often referred to as *Fourier analysis*. Likewise, a *Fourier transform* is the process of decomposing a signal into a sum of sine waves.

Fourier analysis is represented graphically in Fig. 12.15, where a 1-MHz digital clock signal is shown broken into four separate sine waves. The sine wave with the same frequency as the clock is referred to as the *fundamental frequency.* Subsequent sine waves are multiples of the fundamental frequency and are called *harmonics*. If a sine wave is three times the fundamental frequency, it is the third harmonic. It is clear that, as higher-order harmonics are added to the fundamental frequency, the resulting signal looks more and more like a clock signal with square edges. This example stops after the seventh harmonic, but a more perfect clock signal could be constructed by continuing with higher-frequency harmonics. From a practical perspective, it can be seen that only a few harmonics are necessary to obtain a representation that closely approximates the real digital signal. Therefore, it is often convenient to consider the few sine wave terms that compose the majority of the signal's energy. This simplification allows many less-significant terms to be removed from the relevant calculations. Depending on how accurately the digital signal really needs to be represented, it may be possible to make a gross simplification and consider just the fundamental frequency and one or two subsequent harmonics.

Each harmonic in a Fourier analysis has varying amplitude, frequency, and phase relationships such that their sum yields the desired complex signal. The energy in harmonics generally decreases as their frequency increases. The clock signal shown in this example has energy only at the odd harmonics, because it is a symmetrical signal. Furthermore, the harmonics are in phase with each other. More complex real-world asymmetrical signals can also be handled with Fourier analysis but with more variation across the harmonics, including even harmonics and phase differences.

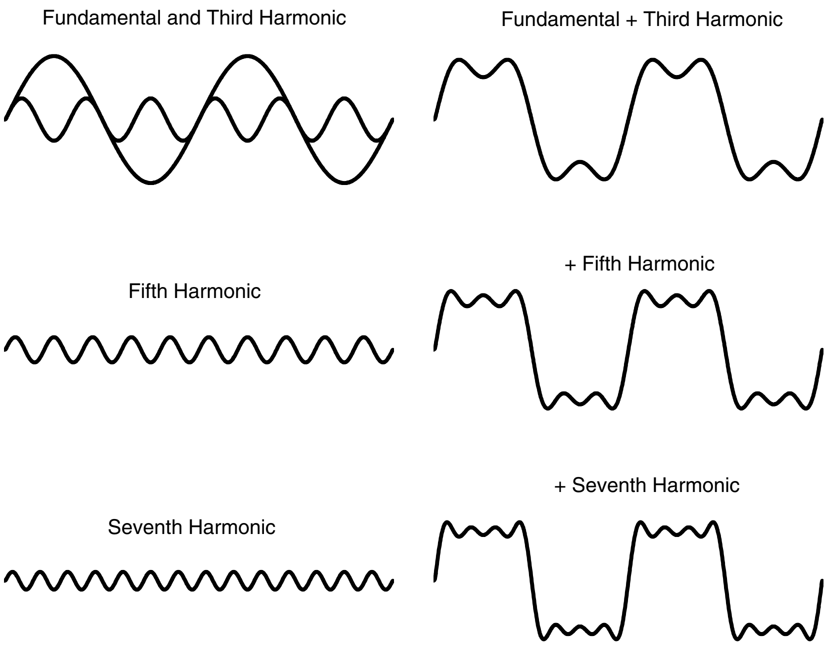

FIGURE 12.15 Digital clock composed of sine waves.

Oscilloscopes are used to view signals in the time domain, whereas *spectrum analyzers* are used to view signals in the frequency domain. Figure 12.16 shows an example of a frequency-domain view of an electrical signal as observed on a spectrum analyzer (courtesy of Agilent Technologies). Rather than viewing voltage versus time, amplitude versus frequency is shown. Time is not shown, because the signals are assumed to be repetitive. Clearly, AC circuits operate on both repetitive and nonrepetitive signals. The analysis assumes repetitive signals, because an AC circuit's response is continuous. It does not have the ability to recognize sequences of signals in a digital sense and modify its behavior accordingly. Pure sine waves are represented by a vertical line on a frequency domain plot to indicate their amplitude at a single specific frequency. Since most real-world signals are not perfect sine waves, it is common to observe a frequency distribution around a single central frequency of interest.

While not strictly necessary, frequency-domain plots are usually drawn with *decibel* (dB) scales that are inherently logarithmic. The decibel is a relative unit of measurement that enables the comparison of power levels *(P)* entering and exiting a circuit. On its own, a decibel value does not indicate any absolute power level or measurement. A decibel is defined as a ratio of power entering and leaving a circuit:

$$\text{dB} = 10\log_{10}\frac{P_{OUT}}{P_{IN}}$$

When the input and output power are identical, a level of 0 dB is achieved. Negative decibel levels indicate attenuation of power through the circuit, and positive decibel levels indicate amplification.

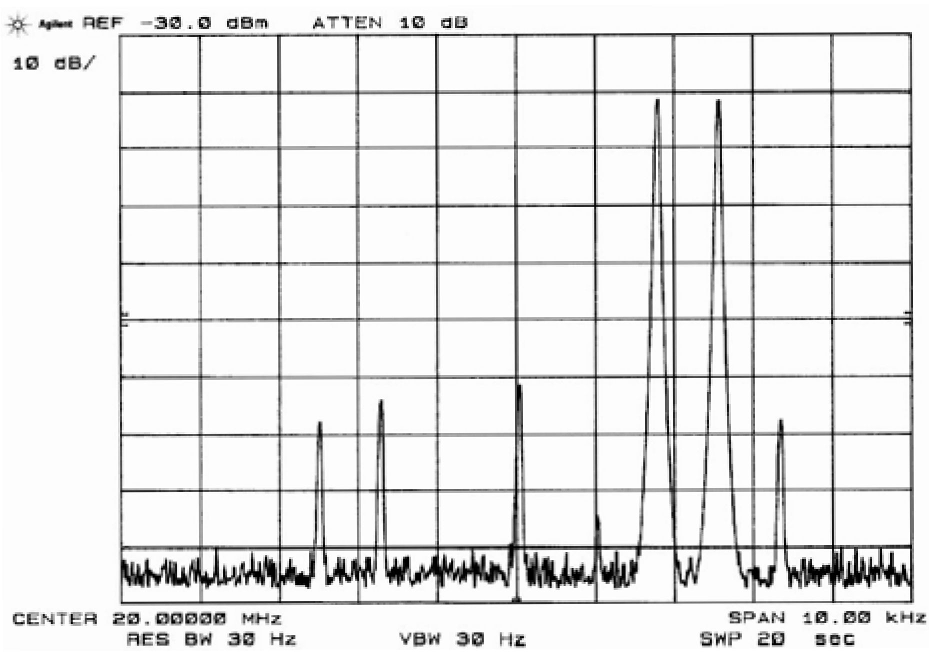

FIGURE 12.16 Spectrum analyzer frequency/amplitude plot. *(Reprinted with permission from Agilent Technologies.)*