Digital Logic in VCR Servicing

Part 2—Gates, truth tables, transistors and diode logic—they're all easier to understand when you see how they can simplify VCR control.

FOREST BELT

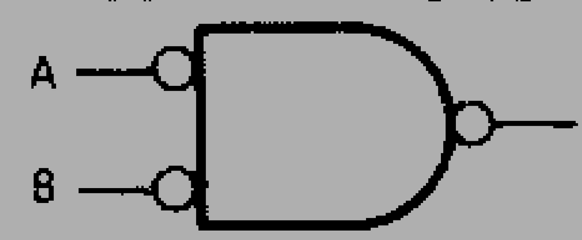
LAST MONTH YOU WERE INTRODUCED to the basic logic circuits. Now let's take a look at some interesting adaptations.

CHART 6—NEGATIVE AND + NEGATIVE OR GATES

NEGATIVE OR GATE

INPUT A	INPUT B	OUTPUT
0	0	0
0	1	1
1	0	1
1	1	1

NEGATIVE AND GATE



INPUT A	INPUT B	OUTPUT
0	0	0
0	1	0
1	0	0
1	1	1

Positive and negative logic

The gates and logic principles discussed so far assume the use of positive logic. This means that a positive DC voltage represents logic high. Gate turn-on results from some combination of positive-voltage highs. An output high also goes in a positive direction.

Some logic systems operate with negative logic. Gate turn-on occurs because of negative-going input or high negative voltage. An output high from a negative-logic gate would be in the negative direction from zero or near-zero voltage.

In theoretical discussions of digital logic, and for design purposes, you need to understand negative logic and negative-logic gates. But for practical purposes as when you troubleshoot most VCR digital stages and sections, you can deal with negative gates on a basis of what you already know. Just remember that:

1. A shift of positive logic from high to low is a negative shift, as a negative-logic high would be and:

2. A shift of positive logic from low to high can be construed as a negative-logic low.

To make life easy among the VCR's digital circuits, don't worry about negative logic. In virtually every instance, you can treat all gates *in terms of* positive logic regardless of the gate configuration. And best of all, this approach simplifies understanding.

You've already seen gates with a Not-circle. The NOR and NAND gates are examples. Keep in mind that each Not-circle represents logic inversion. The circle makes a low become high and a high become low.

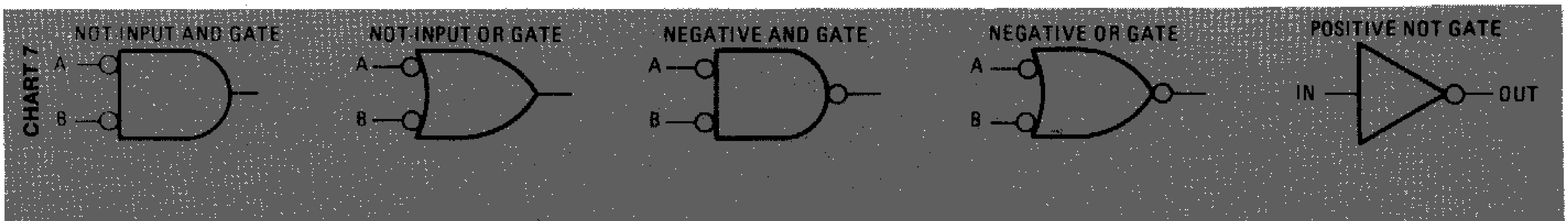
Negative-AND Gate—The symbol for a Negative-AND gate is the usual AND sign with NOT-circles at inputs and output. Let's consider operation in regular logic terms.

Low-logic input at A, through a Not-circle, inverts to logic high as it enters the gate. Low-logic input at B also inverts to logic high as it enters. The AND gate inside, effectively seeing two high inputs, turns on and produces high output. But then the output Not-circle inverts it. Hence a Negative-AND gate, with two logic-low inputs, delivers a logic-low output (see truth table line 1).

One logic high to either input gets inverted to a logic low. The AND gate can only put out low logic. But again the Not-circle inverts the input logic. So, Negative-AND output goes high when either input sees a logic high (see lines 2 and 3).

Suppose both inputs go logic high (see line 4). Both input Not-circles invert the logic. The gate, seeing lows internally, starts logic low out. The output Not-circle then inverts the logic. So logic high at both inputs of a Negative-AND gate produce output high.

Hence, the truth table lays out overall operation of a Negative-AND gate for you. Remember, you can "convert" positive logic to negative logic by considering the *direction* of the logic change.



Not-Input AND Gate

INPUT A	INPUT B	OUTPUT
0	0	1
0	1	0
1	0	0
1	1	0

Not-Input OR Gate

INPUT A	INPUT B	OUTPUT
0	0	1
0	1	1
1	0	1
1	1	0

Negative AND Gate

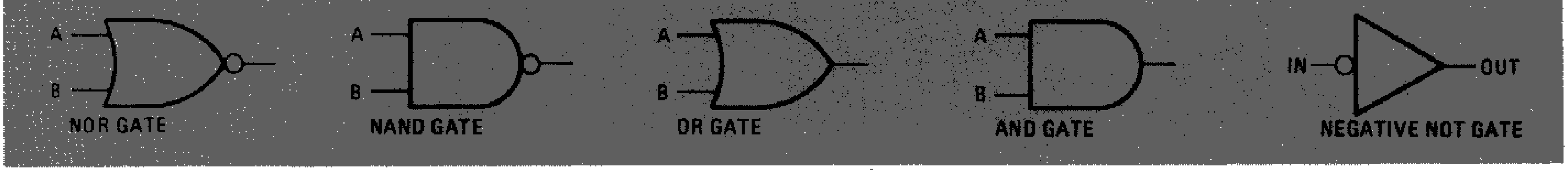
INPUT A	INPUT B	OUTPUT
0	0	0
0	1	1
1	0	1
1	1	1

Negative OR Gate

INPUT A	INPUT B	OUTPUT
0	0	0
0	1	0
1	0	0
1	1	1

Positive Not Gate

INPUT	OUTPUT
0	1
1	0



However, you seldom need to do this in VCR logic circuits.

Negative-OR Gate—Add Not inputs and a Not output to an OR-gate symbol, and you have a Negative-OR gate. You can cover up the Negative-OR truth table and write one yourself to prove you can reason through the operation.

Line 1: Two logic-low inputs invert and become two logic highs. This turns on the OR gate (it is inclusive). A gated high becomes inverted at the output to give a Negative-OR output low.

Line 2: Input A low (becomes high); input B is high (becomes low). One high is enough to turn on the OR gate, for a high inside. But inverted output delivers a logic low.

Line 3: Input A high (inverts to low); input B is low (inverts to high). As always one high input sends an OR gate high, and the output inverts again to logic low.

Line 4: Two high inputs. Both invert to logic low. The gate stays off, developing an internal logic low. Inversion then makes the output high.

You may begin to suspect there is no end to logic-gate configurations, and you may be right. But when you reach a certain point, the logic begins repeating itself.

Let's look at the Primary Gates Master Chart. The first gate shown in the upper left is an AND gate with both inputs Not. At this point you know the truth table has been written as follows:

Line 1: Two low inputs invert and turn on the gate, for an output high.

Lines 2 and 3: One input low and the other high (both inverted) still leave one input low and one high, which keeps the output low for either condition.

Line 4: Two highs invert to lows and leave the gate off (output low).

One aspect about this Not-Input AND gate is well worth noting. Its truth table exactly matches that of a simple NOR gate. The two gates are thus interchangeable. This accounts for the OR-gate symbol placed beneath this first truth table.

Look at the second truth table: It sets forth the operation of a Not-Input OR gate:

Line 1: Two inputs invert to high, and turn on a high output.

Lines 2 and 3: If either input is low, it inverts to a high, triggering a high output.

Line 4: Two high inputs invert to both low, and the gate sends out a logic low.

This coincides with the operation of a plain NAND gate. In typical use, the two really are interchangeable.

Why do both configurations exist for each operation? It's largely a matter of construction. Some digital IC's feature MOS (*M*etal-*O*xide *S*ilicon) materials; others offer bipolar-type TTL (*T*ransistor-*T*ransistor *L*ogic) and other non-MOS construction. IC designs often boil down to cost and availability. The MOS-type gates are usually OR-related; the TTL gates and the like are generally AND-based. A logic diagram shows the symbol for whichever kind of gate a function uses.

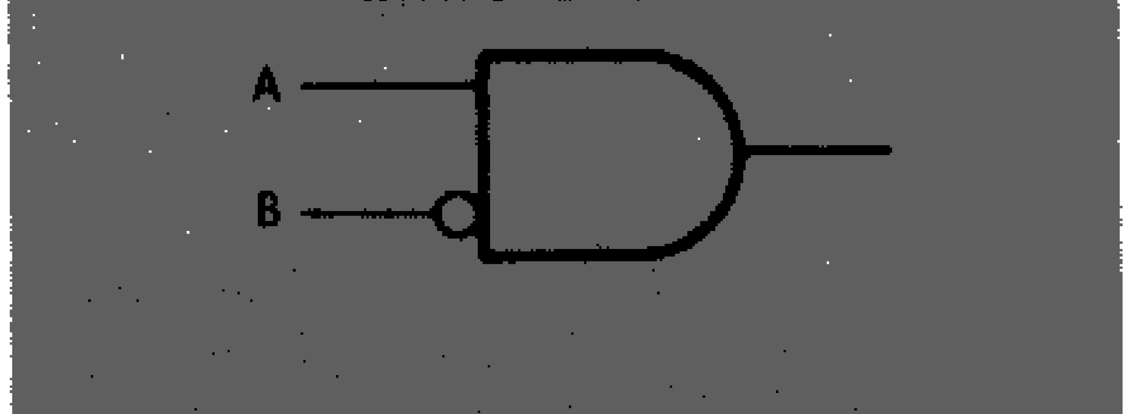
You have already spotted the other interchangeables in the Master Chart. A Negative-AND gate manipulates logic exactly the same way as an OR gate. A Negative-OR gate works just like an AND gate. Both their respective truth tables prove this.

Moreover, it's not uncommon to find logic-circuit descriptions that substitute one name for another. A Not-Input OR gate, for example, can be described as performing a NAND operation—which it does. Hence, the Primary Gates Master Chart helps you avoid confusion. I suggest you copy this chart and post it near your service bench. It can save you many wasted hours until you are a 100% familiar with logic gates.

A Not-Input Gate—Finally, here's one more hybrid gate that is commonly found VCR logic systems. Look at the symbol showing only one Not Input to an AND gate. The Not circle is at input B.

The *Not* symbol indicates logic inversion. So, logic low reaching input B of this AND gate finds itself inverted, and acts on the AND gate as a high input would. Conversely, a high to input B has the same effect on the gate as a low input would on an ordinary AND gate.

CHART 8—AND GATE WITH ONE NOT INPUT



INPUT A	INPUT B	OUTPUT
0	0	0
0	1	0
1	0	1
1	1	0

Now, figure out the truth table for this Not-Input gate, using the following reasoning:

Line 1: Input A shows logic low. Any AND gate requires both inputs to be high to turn on, so the output here must remain low. (It doesn't matter what happens at the other gate.)

Line 2: Input A is still low. The AND gate cannot turn on no matter what happens at input B. So the output stays logic low.

Line 3: Input A is high, one condition for an AND gate to turn on. Input B sees logic low. However, that low is inverted by the Not-Input configuration, so the gate (internally) sees high from input B. Therefore, the gate turns on and output goes high.

Line 4: Input A is high, meeting one condition for AND-gate turn-on. Input B sees high. But the *Not*-input configuration inverts that condition, so the gate internally finds logic low from this input.

Since the gate sees only one high input, the output stays low.

Why bother, you wonder. Some VCR controls must be activated when only one particular input reads high. Neither an AND gate nor an OR gate could manage that directly. A NOT gate could be inserted in the B-lead of an ordinary AND gate. But this means using an extra device, which is sometimes easy and sometimes not. An AND gate with one inverted input does the job more easily.

Analyzing gates

Gates such as those just described are connected every-which-way to form digital-logic circuits and systems. Your primary tool in digital troubleshooting is your knowledge of how each type of gate works. Once you identify each gate in a system, you check its inputs and then verify that the gate turns on or off in accordance with its truth table. You can thus trace highs and lows through a whole system.

Figure 3 contains the logic circuits that are involved in the automatic shutdown of the tape transport mechanism in a VHS type of video cassette recorder. The diagram shows the Stop Solenoid and four of its sensor systems. The Stop Solenoid, when it is activated, releases any control pushbuttons that are depressed. This delivers the same effect as manually depressing the Stop pushbutton on the machine.

The best way to analyze this sytem is to begin at the solenoid and work your way back. Here's how the logic goes:

During normal operation, the solenoid remains inactive. Transistor Q617 is not conducting. No current flows in it or the coil. The transistor, for all practical purposes, is open. Logic (voltage) at the collector is therefore high.

As you work your way back from any point in a diagram, label the logic at each gate, as has been done in Fig. 3. This requires only that you know how each type of gate works.

If logic is high at the collector (the output) of Q617, it must be low at the base (the input). Remember the inversion in a common-emitter amplifier (Fig. 1-a)? Label the base LO.

Transistors Q614 and Q613 are shown in Fig. 3 as NOT gates. Actually, they too are transistors that invert the logic as you saw in Fig. 1-a. So, logic must be normally high between the two and must be low at the output of the four-input Diode-OR gate.

You know that an OR gate turns on when any one of its inputs goes high. Since the output is now at logic low, all four inputs must also be at logic low. So you would label all four input lines as shown in Fig. 3. (In an actual shop situation, you would do the labeling on the manufacturer's schematic.)

Now, move down the D-input leg from the Diode-OR gate. The capacitor prevents DC from passing through, but insures that a sudden upward surge on the line passes up to the OR gate. In the quiescent state, however, logic across the capacitor is low, meaning that Not-gate output is low. Its input, therefore, must be high during normal operation, which is indicated by the HI label.

Now for the C-input leg: Logic low at the OR-gate input indicates logic low at the resistor junctions. But imagine a burnout in the end-of-tape (EOT) light. The voltage at those junctions goes high. Logic high reaches the OR gate and turns it on.

Logic high at the OR-gate output inverts to logic low after Q613, and to logic

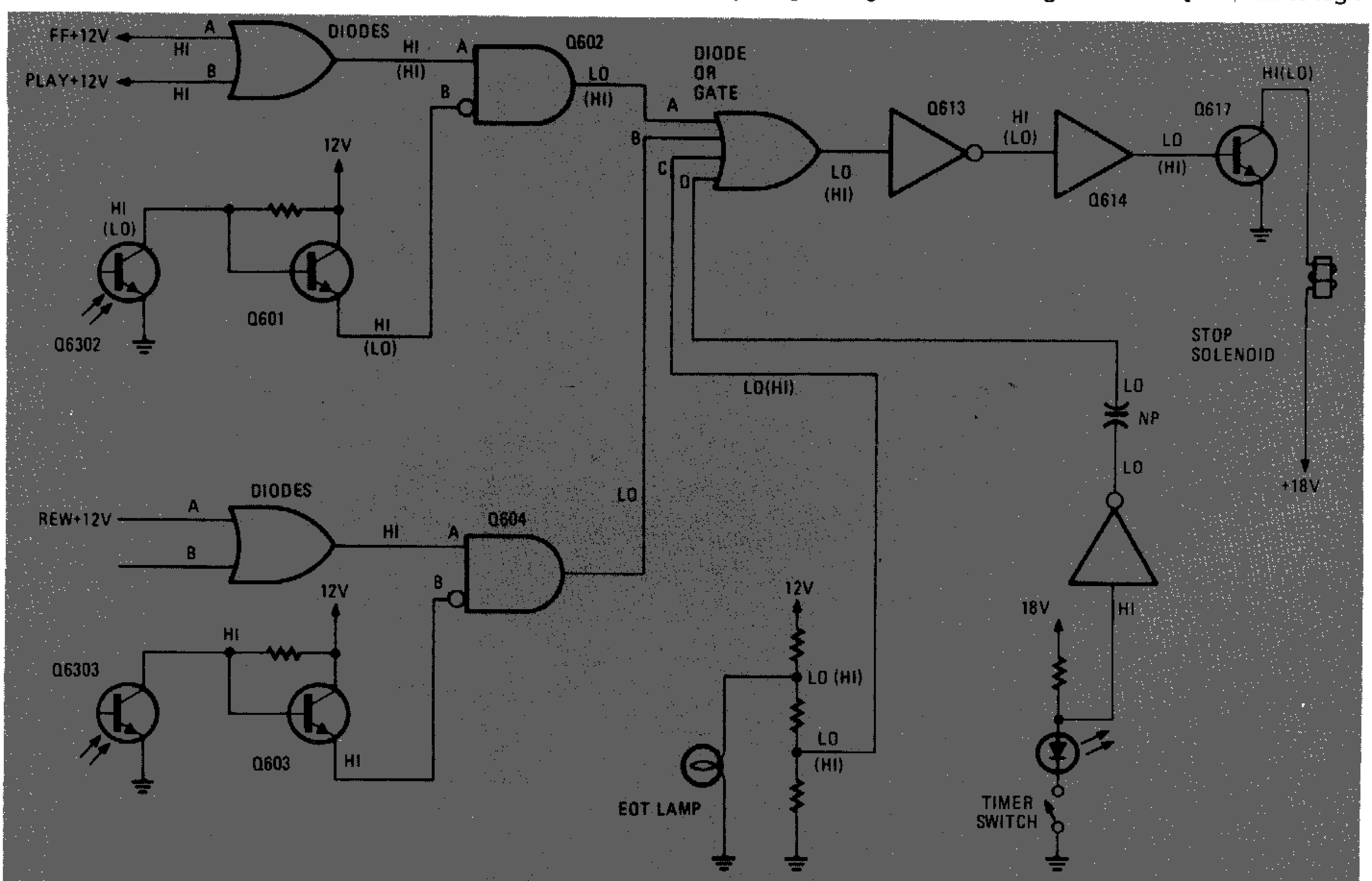


FIG. 3—LOGIC DIAGRAM of a complicated automatic shutoff system is easier to trace than a regular schematic diagram. Here, many logic devices are same components you have always dealt with. In other instances, they may be inside IC's.

high following Q614, which turns on transistor Q617. Current through the coil pulls the solenoid in, tripping the STOP mechanism.

Each of these "in action" logic levels goes on your schematic in parentheses, as shown in Fig. 3.

Turn to the input-B branch. Logic low at the AND-gate output means at least one of the gate inputs must be low. But which one? In this case, it is the automatic shutoff for the end of rewind. You can tell because the REWIND switch places 12 volts on one OR-gate input, which then delivers logic high at its output.

This makes input A of the AND gate go high. The AND gate is thus "armed," (in digital parlance, this is called *enabling the gate)*. But the AND gate is still not operative during Rewind. Therefore, the gate must be seeing logic low internally from input B. Because of the Not-input configuration, the actual B input must be high during normal operation.

Transistor Q603 is connected as an emitter-follower. This means it acts merely as a pass-along amplifier. It does not invert (see Fig. 1-b). Logic high at its emitter (the output), then, suggests logic high at its base (the input).

Transitor Q6303 is a light-sensitive transistor that acts as a variable resistor. It forms a divider with the resistor from the 12-volt line. With the transistor dark, as it is while the tape runs through the transport, resistance is high. Thus, logic high is maintained at the base of Q603, as long as opaque tape intervenes between the sensing transistor and the (EOT) light.

Now, trace the action of this automatic Stop arrangement. When tape comes to the end at the takeup reel, a transparent trailer lets light fall on the EOT transistor. Resistance goes way down. This brings logic low to the base of Q603, and logic low to input B of AND gate Q604. The Not-input inverts the logic low, making it logic high inside the gate. Input A is already at logic high. This is an AND gate, so logic high at both inputs turns it on.

Logic high from the AND-gate output goes to input B of the large OR gate. A logic-high output develops. And you already know how the rest of the gates pull in the Stop Solenoid. The VCR thus returns to its STOP mode when the tape is fully rewound.

Branch A from the OR gate operates almost the same as branch B just described. The difference is that either the PLAY button or the FAST-FORWARD button enables an AND gate through its input A. Then, when all the tape has been used up from the supply reel in the cassette, EOT sensing changes logic high to logic low at AND-gate input B. The AND gate—through its Not-input—turns on, Initiating the Stop-Solenoid sequence.

Tracing and testing

Both low and high logic states consist merely of DC voltage levels. You could use a DC voltmeter when you need to check gate operation. In some digital systems, a voltmeter *can* do the job. In other systems, digital states occur and change very rapidly, and a voltmeter can't keep up.

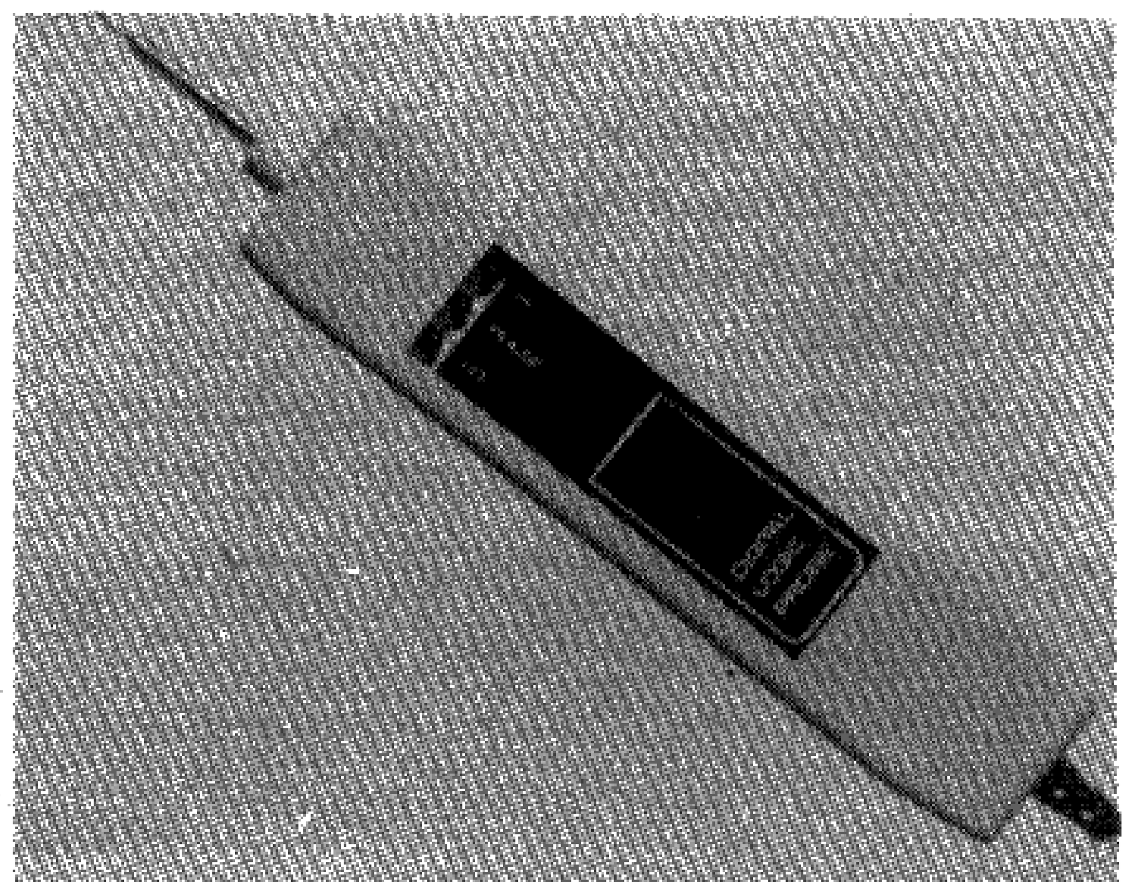
A device called a *logic probe* takes the place of a voltmeter rather handily. It contains circuitry that senses either logic-low or logic-high conditions when you touch the probe to a test point (the input or output of a gate). A light-emitting diode (LED) turns on when the probe touches logic high. The LED extinguishes on logic low. You can trace low or high conditions even though the logic changes too quickly for a voltmeter. You just need to know the gates and what to expect at their inputs and outputs.

In many digital-logic systems, however, the voltage levels switch from low to high and back *very* rapidly. The logic consists actually of voltage *pulses,* which are often very precisely timed. You need an *oscilloscope* to view these logic levels.

Exactly when a gate turns on and off depends on the timing of its inputs. A dual-trace scope, with a bandwidth to 15 or 20 MHz, is absolutely vital in comparing logic timing. A scope with even more traces comes in handy for some digital diagnosis, but you can manage with two in VCR servicing.

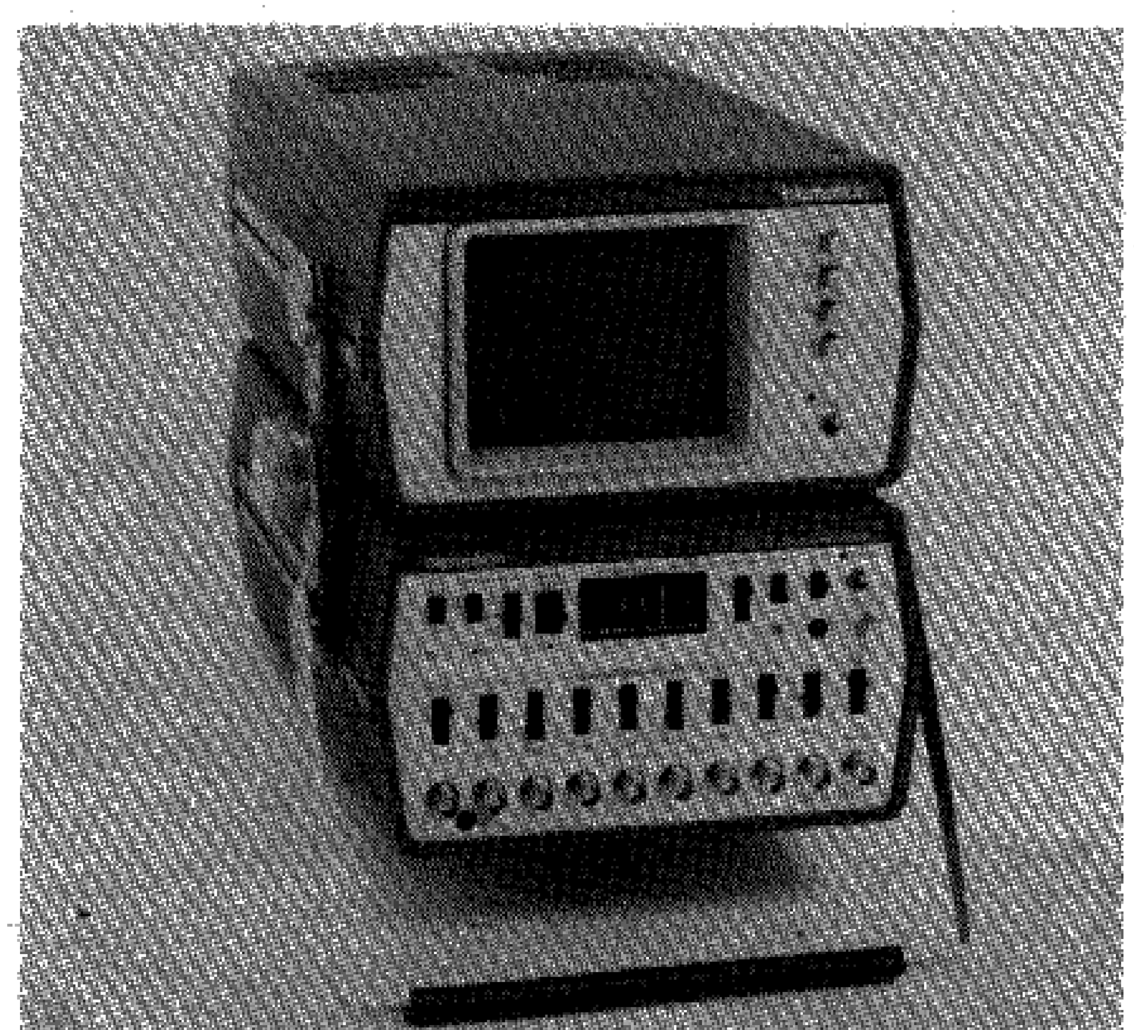
Let's now turn our attention back to what I call a steady-state logic system. Figure 3 is an example of this. Only in one branch (D) does a pulse get involved, The others are run by logic "states."

You have to see how you can trace your way through a string of logic gates to determine whether each gate is functioning properly or not. With this knowledge of logic tracing, you can then analyze pulse-handling logic systems more readily. A logic probe is the test instrument to use in this case.



LOGIC PROBE by Continental Specialties speeds digital-logic troubleshooting.

Remember that every gate in a system always exhibits one of two output states—low or high. Either state may be "normal." So, consider "normal" whichever state exists during regular system operation.



MULTITRACE SCOPE by Gould aids analysis in complex digital pulse stages and circuits, but dual-trace model suffices for VCR diagnosis.

Generally, a gate itself is considered to be off when its output is logic low, and on when its output is logic high. In that case, on may be the so-called normal condition for a gate (or off may be). Hence, you should test every gate for both conditions. To accomplish this, you will have to operate the system in both states—active and inactive—as you check the gate output. If you do not follow this procedure thoroughly, you may not find out whether the gate functions altogether properly.

Refer again to Fig. 3. Start by assuming the VCR is in a "normal" operating state for the Fast-Forward end-of-tape branch. This is the sensing branch that connects to input A of the diode-OR gate.

Insert a cassette, and start the cassette tape on Fast Forward by depressing that particular pushbutton on the VCR's front panel.

Touch your logic probe to input A of the first OR gate, where the FAST-FORWARD switch applies 12 volts. When you examine the manufacturer's schematic and the VCR itself, you will discover that this OR gate actually consists of two diodes. Figure 4 is a detailed partial schematic diagram of this sensing system.

Input A is the anode end of diode D601. Output (C) is the cathode end, where it and D602 join. Your logic probe should light up at both ends of D601, verifying that the switch does apply logic high and that the "gate" is passing it along. The probe should also show logic high at input A of the AND gate (see Fig. 3). Finding where to touch the probe reveals again that logic gates are not necessarily inside an IC. As it happens, in the video recorder section chosen for this demonstration, the AND gate is transistor Q602. Figure 4 shows the hookup.

The A′ input, the one that enables the transistor—which makes it ready for AND-gate operation—actually is the collector-supply connection. Diode D601 carries logic high from the FAST-FORWARD switch to the collector-supply resistor—input A′.

The B′ input, meanwhile, is at the transistor base. That's why input B′ happens to be shown in the logic symbol as an inverting (Not) input. A common-emitter stage always inverts its input logic. For now, your logic probe at input B′, the base of Q602, shows logic high.

The transistor conducts; in fact, it saturates, dropping voltage low (near ground potential)at the collector. Hence, the probe fails to light up at that point, signifying logic low at output C′ of the Q602 AND gate.

As you find the multi-input OR gate of Fig. 3 in the VCR, you will see it consists of several diodes connected just like the two-diode OR gate in Fig. 4. The inputs are the anode ends; the output is the cathodes tied together. The A input for

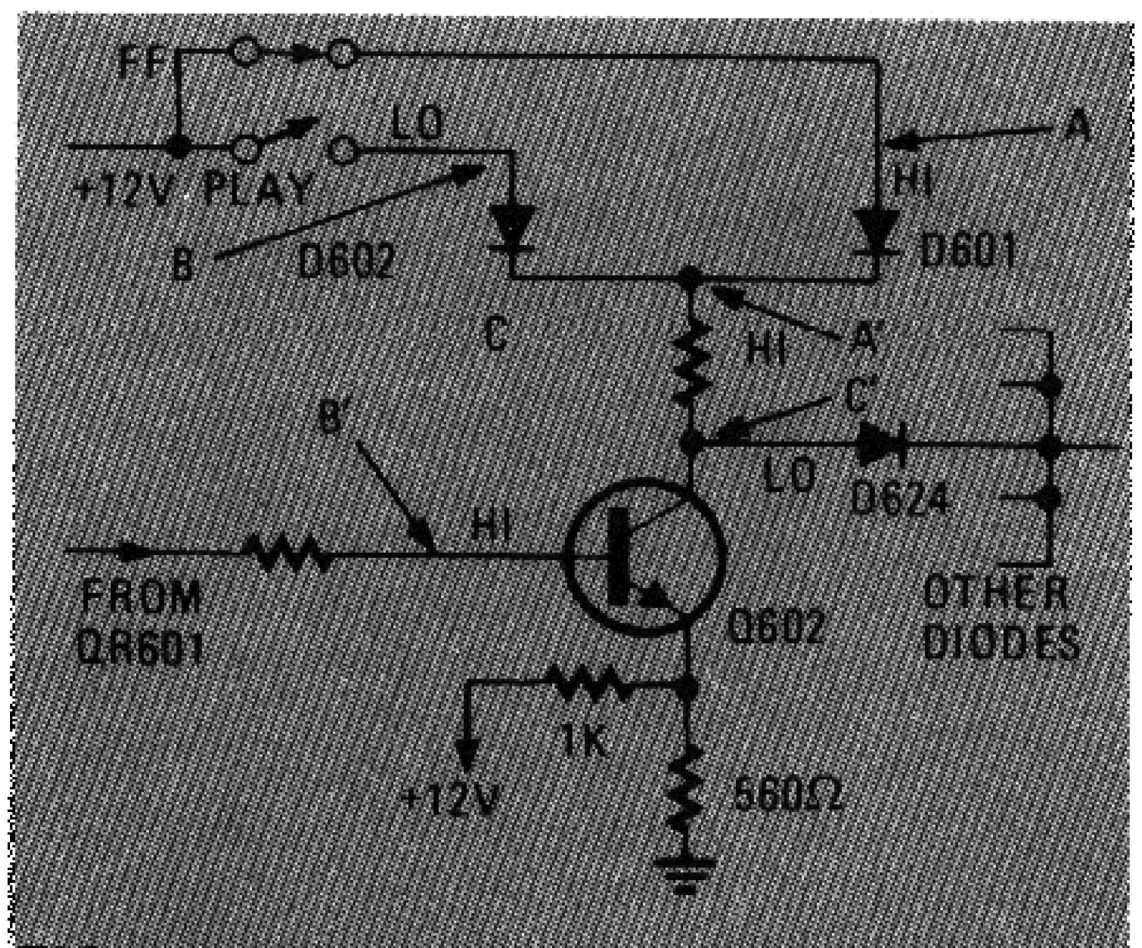


FIG. 4—SCHEMATIC DIAGRAM shows discrete components that form some logic circuits. As you can see, not all logic gates are in an IC.

this Diode-OR gate is diode D624. Your logic probe at its anode (the input) end shows low. But why does the probe show low at the cathode (the output) end? Because only a high positive voltage (logic high) on the anode makes the diode conductive, which turns the Diode-OR gate on from this particular input.

(I hope you realize from all this discussion how really simple and sensible digital logic is. Of course, the concept is new. It's vital that you learn to think in these new "gate" concepts. Gates do seem more complicated when there are groups of them inside IC's that are designed for special purposes. But it all remains just digital logic and based on the primary gates we have been looking at here.)

So, now we proceed to the next step in diagnosing Fig. 3. Touch your logic probe to the input of NOT gate Q613. This input happens to be the base of a transistor. The probe should read low (DC voltage at the base is low).

The NOT gate Q613 inverts the logic. In other words, voltage at the collector (the output) is high because the transistor is not conducting. Your logic probe should light up when you touch it to the collector of Q613.

The same is true at the base (the input) of NOT gate Q614. And because Q614 inverts the logic, the output (the collector) of Q614 should register logic low; the probe does not light up there.

Of course, Q617 is, in effect, another NOT gate, albeit one that can handle the heavy current drawn (later) by the solenoid coil. No current flows in Q617 right now, because of the logic low on its base. Therefore, your logic probe finds logic high on the collector of Q617. So far, everything appears OK.

Tracing the opposite mode

If all logic is correct from start to finish, the stages are ready to perform their shutoff function. But suppose the tape reaches its Fast-Forward end and the stages do not return the machine to Stop. How do you find out why this happens? By again tracing the logic through every gate. I suggest you follow this hypothetical malfunction in Fig. 3.

Start at the end-of-tape phototransistor sensor. Light reaches it through a transparent strip on the end of the tape. The phototransistor resistance goes low, as does voltage across it. Your logic probe therefore should not light up (logic low). If the probe does illuminate, you have already found the trouble.

Low logic across Q6302 should be passed on as logic low at the emitter of Q601 and at the base (input B) of AND gate Q602. If the FAST-FORWARD switch is OK, logic should still be high at input A (the end of the load resistor) of AND gate Q602. Low at the Q602 base should bring about logic high at the collector (the output) of Q602. Your logic probe should light up when you touch it there.

Logic high passes through the Diode-OR gate because high positive DC forward-biases the diode that serves as input A for this gate. Your logic probe should find logic high at the input to NOT gate Q613. If not, the diode is probably open.

At the input to NOT gate Q614, your probe should now register logic low. Suppose it does not. And suppose you find logic high at both input and output of NOT gate Q613. The NOT gate fails to invert. Because Q613 is a transistor, with logic high on its input (the base) it should run saturated. Voltage tests show it does not. The transistor proves defective. You replace it. Meanwhile, what happened in the rest of the system as a result of the failure at Q613?

Here's what occurred: Q614 found logic high on its base, just as if the end-of-tape sensor were inactive. Logic low remained on the base of Q617, and no current flowed to pull in the Stop Solenoid. Automatic shutoff failed. So the transport mechanism could keep tugging on the tape in the cassette, perhaps eventually breaking it.

However, with your trusty logic probe, you quickly found your way to the trouble. Plus you did it a lot faster than you might have had you been thinking of the system in old-fashioned analog terms. Digital logic can actually be easier and faster to troubleshoot, once you come to understand it. **R-E**