mutations of incompatibilities are so numerous that debugging a 1960s-era RS-232 connection may not be a quick task.

Male DB25 and DE9 connectors consist of a dual row of staggered pins surrounded by a metal rim that serves as an electrical shield. The female connectors consist of matching staggered pin-sockets mounted in a solid frame whose edge forms a shield that mates with the male shield. These connectors are illustrated in Fig. 5.6.

The D-subminiature connector family uses a three-element nomenclature to specify the size of the connector housing, or shell, and the number of pins within the shell. There are five standard shell designations—A, B, C, D, E—that were originally specified with varying numbers of pins as shown in Table 5.3. DE9 connectors are commonly misrepresented as DB9, a connector configuration that is not defined. A modern D-subminiature connector that was not originally specified is the common HDE15, a high-density 15-pin connector using the E-size shell. The HDE15 is commonly used to connect monitors to desktop computers.

TABLE 5.3 Standard D-Subminiature Shell Sizes

Shell Size	Pins
A	15
B	25
C	37
D	50
E	9

Logical transceiver-level characteristics such as bit rate, error detection, and framing are accompanied by electrical transducer-level characteristics, more commonly referred to as the *physical layer* of a communications link. RS-232 refers to the logic 1 state as a *mark* and assigns it a negative potential from –3 to –25 V. The logic-0 state is a *space* and is assigned a positive potential from +3 to +25 V. Since RS-232 inverts the logic levels, an idle link is held at negative voltage, logic 1.

While RS-232 is specified with a transmitter voltage range of ±3 to ±25 V, most modern transmitters operate well below the 25-V upper bound. Many systems have been based around the ubiquitous and inexpensive 1488/1489 transmitter/receiver chipset that operate at ±12 V. These chips require an external ±12-V source for power. RS-232 circuitry was fundamentally simplified when Maxim Semiconductor created their MAX232 line of single-supply 5-V line interface ICs. These chips contain internal circuitry that generates ±8 V. Today, a variety of flexible RS-232 interface ICs are avail-

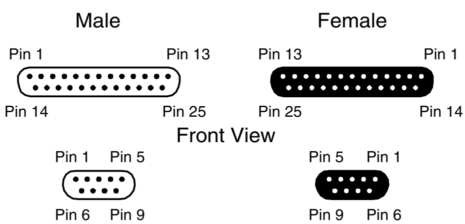

FIGURE 5.6 DB25 and DE9 connectors.

able from other manufacturers including Linear Technology, National Semiconductor, and Texas Instruments. RS-232 ports work quite well on even lower voltage ranges, because modern receivers are sensitive to smaller absolute voltages, and most RS-232 links are several meters or less in length. RS-232 was never intended to serve in truly long-distance applications.

5.5 RS-422

For crossing distances greater than several meters, RS-232 is supplemented by the *RS-422* standard. RS-422 can provide communications across more than 1.2 km at moderate bit rates such as 9.6 kbps. It is a *differential*, or *balanced*, transmission scheme whereby each logical signal is represented by two wires rather than one. RS-232 signals are *single-ended*, or *unbalanced*, signals that drive a particular voltage onto a single wire. This voltage is sensed at the receiver by measuring the signal voltage relative to the ground potential of the interface. Over long distances or at very high speeds, single-ended transmission lines are more subject to degradation resulting from ambient electrical noise. A partial explanation of this characteristic is that the electrical noise affects the active signal wire unequally with respect to ground. Differential signals, as in RS-422, drive opposing, or mirrored, voltages onto two wires simultaneously (RS-422 is specified from ±2 to ±6 V). The receiver then compares the voltages of the two wires together rather than to ground. Ambient noise tends to affect the two wires equally, because they are normally twisted together to follow the same path. Therefore, if noise causes a 1-V spike on one-half of the differential pair, it causes the same spike on the other half. When the two voltages are electrically subtracted at the receiver, the 1-V of *common-mode* noise cancels out, and the original differential voltage remains intact (subject, of course to natural attenuation over distance). The difference between RS-232 and RS-422 transmission is illustrated in Fig. 5.7.

Because of the longer distances involved in RS-422 interfaces, it is not common to employ the standard set of hardware handshaking signals that are common with RS-232. Therefore, some form of software handshaking must be implemented by the end devices to properly communicate. Some applications may not require any flow control, and some may use the XON/XOFF method. RS-422 does not specify a standard connector. It is not uncommon to see an RS-422 transmission line's bare wire ends connected to screw terminals.

Another common difference between RS-422 and RS-232 is transmission line *termination*. Transmission line theory can get rather complicated and is outside the scope of this immediate discussion.

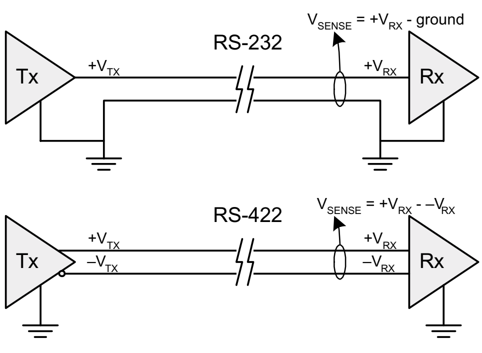

FIGURE 5.7 RS-232 vs. RS-422 signaling.