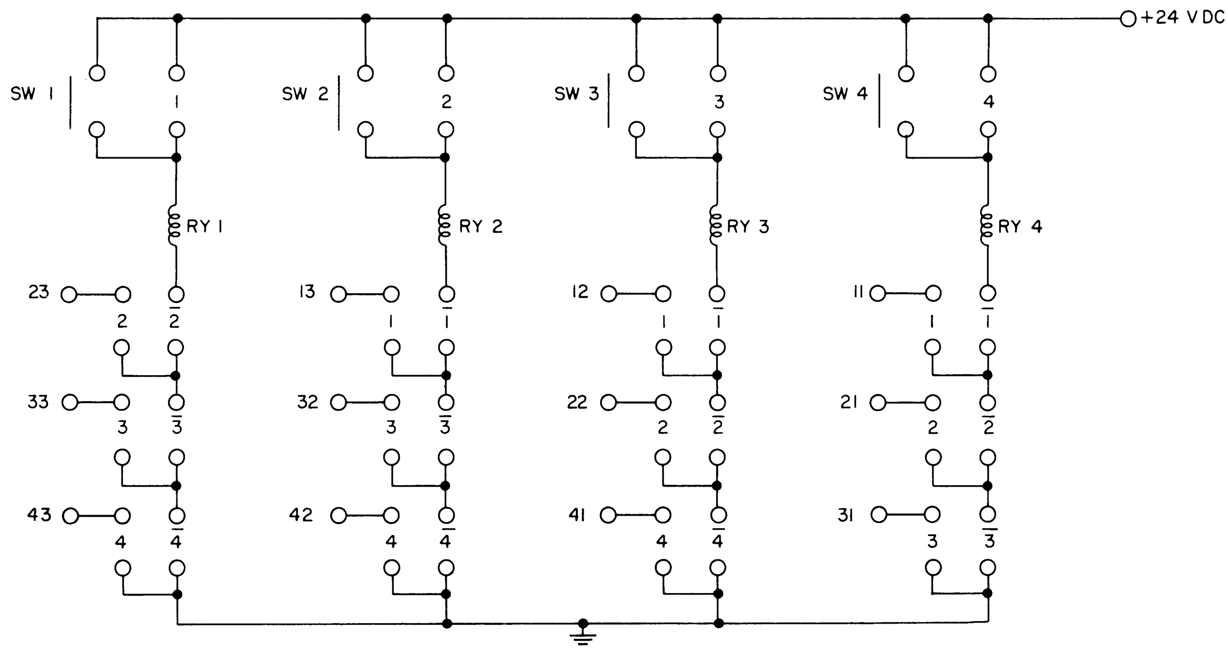
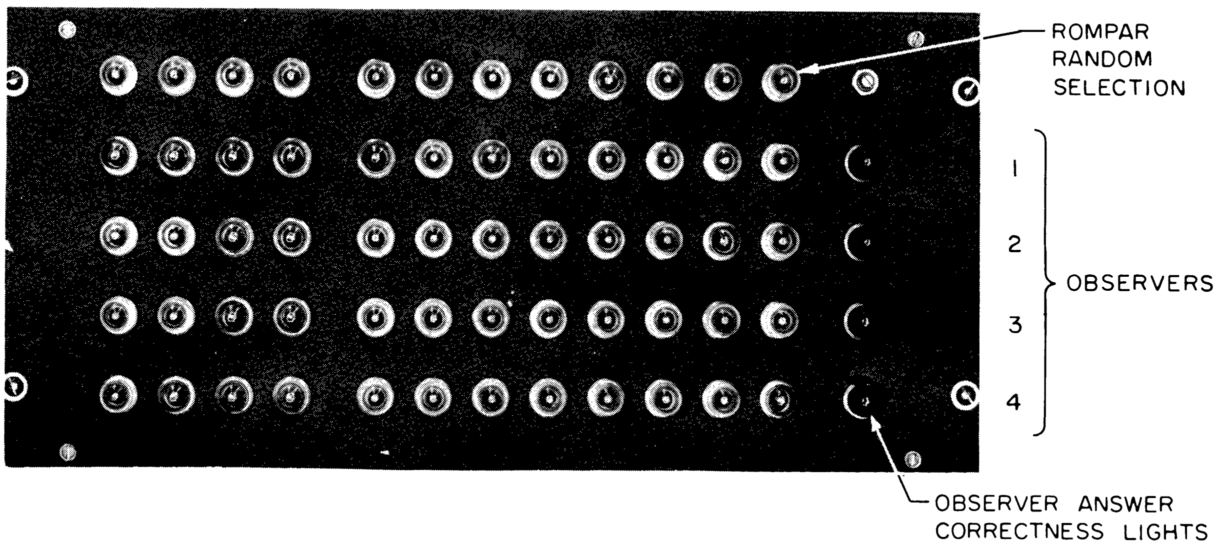


Fig. 40. Typical circuit for lock-out and storage of observer's answer.



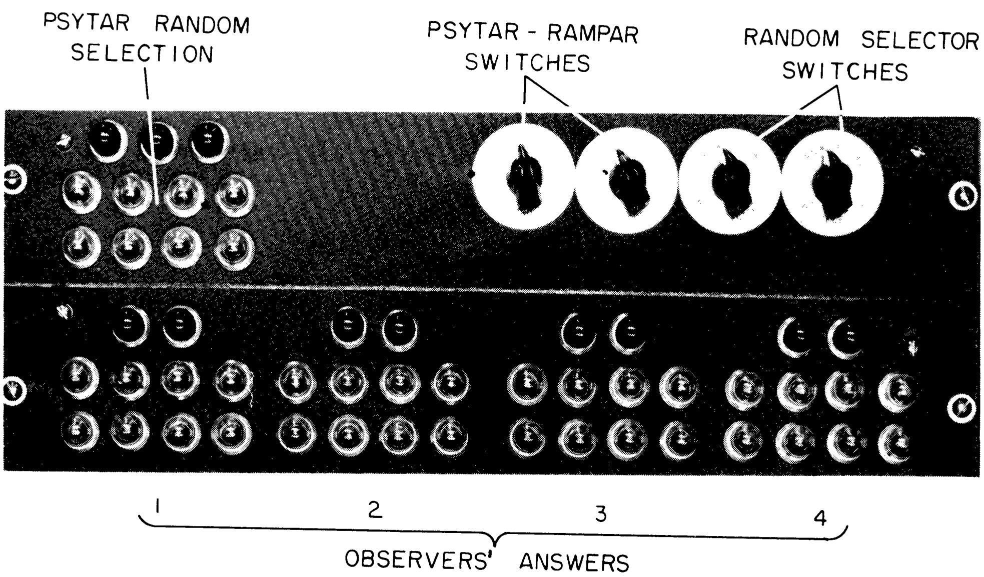


Fig. 41. Psytar answer-light panel.

lock-out circuits. At the input to the first set of answer correctness sensing relays, a switch is provided to connect the circuit to any one of the three random selectors, and similarly for set 2. These are switches SW-3 and SW-4 in Fig. 7 (Appendix B). A simplified circuit of the correct answer sensing circuit is shown in Fig. 42.

If observer 1 operates button 1 of set 1, then his correct answer relay set 1 answer 1 is operated, and if the correct answer is 1 then a closed circuit will exist from the +100 vcd to the C. A. counter and the two answer correctness lights. If SW-1 is in position 1 then the C. A. counter and the answer correctness lights are operated. For the observer to have a correct answer recorded it is necessary that his answer be the same as the random selector's selection.

The simplified circuit of Fig. 42 does not show the selector switch, located between the correct answer relays and the counters and lights, which allows a change from forced-choice to yes-no data recording. A block diagram is shown in Fig. 43. A simplified circuit of the switch is shown in Fig. 44.

The remaining blocks in Fig. 29 relate to the IBM machine. Information relating to the use of IBM machines for recording may be found in "Automatic Recording and Reading of Digital Data Using IBM Summary Punches" put out by IBM. This booklet contains much valuable information on the IBM 523 summary punch. Briefly, the requirement for punching a hole at a given point on the card is that a closed circuit be provided at the proper point in a 12 x 80 matrix. Therefore, a floating contact set must be provided for every possible hole that is to be punched in the card. The 523 can be wired to duplicate information from one card to the next. Also, IBM provides a counter which is used

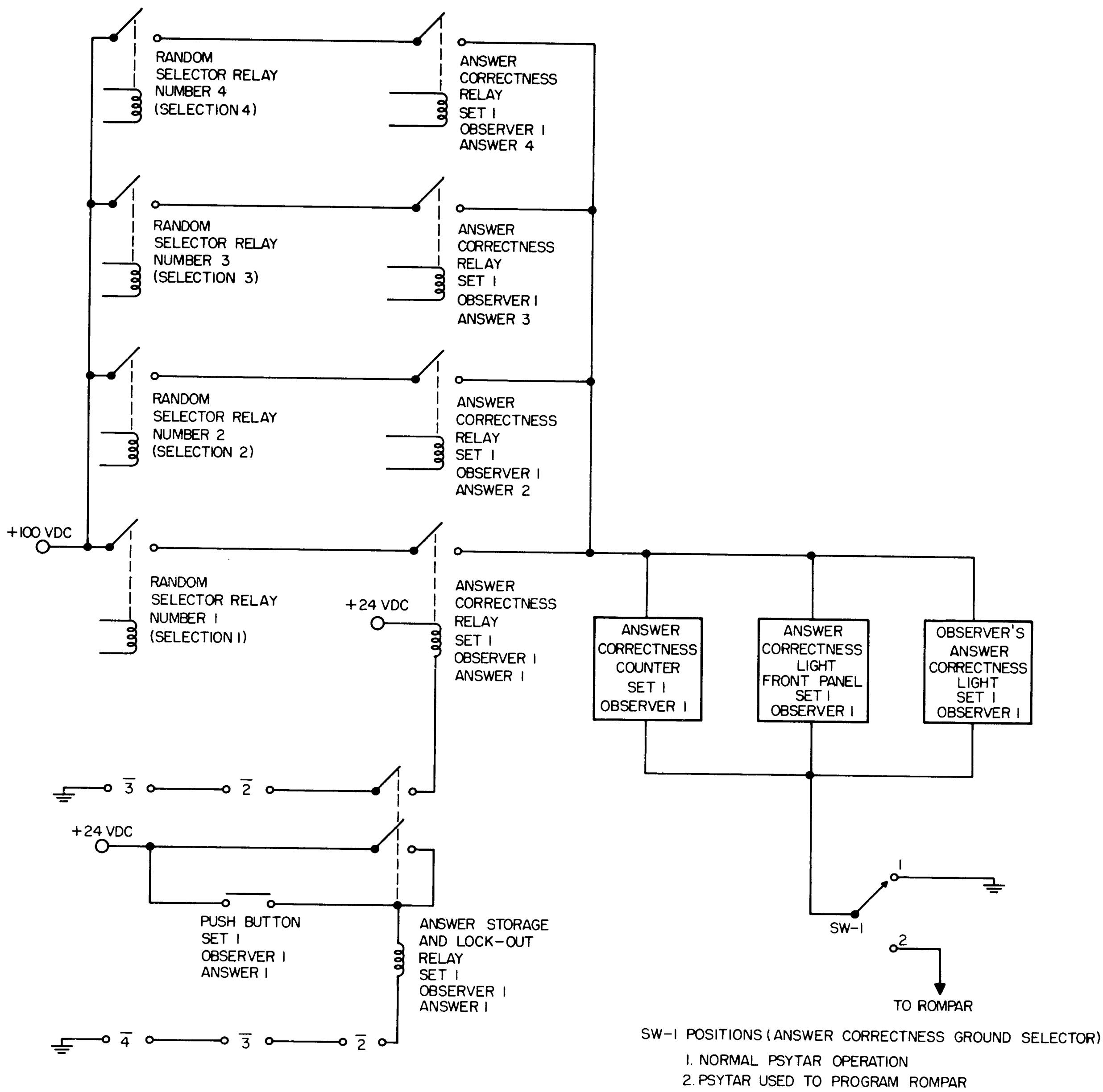


Fig. 42. Simplified circuit for the observer answer-correctness-sensing circuit.

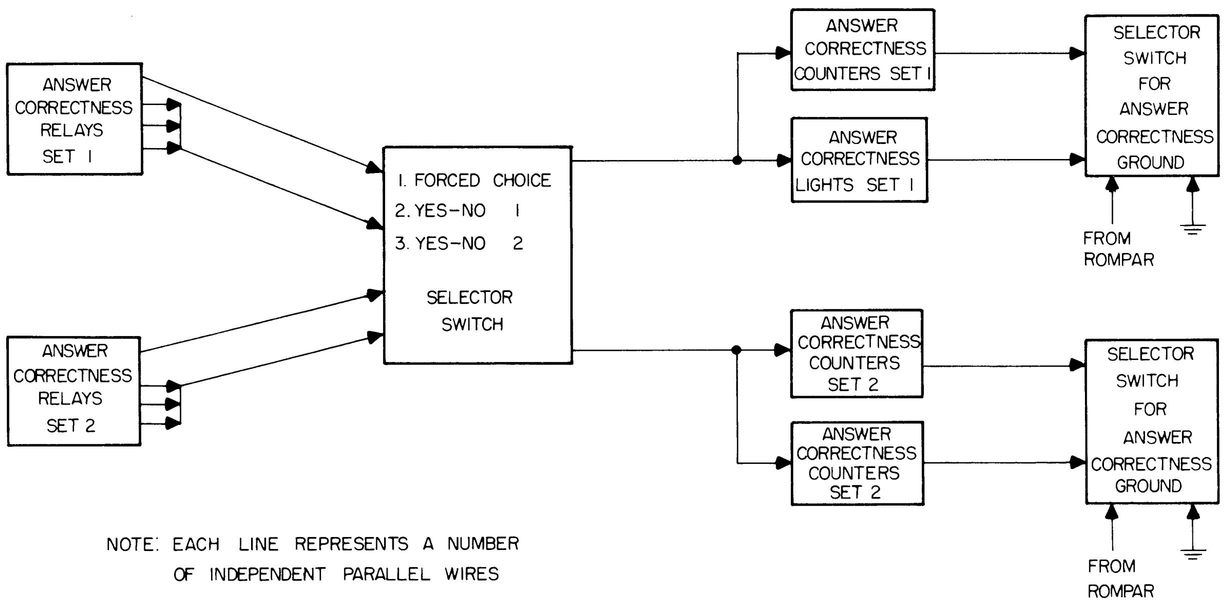


Fig. 43. Block diagram for selector switches for answer correctness counters and lights.

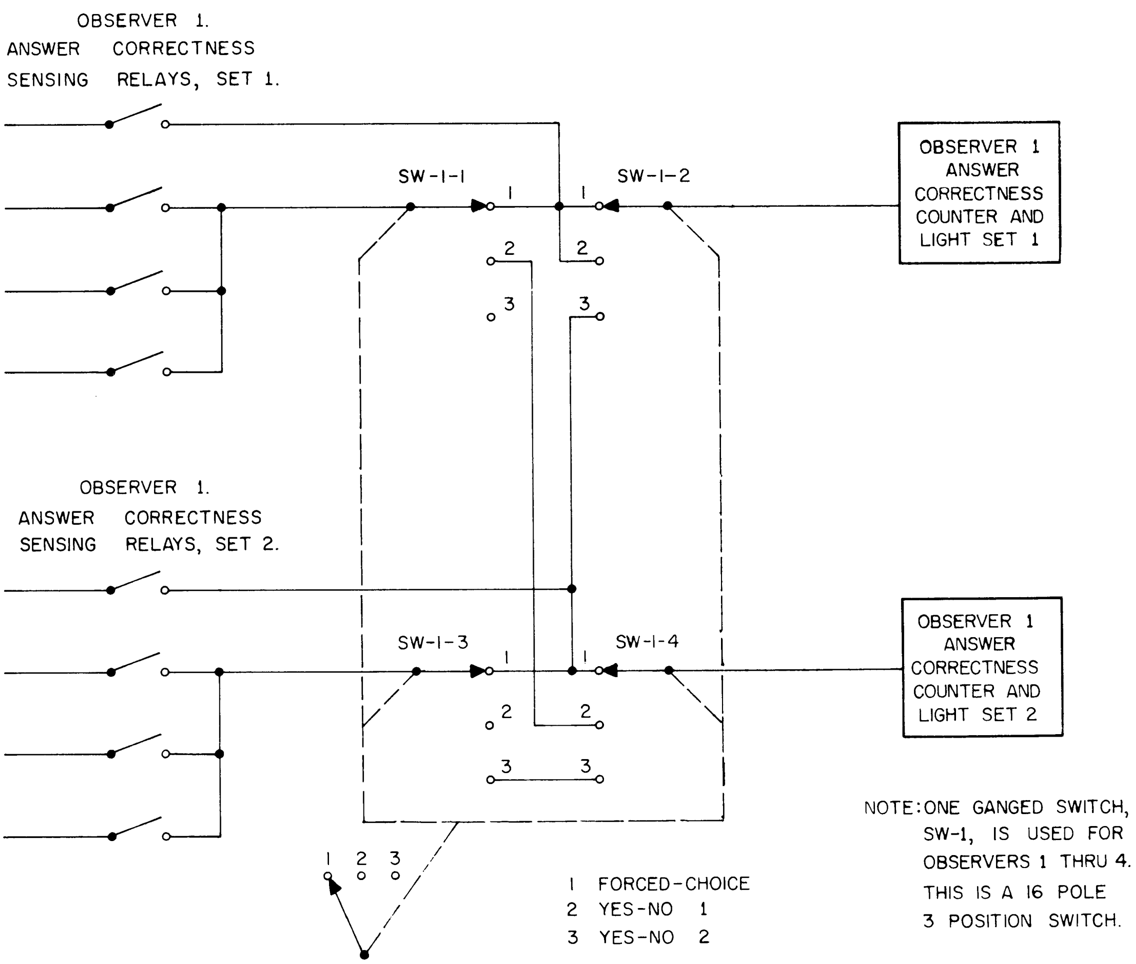


Fig. 44. Answer correctness data selector switch (shown for observer 1 only).

to supply the card number.

The information in columns 1 through 11 is punched by a manual IBM card punch on a master card. This card is then used at the start of an experiment, and this information is duplicated from one card to the next. All other information, except columns 78, 79, and 80, requires one relay for each possible hole. Columns 78, 79, and 80 are punched by the IBM card counter. Recording of the selections from the random selectors requires 24 relays. Figure 45 is a simplified circuit for recording the random selections on an IBM card. This circuit merely takes the standard random selector output and transforms it to a set of floating contracts.

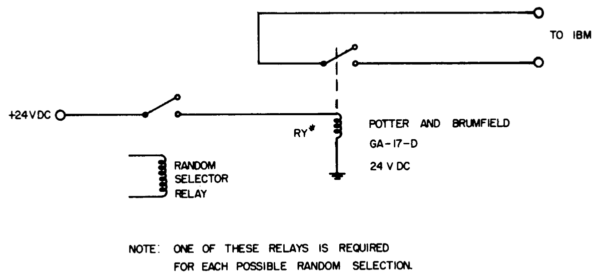


Fig. 45. Simplified circuit for recording the random selections on an IBM card.

To record the observers' answers 40 relays are required. A simplified circuit for one relay is shown in Fig. 46. A hold circuit is used on this relay in order to store this information from interval 7 through interval 8.

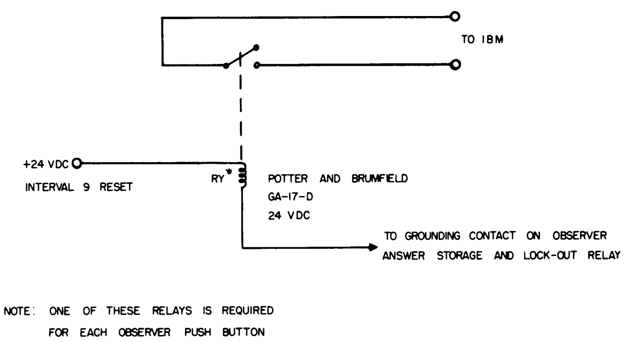


Fig. 46. Simplified circuit for recording the observers' answers on the IBM card.

6. WARNING INFORMATION

6.1 Block Diagram

The block diagram for the warning information equipment is shown in Fig. 47. Three bits of warning information must be presented to the observers in each trial cycle: (1) trial warning, (2) coincidence warning during the possible signal times, (3) record answer warning. The warning information may be presented in either of two ways: visually or aurally.

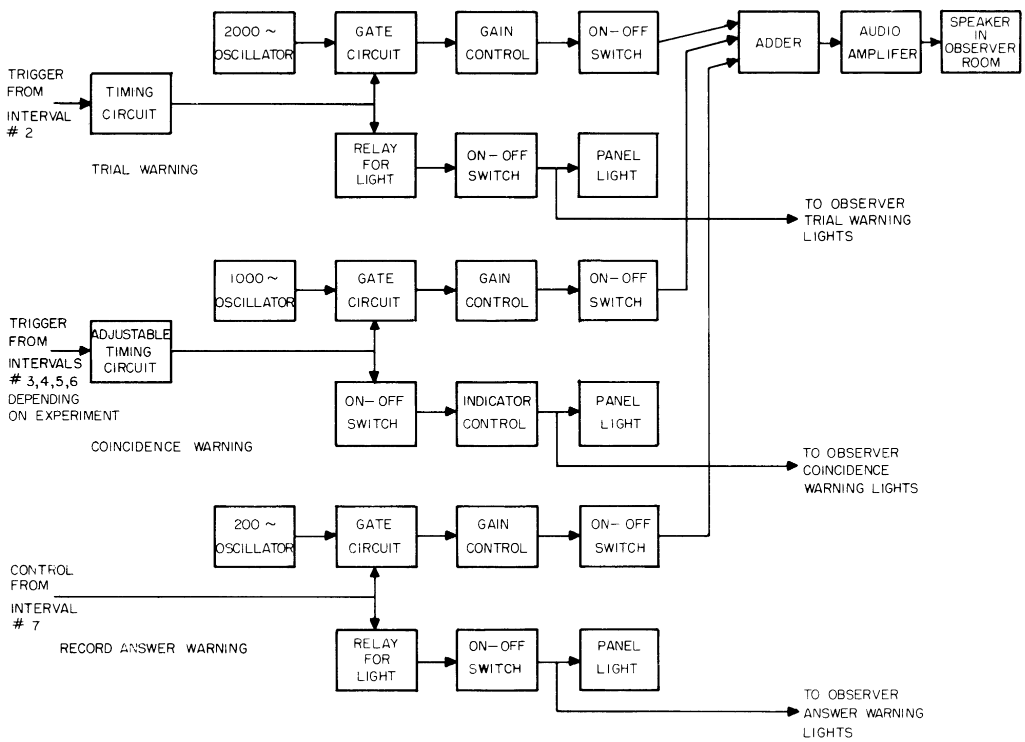


Fig. 47. Block diagram of warning information equipment.

For visual presentation of warning information, each observer has three indicator lights, one for each bit of information (see Fig. 32).

For aural presentation of warning information a common speaker is used, and the three separate bits of information are identified by three tones of different frequencies.

The trial warning information is presented for about 0.1 second at the beginning of interval No. 2. Both the tone and light circuit relay are operated. The output is determined by the respective on-off switches.

The coincidence warning information circuit is similar except that an adjustable duration control is provided.

The answer warning information circuit is required throughout interval 7. For auditory warning an adder combines the three warning signals. The output of the adder is amplified and fed to the speaker.

6.2 Inputs and Outputs

The inputs to the warning information circuit are all derived from the master timing generator. The trial warning circuit is triggered from the positive output pulse of interval No. 2 (output D). The coincidence warning circuit is triggered from the four intervals 3, 4, 5, and 6. These inputs are coupled through diodes to reduce loading on the other intervals. The record answer warning circuit is coupled directly from interval 7, output D.

The visual output consists of three lights. The left light is the trial warning indicator. The center light is the coincidence warning indicator. The right light is the record answer warning indicator. The auditory output is 2000 cps for trial warning, 1000 cps for coincidence warning, and 200 cps for record answer warning.

6.3 Schematic Diagrams

The complete schematic for the warning information chassis is shown in Appendix B. Simplified circuits for the three signal sources are shown in Figs. 48, 49, and 50. A simplified diagram for an observer's

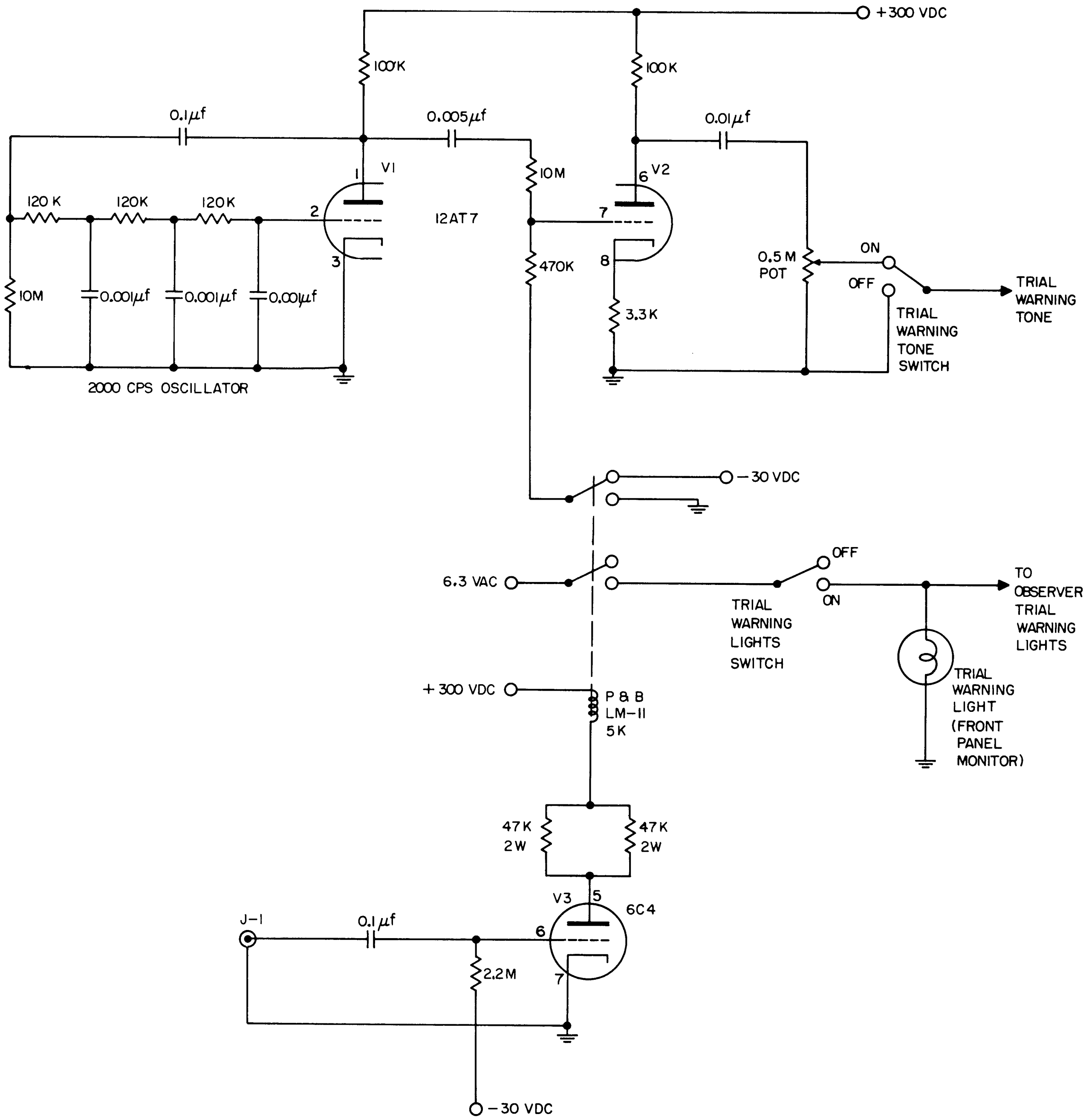


Fig. 48. Simplified schematic diagram of the coincidence warning circuit.

indicator chassis is shown in Fig. 51. The complete schematic, including the interconnecting wiring diagram is shown in Appendix B. The remainder of this section is devoted to a brief description of the simplified circuits.

The simplified schematic for the trial warning circuit is shown in Fig. 48. This circuit must provide a warning information signal for a duration of approximately 0.1 second, beginning at the start of interval 2. Either one of two signals must be produced, a

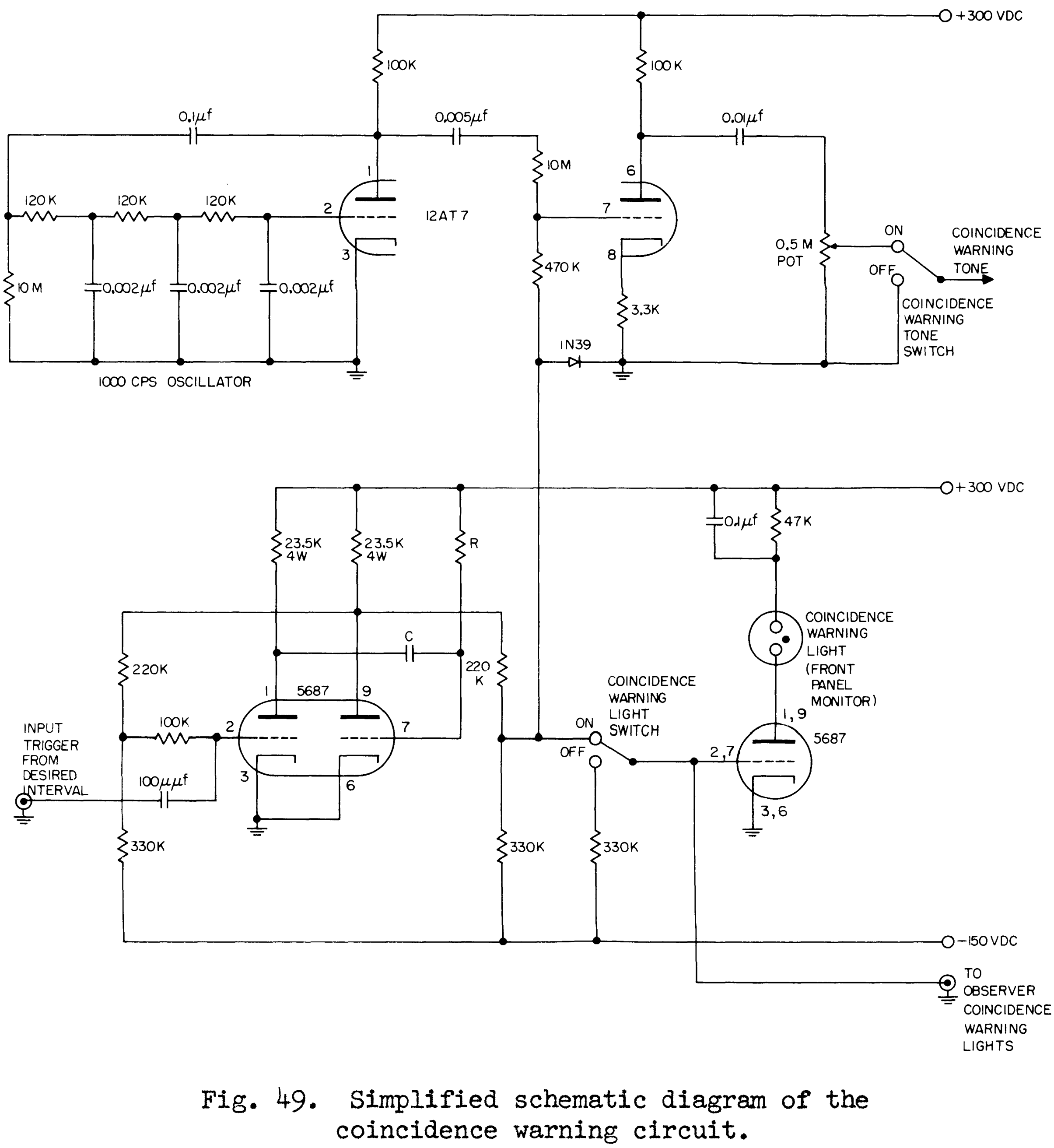


Fig. 49. Simplified schematic diagram of the coincidence warning circuit.

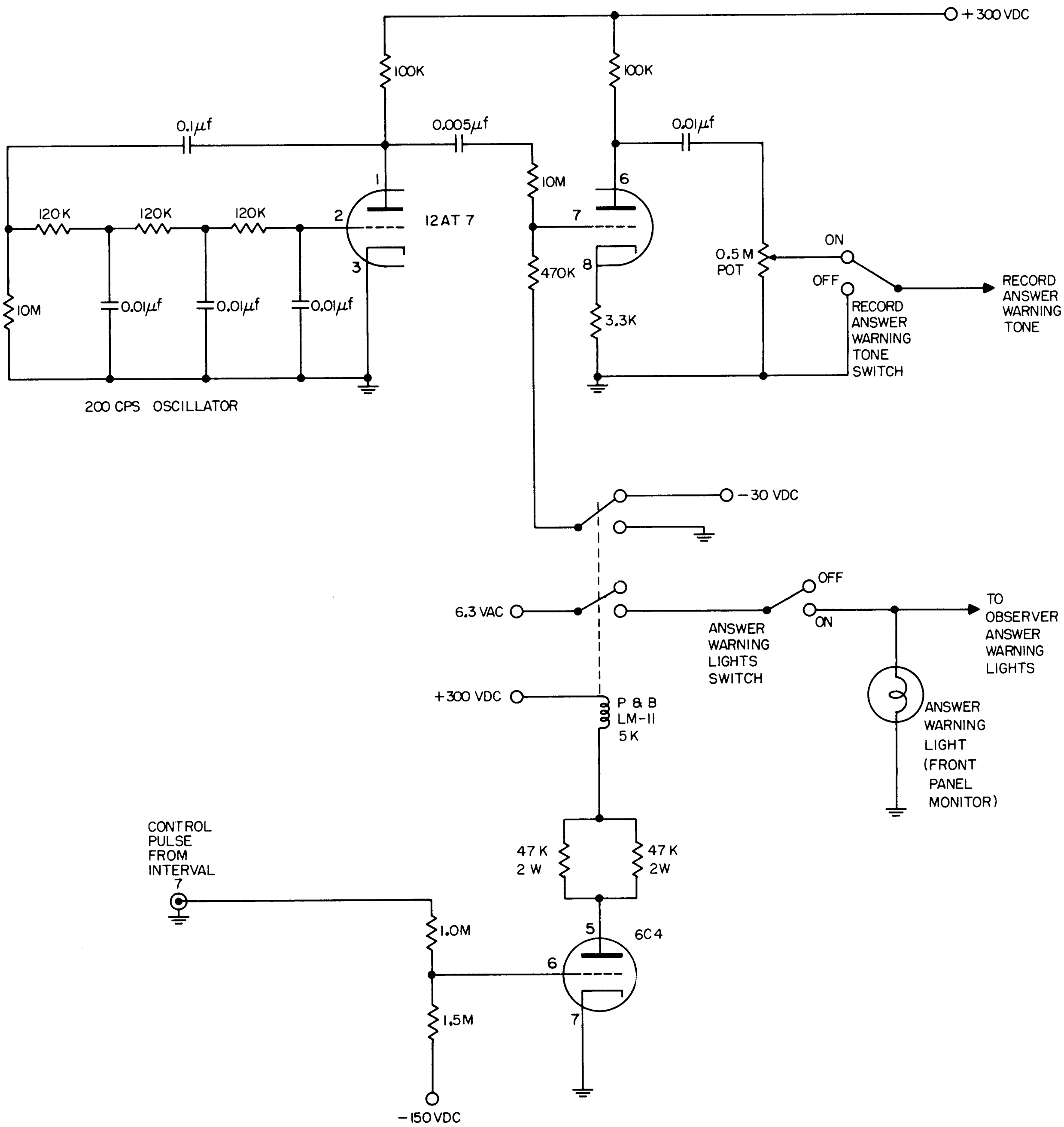


Fig. 50. Simplified schematic diagram of the answer warning circuit.

2000-cps tone or an energized light bulb. The duration control is obtained as follows: A rectangular waveform of a minimum duration of 0.5 second is applied to the input of J-1 from interval No. 2. This turns on V-3, and V-3 remains on until the 0.1-μfd capacitor discharges sufficiently.

This takes approximately 0.1 second. V-3 in its "on" state energizes the IM-11 relay. If visual warning is required, then the lower closed contact energizes the observer light bulbs. If auditory warning is required, then the upper relay contact turns on the audio signal source. The audio portion works as follows: The circuit associated with V-1 is an RC phase-shift oscillator. This is always operating. V-2 is a gated audio amplifier. Normally V-2 is cut off by a -30 v bias. When the relay is energized this bias is reduced to near zero, bringing V-2 into its amplifying state.

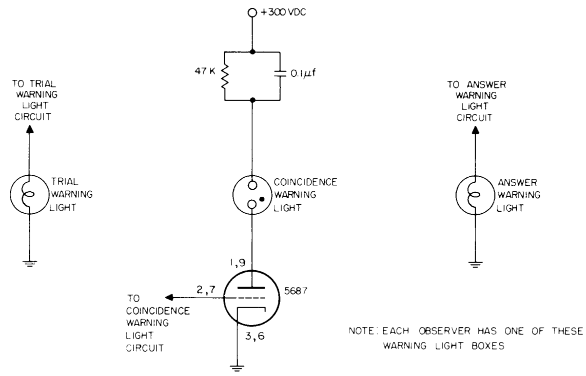


Fig. 51. Simplified circuit for the observer visual warning information box.

The simplified schematic for the coincidence warning circuit is shown in Fig. 49. This circuit performs basically the same function as the preceding one. The major difference is that for coincidence warning the duration must be adjustable over a wide range of times. The time duration in this circuit is determined by a single-shot multivibrator with R and C being the two parameters adjusted. The light source for visual warning must respond to short durations, therefore a neon bulb in series with a parallel combination of resistance and capacitance is used. Because of the high initial current through the neon bulb, darkening of the envelope will occur within about three months. At intervals of about 3 months the bulbs should be replaced. The audio section differs from the trial warning circuit in that the frequency is 1000 cps, and the gating is controlled by a dc signal from the single-shot multibibrator instead of a relay contact.

The simplified schematic for the answer warning circuit is shown in Fig. 50. There is essentially no difference between this circuit and the one of Fig. 48 except that the oscillator is 200 cps and the IM-11 is energized during the entire interval 7.

Figure 51 is a simplified diagram of the Observer Visual Warning Information Box. Note that a control tube for the coincidence warning light is provided in each observer box.

APPENDIX A

TIME DISTRIBUTION OF PULSES

Assume a source with the time between pulses exponentially distributed. Then the distribution for the time between a pulse and the Nth subsequent pulse is given by

$$f(t) = \frac{t^{N-1} e^{-t}}{(N-1)!} \qquad t > 0 .$$

The mean value of this distribution is N, and the standard deviation is $\sqrt{N}$. Consider t to be a normalized variable. For real time calculations let t' = kt where t' is the real time variable and K is a multiplying factor. The ratio of standard deviation to the mean of a distribution remains constant when scaling is performed. Thus, if the mean value, $\mu_{t'}$, of f(t') (in real time) is known, then in real time the standard deviation is $\sigma_{t'} = \mu_{t'}/\sqrt{N}$. Curves of f(t) for four values of N are shown in Fig. A.1. Note that for N = 10 the curve begins to approximate a normal distribution.

The curve for N = 10 may be obtained readily in a practical circuit by feeding the pulses from a source with an exponential distribution to a decade counter. Then the output pulses from the decade counter will be distributed according to f(t) for N = 10.

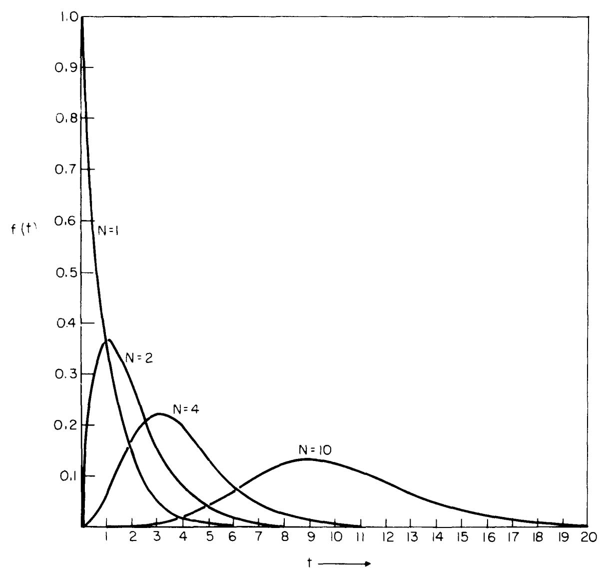


Fig. A.1. f(t) for four values of N.

APPENDIX B

CIRCUIT DIAGRAMS FOR N. P. PSYTAR

Physical limitations prohibit the inclusion of these diagrams in this volume. They are available, however, on request.

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