nibal circuits are closed when any two missionaries are opposite the third missionary. Circuit 1 [*Fig. 170*] conducts when any two or three cannibals are on one side of the river. It also shows which side they are on. Circuit 2 [*Fig. 171*] similarly indicates when all three cannibals are on the same side of the river and which side they are on. In combination, the three configurations register all the possible trouble situations: (1) when all three cannibals are on the same side with just two, any two, missionaries, (2) when any two or three cannibals are on the same side with a lone missionary.

5

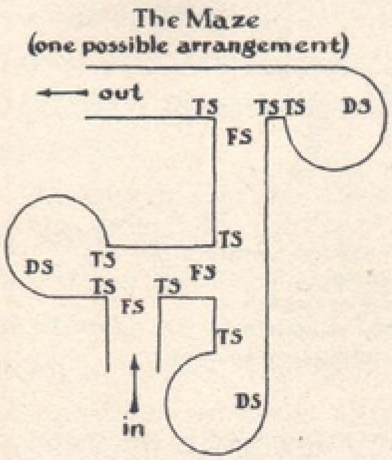
AN ELECTRONIC MOUSE THAT LEARNS FROM EXPERIENCE

Harry Rudloe describes his variation on Claude Shannon's celebrated robot. Rudloe's mouse can scarcely be called a thinking creature, but it demonstrates that, with a few hand tools and junk parts, the amateur can design and build a machine capable of exercising choice and profiting from experience

After constructing a variety of games and puzzles with built-in "intelligence," I became interested in the problem of designing a machine with the ability to learn from experience and apply its acquired knowledge in avoiding future mistakes. Claude Shannon's famous "mouse," which investigates a maze and learns how to avoid blind passages by trial and error, fascinated me and I decided to have one of my own.

His mouse is a simple bar magnet enclosed in a mouse-shaped covering and equipped with copper whiskers which "ground" the mouse upon contacting the brass walls of the maze. It is moved by other magnets concealed beneath the maze. Its "brain" is located outside the maze. I wanted a self-contained mouse – even if that meant building him the size of a jack rabbit.

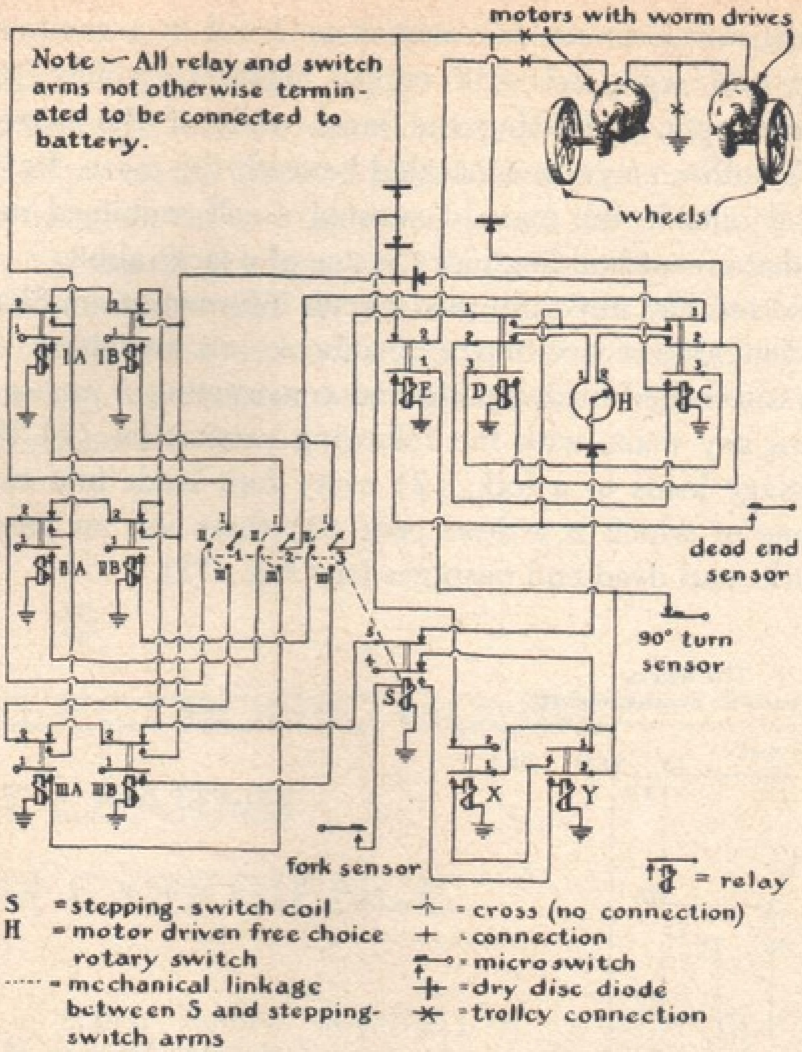
I could not find any published circuit information on Shannon's mouse, but after consulting a few books on switching systems I finally succeeded in designing and constructing a mouse which can learn any maze with the following properties: (1) the correct passage leads to a fork; (2) every fork leads into two passages, one of which is a dead end; (3) there are no more than three forks and dead-end passages [*see Fig. 172*].



172
Mouse maze showing location of sensing switches (trolley omitted)

This last limitation was imposed by the size of my pocketbook, for the cost goes up with the complexity of the maze and the necessary increase in the mouse's memory capacity. Cost also prevented my mouse from being completely self-contained; its power supply and brain are located outside the maze.

The mouse is powered by two motors, each driving a front wheel, as shown in Figure 173. Its rear is supported by two contact shoes which slide over a pair of electrically independent metal strips fastened to the floor of the maze. One strip serves as a ground return. The other strip supplies juice to one of the motors; the second motor gets its power by way of a trolley fastened



173
Circuit of mechanical "mouse" that learns by experience to run maze

to the ceiling of the maze. Information is transmitted from the brain to these motor "muscles" through the conducting strips.

Steering is accomplished by cutting off power to one or the other of the driving wheels, as in the case of tread-equipped tractors and bulldozers. Friction against the sides or walls of the maze is reduced by mounting rubber wheels on each side of the mouse. They also help the mouse negotiate dead-end passages. These dead ends terminate in circular or "cheesebox" walls which force the mouse through a 270-degree turn. By pivoting an additional 90 degrees the mouse can leave the dead-end passage and continue to the next fork without reversing its motors.

If it is to profit from experience, the mouse must be fitted with some means of sensing its environment, of storing this information and of drawing upon it for subsequent use. As a minimum, the creature must be able to count the forks as it proceeds through the maze and remember where it went wrong in the sequence; for instance, if a right turn at fork 2 led to a dead end during the exploratory run, it must remember and go left at the same fork the next time.

This information is sensed by means of three "organs," all composed of microswitches. The first group of microswitches is distributed along the ceiling of the maze – one at the entrance of each fork. This sequence of switches advises the brain whenever the mouse comes to a fork. The second set of switches, mounted on the walls, signals the mouse whenever it arrives at a dead end. The third group of switches, also wall-mounted at the entrance to each straightaway passage, informs the brain that power should be restored to both motors. All switches of each group are wired in parallel.

The mouse's brain consists of three basic elements: "neurons" for remembering (in the form of two relays for each fork), an associative device (a stepping switch) and an element enabling the mouse to choose a fork at random when it does not know which is correct. The heart of the latter element is a motor-driven rotary switch which is alternately conducting and nonconducting.

When the mouse first enters the maze, both of its driving motors receive power through a master relay. The mouse accordingly proceeds to the first fork. Here an impulse from the fork sensor signals the brain. As a result: (1) the master relay cuts off power to the motors; (2) a secondary relay then supplies power to one or the other of the motors, depending upon the position of the rotary switch at the moment; (3) the stepping switch advances to the first set of contacts through which the memory relays are actuated. The mouse, powered by one motor, turns to the right or the left as the chance position of the rotary motor has selected. Now the straightaway sensors advise that a straight passage lies ahead, actuate the master relay and restore power to both motors. The mouse proceeds through the passage.

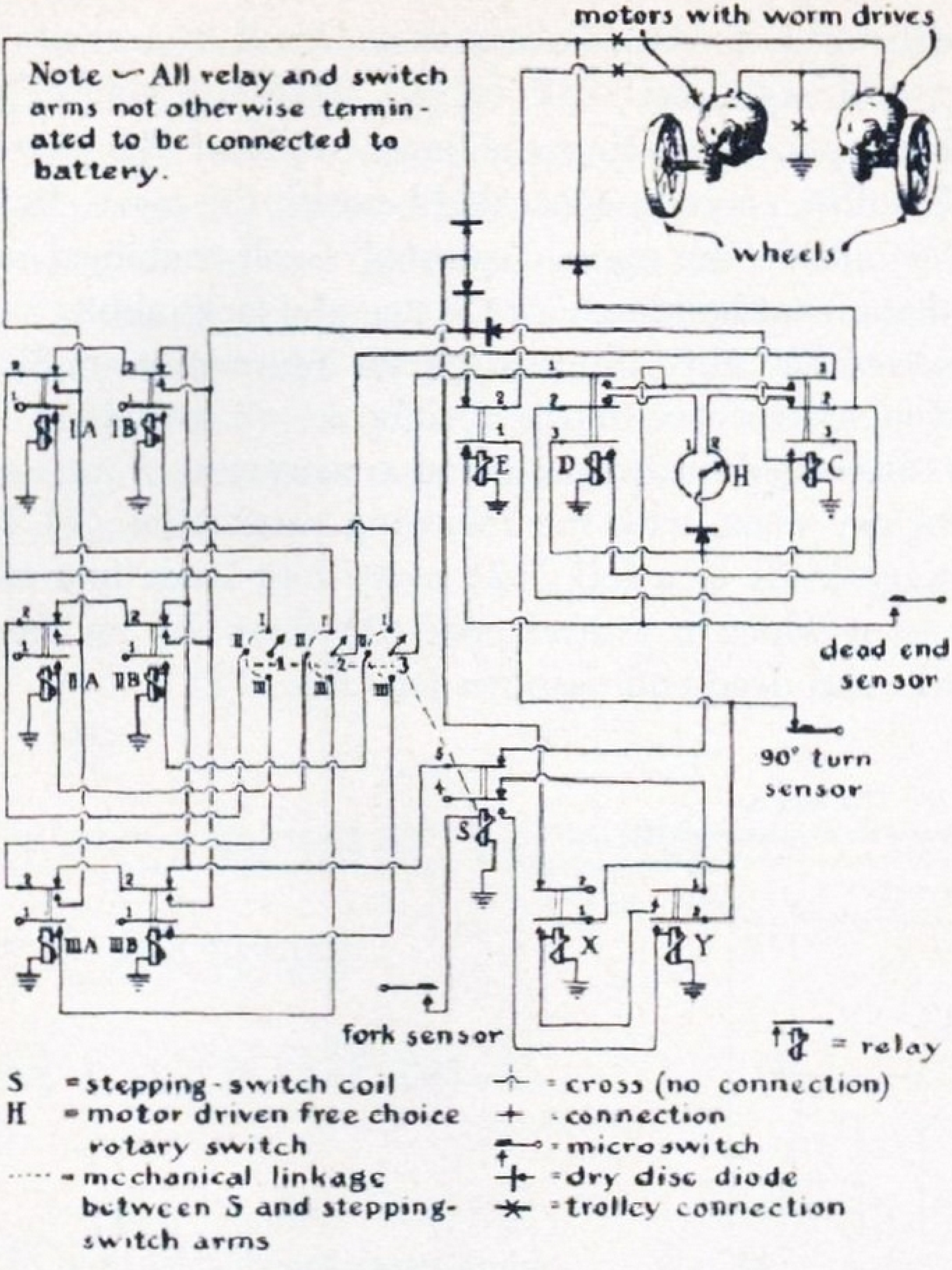
If the mouse reaches a fork at the end of the passage, the cycle of operation repeats. The mouse has learned nothing. If the passage leads to a dead end, however, the memory relays come into action. The dead-end sensor transmits a pulse through the appropriate spring of the stepping switch and thus locks down either a "right-turn" or "left-turn" memory relay. With this information stored, the mouse negotiates the circular wall of the dead end and proceeds to the next fork. The mouse thus learns only from *hard* experience. Chance may lead it through the maze successfully on the very first run. In that case the mouse emerges from the experience as ignorant as though the run had not been made. On the other hand, chance may cause it to explore every dead end in the course of a single run. If it does, the mouse has learned all there is to know: it will never make a mistake again!

The mouse's memory works this way: When it reaches the first fork on a second run, the fork sensor transmits an impulse which advances the stepping switch to the first set of contacts and trips the master relay, cutting power to both motors. If neither relay is locked down, the mouse chooses at random. But if one relay is locked, its break contact inactivates the random-choice circuit, and a set of "make" contacts on the same relay feeds power to the motor that turns the mouse in the correct direction.

6

COMPUTERS AND THE TERROR OF MATHEMATICS

DESPITE THEIR FASCINATION with science, many amateur scientists shudder at the thought of having to use mathematics. Doubtless the rush to embrace the new hobby of building electrical computers may be attributed in part to this aversion to direct mathematical methods. Many who build these machines firmly believe they are working with nonmathematical methods


motors with worm drives
Note — All relay and switch arms not otherwise terminated to be connected to battery.
wheels
IA
IB
IIA
IIB
IIIA
IIIB
E
D
H
C
S
X
Y
dead end sensor
90° turn sensor
fork sensor
= relay
S = stepping-switch coil
H = motor driven free choice rotary switch
= mechanical linkage between S and stepping-switch arms
= cross (no connection)
= connection
= microswitch
= dry disc diode
= trolley connection