The Lenkurt Demodulator

NEWS FROM LENKURT ELECTRIC

VOL. 11, NO. 8 AUGUST, 1962

More About LOGIC

Most electronic computers live in their "own little worlds," usually confined to such hum-drum tasks as payroll accounting or inventory control. However, the wedding of computer and data transmission technology has opened the door to a wide variety of new applications such as inter-city banking, air and rail passenger reservations, traffic control, and the like. Certain basic principles of electronic logic have become the common denominator in integrated computer-transmission systems, or in the closely related field of telemetry and control. Accordingly, the study and understanding of these principles assumes new importance. This article reviews elementary logic principles and some of the ways in which they are used.

Surprisingly, the basic principles underlying today's extensive switching and computer technology can be traced back to Aristotle in approximately 330 B.C. The Greek philosopher, to explain his discoveries, developed a system of logic, dealing with statements that were either true or false, but never partially so. He determined that an answer could be obtained for most problems by logical testing of a sufficient number of facts, much like the parlor game called "Twenty Questions." Any "false" answer indicated that the inquiry was on the wrong track, while "true" statements, on the other hand, justified continuing with the problem.

The system was refined from its sentence form into a kind of mathematical shorthand in 1847 by an English mathematician, George Boole. Boolean Algebra, as his shorthand system is known, has become the almost universal language of logic, when applied to systems design. It is an efficient tool that can be used to design many kinds of systems, including mechanical and electronic computers, telephone switching systems, telemetry and alarm circuitry, and even hydraulic systems.

The systematic approach typified by Boolean Algebra enables very complex systems to be devised efficiently, using very simple basic elements. In earlier days, most systems of any sort were relatively simple. Decisions or choices could be made readily by an attendant or operator. In the much vaster systems

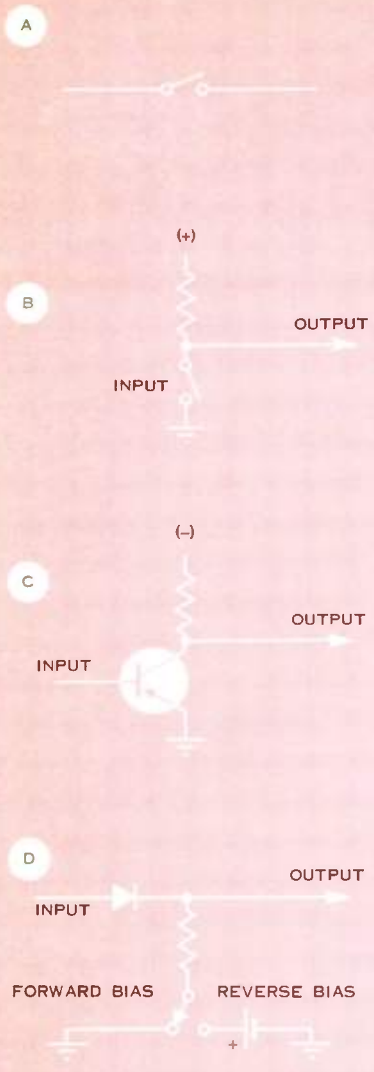


Figure 1. Several versions of basic gate. Transistor gate (c) is equivalent to switch in (b); incoming pulse cuts off transistor, increasing collector voltage on output. Diode gate (d) blocks or conducts in response to input according to its bias.

which exist today (such as the national and continental telephone networks which allow one to dial up a connection to any one of millions of other telephones), such hand operations are obviously impractical.

In Boolean algebra, four basic functions or relationships are used in constructing logical statements; these are often represented by the conjunctions AND, OR, NOT, and NOR. These words express special cases of the basic "true or false" approach of Aristotle. Thus, Aristotle might have said, "Virtues are good. Charity is a virtue. Therefore, charity is good." The same proof, using a sentence equivalent of the Boolean system, might be, "If virtues are good AND charity is a virtue, then charity is good." Another variation could be, "Virtues are good; cruelty is NOT a virtue. Therefore, cruelty is NOT good."

Binary Logic

Although four relationships are used, they are actually only special cases of the basic true-false approach, since they basically include or exclude some fact or statement. This two-state or binary approach is particularly well suited for use in machine or electrical logic. The important characteristic is that there be two distinct, contrasting states or conditions. While these might be called "true" or "false" when in the form of words or thoughts, they can be represented in machines or electrical devices by the presence or absence of electrical or magnetic fields, tones, voltages or many other conditions. Indeed, two values or amplitudes can be used, as can two frequencies. The two basic conditions can be represented mechanically by open or closed, locked or unlocked, and so forth. Any device, then, that performs some function or "makes a decision" on the basis of the presence or absence of some variable condition

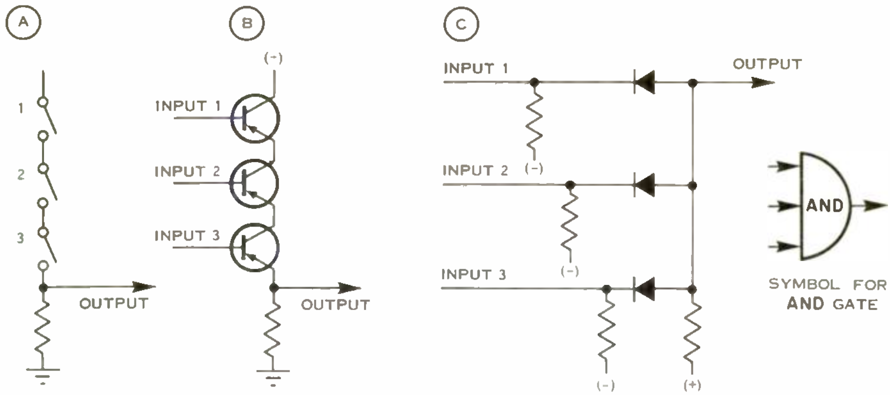


Figure 2. Typical AND gates. Output produces a **I** *only when all input circuits are also in* **I** *state. In (c) each diode conducts for others except when blocked by input. Only when all are blocked can voltage register in output.*

can be thought of as an elementary logic circuit. A thermostat is such a device, as are safety valves, limit switches, and many forms of communication devices. These two states are represented here by **I** and **O**.

In electronics, the basic elements of logic are very simple circuits called *gates* which are made to either block or pass a signal in response to some clue. In the earliest electrical computers and in many switching systems today, the basic gate is an electromagnetic relay.

The basic gate circuits can be made in many other ways, of course. One method is to alter the impedance of a circuit, to block or pass a signal. Another is to use an amplifier which has no gain in one condition but substantial gain in the other. The most common technique, however, is to use some sort of electronic device such as an electron tube, transistor, or diode.

Semiconductor devices in particular are most used because of their small size, reliability, low power requirements, and the simplicity of the circuits in which they are used. Figure 1 illustrates a basic gate circuit and several ways of obtaining it. In part *c* of the illustration, the polarity of the bias on the diode determines whether an input signal induces or blocks the flow of current in the output circuit.

Electronic gates may easily be arranged to perform the AND, NOT, OR, and NOR functions of Boolean algebra. In the simplest case, an AND circuit may consist of two or more switches in series. A current flows in the circuit only if switch 1 and switch 2 are both closed. An OR circuit may consist of switches connected in parallel so that current will flow if switch 1 OR switch 2 are closed. A NOT circuit could be made by shunting a switch across a load so that current will flow (through the load) if the switch is NOT closed.

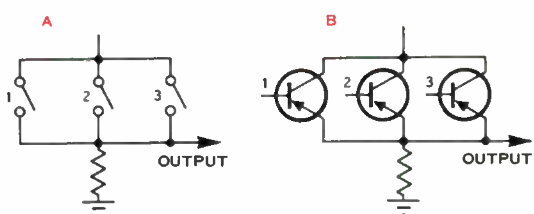
The *inverter* has the special function of "negating" or reversing the effect of a signal applied to its input. Thus, a positive voltage at the input may result in a *negative* output voltage or the blocking of an existing current. In the inverter shown in Figure 4, note that a common-emitter transistor circuit is used to provide the phase reversal which is required of an inverter. If a common-base circuit is used, no phase reversal occurs, and the transistor may be used for an OR circuit, as shown in Figure 3 *(c)*.

The inverter's capability of signal negation is most useful when combined with other logic circuits. A NOT circuit can be formed by combining an inverter with an AND circuit. The AND gate will conduct if all its inputs are in the **I** state. An inverter in any of the input leads to the AND gate, however, prevents the AND gate from conducting unless its input is NOT **I**.

Figure 5 shows how an inverter may be used to obtain a NOR gate. A **I** on any of the input circuits causes the transistor to conduct, thus shunting the output and producing a **O**.

Information Storage

In the more complex logical devices, some means of storing information about the condition of some gate or circuit is needed so that it can be compared with other information in performing further logical functions. One way of storing a **I** is to use a latching relay, one that, once energized, locks itself on until its source of power is interrupted by some other circuit. The equivalent electron tube or transistor device is the so-called "flip-flop." Like a relay, it has two possible states. One transistor is always conducting, and the other non-conducting. When one transistor is cut-off, its output (collector) is negative, and this negative voltage, applied to the base of the other transistor, keeps it conducting. A short positive pulse at the base of the non-conducting transistor allows it to draw current, thus forcing the base of the conducting transistor negative and causing it to cut off. By applying suitable positive pulses to one side or the other, the circuit can be "flipped" or "flopped" from one state to the other. The more practical circuit shown in Figure 6 will switch from one state to another by repetitive pulses applied at a single point in the circuit.



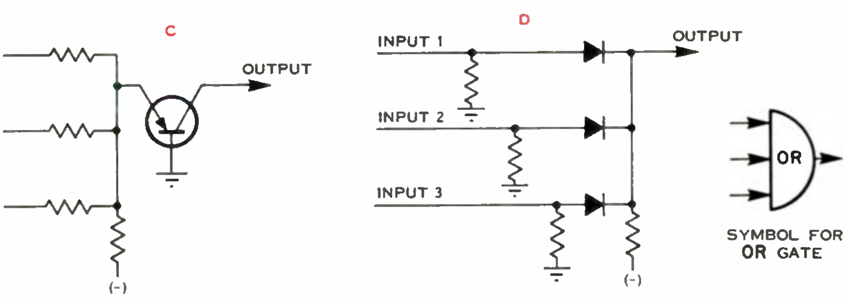


Figure 3. Typical OR circuits. Any of several inputs are able to cause output. Common-base transistor circuit (which has no phase reversal) may be used as OR circuit.

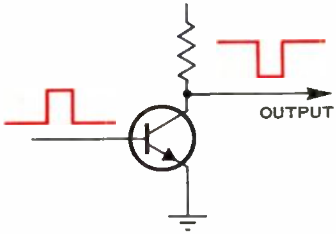


*Figure 4. Inverter requires electron tube or transistor circuit arrangement which produces phase reversal to convert **1** into **0**. Used with basic AND and OR gates, inverter provides additional functions.*

By connecting several flip-flops in series so that the "flip", or change of state, of one triggers the next, it becomes possible to count pulses, delay their application to other circuits a known amount, or devise networks which can trigger certain functions when a certain number or combination of pulses have appeared. This capability is the basis of the large digital computers which are revolutionizing many aspects of modern industry and business.

Communications Logic

The designers of modern computers have turned to more refined techniques than mentioned here, in order to compress more and more complicated circuits into more compact units. The flip-flop is becoming obsolete as a storage device in large computers and giving way to magnetic cores and other two-state devices that can be assembled in elaborate matrixes which are less expensive and allow faster handling of the huge amount of data required.

Although some larger computers have reached the point where they can simulate some of the more subtle functions of the brain, not every computer needs this ability. In most applications, the ability would be wasted. Modern computer design is showing an increasing trend toward specialization in order to make the most efficient use of these expensive tools.

Similarly, the use of logic principles in communications networks repeats this "form follows function" concept. The increased availability of good semiconductor components has resulted in much greater use of logical circuits in relatively simple applications, as well as those requiring great complexity. Several examples have already been described (DEMODULATOR, September, 1960).

An important area where increased use of logic techniques is paying large dividends is that of *fault alarm reporting*. As communications systems become more elaborate, it becomes necessary to operate more equipment in remote locations, unattended and sometimes difficult to reach. This is made possible by including alarms in the equipment and in the remote station that monitor performance and conditions and report malfunctions.

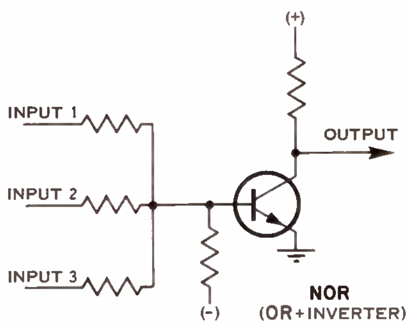


*Figure 5. NOR circuit is obtained by combining AND gate and inverter, so that **1** is obtained at output only when all inputs are **0**.*

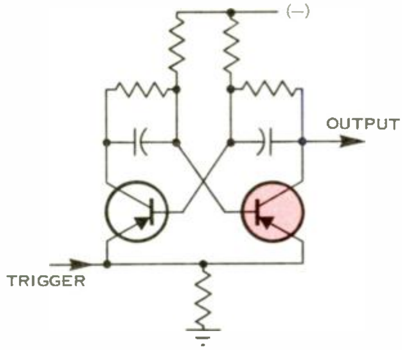


Figure 6. Typical simple transistor flip-flop circuits used for information storage and memory in computers and other logical devices.

In elaborate systems, however, there are many things that can go wrong, and some are more critical than others. The alarm system of a typical carrier-microwave communications system must be able to sense the failure of any part of the microwave transmitting or receiving equipment, switch service to alternate equipment, and report the happening to a central station. Typically, such a fault alarm system will report on unauthorized entry, fuel supply (for stand-by power) various kinds of equipment failure, and the quality of the transmission.

In order to handle the diversity of information that should be reported, relatively simple logic circuits have enabled the alarm systems to be greatly simplified. For example, in the receiver alarm circuit shown in Figure 7, a logical circuit has to make a decision about the severity of a failure and then report. If the pilot tone is not received for any reason, or should noise exceed certain limits, a failure indication (1) is applied to OR gate 1 or OR gate 2, the outputs of which are applied to OR gate 3. Gate 3 accordingly reports a "minor" alarm. Any additional failure keys the AND gate, causing a "major" alarm.

A more elaborate use of logic circuitry is found in the fault alarm transmission equipment itself. Figure 8 shows a simplified diagram of the encoding and transmission arrangement used in the Lenkurt Type 936 Telemetry/Alarm Systems for reporting alarm conditions to a central location.

At the remote location, any failure grounds one of the leads into a matrix of logic circuits. The coincidence of the grounded lead and the stream of pulses from the pulse generator into the matrix results in a sequence of pulses which control the "state" of two flip-flop circuits. These, in turn, determine the phase shift of a tone transmitted back

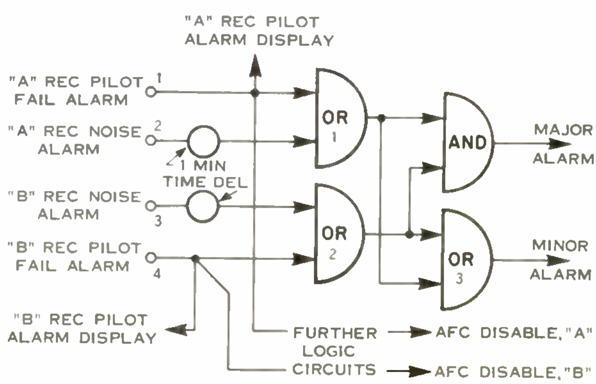


Figure 7. Typical simple communications application for logic is alarm arrangement in microwave system. Minor alarm is sounded by any single fault, major alarm when any two faults occur.

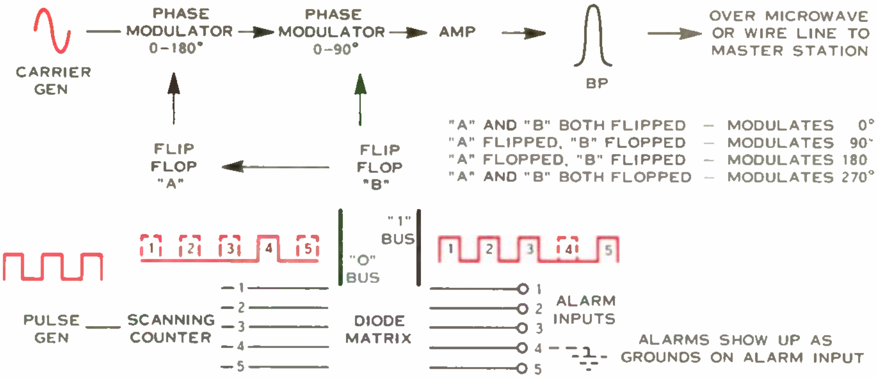


Figure 8. Entire operation of Type 936 alarm and control units depends on logic circuitry, even for modulation. System works on one form of time-division multiplex. Phase shift of transmitted signal indicates which of several conditions prevail at transmitter.

to a central station. At the central station, the phase of the received tone is detected and the fault identified. This use of time-division multiplexing and phase shift modulation makes optimum use of the bandwidth available, and permits many functions to be monitored, yet provides great freedom from interference, despite a relatively narrow transmission bandwidth.

Looking Forward

There is a remarkable similarity between the inner workings of modern computers, communications switching centers, and certain types of time-division multiplexers. All of them use the same basic logic technology to achieve their ends. Just as the various seemingly unrelated diverse fields of science are growing toward each other and fusing into one, it will not be surprising to see the distinction between local exchange switching centers and long distance toll transmission centers fade, and even disappear. Perhaps the switching/multiplex/transmission center of the future will even be able to perform "odd jobs" of computing for customers during slack periods! •

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