began to recognize a market for standard, off-the-shelf logic ICs. In 1963 and 1964, Sylvania and Texas Instruments began shipment of the 7400-series discrete logic family and unknowingly started a *de facto* industry standard that lasts to this day and shows no signs of disappearing anytime soon. Using the 7400 family, an engineer can select logic gates, flip-flops, counters, and buffers in individual packages and wire them together as desired to solve a specific problem. Some of the most common members of the 7400 family are listed in Table 2.1.

TABLE 2.1 Common 7400 ICs

Part Number	Function	Number of Pins
7400	Quad two-input NAND gates	14
7402	Quad two-input NOR gates	14
7404	Hex inverters	14
7408	Quad two-input AND gates	14
7432	Quad two-input OR gates	14
7447	BCD to seven-segment display decoder/driver	16
7474	Dual D-type positive edge triggered flip-flops	14
7490	Four-bit decade counter	14
74138	Three-to-eight decoder	16
74153	Dual 4-to-1 multiplexer	16
74157	Quad 2-to-1 multiplexers	16
74160	Four-bit binary synchronous counter	16
74164	Eight-bit parallel out serial shift registers	16
74174	Quad D-type flip-flops with complementary outputs	16
74193	Four-bit synchronous up/down binary counter	16
74245	Octal bus transceivers with tri-state outputs	20
74373	Octal D-type transparent latch	20
74374	Octal D-type flip-flops	20

These are just a few of the full set of 7400 family members. Many 7400 parts are no longer used, because their specific function is rarely required as a separate chip in modern digital electronics designs. However, the parts listed above, and many others that are not listed, are still readily available today and are commonly found in a broad range of digital designs ranging from low-end to high-tech devices. 7400-series logic has been available in DIPs for a long time, as well as (more recently) SOICs and other high-density surface mount packages. All flavors of basic logic gates are available with varying numbers of inputs. For example, there are 2-, 3-, and 4-input AND gates and 2-, 3-, 4-,

8-, 12-, and 13-input NAND gates. There are numerous varieties of flip-flops, counters, multiplexers, shift registers, and bus transceivers. Flip-flops exist with and without complementary outputs, preset/clear inputs, and independent clocks. Counters are available in 4-bit blocks that can both increment and decrement and count to either 15 (binary counter) or 9 (decade counter) before restarting the count at 0. Shift registers exist in all permutations of serial and parallel inputs and outputs. Bus transceivers in 4- and 8-bit increments exist with different types of output enables and capabilities to function in unidirectional or bidirectional modes. Bus transceivers enable the creation and expansion of tri-state buses on which multiple devices can communicate.

One interesting IC is the 7447 seven-segment display driver. This component allows the creation of graphical numeric displays in applications such as counters and timers. Seven-segment displays are commonly seen in automobiles, microwave ovens, watches, and consumer electronics. Seven independent on/off elements can represent all ten digits as shown in Fig. 2.11. The 7447 is able to drive an LED-based seven-segment display when given a *binary coded decimal* (BCD) input. BCD is a four-bit binary number that has valid values from 0 through 9. Hexadecimal values from 0xA through 0xF are not considered legal BCD values.

Familiarity with the 7400 series proves very useful no matter what type of digital system you are designing. For low-end systems, 7400-series logic may be the only type of IC at your disposal to solve a wide range of problems. At the high end, many people are often surprised to see a small 14-pin 7400-series IC soldered to a circuit board alongside a fancy 32-bit microprocessor running at 100 MHz. The fact is that the basic logic functions that the 7400 series offers are staples that have direct applications at all levels of digital systems design. It is time well spent to become familiar with the extensive capabilities of the simple yet powerful 7400 family. Manufacturers' logic data books, either in print or on line, are invaluable references. It can be difficult to know ahead of time if a design may call for one more gate to function properly; that is when a 40-year old logic family can save the day.

2.4 APPLYING THE 7400 FAMILY TO LOGIC DESIGN

Applications of the 7400 family are truly infinite, because the various ICs represent basic building blocks rather than complete solutions. Up through the early 1980s, it was common to see computer systems constructed mainly from interconnected 7400-series ICs along with a few LSI components such as a microprocessor and a few memory chips. These days, most commercial digital systems are designed using some form of higher-density logic IC, either fully custom or user programmable. However, the engineer or hobbyist who has a relatively small-scale logic problem to solve, and who may not have access to more expensive custom or programmable logic ICs, may be able to utilize only 7400 logic in an efficient and cost-effective solution. Two examples follow to provide insight into how 7400 building blocks can be assembled to solve logic design problems.

A hypothetical example is a logic circuit to examine three switches and turn on an LED if two and only two of the three switches are turned on. The truth table for such a circuit is as follows in

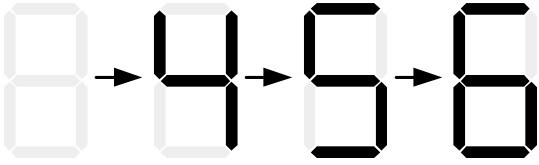

FIGURE 2.11 Seven-segment display.