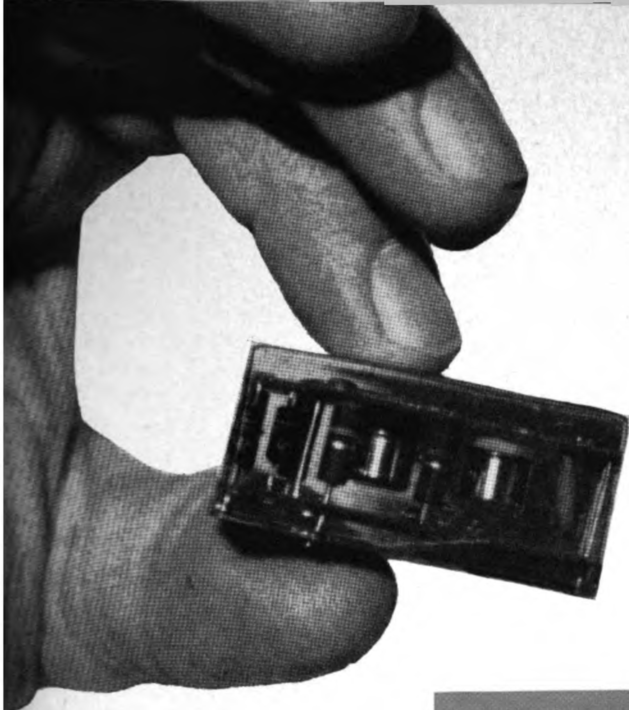
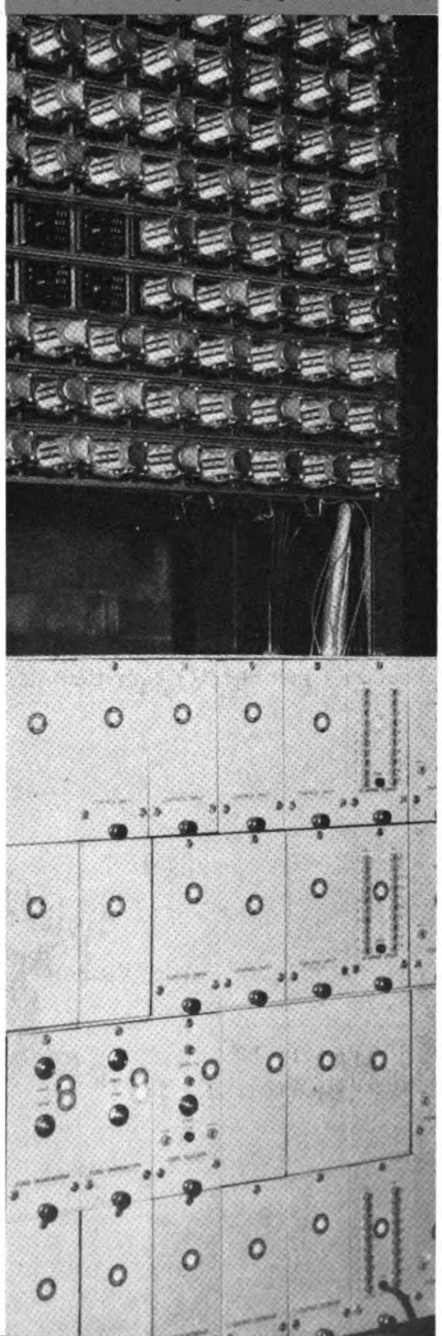
Railway Signaling & Communications



Heart of solid-state controls are logic elements—flip-flops, gates, etc.—in encapsulated modules (shown in photograph above).

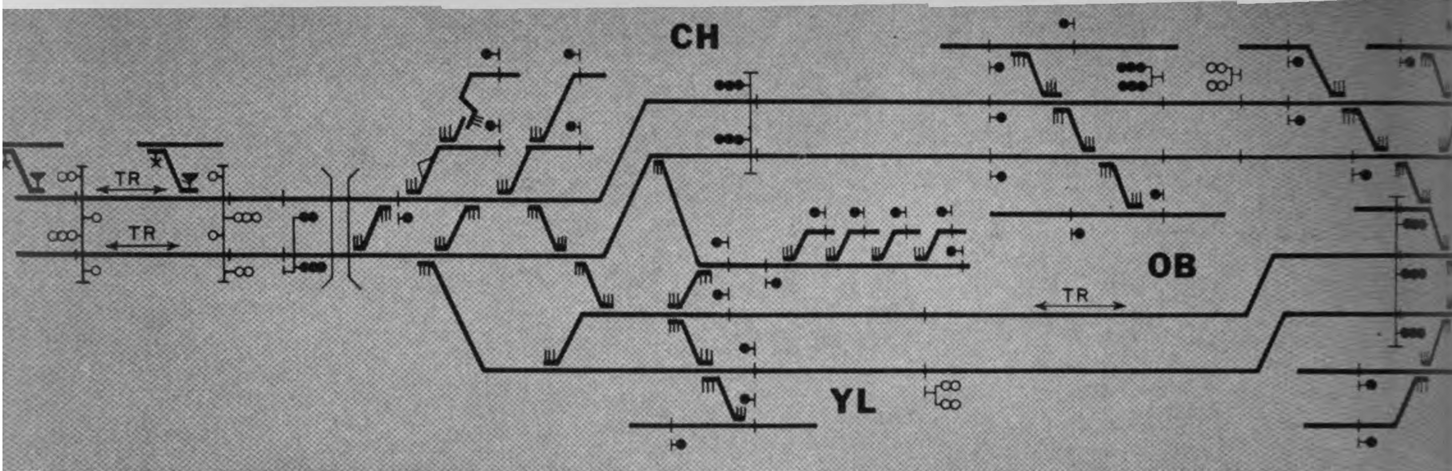


INTERLOCKING:

New Solid State Devices Save Money

In a consolidation of interlocking controls at McKees Rocks, Pa. on the Pittsburgh & Lake Erie, a solid state system has been installed to handle controls and indications between the new control point (MA) and two former interlocking towers (FM and CH, each 1½ miles from MA). A solid state control system was chosen because of the lower initial cost, higher speed of operation, greater coding security (less chance of error with special self-checking code), and fewer moving parts (less maintenance) than a comparable relay coding system. Further, the system continuously supervises itself so that the operator knows that the entire system is functioning. Other factors favoring the solid state system were its space saving design with modular construction for ease of maintenance and quick trouble shooting, and the 30-day delivery time from the manufacturer, Noller Control Systems, Inc. This prompt delivery schedule was important in that the entire project was completed 90 days after the order was placed with the manufacturer for the solid state control system.

A miniature-lever control machine at FM controlled that interlocking via direct wire, and also controlled interlockings at MR, K and WE via two Union Switch & Signal 506A code systems. The CH machine controlled interlockings at CH, OB and YL via direct wire. As part of the consolidation project, the track diagram panel on the FM machine was condensed to fit into about one-half of the machine's 10-ft length (a 5-ft main section and two 2½-ft wing sections). A new track diagram panel was con-



CH plant controlled CH, OB and YL while FM plant controlled FM, MR, K and WE. All are now controlled from a m

structed by the P&LE signal-communications department to contain the CH, OB and YL interlockings. The FM machine was rewired and the levers for FM, MR, K and WE were moved to fit the new configuration. Levers from the CH machine were moved to the FM machine. They were replaced by toggle switches on the CH machine so as to keep that machine in service until the cutover date of the consolidation of the controls.

The CH machine controlled 10 crossovers, 10 turnouts, 2 traffic (levers), 22 signals and 1 electric lock; and the FM machine controlled 20 crossovers, 8 turnouts, 41 signals and 2 electric locks. Traffic in a typical 24-hour period averages 101 movements through CH and 85 moves through FM.

After the circuit design was well under way, one of the first tasks was the rewiring of the FM machine while keeping it in service. Levers were moved one at a time to fit the new condensed track plan. Also, wiring for the main section and each of the two wing sections was terminated in Burndy plug couplers. Thus when the time came to transfer the control machine to MA at McKees Rocks yard office, the machine could be separated into its three sections for ease in handling. The 1½-mile move using a work train and crane took about 3 hours.

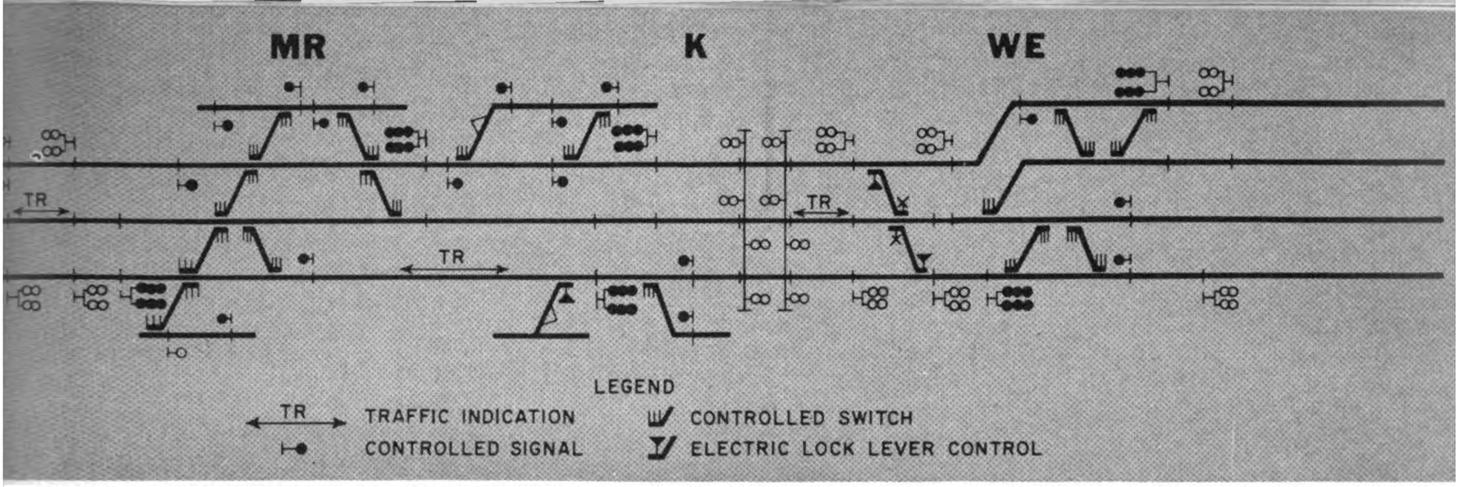
In addition to machine rewiring, connections had to be made between the solid state transmitter-receiver equipment and the terminal board in the FM tower, and also between the solid state units and the control machine. For these connections, multi-conductor cable with 50 color-coded wires were used. Cables from the control machine were terminated in Burndy plug couplers, as were cables from the terminal board. These couplers were connected, after wiring checks of 50 wires at a time, and the FM machine continued to operate through the plug-coupled cables between the terminal board and the control machine.

Two solid state transmitter-receiver units were set up at FM—one field unit which would be located at the FM interlocking tower, and the other (an office unit) which would be moved to MA with the control machine. These solid state units were wired with the multi-conductor cables terminating in plug couplers. After testing, the office and field solid state units were plug coupled to the terminal board, to the FM control machine and to each other on a back-to-back basis. Thus the FM machine operated via the solid state equipment. For example, when the operator wanted to clear a signal, he turned the signal lever and pressed the code start button. The control went via the plug-coupled cable to the office solid state equipment rack. The machine lever keyed the solid state transmitter to send the control to the field solid state equipment (back-to-back via plug-coupled cable). The receiver of this field unit upon receipt of the output code controlled conventional signal circuits and equipment. Where necessary, Automatic Electric telephone-type interposing relays were used. This back-to-back operation was carried out for about one month, at which time the FM machine and the solid state office equipment were moved to the new location at MA.

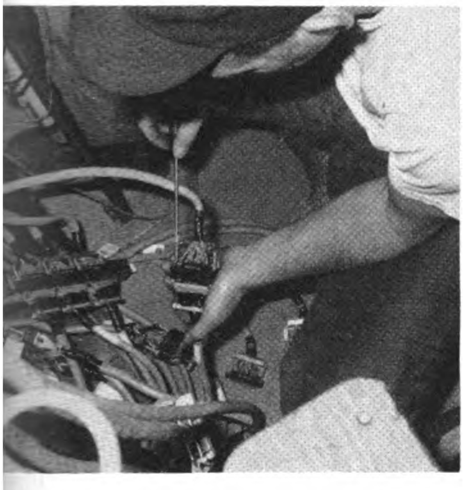
When it came to consolidating CH interlocking control into the FM machine (now at MA, 1½ miles distant), essentially the same procedure was followed as mentioned earlier. The operator at CH continued to control that interlocking from a miniature lever control machine until the cutover date. As each group of 50 wires of a multi-conductor cable was checked out and found to be properly wired, a further test was made in which control would be given to the operator at MA via the solid state system. He would send a control to position a switch or clear a signal, and the indication would be sent to the CH machine, also via the solid state control system. Then the procedure would be reversed—the operator at CH would send out a control, and the indication would be received at the MA control machine. A further test would be made in which the MA operator would send out a control and the indication would come back to his machine. On May 1, when the cutover was made to change the control point from CH to MA, the signal maintainer changed six plug couplers in just 13 minutes. Thus the CH plant was out of service only 13 min.

During the testing and checkout period, P&LE signalmen gained valuable experience in the application of preventive maintenance and trouble shooting techniques to be used on the solid state control equipment. An ordinary multimeter, such as the Simpson model 260, and high impedance headphones are all that are required for troubleshooting. After checking to insure that supply voltages are correct, the signalman follows a procedure of simply listening with his headphones to the clicks which are produced in various parts of the system. Pen jacks for plugging in the headphones are provided on the front of the panels. By noting that clicks or beeps in a defective unit sound differently than when a unit is functioning properly, the signalman can quickly locate the defective module which is then unplugged and replaced with a spare module.

The solid state equipment handles controls and indications between the MA control machine and the interlocking field locations at CH and FM towers over a wire pair in an existing communications cable. Engineering, circuit design and installation was carried out by signal department forces under the jurisdiction of D. W. Shackley, superintendent signals and communications.



between OB and FM). Change of six plug couplers (below left picture) enabled CH to be cut over in 13 minutes.



A description of the Noller solid ıte control system operation and gic follows:

The Noller N420 supervisory con- ɔl system is a high speed scanning pe of supervisory control specifically ›signed to supply optimum reliability the transmission of control and data formation. To obtain the necessary gh security transmission, the N420 stem utilizes a two-out-of-five coding chnique and is capable of scanning maximum of 100 separate inputs and porting their status to a remote ɔint.

Three independent checks of the formation are made, all of which ıe receiver must recognize before ıy action is initiated. The N420 sys- m uses a double bus coding method ılled for convenience a "1" and a)" bus.

The code consists of five pulses, vo of which must appear on the "1" us and three on the "0" bus. The ›ceiver counts the total number of ulses, ascertains that two pulses ɔpear on the "1" bus and that three re on the "0" bus.

If for any reason the code does not ass these three checks, due to noise r other system disturbance, the infor- ıation is discarded and an alarm appears to indicate this fact. In addition, the N420 system continuously monitors its own circuitry, thus providing a constant check on the operating condition of the system.

Several features of the N420 system are discussed below:

Modular Construction: Most basic circuit functions are encapsulated to protect them against environmental and mechanical change and are grouped on logic subassembly units. These, in turn, are incorporated in logic plug-in assemblies. To expand the system to its maximum of 100 inputs, it is only necessary to add appropriate standard plug-in assemblies.

Two-Out-Of-Five Coding: The two-out-of-five coding technique not only insures maximum security of transmission data but requires only the recognition of the presence or absence of a pulse and is not dependent on length, amplitude or coincidence, thus removing the need for exact synchronization between the transmitter and receiver.

Compact Design: In the employment of solid state devices throughout the system operating at well below manufacturer's ratings, compactness is achieved and system reliability is further enhanced.

Self Monitoring: The continuous tone transmission in the monitoring of remote imputs further provides a check on the operating condition of the system. False coding, channel interruption or any other malfunction is immediately indicated.

Automatic Conditioning: When power is first applied, the entire system is automatically reset to condition zero. This insures that no false information will be received prior to the receiving of the first properly checked code.

Adequate Test Points: Sufficient test points have been installed on the face plate of each plug-in assembly to accommodate signal tracing equipment, thus permitting monitoring without removing the assembly from the rack.

Phase Shift Modulation: A pulse on the "1" bus causes a 90° phase rotation in a counter-clockwise direction. A pulse on the "0" bus produces a 90° clockwise rotation from the unshifted or reference phase of the channel. The receiver contains a floating phase reference memory, which eliminates any need for carrier synchronization with the associated critical adjustments.

A general understanding of the

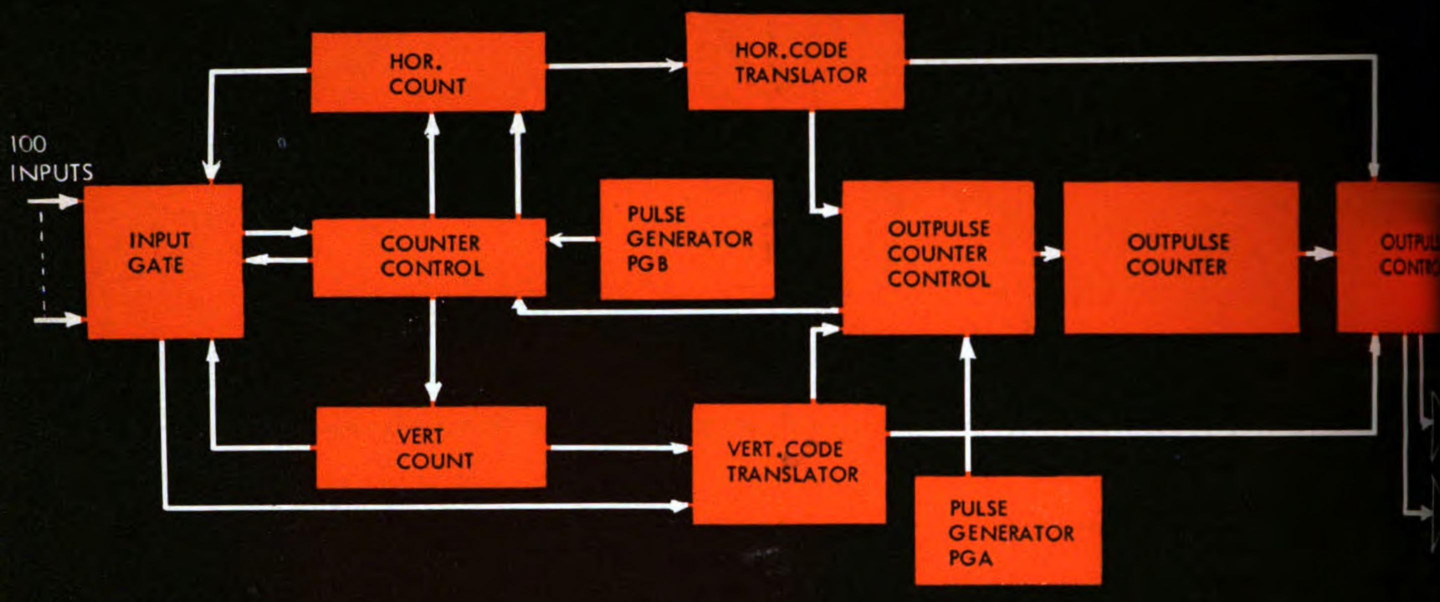


Fig. 1—Left, shows the N420 transmitter of the solid-state system which is typical of the equipment installed on the P&LE A

operation of the N420 transmitter may be obtained by reference to Fig 1. Up to 100 input contacts may be connected to the input gates. The connections in the gating circuits are such as to give the effect of a rectangular coordinate system with the contacts connected at the intersection of the vertical and horizontal lines. The contacts are connected in groups of ten to the horizontal busses, with one to ten horizontal busses being used, depending on system capacity.

The horizontal counter, driven by pulse generator PGB, applies potential in sequence to each horizontal line. If an off-normal contact is detected, the counter control stops the scanning and sets up circuitry in the outpulse control unit which allows pulses from pulse generator PGA to send out a two-out-of-five coded signal to the "1" and "0" amplifiers.

The code translators act to produce two outputs from each single input to the translator. These outputs are assigned values of 0, 1, 2, 4, and 7. Each combination of two will thus represent a number from 1 to 10; i.e., 1 & 2 = 3, 2 & 4 = 6, 0 & 7 = 7, etc. 4 & 7 is assigned the value 10.

The outpulse control determines to which bus the pulses are applied in accordance with information from the counter control, outpulse counter control and the horizontal and vertical code translators.

A start pulse is sent prior to the two-out-of-five code. This pulse is sent on the "1" bus to identify a horizontal code and on the "0" bus to identify a vertical code.

The two pulses representing the number to be transmitted are always sent on the "1" bus, with the other three pulses on the zero bus, to preserve the five digit code and to identify the individual pulse location. As an example, the number 3 would be transmitted by sending the first pulse after the start pulse on the "0" bus, the second and third pulses on the "1" bus and the fourth and fifth pulses again on the "0" bus.

After the code identifying the horizontal line on which the horizontal counter was stopped has been transmitted, the counter control directs pulses from PGB to the vertical counter. The vertical counter now scans the vertical rows of contacts to locate the vertical coordinate of the off-normal contact.

When this point is reached, the counting again stops and a two-out-of-five code, identifying the number on which the counter stopped, is sent out through the outpulse circuitry as before. The start pulse in this case is on the "0" bus so that the receiver may recognize this as a vertical code.

After the vertical code has been sent, the vertical counter is again started to scan the remainder of the vertical lines. When the last vertical has been interrogated, scanning is again stopped and the outpulser sends an "end-of-scan" code which consists of five pulses plus a start pulse, all on the "0" bus.

When the end of scan code has been sent, the horizontal counter is advanced to the next horizontal row and continues to scan until another off-normal point has been found.

Pulse generator PGB operates at approximately ten times the puls rate of PGA. The scanning rate i thus much higher than the transmitted code pulse rate. To further increas the scanning speed, the verticals ar not normally scanned unless an off-normal point has been located by the horizontal scanner. If no off-normal points are present, the horizontal counter would scan continuously and no codes would be transmitted.

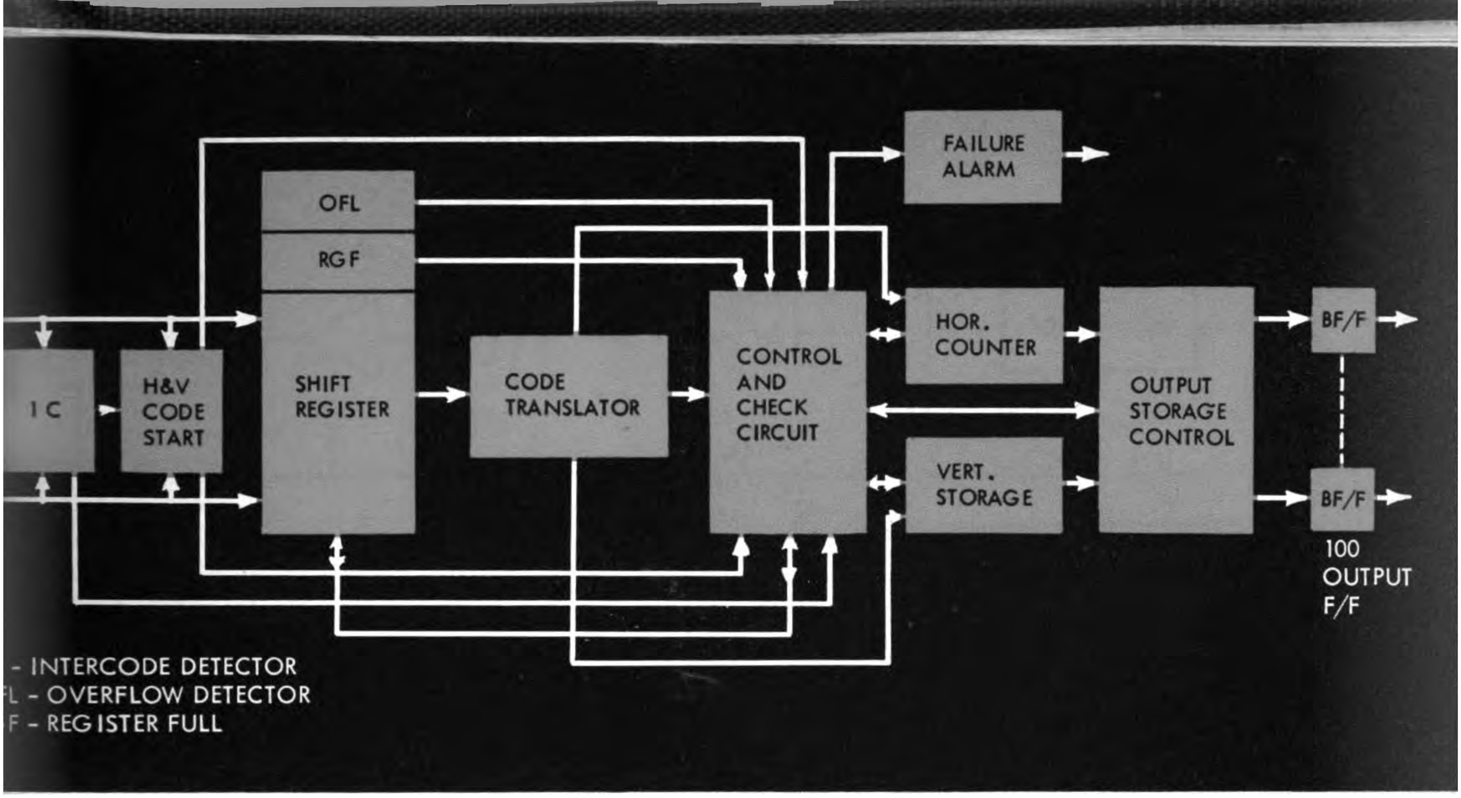
It is desirable that some codes be transmitted at all times so that the receiver will recognize that the sys- tem is operating properly by receiv- ing valid codes. To accomplish this, a strapping option is provided on each horizontal row.

Normally the first row is so strap- ped. Under this condition, each time the first horizontal row is interrogated the scanning is stopped, the row code transmitted and then the verticals for that row are scanned, as explained above. The other horizontals, not so strapped, are then interrogated in sequence with no codes being sent unless an off-normal is found.

The receiver thus receives a mini- mum of two code groups for each complete scan: the first horizontal row code and the end-of-scan code after the vertical counter has completed its scan.

For some applications it may be desirable to scan each point whether or not an off-normal point exists. In these cases, each horizontal row is strapped so that the vertical counter will then scan each point on each horizontal every time the horizontal counter is advanced.

The block diagram of the N420



of the N420 receiver is shown in **Fig. 2**, above, which together make up a field location or an office location.

eiver is shown in Fig 2. The pulses m the "1" and "0" busses at the nsmitter appear on the similarly ntified busses of the receiver after ssing through the transmission medi-ı. These pulses are directed into the ercode detector circuit, the horizon- and vertical code start memory and shift register.

The intercode detector functions to e an output when an interval be-een codes is detected. Gating cir-its are controlled by this output to ntrol a readout pulse generated in e control and check-out circuit.

The H & V code start circuit serves a memory to direct subsequent lses to control the horizontal counter d vertical storage, depending on ether the start pulse is on the 0 1 bus.

The code utilized in the N420 sys-m is a six-pulse code. The first pulse used to start the control functions the receiver and also as an address lse to indicate horizontal or vertical des. This start pulse is always intro-ced into the register as a "1".

The shift register is a five-stage gister, all of whose stages will be tivated by the ensuing five pulses. he start pulse, originally introduced, thus transferred to the RGF stage hen the six pulses have been re-eived. Pulses on the "1" bus set the gister stage and pulses on the 0 bus ause it to reset. The OFL stage will e turned ON if more than a total f six pulses is received.

The action of the register is such hat the condition of each stage (set r reset) is transferred to the next tage every time a pulse is received. The register thus receives information serially which may then be read out in parallel at the output of its stages.

When the complete six pulse code has been received, the RGF must be ON, the shift register must have two stages ON and three stages OFF (which will be the case if two pulses are received on the 1 bus and three on the 0 bus), and the OFL stage must be OFF.

If all of these conditions are met, the control and check circuit causes the horizontal counter or the vertical storage to generate an output corresponding to the number represented by the code pulses. In accomplishing this, the code translator acts to transform the two-out-of-five code to a one-of-ten code for operation of the control circuits.

In operation, the transmitter always transmits a horizontal code first (start pulse on the 1 bus). The actions indicated above then cause the horizontal counter to assume an output corresponding to the number represented by the code digits which were transmitted. The intercode detector then operates to cause the horizontal counter to temporarily store the information.

The next code received will be a vertical code (start pulse on 0 bus) which the control circuits now direct to the vertical storage, causing one or more stages in this unit (depending on the number of codes transmitted) to be activated.

When all of the verticals have been scanned, an end-of-scan code (six pulses all on the 0 bus) is received, which causes a readout pulse to be generated. This pulse then causes the output storage control to turn the output flip-flops on or off in accordance with the received information as stored in the output storage.

All circuits except the output flip-flops are then reset and the receiver is then ready to receive the next set of codes from the transmitter.

The next code will again be a horizontal, which steps the horizontal scanner to assume an output corresponding to any other off-normal points at the transmitter. The above actions are repeated until all of the points at the transmitter have been processed.

If, for any reason, correct codes are not received, the control and check circuit will not process the information and will either reset all output flip-flops or leave them in condition corresponding to the last valid information received, depending on the optional strapping selected. In either case the failure alarm will operate to indicate system failure.

Many Noller systems are logic systems, using solid-state circuits of advanced design and great reliability. Most logic operations in Noller equipment take place in semi-conductor modules, miniature building blocks comprising encapsulated groups of components that reduce maintenance to simple substitution. From these modules entire systems are built, a limited variety of modules being able to perform an extremely large number of different functions if enough of them are included in the system.

A logic system operates by passing or blocking pulses. Since the pulses

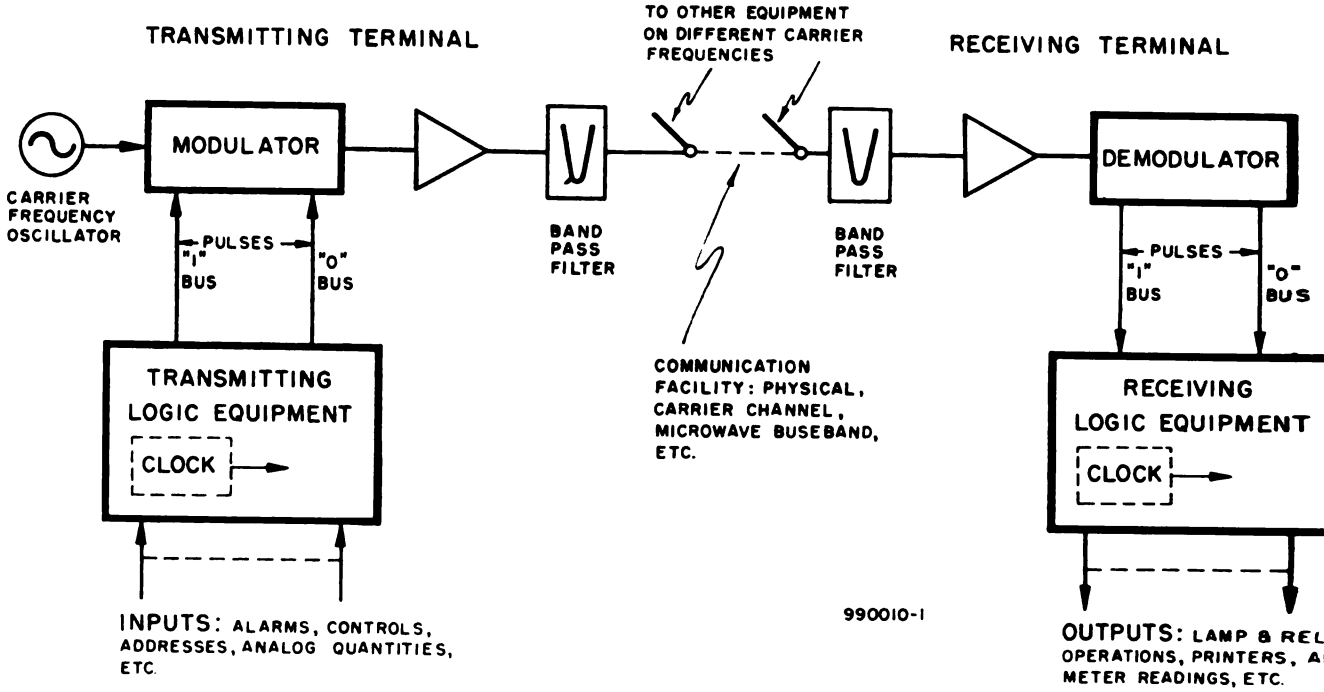


Fig. 3—Application of a logic system to a standard communication circuit.

are distorted in passing through circuit elements, the system contains the means to amplify and restore pulses, as well as to generate them.

The passing, blocking, generation, and storage of pulses is performed by gates, flip-flops and pulse generators. Relays are not used except where they are needed to ensure compatibility with other systems and devices.

Switching with transistors is similar in some respects to switching with relays, although the two methods are not identical. For example, a gate that can be open or closed (enabled or inhibited) is somewhat comparable to an SPST relay. Again, a flip-flop can be compared to a latching relay, which requires one signal to latch and a second signal to unlatch.

A typical application of logic equipment for alarm and control functions is shown in Figure 3. The transmitting logic equipment encodes the input information into sequential (serial) form, the output then appearing as pulses on the "1" and "0" busses. These pulses cannot, however, be placed directly on a communication circuit, since they require a wide band for transmission. Further, the pulse shape is destroyed by even a small end-to-end frequency error, typical of carrier channels.

Instead, the pulses are used to modulate a carrier frequency (typically below 100 kilocycles). The modulator is not a linear type as used with speech or music, but is designed for data transmission. It produces a sudden change in some characteristic of the carrier signal for every pulse on the "1" bus, and a different change for every pulse on the "0" bus. Most Noller systems use phase modulators which generate rapid and distinctive phase rotations to represent the "1" bus and "0" bus pulses.

The modulated carrier tone is transmitted by conventional radio, wire, or telephone facilities to the receiving station. In the receiver, the demodulator output, consisting of pulses on the "1" and "0" busses, is identical to that used to modulate the transmitter. The receiving logic decides this pulse information and uses it to operate various output devices.

Some features of the system in Figure 3 are:

(1) In alarm-reporting service, the monitored points are scanned continuously, allowing off-normal conditions to be detected quickly. The entire system, including the communication channel, is continuously monitored.

(2) The process of parallel-to-serial conversion at the transmitter and serial-to-parallel conversion at the receiver is a form of time multiplexing that conserves the bandwidth of the communication channel by transmitting information consecutively (serially) rather than all at once.

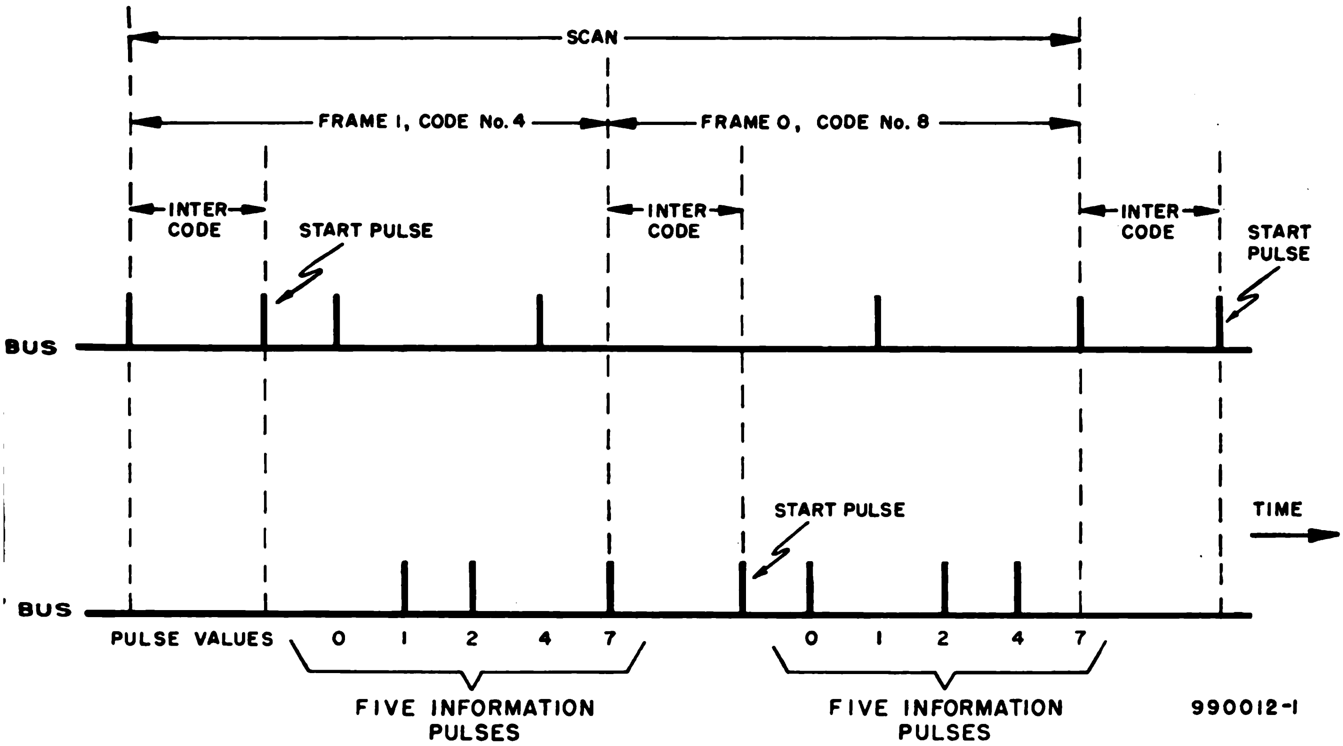
(3) Operating speed depends ultimately upon the bandwidth of the communication channel. A system using a narrow-band (100 cycles per second) tone channel typically operates at 20 pulses per second and, in alarm service, scans each of 20 points in little more than one second. ; tems 4 kilocycles wide can operat 850 pulses per second. The opera rate of the logic circuits is determi by a clock or pulse generator at transmitting end and has no fixed r tion to the carrier frequency.

(4) The communication chan requirements depend on the sys plan. A one-way channel suffices the simpler alarm systems or con systems. A two-way channel is nee for the conventional sequence of lect, confirm, operate and verify. Sl speed data logging, high-speed ana data telemetering, set-point selecti interrogation, and continuous syste all have unique requirements.

(5) In Noller systems, the rece ing clock is synchronized by ev *pulse* or bit received from the tra mitting end. As a result, the two clo do not have to keep independen in step, with only block synchro zation.

The details of the code used grea affect the security of the system; th is, its ability to transmit informati correctly and recognize errors, even the presence of equipment failure a noise.

Three-state codes require a thre state carrier system for transmissi and provide a substantial improv ment in security. Figure 3 is such system. When a pulse does not appe on the "1" bus, it appears on the "0 bus. If noise bursts, drop outs, and s on, add or cancel pulses, they a detected as errors by the parit checks, rather than changing th



4—Two-out-of five code. In this code, two information pulses must be on the "I" bus, and three on the "0" bus.

aning of the code as in two-state ies.

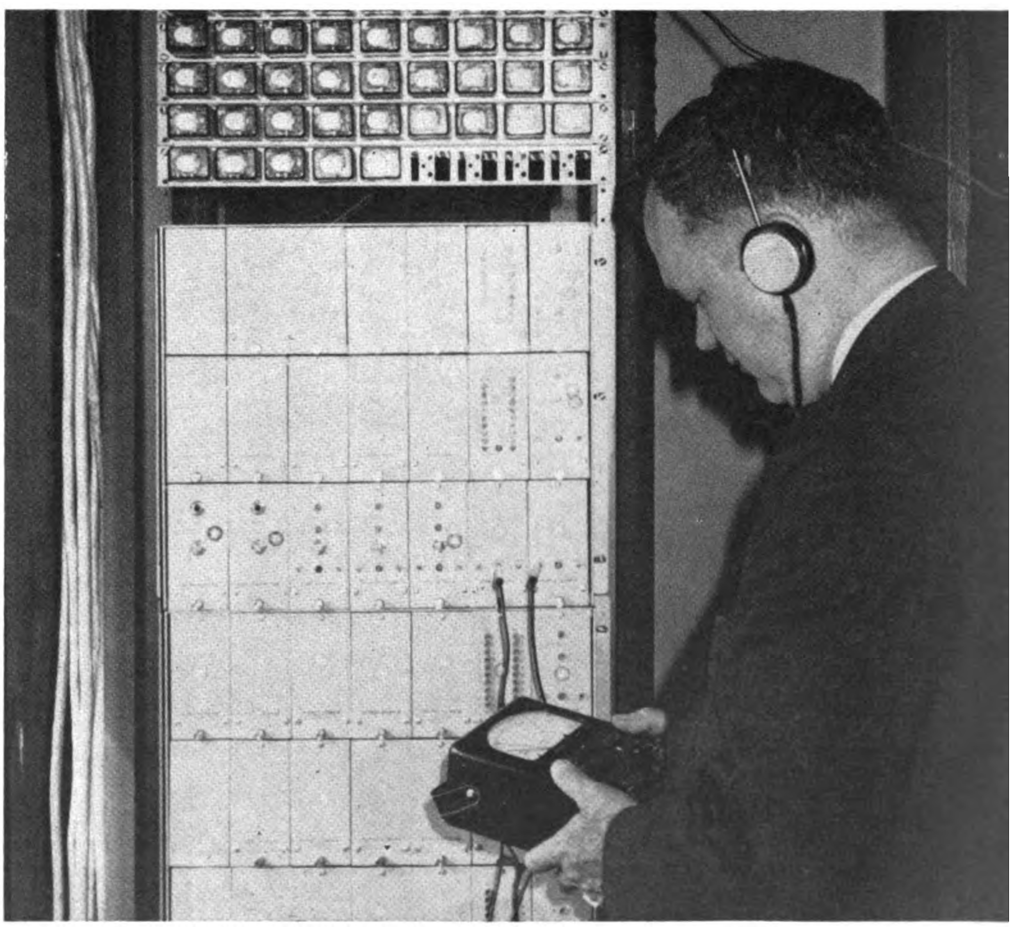
\ three-state, 2-out-of-5 code, wn in Figure 4 is used for the hest-security applications, such as itrol functions and station addresses, well as horizontal and vertical co-linates.

There are ten possible 2-out-of-5 des. Each is given a number from to 9, determined by adding the ight or value of the two pulses on "1" bus. As shown under the pulse sitions in Figure 4, the values are 1, 2, 4, and 7. When the two "1" lses appear in the 4 and 7 positions, e resulting code value, 11, is defined "0". Three code checks are made each frame.

To be acceptable, the frame must ntain no more and no fewer than re information pulses, with two on e "1" bus and three on the "0" bus. o produce an error, a "1" must be anged to a "0", and a "0" to a "1".

In the codes of Figure 4, the end each frame and the beginning of e next is indicated by a period of o modulation, called the "intercode" IC). If any signals arrive during the rger part of the intercode, they de-troy the parity check, thus providing rther protection against false opera-ion by interference.

Information received from each rame is stored in the logic circuitry ntil the intercode has been detected nd the parity check and other tests ave been passed. Only then is it read ut. Incorrect information is "dumped" nd may sound an alarm. RSC



Trouble shooting on the solid-state equipment can be done with a Simpson 260 meter and high-impedance headphones. After checking to insure that supply voltages are correct, a signalman listens to the clicks or beeps which are produced in the various parts of the system. By noting that beeps in a defective unit sound differently than when the unit is functioning properly, the defective unit can be located quickly. The defective unit is then unplugged and replaced with a spare module. Pen jacks are provided on the front of the panels for plugging in the headphones.