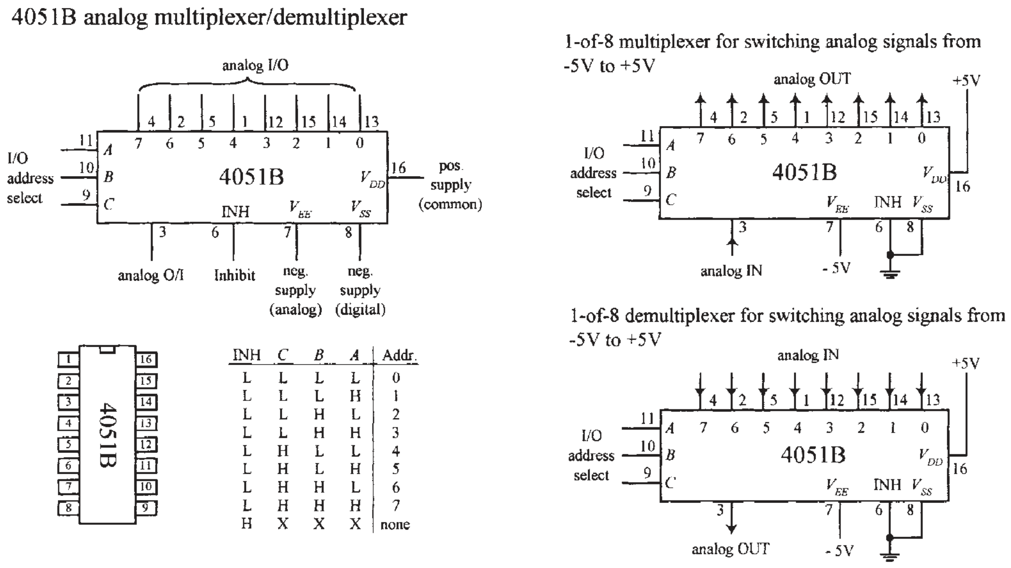

FIGURE 12.115

(pin 3) and passes out through one of the seven analog I/O lines. The specific output is again selected by the digital inputs A, B, and C. Note that when the inhibit line (INH) is high, none of the addresses are selected.

The I/O analog voltage levels for the 4051B are limited to a region between the positive supply voltage V_{DD} and the analog negative supply voltage V_{EE}. Note that the V_{SS} supply is grounded. If the analog signals you are planning to use are all positive, V_{EE} and V_{SS} can both be connected to a common ground. However, if you plan to use analog voltages that range from, say, −5 to +5 V, V_{EE} should be set to −5 V, while V_{DD} should be set to +5 V. The 4051B accepts digital signals from 3 to 15 V, while allowing for analog signals from −15 to +15 V.

12.9.5 Analog-to-Digital and Digital-to-Analog Conversion

In order for analog devices (temperature sensors, strain gauges, position sensors, light meters, and so on) to communicate with digital circuits in a manner that goes beyond simple threshold triggering, we use an analog-to-digital converter (ADC). An ADC converts an analog signal into a series of binary numbers, each number proportional to the analog level measured at a given moment. Typically, the digital words generated by the ADC are fed into a microprocessor or microcontroller, where they can be processed, stored, interpreted, and manipulated. Analog-to-digital conversion is used in data-acquisition systems, digital sound recording, and within simple digital display test instruments (such as light meters and thermometers).

In order for a digital circuit to communicate with the analog world, we use a digital-to-analog converter (DAC). A DAC takes a binary number and converts it to an analog voltage that is proportional to the binary number. By supplying different binary numbers, one after the other, a complete analog waveform is created. DACs are commonly used to control the gain of an op amp, which in turn can be used to create digitally controlled amplifiers and filters. They are also used in waveform generator and modulator circuits and as trimmer replacements, and are found in a number of process-control and autocalibration circuits.

Many digital consumer products such as MP3 players, DVDs, and CD players use digital signal processing ADCs and DACs often contained in a microcontroller.

ADC and DAC Basics

Figure 12.116 shows the basic idea behind analog-to-digital and digital-to-analog conversion. In the analog-to-digital figure, the ADC receives an analog input signal along with a series of digital sampling pulses. Each time a sampling pulse is received, the ADC measures the analog input voltage and outputs a 4-bit binary number that is proportional to the analog voltage measured during the specific sample. With 4 bits, we get 16 binary codes (0000 to 1111) that correspond to 16 possible analog levels (for example, 0 to 15 V).

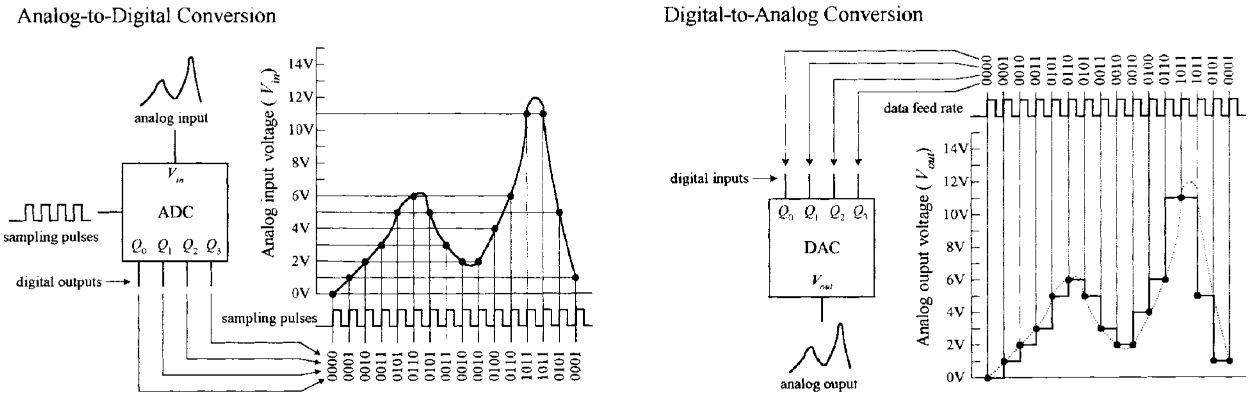

FIGURE 12.116

In the digital-to-analog conversion figure, the DAC receives a series of 4-bit binary numbers. The rate at which new binary numbers are fed into the DAC is determined by the logic that generates them. With each new binary number, a new analog voltage is generated. As with the ADC example, we have a total of 16 binary numbers to work with and 16 possible output voltages.

As you can see from the graphs, both these 4-bit converters lack the resolution needed to make the analog signal appear continuous (without steps). To make things appear more continuous, a converter with higher resolution is used. This means that instead of using 4-bit binary numbers, we use larger-bit numbers, such as 6-bit, 8-bit, 10-bit, 12-bit, 16-bit, or even 18-bit or higher numbers. If our converter has a resolution of 8 bits, we have $2^8 = 256$ binary numbers to work with, along with 256 analog steps. Now, if this 8-bit converter is set up to generate 0 V at binary 00000000 and 15 V at binary 11111111 (full scale), then each analog step is only 0.058 V high ($\frac{1}{256} \times 15$ V). With an 18-bit converter, the steps get incredibly tiny because we have $2^{18} = 262{,}144$ binary numbers and steps. With 0 V corresponding to binary 000000000000000000 and 15 V corresponding to 111111111111111111, the 18-bit converter yields steps that are only 0.000058 V high! As you can see in the 18-bit case, the conversion process between digital and analog appears practically continuous.