

# A Mind-Reading (?) Machine\*

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This machine is a somewhat simplified model of a machine designed by D. W. Hagelbarger. It plays what is essentially the old game of matching pennies or "odds and evens." This game has been discussed from the game theoretic angle by von Neumann and Morgenstern, and from the psychological point of view by Edgar Allen Poe in the "The Purloined Letter." Oddly enough, the machine is aimed more nearly at Poe's method of play than von Neumann's.

To play against the machine, the player should guess out loud either "right" or "left." The center button of the machine is then pressed and the machine will light up either the right or left light. If the machine matches the player, the machine wins, otherwise the player wins. The player should then move the key switch in the direction corresponding to the choice he made. The machine will then register a win for the machine or the player, as the case may be, by shooting a ball into the proper glass tube. The overall score against all players since the machine was started is shown on the two counters visible through the front panel.

## The Strategy of Operation

Basically, the machine looks for certain types of patterns in the behavior of its human opponent. If it can find these patterns it remembers them and assumes that the player will follow the patterns the next time the same situation arises. The machine also contains a random element. Until patterns have been found, or if an assumed pattern is not repeated at least twice by the player, the machine chooses its move at random.

The types of patterns remembered involve the outcome of two successive plays (that is, whether or not the player won on those plays) and whether he changed his choice between them and after them. There are eight possible situations and, for each of these, two things the player can do. The eight situations are:

1. The player wins, plays the same, and wins. He may then play the same or differently.
2. The player wins, plays the same, and loses. He may then play the same or differently.
3. The player wins, plays differently, and wins. He may then play the same or differently.
4. The player wins, plays differently, and loses. He may then play the same or differently.
5. The player loses, plays the same, and wins. He may then play the same or differently.
6. The player loses, plays the same, and loses. He may then play the same or differently.
7. The player loses, plays differently, and wins. He may then play the same or differently.
8. The player loses, plays differently, and loses. He may then play the same or differently.

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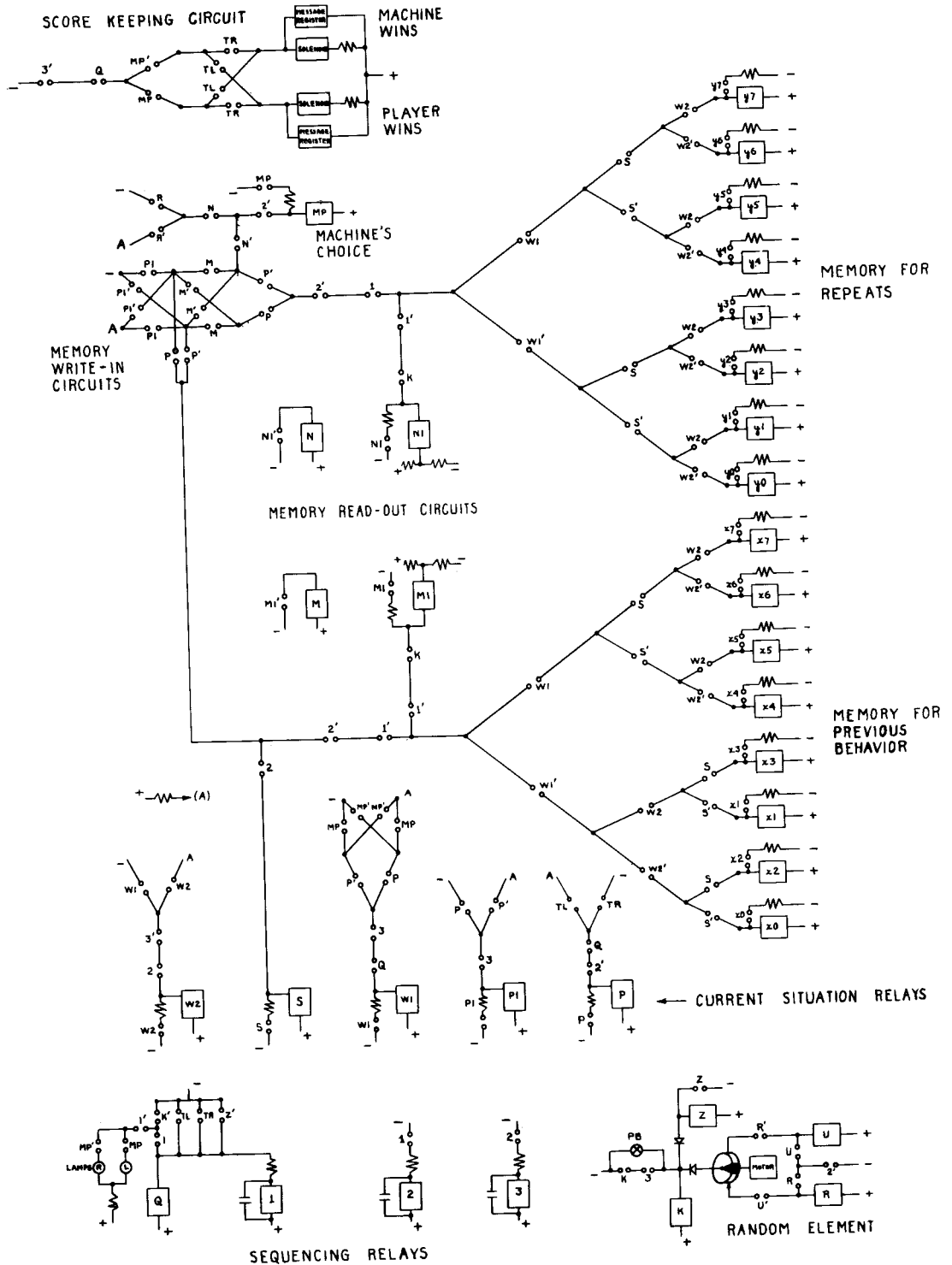
\* Bell Laboratories Memorandum, March 18, 1953.

Each of these corresponds to a different cell in the memory of the machine. Within the cell two things are registered: (1) whether, the last time this situation arose, the player played the same or differently; (2) whether or not the behavior indicated in (1) was a repeat of the same behavior in the next preceding similar situation. Thus consider the situation win, same, lose. Suppose that the last time this situation occurred in the game the player played "differently". Then "differently" is recorded in the (1) part of this memory cell. If the preceding time this situation arose the player also played "differently", the (2) part of the memory cell registers this as a repeat. The machine will assume, should this situation arise again, that this is a definite pattern in the player's behavior and will play correspondingly. If the player has not repeated, the machine plays from its random element. The memory cells are always kept up to date. A particular memory cell, for example, will change from one prediction to the opposite in two repetitions of the corresponding situation.

A mathematical analysis of the strategy used in this machine shows that it can be beaten by the best possible play in the ratio 3:1. To do this it is necessary to keep track of the contents of all the memory cells in the machine. The player should repeat a behavior pattern twice, and then when the machine is prepared to follow this pattern the player should alter it. It is extremely difficult to carry out this program mentally because of the amount of memory and calculation necessary.

The ball counter used in this machine for score keeping is an application of the conservation of momentum principle. If a ball is struck against a stationary row of equal balls, the momentum of the first ball is transferred down the line and the last ball in the row moves off with the velocity of the original striking ball. In this counter the momentum is transferred through a row of up to fifty balls!

The random element in the machine is actually a commutator rotating at about 10 revolutions per second. Two brushes separated by  $180^\circ$  bear on this commutator. A copper segment of the commutator contacts the brushes alternately. When the button is pressed and a random choice is to be made, the first brush contacted by the commutator determines whether the choice be "right" or "left". Basically, therefore, the randomness of the device depends on the uncertainty of the interval between moves, the variation of which due to human variability is typically large compared to the tenth of a second period of the commutator.



"MIND READING" MACHINE