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Logic Circuits and the Quality of Life

Vincent W. Childress
North Carolina A & T State University

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LOGIC CIRCUITS AND THE QUALITY OF LIFE

Vincent W. Childress

The applications of logic circuits are countless.

Introduction

With the flooding of New Orleans in the wake of Hurricane Katrina, people around the world became all too aware of human dependency on technology to manage the forces of nature and maintain a high quality of life. New Orleans' sewage and water control systems depend on water pumps to move sewage, storm-water runoff, and fresh water around the city. Under normal conditions, when it rains in New Orleans, a city that sits below sea level, massive water pumps are automatically engaged, and rain water is pumped into Lake Pontchartrain, a nearby reservoir. However, when Katrina hit and electrical power to the city was cut, the system failed.

The transport of drinking water is one of the technological marvels that people do not think about until they have to go without. Water systems need several important components in order to operate efficiently, such as pumps and pump motors and reliable automation.

At the heart of the system that automates water pumping is an electronic control circuit. Electronic control circuits are used in a wide variety of applications, from controlling pump motors to making automobiles more safe and efficient. The same technology that forms the essence of this control and automation is also the basic building block of central processing units in computers. This technology is so pervasive in everyday life that it is truly a fundamental of technology that middle school and high school students need to understand.

This technology is known as the binary logic gate.

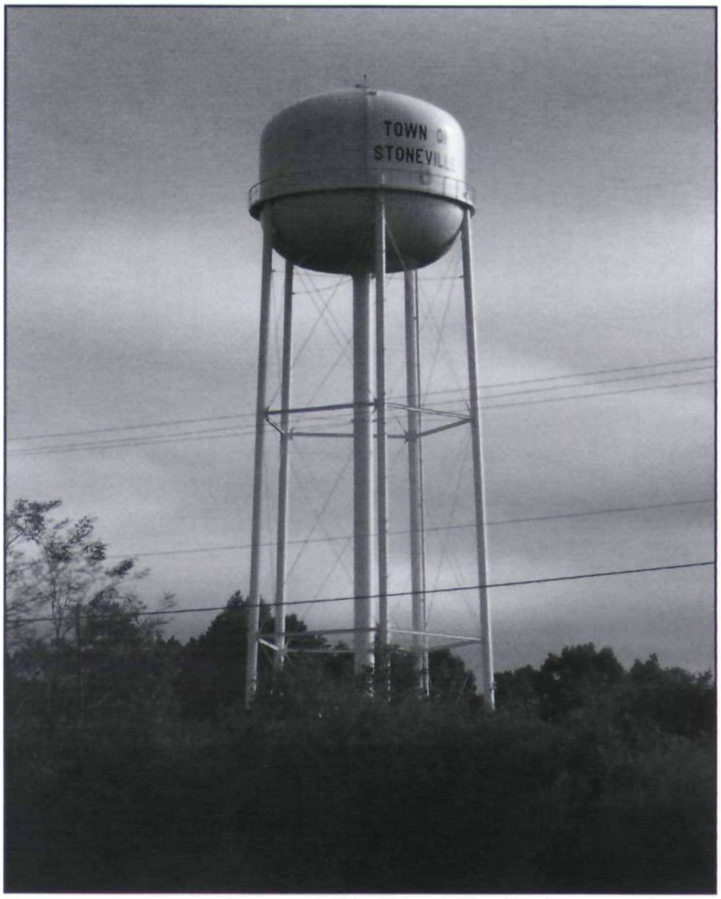


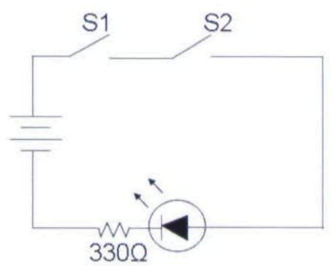
Figure 1. Efficient pumps and pump motors and reliable automation are important components of water systems.

Logic Control Circuits

Often, logic circuits are interfaced with other devices, such that the electronic circuits control the behavior of the other devices. For example, if there is water present in a storm drain, a water pump should automatically turn on. In order to do this, the logic circuit must be able to tell if water is present. This is accomplished by using sensors. There is a variety of ways to sense the presence of moisture. On some sensors, if water is present, the water changes resistance to electrical current flow. In turn, the sensor device will output a specific level of electrical voltage. It is the sensor's output voltage that becomes the input to the binary logic gate. In this case, if the sensor's output voltage is low (say 0 to 1VDC), then the output is low or zero. If the output voltage is high (say 4.7 to 5 VDC), then the output is high or 1.

1 = high = on

0 = low = off



AND Truth Table

Inputs		Output
B	A	Y
0	0	0
0	1	0
1	0	0
1	1	1

Boolean Expression

A • B = Y

Gate Symbol

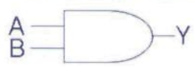


Figure 2. This circuit shows Boolean logic for an AND gate. If S1 (input A) AND S2 (input B) are closed, then the LED (output Y) will light. A circuit like this one is referred to as a Logic Gate.

Binary logic gates may be thought of as configurations of simple switches (see Tokheim, 2003). Suppose an electrical switch is being used to control a light. When a switch is closed, the light is on. When the switch is open, the light is off. In the world of logic, "on" is represented by 1, and "off" is represented by 0. On/off, 1/0, this is why the gates are referred to as "binary." They work on a base 2 number system like the central processing unit in a computer.

Logic gates are systems within themselves. They receive input. They process that input and change it into an output. When the sensor sends a 1 (or high voltage) to the input of a logic gate, the logic gate processes that input signal into an output. Whether or not the output of the logic gate is a 1 or 0 (high or low) depends on how the logic gate is designed.

In Figure 2, an AND gate has been constructed from simple switches. Only when switch 1 (S1) AND switch 2 (S2) are both closed will the light-emitting diode (LED) illuminate.

Two conditions must be met before the device being controlled can be turned on. There must be moisture present AND the water valve leading to the reservoir must be open before the pump will turn on. In the truth table for the AND gate, notice the inputs (A and B). If any input is 0 (low), then the output will remain 0 (low). Only when both inputs are 1 (high) will the output be 1 (high). That is the condition under which the logic control circuit will cause the device (such as a water pump) to be turned on.

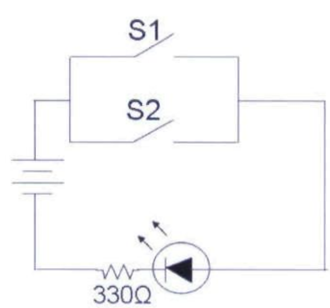
In Figure 3, an OR gate has been constructed from simple switches. When S1 OR S2 are closed, the LED will illuminate.

The OR gate is useful when either one of two conditions are met before the device being controlled can be turned on. If there is moisture present OR the water level is high, the pump will turn on. In the truth table for the OR gate, notice the inputs A and B. If any input is 1, then the output will be 1. Only when both inputs are 0 will the output be 0. That is the condition under which the logic control circuit will cause the device (water pump) to be turned off.

A transistor (Q) is like a switch. If the correct electrical current (a smaller current) is present at its base (b), a larger current can flow from emitter (e) to collector (c). It is a lot like turning on a switch. In Figure 4, the transistors are used to form an OR gate the same way that switches were used in Figure 3. If Q1 *OR* Q2 conduct current, then the LED will illuminate.

Gates are usually packaged inside of integrated circuits (IC). The pictorial view of the integrated circuit in Figure 4 is simply a representation of how the four OR gates are situated. A pin diagram is needed to know exactly which pin on the IC is an input and which pin is an output.

The interface in Figure 5 has three basic parts: an OR gate IC; a transistor Q1; and a relay. The relay is recognizable by the symbol for electrical contacts labeled NO and NC for normally opened and normally closed. Relays



OR Truth Table

Inputs		Output
B	A	Y
0	0	0
0	1	1
1	0	1
1	1	1

Boolean Expression

A + B = Y

Gate Symbol

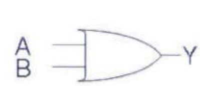


Figure 3. This circuit shows Boolean logic for an OR gate. If S1 (input A) OR S2 (input B) are closed, then the LED (output Y) will light.

are useful for controlling large voltage and current with a relatively smaller voltage and current. The relay in Figure 5 is controlled by 6 volts, but it is running a piece of equipment that uses 12 volts. The transistor is using 1 volt to control the 6-volt circuit that is used to energize the coil on the relay. R1 provides the correct current to the base of the transistor. The OR gate is powered by 6 volts, but it only outputs about 1 volt. R1 and R2 make sure that the OR gate senses zero volts when the input is low. The inputs to the circuit are A and B. They are where a moisture sensor and a water-level sensor are connected to the OR gate.

For the circuit in Figure 5, if A OR B are high, the OR gate output at the base of Q1 will be high. The LED is simply placed as an indicator for the logic of the gate's output. High output will cause the transistor to allow six volts to cross the relay, just like closing a switch. In turn, the six volts will cause a coil in the relay to become magnetic. The magnetism causes the normally opened switch in the relay to close, and the electric motor (M) using 12 V will begin to operate. It is important not to confuse the function of Q1 in this circuit with the functions of Q1 and Q2 in Figure 4. Here the transistor is simply a means for allowing a smaller voltage to control a higher voltage, but in Figure 4, the transistors are forming the actual OR gate. Figure 6 shows a similar circuit being used to control a small windshield washer pump and motor. A 9-volt battery is being used to control a 12-volt circuit powering the pump.

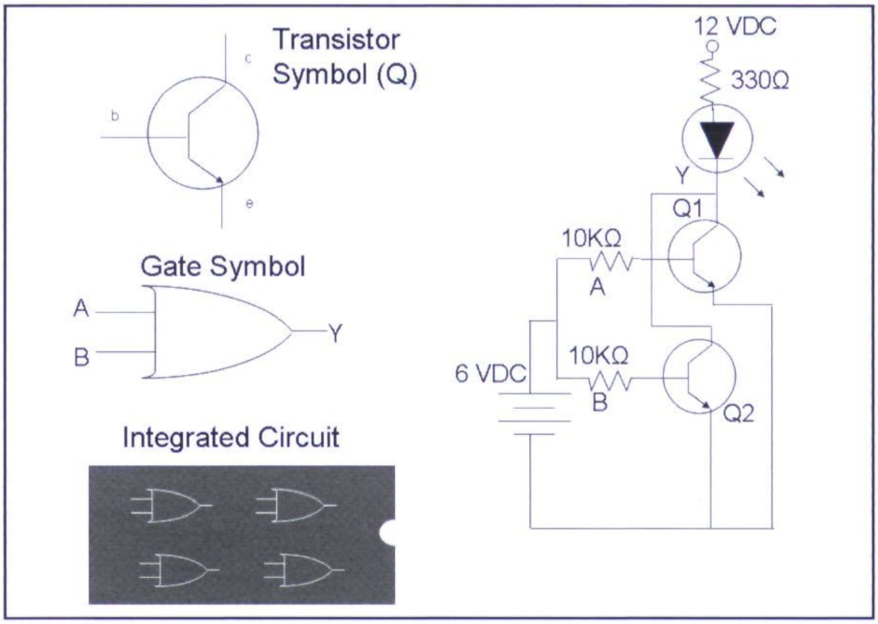


Figure 4. The gate symbol really represents a set of electronic components (transistors and supporting components).

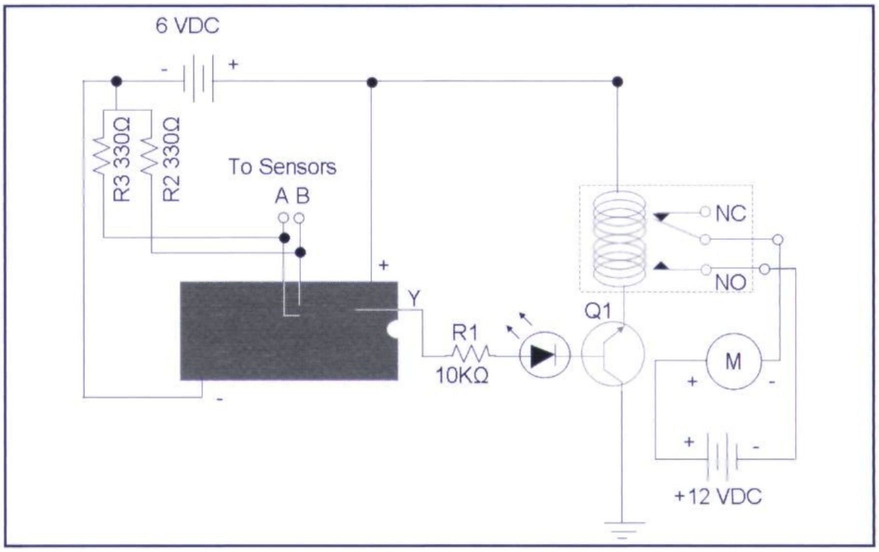


Figure 5. Here is an interface that is controlling a piece of equipment. It could be a milling machine or a communication device; it could be a pump or an electric motor or another electronic circuit.

Tips for the Teacher

Students will understand the concept of the logic gate on a more concrete level if they are provided the opportunity to build the three basic approaches to logic gates shown above: (1) using simple switches, (2) using discrete components like the transistors, and (3) using the IC. Instead of using actual sensors, low input can be obtained by connecting the OR gate inputs to the negative side of the 6-volt battery (see Figure 5). Positive input can be obtained by connecting the inputs to the positive side of the battery. The output device can be a lower voltage device, such as a lamp, LED, or 9 VDC electric motor. Some experimentation will be required on the part of the teacher.

Digi-Key Corporation is an excellent source of inexpensive electronic components used here. Its Web site is located at www.digikey.com. The Web site also has all of the pin diagrams needed to understand the configuration of any ICs that are purchased. The windshield-washer pump and motor assembly (see Figure 6) may be purchased at any auto parts store. If a 12-volt deep cycle battery is preferred over smaller voltage sources to run the pump, such a battery may also be purchased at any auto parts store.

Applications of Logic Circuits

The applications of logic circuits are countless. However, some very common applications include temperature control units, security systems, and arithmetic circuits for a variety of microprocessors built into everything

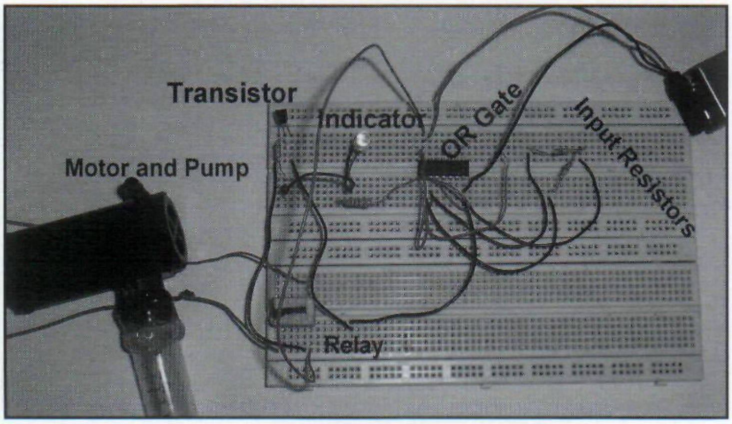


Figure 6. An actual interface circuit is shown here. In this case, the presence of moisture causes the logic gate to output a high signal. A transistor then allows 9V to close the relay, which in turn allows 12V to run the pump.

from computers to microwave ovens (Abul-Fadl, 2005). Figure 7 shows the logic involved in a simple security system. One thing that all of the applications have in common is that they automate some function so that the technologies they control make life easier and safer for humans.

With practice, students should be able to engineer their own logic circuits to control systems of their own design. What kind of logic gate is being used in the security system application in Figure 7?

Technology, Science, Mathematics Interfaces

Technology

The extent to which this activity addresses *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000/2002) really depends on what the teacher emphasizes. However, the binary logic gate activities could address Standards 2 and 17.

- Standard 2
  Students will develop an understanding of the core concepts of technology. (p. 32)
  - Benchmark V
    Controls are mechanisms [technical devices] or particular steps that people perform using information about the system that cause systems to change. (p. 40)
- Standard 17
  Students will develop an understanding of and be able to select and use information and communication technology. (p. 166)
  - Benchmark L
    Information and communication technologies include inputs, processes, and outputs associated with sending and receiving information. (p. 173)

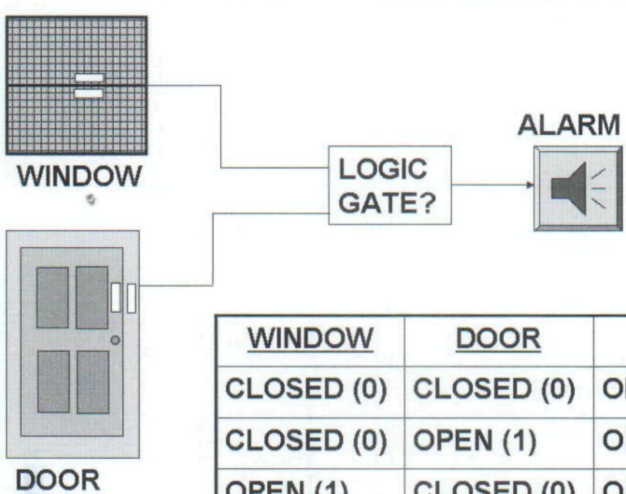
If students become accomplished at engineering-control-circuit applications, they will also be able to address Standard 2, Benchmark BB.

- Standard 2
  Students will develop an understanding of the core concepts of technology. (p. 32)
  - Benchmark BB
    Optimization is an ongoing process...of designing...a product and is dependent on criteria and constraints. (p. 42)

Science

The *National Science Education Standards* (National Research Council, 1996) help to highlight a number of opportunities that the technology teacher and the science teacher may have to teach students about the process of science. As teachers provide students with a basic understanding of electricity and electronics, a prerequisite for an understanding of interfacing, the following science standards are important.

- Motions and Forces
  Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students to understand electric motors and generators.
  - Interactions of Energy and Matter
    In…metals, electrons flow easily, whereas in insulating materials…they can hardly flow at all. Semi-conducting materials have intermediate behavior. At low temperatures…superconductors…offer no resistance to the flow of electrons.



WINDOW	DOOR	ALARM
CLOSED (0)	CLOSED (0)	OFF (0)
CLOSED (0)	OPEN (1)	ON (1)
OPEN (1)	CLOSED (0)	ON (1)
OPEN (1)	OPEN (1)	ON (1)

Figure 7. Logic gates are commonly used in security systems. What type of logic gate is needed in the application shown here? (Diagram content courtesy of Ali Abul-Fadl, 2005)

Mathematics

If students advance in the study and engineering of binary control circuit applications, the use of Boolean algebra would provide a mathematical means for students to model and optimize their control-circuit designs. Perhaps the most useful of the mathematics standards described in *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics, 2000) related to the engineering process of optimization in design is:

- Representations
  Create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; use representations to model and interpret physical, social, and mathematical phenomena...

References

Abul-Fadl, A. (2005). Personal communication.

Tokheim, R. L. (2003). *Digital electronics: Principles and applications.* Columbus, OH: McGraw-Hill.

International Technology Education Association (2000/2002). *Standards for technological literacy: Content for the study of technology.* Reston, VA: Author.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics.* Reston, VA: Author. Retrieved October 5, 2005 from: www.nctm.org/standards/standards.htm

National Research Council (1996). *National science education standards.* Washington: National Academy Press. Retrieved October 5, 2005, from: http://bob.nap.edu/html/nses/6e.html#csb912

Vincent W. Childress, Ph.D. *is an associate professor in Technology Education at North Carolina A&T State University in Greensboro, North Carolina. He can be reached via e-mail at childres@ncat.edu.*

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