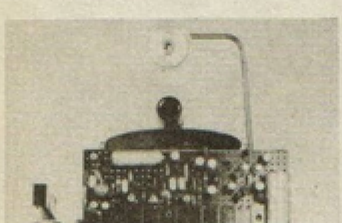
This is the fifth article in the series concerning robots and cybernetic devices, and it continues with the construction of Cyclops.

CYCLOPS

PART FIVE

by

L. C. Galitz



IN THE LAST ARTICLE, CONSTRUCTION of the basic reflexes – reflexes that are instinctive and innate – was discussed. In this article, another type of reflexive response is dealt with; one which is not inborn but is conditioned by the environment – the conditioned reflex.

The first person to study the realms of the conditioned reflex in great detail was Pavlov. In his experiments he would firstly show food to a hungry dog, and measure the amount of saliva produced. Here we have an innate reflex. There is a specific stimulus, which we shall designate Ss, evoking a specific effect, which we shall call Es. After measuring the extent of Es, on the second and subsequent times of feeding, just prior to showing the hungry animal the food Pavlov would present to the animal another stimulus. This second stimulus was a neutral stimulus, having no relevance to the specific stimulus. To the neutral stimulus we shall designate the symbol Sn, and to the effect it evokes we shall designate the symbol En. In Pavlov's experiments, this second stimulus was the ringing of a bell, producing say a pricking up of the dog's ears. Thus the animal would hear a bell and, immediately after this, would be given some food. After about twenty of these coincidences, Pavlov found that on hearing the bell, the animal commenced salivating. In other words, the animal had been conditioned to associate the bell with food.

Pavlov found that in order to build the conditioned reflex quickly, Sn had to be presented a very short time before Ss. He also found that the animal did not produce the conditioned reflex if the bell was rung after the food, or if the bell was rung a long time before the food. He also discovered that in order to maintain the conditioned reflex, the association had to be continually reinforced. It was no use ringing the bell without giving the animal the food; and if the conditioned response was produced it would fade away just as surely if the coincidence of signals never again occurred. Furthermore, if the food was presented without previously ringing the bell, the conditioned response would also fade away, but not as quickly as with the case where the bell is rung without the food.

The conditioned reflex is used with animals extensively today. One often sees an animal at a circus performing a trick and then getting a lump of sugar as a reward. He has been conditioned to associate a correct performance with food. However, we have also seen that some animals go through trick routines without getting a reward. This is accomplished by having two interlinked conditioned reflexes. The animal is given a pat and then receives some food. Hence, it associates a pat with food. Then after performing the trick successfully, it gets a pat, and begins to associate that a good performance means a pat. Thus we now have trick means pat means food, and in order that the animal performs his routine correctly without having to feed it in the circus ring, all the trainer has to do is pat the animal after the trick. This process is known as establishing a second-order-conditioned-reflex.

So far, we have dealt with conditioned reflexes where success means reward. There is another variety where failure means punishment. An example of the latter variety is where a crack of the whip follows an animal's misbehaviour, and all reflexes built up where the second stimulus is painful are known as defensive reflexes. With these defensive reflexes, often one association where the second stimulus is more than just discomfort is sufficient to establish a conditioned response, and it often never needs reinforcing.

BLACK BOX ANALYSIS

We can imagine the conditioned reflex unit in animals as a little black box with two inputs, Ss and Sn, and two outputs, Es and En. Normally there are two transmission lines inside; one joins Ss to Es, and the other joins Sn to En. After conditioning, the second transmission line breaks, and reforms to connect Sn to Es. The main problem in synthesizing a conditioned reflex black box is designing the 'bookmaker' which decides when two inputs are associated or not. The way in which our 'bookmaker' works will be described next. (The term 'bookmaker', employed by Dr. W. Grey Walter in his book 'The Living Brain', is applied here to a circuit which tries to work out whether conditioning is profitable or not).

Firstly, we must differentiate Ss and contract it. When our animal is feeding, there is a long output from its food detectors to the input of the black box, and this must be made of short duration. Contrary to this, the second step is to extend Sn from the short period the bell rings, to a much longer period, for it must be 'remembered' for a while. The third stage compares the differentiated Ss and the extended Sn. If there is any overlap, the overlap areas are fed to a summer, which

executes the fourth stage of conditioning. The summer thus sums the coincidences between Ss and Sn, and it is also designed to 'leak' its output away very gradually, so that the summer level will fall if Ss and Sn never again coincide. Incorporated in the summer is a device which gives an output once the summer level has reached a critical level – the threshold of learning. It is this output which operates the switching of the transmission lines, and in Fig.24, details of the operations involved are given pictorially. The sections in Fig.24(c) go through a period of conditioning, which then finally becomes inhibited through lack of reinforcement.

BLOCK DIAGRAM

The operations just described must now be converted into electronic circuitry for it to be incoporated into Cyclops, and the block diagram equivalent is given in Fig.25. It will be noticed that both differentiation and extension are carried out by monostables. This is due to the fact that in order to give a sufficiently long pulse to the summer, a capacitor used in a differentiating circuit would have to be of gargantuan proportions. The differential monostable has a quasi-stable time of one second and the extension monostable has a quasi-stable period of seven seconds. The output of each is fed to one input of a 2-input And-gate. Thus, there will only be an output from this coincidence gate when both monostables are in their quasi-stable period. This will only happen if Sn is given within a period seven seconds before Ss, and the gate will not give an output if Sn is given more than seven seconds before Ss, or if it is given after Ss. The output will also be of reduced duration if Sn is given between six and seven seconds before Ss, because the extension monostable will cut off during the period that the differential monostable is in its quasi-stable state.

The output of the coincidence gate goes to a summer which sums the outputs of the gate, and also 'leaks' slightly during the periods that the gate is not giving an output, so that if reinforcement does not occur the summer level drops. The output of the summer is monitored by a Schmitt trigger whose output is normally at logic nought.

It can be seen from Fig.25 that, whenever Ss is applied, the stimulus also travels down the transmission line to an Or-gate which subsequently gives an output to the Es terminal. Thus Ss evokes Es. Similarly, Sn travels down the transmission line to a gate, but this time it is an And-gate. The other input of this And-gate comes from the Schmitt trigger via an inverter, so that when the Schmitt trigger is off, there is a logic one on the upper input of the And-gate, and thus the Sn pulse goes through the gate to the En terminal. At the same time, the

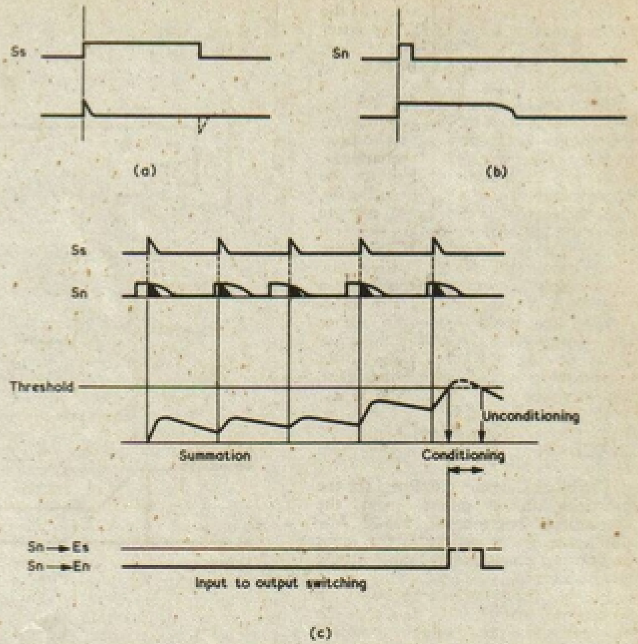


Fig. 24 (a). How Ss is differentiated
(b). The extension of Sn
(c). The creation of the conditioned reflex. Ss and Sn coincide a number of times, causing the summation which appears below them. When the summation characteristic exceeds the threshold level conditioning takes place, with the consequent input to output switching shown at the bottom

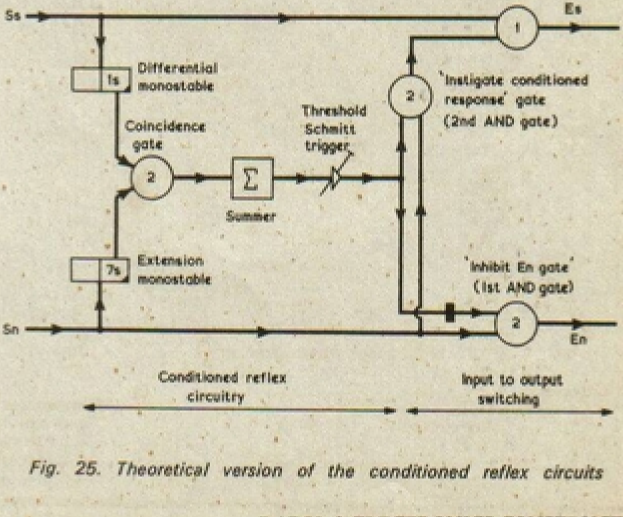


Fig. 25. Theoretical version of the conditioned reflex circuits

Sn pulse goes to another And-gate, whose other input goes directly to the Schmitt trigger; and so when the latter has not fired there will be a logic nought on the And-gate's input, and the second And-gate will not fire.

When the summer level reaches the input threshold of the Schmitt trigger, the trigger fires, making its output change to logic one. Once this happens, there will be a logic nought on the upper input of the first Sn And-gate, and therefore the Sn pulse coming along the lower transmission line will not get through this gate. On the other hand, there will now be a logic one input on the second gate, and when a pulse from Sn comes along the transmission line, there will be an output from this gate which leads to the other input of the Or-gate. Thus, after conditioning, instead of Sn evoking En, it now evokes Es.

THE PRACTICAL BLOCK DIAGRAM

The block diagram employed for the practical model differs from the theoretical diagram of Fig.25, the differences being mainly in the input and output stages rather than with the 'bookmaker'.

Firstly, the conditioned reflex in Cyclops is made to do two jobs. In one mode, the inputs and outputs are switched so that it is allowed to associate magnetism with touch, and

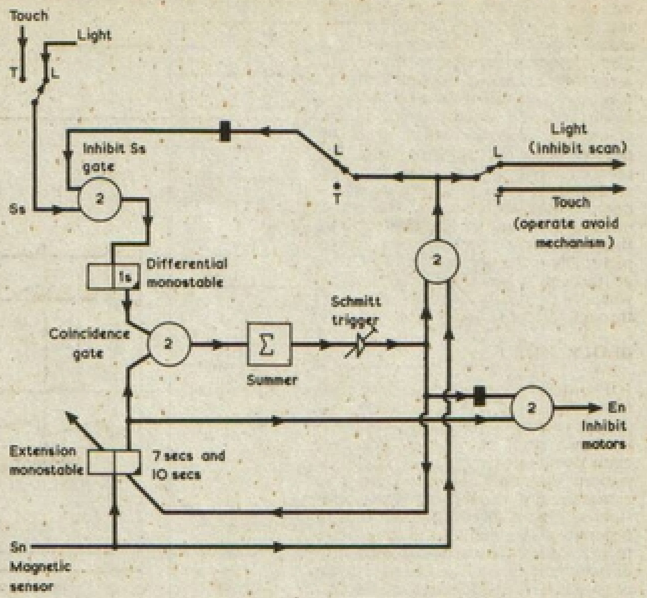


Fig. 26. Practical conditioned reflex unit. Note that the Ss to Es transmission line already exists in the basic circuitry.

COMPONENTS

Resistors

(All fixed values ¼ watt 10%)

R23	1kΩ
R24	2.2kΩ
R25	2.7kΩ
R26	2.2kΩ (see text)
R27	6.8kΩ
R28	100kΩ
R29	2.7kΩ
R30	1kΩ
R31	1kΩ (see text)
R32	2.7kΩ
R33	100kΩ
R34	15kΩ
R35	15kΩ
R36	2.7kΩ
R37	1kΩ
R38	4.7kΩ
R39	22kΩ
R40	10kΩ
R41	470Ω
R42	4.7kΩ
R43	56kΩ
R44	1kΩ
R45	1kΩ
R46	56kΩ
VR4	10kΩ potentiometer, preset skeleton

Capacitors

C6	0.05μF
C7	125μF electrolytic, 10 V.Wkg.
C8	0.05μF
C9	400μF electrolytic, 10 V.Wkg.
C10	1,000μF electrolytic, 10 V.Wkg.

Semiconductors

TR15–TR18	Any p.n.p. transistor, e.g. OC71
TR19, TR20	2N2926
TR21, TR22	As TR15–TR18
TR23	Any p.n.p. transistor with low leakage
TR24, TR25	As TR15–TR18
TR26, TR27	Any n.p.n. transistor, e.g. AC127
TR28	Any p.n.p. transistor capable of driving relay, e.g. OC81
TR29, TR30	As TR15–TR18
TR31	As TR28
D4	Any silicon diode, e.g. OA200
D5	Silicon diode with high reverse resistance
D6–D9	As D4

Magnetic Sensor

X2	Dry reed switch, R.S. Components type 7RSR (Home Radio Cat No. WS121)

Battery

BY3	6V 225mA/H Deac rechargeable battery (Ripmax Ltd.)

Veroboard, Connector

Veroboard: 0.15in. matrix, 2 × 5in., 13 strips × 33 holes

Connector: Painton 15 pin in-line connector (see text)

Miscellaneous

Tank clip (for securing BY3) (Ripmax Ltd.)
2-off Meccano double brackets, part 11 (see text)
1-off Meccano rod and strip connector, part 212a
1-off Meccano rod, 3½in., part 16.

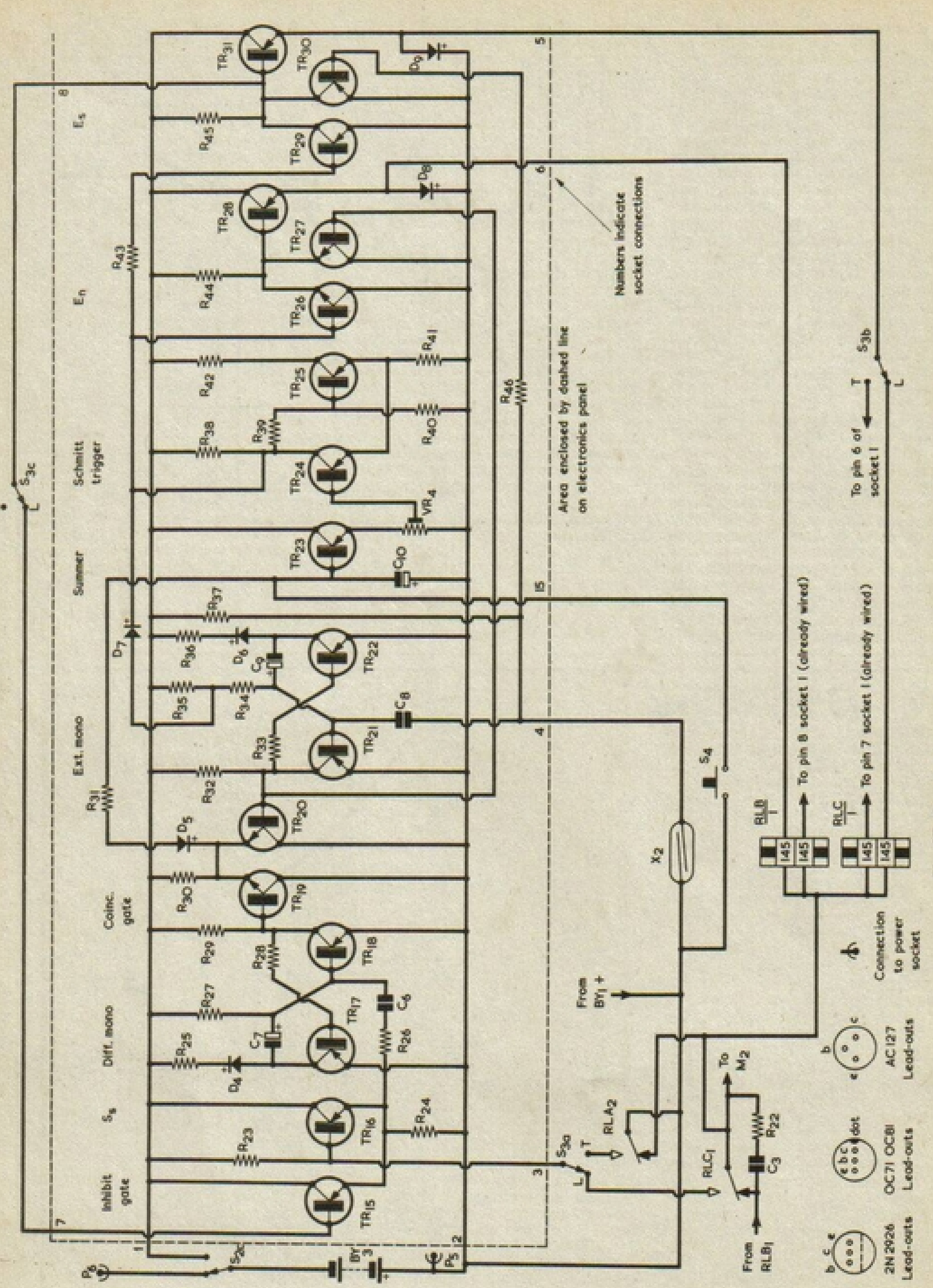


Fig. 27. Circuit diagram for the conditioned reflex unit

in the other mode, the inputs and outputs are switched so that Cyclops has the ability to associate magnetism with light.

An extra gate had to be included because of this since it was found that, when Cyclops was conditioned, giving Sn evoked Es, but in both cases, the action of Es was to produce Ss. Due to the fact that touch means pain in Cyclops, in the 'magnetism means touch' mode, this automatic reinforcement of the coincidence between Sn and Ss is desirable. The conditioning does not need to be reinforced – this being found in real life with defensive reflexes. However, the effect is undesirable with 'magnetism means light' conditioning, and the extra gate temporarily disconnects Ss whilst Es is being evoked in the 'magnetism means light' mode. In the other mode, there is no feedback supplied to the new And-gate via the inverter, and thus Ss is never inhibited, and automatic reinforcement is allowed to take place.

Another modification used concerns what is known as the trace reflex. After conditioning, an animal can allow Ss to occur after a longer period after Sn than before conditioning. Accordingly, the output of the Schmitt trigger alters the time constant of the extension monostable from seven seconds before conditioning to ten seconds after conditioning.

In Cyclops, Sn is always the output from a magnetism sensor. It will be appreciated that strong magnetic fields could upset the operation of Cyclops' circuitry by inducing unwanted voltages in the circuit whilst Cyclops roams around. (In actual fact, extremely powerful fields not normally encountered outside the research laboratory would be required to do this, but Cyclops is only demonstrating the principle involved.) To prevent this, whenever Cyclops encounters a strong enough magnetic field he stops dead to prevent these voltages being induced, and he 'plays possum' for a short while; after a few seconds, he slowly creeps off again. Thus, En is to stop the motors for a while. In the interests of economy, therefore, instead of having a third monostable to do this after the En And-gate, Cyclops uses his extension monostable instead, and the input of the En gate goes to the output of this monostable instead of directly to Sn. The altering of this monostable's time constant bears no relevance, because En is inhibited whenever the monostable runs with a ten second time constant. Fig.26 gives details of the modifications.

Therefore, when Cyclops operates in the 'magnetism means light' mode, in order to establish the conditioned reflex one must apply a magnet to his magnetic sensor, and then shine a light into his eye. After several such coincidences, instead of stopping when one applies the magnet he will continue in the direction he was going when the magnet was applied. He has thus built up the association that magnet means light which is food, and so keep going in the same direction in order to home into the magnet.

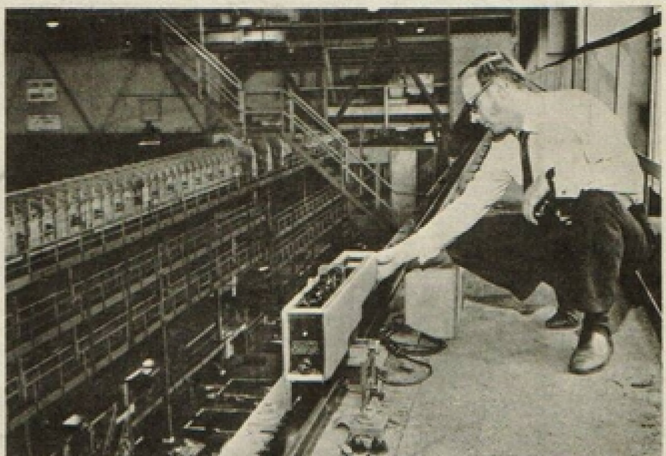
When Cyclops operates in the 'magnetism means touch' mode, to set up the conditioned response one must apply the magnet, which makes Cyclops stop in his tracks for a short while, and then jar his touch sensor, which makes him go through his avoid reflex. After a few coincidences, upon applying the magnet he will immediately start twisting and turning in an attempt to avoid the magnet, because the association that 'magnet means touch' which is pain, and so has to be avoided, has been set up.

CIRCUIT

The circuit for the conditioned reflex unit is given in Fig.27. This will be discussed in the next issue, in which the concluding article in the present series on Cyclops will be given. Also given this month is a Components List showing the additional parts required. Some of these are discussed in detail next month and readers are advised to wait until the appearance of the next article before obtaining any components over which they may have any doubt.

(To be concluded)

'LASER-LINE'



The accompanying photograph illustrates the Marconi-Elliott 'Laserline' in operation at the British Steel Corporation plant in Ebbw Vale, South Wales. The 'Laserline', is produced by Marconi-Elliott Avionic Systems Ltd., a member of GEC-Marconi Electronics Limited.

At the Ebbw Valve works B.S.C. surveyors have, with the aid of the 'Laserline', cut by 80% the time spent in checking the alignment of overhead crane rails. The first survey incorporating the 'Laserline' was of the 700 ft. rails in the No. 2 galvanising line, where 25 ton loads of steel strip are handled by an overhead crane with a span of 90 ft. The rails are 60 ft. above floor level and heat haze makes visual sighting difficult, whereupon survey work could only be carried out previously during the few hours when the plant was not fully operating. There are a score of overhead crane rails in the Ebbw Vale works.

The beam of the 'Laserline' penetrates haze and enables more accurate measurements to be obtained. It can be set up very quickly, so that a survey at Ebbw Vale can now be completed in three hours at any time of the year instead of over several days during the annual shut down period.

The 'Laserline' is a portable laser beam projector designed specifically for field operation, and it provides an accurate linear reference in pipe-laying, tunnel guidance and other civil engineering applications. It is rugged and waterproof, is fitted with a sighting telescope and levelling bubble and operates from a 12 volt battery. The advantages of a laser beam are that, once aligned, it operates unmanned and is not disturbed by people or vehicles passing through the reference line. The 'Laserline' is manufactured by the Neutron Division of Marconi-Elliott Avionic Systems Ltd. at Elstree Way, Borehamwood, Herts. ■