Railway Signaling & Communications

ELECTRONIC INTERLOCKING

This article, describing a British Railways interlocking in which no relays are used in the equipment performing the interlocking function, was prepared for this magazine by *John A. Heald and Gerhard W. Gore.*

A new signaling installation at Henley-on-Thames on the Western Region of British Railways features electronic interlocking equipment in which no relays are used in that part of the installation which performs the interlocking function. It is believed to be the first electronic interlocking plant in service (Dec. 10, 1961) in the world and has been developed by Mullard Equipment Limited. The work is based on research carried out originally at London University's Imperial College.

Early work suggested that the possibilities of using ferrite cores for safety switching circuits should be fully investigated (RSC Sept. 1960, page 19). Work has continued in the meantime on the development of a practical interlocking installation in which the electronic equipment is fed with information regarding the state of track circuits, switches, etc., and emits control signals governing the signaling equipment on the ground.

The installation at Henley-on-Thames consists of a single running line having access to three terminal platforms. The installation is controlled by a mosaic-type control panel operating on the entrance-exit principle. There are 34 routes. The controls for the single line working are slotted with the next interlocking plant at Shiplake, with continuous track circuiting between Henley and Shiplake. The switches and facing point locks at Henley are manually operated by existing levers in the locking frame. There is no mechanical interlocking between the levers, but the levers are electrically locked in accordance with the instructions of the electronic interlocking plant. The track circuits are of the conventional DC type, repeated as necessary at the interlocking. The track relays or track repeat relays supply inputs to the electronic equipment.

To aline a route, the operator or leverman turns the entrance switch and presses the exit button for the route required. If that route is available, the relevant switch levers become unlocked, permitting the leverman to operate the switches to the correct positions. As soon as the switches are correctly positioned, bolted and detected, they become electrically locked. With all other safety conditions fulfilled, the signal governing the route then clears automatically.

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The electronic equipment is housed in the lower floor of the interlocking tower at Henley. The lever frame, which is retained for operating the switches, with the original mechanical interlocking removed, has been partitioned off. The electronic equipment racks have been mounted in a convenient space at one end of the lower floor. No arrangements have been made to provide heating or humidity control. By means of the partitioning, the lever frame with its leading-off rods has been kept in a separate room, so that the electronic equipment may be considered to be in an average type of equipment room, with no special conditioning of the atmosphere.

The electronic equipment is mounted on seven racks of dimensions 7 ft 6 in. high, 1 ft 7 in. wide and 10 in. deep. Six of the racks carry safety interlocking units and the seventh rack carries non-fail-safe units for less vital purposes such as indication, etc. Each rack is enclosed and has double doors at both the front and back. The racks are secured to the floor and ceiling with anti-vibration mountings.

Each rack for mounting safety units has a number of chassis on which there are thirteen vertical rows of sockets and five horizontal rows. The lower portion of each rack is equipped with a signal amplifier. To avoid feeding the 5 kc square wave signal at relatively high energy levels to each rack from a central signal generator, with possible distortion of the wave-shape, the signal is fed at a low energy level to a signal amplifier on each rack. The signal is then amplified to a power level adequate to meet the loading on the rack.

Protection against the AND, NOT, STICK, etc. units being plugged into the wrong socket is provided by a judicious choice of pins for the input and output connections, so that a unit wrongly plugged in would be ineffective.

The units are constructed around a commercially available 12-way plug and socket. Each unit has a color-coded anodized light-alloy cover. Adjacent to the plug-in positions on the equipment racks, colored identification labels indicate the color of the unit which should be plugged into that position. Protection against the insertion of a unit into an incorrect position on the rack, is provided by arranging the termination circuitry so that no output will be obtained from a unit wrongly inserted.

The units are plugged into pre-wired racks which can hold 300 units. A position is kept spare at the end of each row of units and by plugging a specially-designed monitor unit into this space the operation of any of the units in that particular row can be checked. As the units have no moving parts and there is no method of visual observation which can be used to check the operation of the units, this system of monitoring has been devised. The monitoring unit indicates whether a unit is giving an output and by means of a rotary switch, the units for monitoring may be selected.

Where a feed to indication lamps on the control panel is required, which can be regarded as a non-vital circuit, a simpler form of electronic unit is employed. There are seven types of indication unit in service.

At the top of the rack, flexible plastic terminal blocks of the pinch screw type are mounted. Inter-rack wiring and signaling input and output circuits are terminated on these blocks. The conductor of each wire terminated on this type of block is reinforced by a crimped ferrule to avoid damage to the conductor due to overtightening of the pinch screw.

On the units, the use of two phases of the 5kc signal and the DC supply allows a judicious selection of the function of adjacent pins to be made, so that a short between two adjacent pins is not dangerous but only renders the unit inoperative. It is impractical for the rest of the rack wiring to employ this method. In the wiring trees and at the terminal blocks each wire must have full protection from adjacent wires, as a vital safety feature.

Investigations were carried out during the development stage to ascertain whether there would be any significant interference effects between information-carrying wires in large cable trees. Tests on the cable trees used in the prototype model showed no appreciable interference of this kind. No precautions were therefore taken in the manufacture of the equipment racks.

The racks are wired with PVC covered wire having a 1/.036 in. conductor (approximately No. 10AWG). It was not considered prudent to employ a smaller conductor than 1/.036 in. since the mechanical strength of the wire is a factor affecting the security of terminations. The insulation is color coded.

From a technical viewpoint the principal incentive towards the development of a contactless switching system is the elimination of moving parts, which can be achieved with solid state devices. No claim of advantage is made in respect of the higher speeds of switching which are possible using electronic techniques. It is considered that there is no real requirement in the interlocking function for higher switching speeds than can be obtained with existing relay techniques. It is, therefore, the possibility of reduced maintenance effort that attracts, with the hope that the rate of deterioration of the electronic components will be so negligible that the installation may be obsolete for other reasons before the electronic units require overhaul.

From the economic viewpoint, the advantages of contactless switching are that it offers the possibility of using standard electronic components which are mass-produced for other industrial applications. Cost trends for electronic components tend to be downwards, as they are required for a wide and expanding market, and relays with a relatively high labor content in their manufacture are thought to have small prospects of cost reduction. The small physical size of electronic units is another advantage which should have the indirect effect of reducing the cost of housing the equipment.

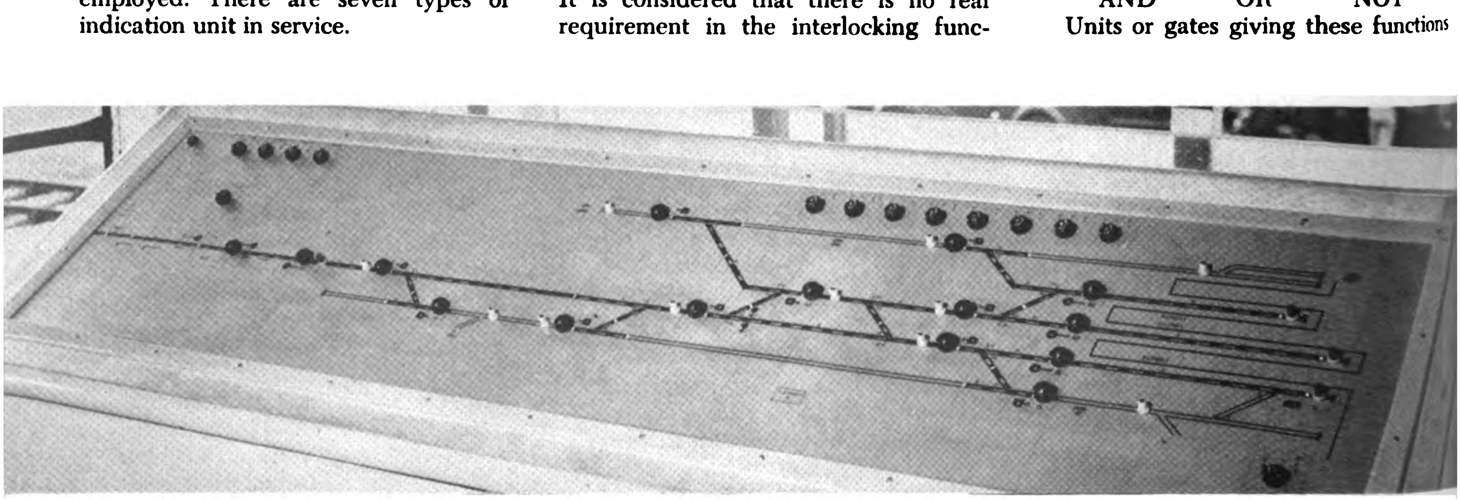
In the case of Henley-on-Thames, the development of the electronic units proceeded concurrently with the development of the logic circuits. It was, therefore, decided to design the units so that they would be capable of versatile application and would fit readily into the logic circuits when these were finalized. A view of a typical logic unit is given in Fig. 1.

Although early in the development there appeared to be scope for combining several units within the confines of a single container this was resisted in view of possible changes in the logic circuits before these were finalized. It is now feasible to envisage certain groupings of logic units, which should reduce the cost of an electronic installation.

The electronic interlocking system is based on the use of three principal types of logic functions. In Boolean terms, these are known as:

AND OR NOT

Units or gates giving these functions



Interlocking panel operates on the entrance-exit principle and controls 34 routes.

rectly do not necessarily constitute ıe most economical method of op-ation, but since they can be used perform any logical requirement, ,eir use gave a simple and yet flexi-e system at a time when final re-ıirements were not fully agreed.

The electronic system in service at enley is based on the use of a two put AND gate. This requires both puts to be present to give an output, other words:

First input *and* second input gives ıtput.

The basic OR function uses a single put gate. The unit gives an output one or more logical inputs are pres-ıt. This may be stated thus:

First input *or* second input gives ıtput.

The basic NOT function allows an ıerriding signal to suppress the out-ut of the unit, either an AND, or ı OR unit. Such a unit is alterna-vely referred to as an inhibited unit, hilst the unit giving such an over-ding instruction is referred to as the ıhibitor.

It is clearly possible to combine a umber of such basic functions into ıore complicated circuits. A typical xample of this type of combination is iven below:

First input *or* second input *and* ıird input *or* fourth input gives out-ut.

A convenient method of achieving ail-safe requirements is to use an al-ernating current as a means of signal ropagation. The transfer from unit unit shall be by means of a trans-ormer, thus ensuring that the short ircuit or the open circuit of an elec-ronic device has no logical signif-cance. (Since a short or open would ause no output from the transformer.) f now the transformer uses a square oop core, this can yield a convenient ıon-linearity for the logic function. Transistor coupling elements provide gain to overcome transformer and cir-cuit losses and this obviates the need or special signal amplifiers at regular ntervals. This allows the units to be connected together in any numbers o perform the required logic, pro-vided that any rules governing such nterconnections are obeyed.

The basic circuit which illustrates the operation of the logic system is shown in Fig. 2. In this circuit sup-pose a square wave of voltage V1 is applied, then pulses of current cor-responding to the positive half cycle would flow in the emitter circuit of the transistor TS1. A current of slight-ly less than this amount would flow in the collector circuit through the transformer winding, (current pulse A of Fig. 2b) and the transformer core would remain biased in the saturated region XX′ after at most one-half cycle of the output voltage. In the same way, if a voltage V2 is applied then the current pulse corresponds to B in Fig. 2b and the transformer core remains biased in re-gion YY′.

If, however, voltages V1 and V2 are applied simultaneously in anti-phase, then pulses A and B occur consecutively at the operating fre-quency of 5 kc and the transformer core switches between X and Y. The voltage developed across the primary winding is only marginally greater than the supply voltage E, due to the bottoming of the transistors. The voltage appearing across the trans-former is therefore a square wave of the same shape as that of the input waveform, and is only available when both inputs are present. This circuit is clearly fail-safe for open circuits, while for short circuit transistors the transformer remains saturated, since under this condition, the pulse cur-rent from the input signal is limited by the emitter circuit resistance.

The NOT function can be per-formed by biasing the transformer core into saturation, and the OR func-tion by direct connection of transistor collectors, if the practical circuit reali-zation of logical elements is such as to allow this. In addition to the above basic units, the following additional units are required:

STICK, TIMER, REPEAT, CON-VERSION, OUTPUT, DELAY.

REPEAT units are provided be-cause logic units are designed to give only one output at each phase and

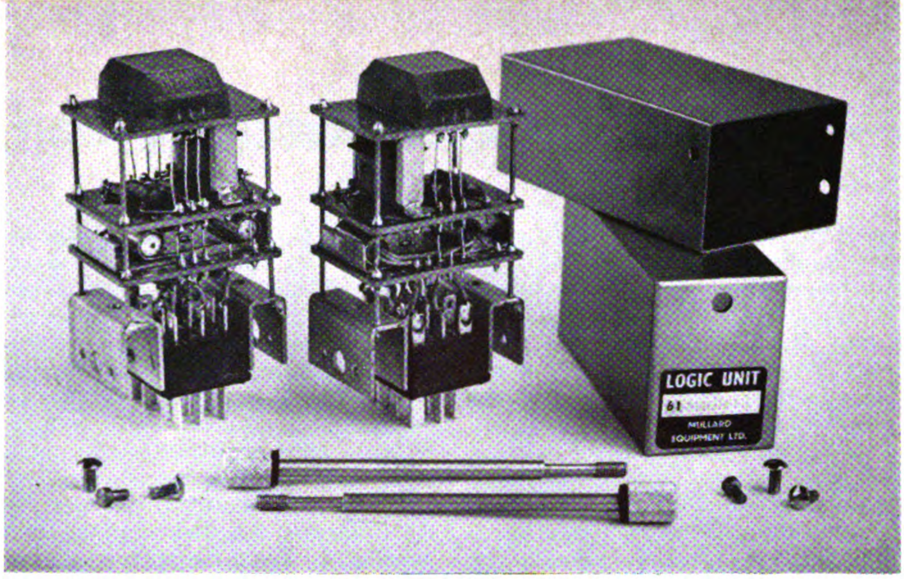


Figure 1—Typical logic unit used in this interlocking.

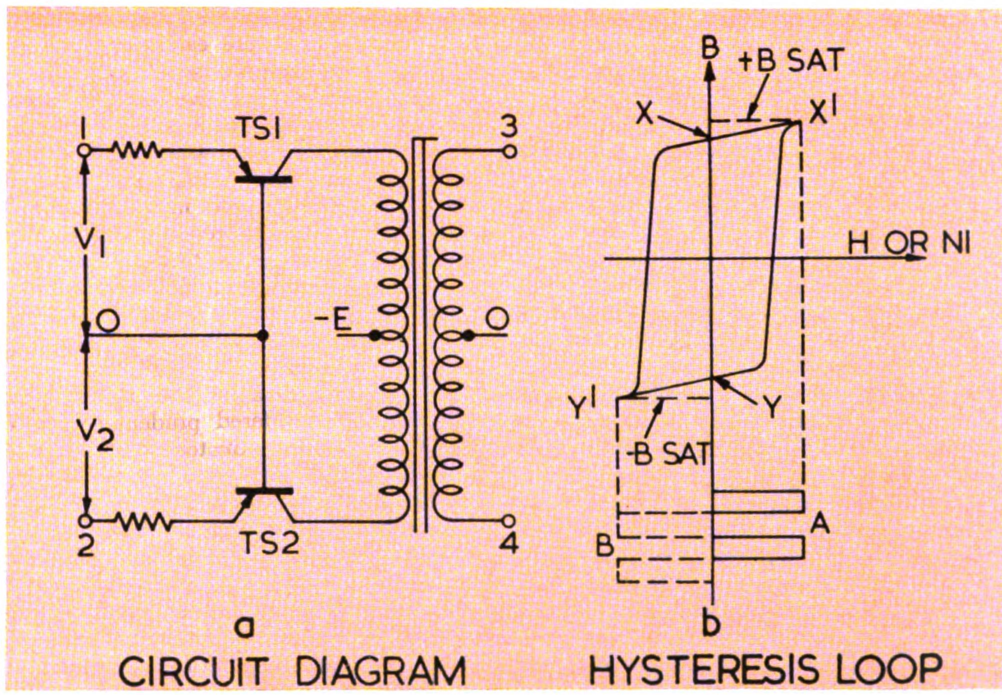


Figure 2—Circuit diagram for the basic logic unit.

Contactless switching can make use of mo

the situation often arises where more than two outputs are required. This unit is essentially a low-power amplifier which is capable of giving up to a total of 20 outputs at either phase when the necessary inputs are present. The unit itself does not perform logic.

CONVERSION units are necessary because the signal obtained from a REPEAT unit has a low source impedance and is not suitable for feeding directly into further logic units. Instead, the signal is passed first through a CONVERSION unit which transforms the source impedance to a value acceptable to logic units. Each CONVERSION unit can perform this function for four independent signals.

OUTPUT units are power amplifiers which are not intended to perform logic functions, but which on the application of the correct input give a DC output suitable for operating electric locks, relays, or other magnetic devices.

TIMER units give an output a certain length of time after an input has been applied to it. By suitable interconnection, the unit can give delays of up to two minutes. The device resets itself, on removal of the input, in a matter of milliseconds even though the full timing period may not have elapsed.

DELAY unit provides for those situations when a delay between an input being applied and an output obtained may be required. If the period is short the use of a TIMER unit may not be justified. The DELAY unit has been developed for this purpose. The delay which is fixed is of the order of three seconds and again the resetting of the unit is practically instantaneous.

Before considering the failure-to-safety performance of the electronic units, it is necessary to give an important definition:

"A system possesses absolute failure-to-safety characteristics only if under any failure condition a safe side situation arises."

A realistic assessment of existing relay interlocking systems would show that some reliance is placed on sound engineering standards to achieve compliance with the fail-safe requirements. For example, the engineering of the armature pivots of a signaling relay to prevent the armature sticking up and the quality of contact materials to prevent contact welding are vital features.

In view of the very different construction and mode of operation of electronic equipment, the designers of the Henley installation encountered these problems in new forms. Engineering features of the electro-magnetic signaling systems which had become accepted as reasonable through experience and usage, were found to be inapplicable to electronic systems. It was, therefore, necessary to think anew in electronic terms and to carefully weigh the standard provided by the electronic equipment against that provided by existing equipment, to ensure that no reduction in safety ensued.

Dealing now with electronic interlocking, it can be shown that provided the basic logic is correct according to the interlocking control table, the failure-to-safety requirements must be achieved within the logic units. Referring to Fig. 2, it is readily seen that an output equivalent to the fulfillment of the necessary input conditions is only obtained when inputs are present at terminals 1 and 2. In order, therefore, to meet failure-to-safety requirements, it is necessary to ensure that no output can be obtained unless the input conditions have been satisfied.

Referring to the AND unit circuit diagram, Fig. 3, an output should be obtained from terminals 3 and 4 only when inputs 1 and 2 are present. Similar conditions prevail for all other units. Basically all units with the exception of the TIMER are AND type units which will give outputs only when the input conditions have been satisfied. It is, therefore, proposed to examine the principal components of the AND unit in detail as this examination covers the other units.

The square loop core transformer is one of the most vital parts of the electronic logic unit as it provides protection against many of the undesirable failure characteristics of electronic components, e.g. transistor short or open circuit faults.

It has been stated that the core, having rectangular hysteresis loop characteristics, will suffer only a small flux density change and, therefore, output voltage, when only one input is present. This is dependent on the "squareness" of the core material which exhibits these properties over a considerably wider temperature range than that which is encountered in railway signaling installations. The retention of a rectangular hysteresis loop is also dependent on having no airgaps in the magnetic circuit, and having no mechanical strain on the core. Experiments have shown that

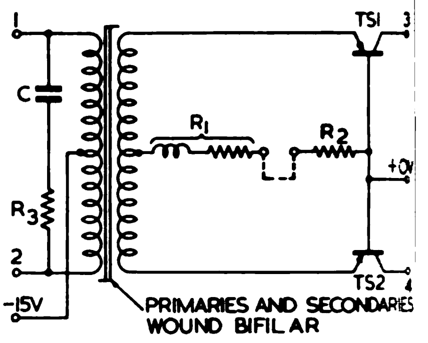


Figure 3—Actual circuits **And** unit.

provided their performance has been established and suitable encapsulation techniques have been employed, then satisfactory operation results.

Having established that the performance of the core yields satisfactory results it remains to discuss the effect of the windings. Bifilar windings (the wire is first doubled on itself, then wound double, starting from the loop) are used, thus ensuring close coupling between the two primaries and two secondaries respectively. The turns ratio is carefully tested and is, therefore, invariant with life. Three types of fault conditions can arise, (1) an open circuit, (2) a short circuited turn (or turns) and (3) short circuits between windings. An open circuit leads to a loss of signal and is, therefore, satisfactory in fail-safe equipment. A short circuit turn (or turns) is equivalent to an increase in the coercive force of the core material and will result in loss of signal which is again satisfactory. A short circuit between windings leads to negative supply voltage being applied to the emitters causing these to "cut off" giving again no output signal.

The requirement for a core without an airgap, in order to achieve fail safe performance, has been stated earlier. A small "hairline" crack is satisfactory while a large airgap is also safe. Conditions may exist under which the airgap, resulting perhaps from a fracture, is potentially of such dimensions as to cause an unwanted output. Reliance is placed on the quality of the encapsulation employed to prevent a major change in the performance of this component.

In the circuit arrangement, the transistors are used in a switching mode and they are, therefore, not capable of giving an AC output under

ɔduced standard electronic components.

ult conditions when an input signal om the transformer is absent. Open rcuits again lead to a loss of signal hile short circuits can arise between l) emitter and collector, (2) emitter ıd base and (3) collector and base. ɔr short circuits between emitter and ıllector, DC current flows through ıe input winding of the transformer ınnected to the short circuited tranıstor and this would result in a large rect current flowing in the collector rcuit of the faulty transistor. This ırrent causes a magnetomotive force ɅMF) to be applied to the output ansformer which is greater than that hich can be overcome by the availɔle current at the second input terinal of such a unit, resulting thereɪre in no voltage from the secondary ! this transformer. A short circuit beveen collector and emitter is thereɪre safe. Similar arguments hold for ıse (3). For the short circuit beveen emitter and base (2), no input 'ould be applied to the transistor nd thus no output is possible.

In addition to the extremes of fault ɔnditions discussed i.e. open circuit nd short circuit, intermediate conitions have been fully investigated. Vhilst intermediate failure conditions f transistors to resistance values beıween open and short circuit are exremely rare, the possibility of this ype of fault cannot be dismissed. 'ortunately the characteristics of the ɔgic units are such that this kind of ıtermediate failure only affects STICK ınits and it has been possible, where uch units are used in a vital manner, o arrange the circuits so that the reults of the failure are not serious.

A choke is required for rectification ıf the output signal when only one nput is present in an AND unit. Rectification is obtained due to the ıction of the emitters and the use ıf a high inductance choke. It is clear herefore that the use of this choke s only acceptable if it remains suffiːiently large and this has been assured ɔy winding the choke with resistance vire, and interleaving insulation beween layers. This precludes, with the ow operating voltage, an inter-layer ıhort circuit. If a single turn becomes ıhort circuited the loss of inductance is negligibly small due to the relatively high resistance per turn of "Constantan" wire employed. A short circuit across the terminals of the choke is clearly not safe but the layout of the terminals precludes this within a sealed, enclosed and carefully inspected unit. The use of this choke is therefore acceptable in safety circuits.

As a direct consequence of the use of the choke, it became necessary to use a damping network in parallel with the primary of the square loop transformer. The reason for this is, that due to the impedance of the choke being connected in the secondary of the square loop cored transformer a ringing phenomena developed in the primary circuit of this transformer. This resulted in excessive "off" signal becoming available in a unit under OFF condition. The use of this damping network removes the effect of ringing and gives a satisfactory solution. However, the damping network cannot be proved in this connection and its use, therefore, is at first sight not acceptable.

It was established, however, that if the damping network became open circuit, no serious consequences followed as the signal output was not sufficient to give enough input to a subsequent unit. Further investigation showed that the worst case occurs, in fact, where a succession of units, are all operating with their damping networks disconnected. Satisfactory performance is still achieved when four consecutive damping networks have failed in this manner and this example was investigated statistically.

Experience gained in a large variety of systems, suggests that the failure of the damping network is of the order of 0.01% per 1000 hours (meaning that 0.01% of damping networks would fail every 1000 hours). On the assumption that no detection of failed damping networks is carried out it can be shown that for a system of the size employed at Henley-on-Thames there exists a probability of 0.1 that four consecutive damping networks will have failed after 26 years. This it is argued should be satisfactory, particularly if some preventive maintenance is carried out.

When the circuit resistance in the common emitter return lead rises, some decrease of current is to be expected. This does not materially affect the operation of a unit as there is sufficient gain provided by the transistor to make up this low output obtained. If, however, an inhibit winding (using a NOT or STICK unit) is connected, then somewhat less overriding inhibit action is applied. As the circuit resistance rises less inhibit current is flowing, and the output of the "inhibited" unit increases while the output of the "inhibitor" unit decreases. A range of resistance conditions can be reached for which sufficient "ON" output from both units can be obtained. This is clearly not fail-safe and where safety is required as in vital circuits, "inhibit" proving techniques have been employed. The range in which unsafe conditions can occur is for rises in circuit resistance between 100 and 250 ohms approximately. Rises in resistances between 0 and 100 ohms are perfectly satisfactory while increases above 250 ohms approximately causes a safe side condition to occur. The potential sources of increases in resistances are thought to be the following:

(1) High resistance soldered connections.

(2) Increases in the value of the emitter circuit resistances.

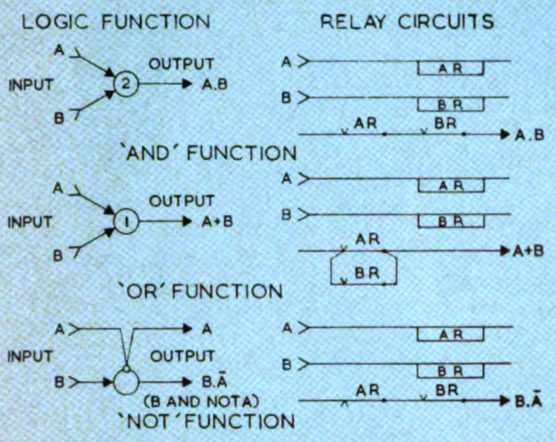
(3) High resistance plug and socket connections.

It is expected that little trouble should be experienced due to (2) while insufficient reliable information is available on (1) and (3). The authors' experience suggests that although high resistance soldered connections are difficult to detect before reaching that condition, little difficulty is expected with joints developing resistances of the potentially unsafe values. A similar argument suggests that no difficulty need be expected with high resistance plug and socket connections.

A model employing prototype logic units has been constructed and this has now been in continuous operation for fifteen months. None of the three potential sources of trouble listed above has been experienced.

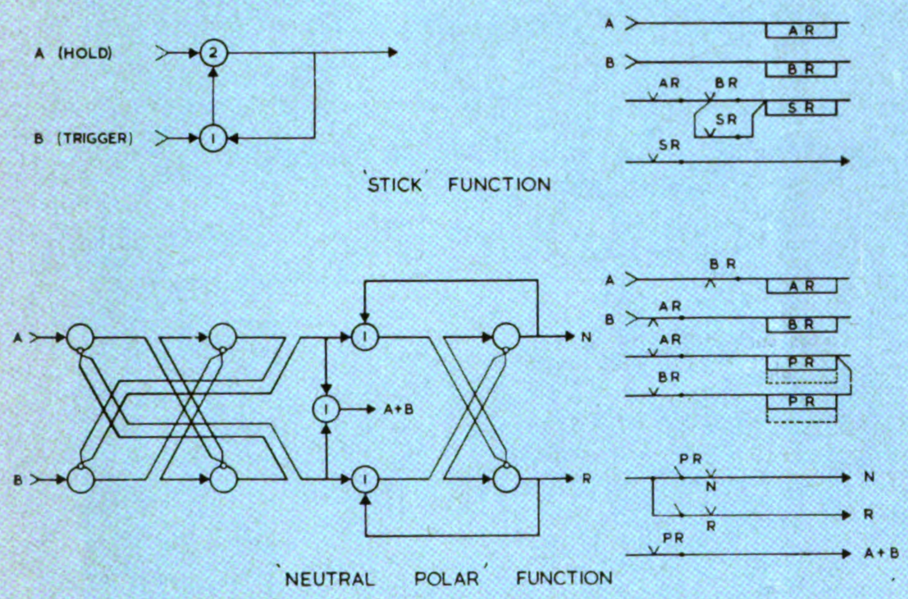
To assist the understanding of the operation of an electronic logic system, there may be some advantage in comparing its operation with that of a relay system. The aim of the two systems is similar in that outputs to operate equipment shall only be given when certain logical conditions are fulfilled. Referring to Fig. 4, the AND function can be seen to be equivalent to the action of the relay coil circuits AR and BR plus two front contacts in series controlling the output. The OR function can be seen to be equivalent to the action of the relay coil circuits AR and BR plus two front contacts in parallel controlling the output. The NOT circuit can be seen to be equivalent to the relay coil circuits AR and BR plus a back contact of AR and a front contact of BR in series controlling the output.

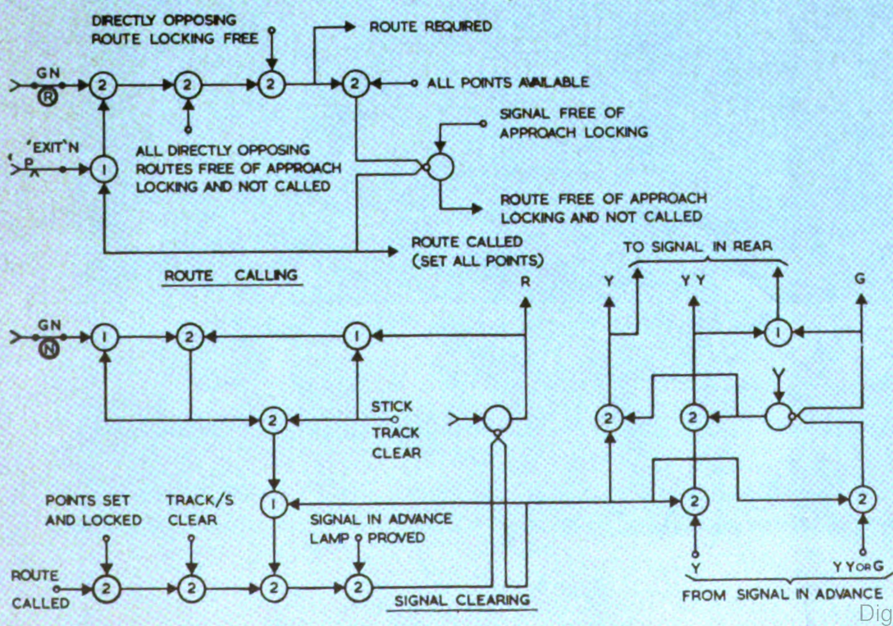
(Please turn to page 20)



Circuits and Functions

The top drawing, **Figure 4,** shows the basic circuits for AND, OR and NOT functions. The middle drawing, **Figure 5,** shows the typical STICK and NEUTRAL POLAR functions. The bottom drawing, **Figure 6,** indicates general logic diagrams concerning this Henley-on-Thames electronic interlocking installation.





ELECTRONIC INTERLOCKING

(Continued from page 17)

One distinguishing feature of the relay system is the separation of the coil control circuits from the output circuits. In the electronic system the action of the coil and contacts is combined within the logic unit and the output feed, in effect, flows through all the logic units in the chain. In the relay system the output feed flows in a separate circuit and is controlled via contacts according to the pattern in which the relays have been set by information feeds from the signaling installation.

In the NOT function, the output is available only if input B is present and input A is not present. In the relay system circuit A is proved and disconnected, but in the electronic system there is a proving that there is no effective output feed from circuit A. It could possibly be claimed that the electronic system gives direct proof where the relay system only proves by inference. The implication that if a relay back contact is made then no front contact can be made depends on the design specification and the care taken in manufacture and inspection, but this electronic system solves it more fundamentally by checking that there is no output on circuits with the electronic equivalent of a front contact. So far, three types of relay circuit have been discussed: contacts in series, contacts in parallel and the proving of one circuit against another. Other important circuits are STICK, POLAR or LATCHED circuits. Referring to Fig. 5, the STICK function can be seen to be quite readily obtained in electronic terms. The method of operation is slightly different to that used with relay techniques. The two versions of stick circuit are based on the independent energization of "Hold" and "Trigger" circuits, shown as A and B in Fig. 5. Momentary energization of "B" circuit is sufficient and continuous energization of "A" circuit is required, to pick up and maintain a STICK ouput. In a relay system, the STICK feature is achieved by bridging out the "Trigger" contact BR with contact SR of the stick relay, the stick circuit being broken down when the "Hold" contact AR is no longer made. In the electronic system an AND unit requiring two inputs to give an output is fed with one of its inputs from a "Hold" circuit and with its other input from a "Trigger" circuit or from a feedback loop. Referring to the logic diagram in Fig. 5, the OR symbol shown is only put in the diagram to clarify the logical intention; in practice, the "Trigger" signal and the feedack signal would be connected to ne half of the input winding of the ND unit. If three inputs were shown o an AND unit requiring two inputs, his would suggest that any two of he three inputs could be accepted y the AND unit as sufficient to give n output, and the condition that one f the inputs must be the "Hold" ignal would not be achieved. The R symbol is therefore introduced n diagrams to clarify this point.

Fig. 5 also shows electronic and elay equivalents of a "neutral polar" ype circuit, such as may be used in witch control circuits. The electronic olution shown has no permanent nemory feature; if power is cut off he circuit does not remember its last tate. No insuperable difficulty is envisaged in producing an electronic ype permanent memory but this has ot been given priority of development as the switches at Henley are nanual lever operated.

The first part of the circuit diagram (Fig. 5) shows a "double-inhibit" unction. In addition to suppressing a ignal on the opposing line, the circuit is so arranged that an existing signal on one of the lines is not suppressed by a subsequent signal on the opposing line. Thus if a signal A giving rise to an output N is existing in the circuit it locks out signal B and prevents it from suppressing signal A, as would be the case with only a single and not a "double inhibit" circuit. Whilst the circuit shown has no permanent memory, the STICK function in the second part of the circuit maintains the output so long as power is available to the circuit and an effective B signal has not passed through the "double-inhibit" configuration. The neutral part of the output is obtained from an OR unit placed between the N and R lines, as shown in the diagram.

It is impossible to describe all of the logic circuits employed for a complete installation, and for this reason it is decided to illustrate the principles used in the generalized logic exemplified by the route calling circuit which will be dealt with in detail and is shown in Fig. 6.

The installation is operated on the entrance switch-exit button method. Turning the entrance switch and depressing the exit button initiates route calling provided:

(a) All directly opposing routes are free of approach locking and have not been called.

(b) All directly opposing route locking is free.

In the diagram the entrance switch feeds a signal into an AND gate and the second input to that gate is obtained from an OR gate (which is fed by the exit push-button or the stick loop). The two subsequent AND gates in the chain summate conditions (a) and (b) above with the ouput of the first AND gate. If these conditions are satisfied an "enquiry" signal goes out to all the switches required for the route—"Route Required" on diagram. This signal ascertains whether the switches are correctly set or are free to be set in the correct position and if so, a confirmatory signal "All Switches Available" is fed into the fourth AND gate in the logic chain. The input is summated with that from the third AND gate to give an output. In this case, the "Route Called" signal will establish itself via the stick loop and thereby becomes independent of the exit button. The stick loop is routed via an inhibit winding on a NOT gate so that the "Route not called and free of approach locking" output signal from the circuit will be suppressed. The "Route Called" signal in addition to being returned via the feed back path to the OR gate is passed forward to the switches logic circuit to initiate switch setting. **RSC**

New Horizons in Railroad Signaling

Recent developments indicate that there is truly new horizons in the art of railroad signaling. For example:

- British Railways use ferrite cores for safety switching circuits in an interlocking (see accompanying article).
- Four crewless 18-car ore trains operate simultaneously on a 6-mile line in Iron Ore Co. of Canada's automatic train operation installation in western Labrador.
- Some railroads, Pittsburgh & Lake Erie and Southern Pacific, among others, use semiconductor communications equipment to handle controls and indications for remote control interlockings.
- Southern Pacific has electronic highway crossing protection controls using semiconductor devices which eliminate special timing circuits with cut-outs and restarts in territory where trains of various speeds are operated.
- Railroads such as Great Northern and Santa Fe have tested radio controlled helper locomotives in long freight trains.
- Southern Pacific has over 500 miles of centralized traffic control in which trains make meets automatically.

These are some of the recent developments resulting from railroad and railroad-supplier research. Take ATO (automatic train operation) for example: The crewless ore trains are the products of research efforts of General Railway Signal, General Motors Diesel Ltd., Iron Ore Co. of Canada, Westinghouse Air Brake and Canadian National. The original ATO tests were held on the CN near London, Ont. The first crewless subway train—New York City Transit Authority's Grand Central Terminal-Times Square shuttle—involved the combined efforts of GRS, Union Switch & Signal and the NYCTA.

As for the future, here is what some railroad men and manufacturers representatives are considering for new horizons in signaling:

- ATO for running mainline freight trains between major terminals.
- ATO to control hump engines in retarder classification yards.
- Integral train concept with locomotives spaced throughout the train automatically controlled from the lead unit or by ATO.
- Automatic train dispatching using CTC and interlockings in which trains would make their own meets without the aid of the dispatcher.
- Extensive use of semiconductor devices for long life, and use of modular units to simplify maintenance will become standard practice. Use of more standardized electronic components with their lower cost due to mass production can be expected.

Bob McKnight