leaded capacitors. Whereas a leaded component can have inductance of many nanohenries, Table 17.2 lists approximate inductances near 1 nH for various sizes of 0.1-μF surface mount ceramic capacitors.* Capacitors, resistors, and inductors are available in standard sized surface mount packages that are designated by their approximate dimensions in mils. Common sizes are 1210, 1206, 0805, and 0603. Larger packages such as the 1810 exist for handling higher power levels. Smaller packages such as the 0402 are used when space is at an absolute premium, but handling such packages whose dimensions are comparable to grains of sand requires special equipment.

TABLE 17.3 Surface Mount Capacitor Lead Inductance

Package	Inductance (pH)
1210	980
1206	1,200
0805	1,050
0603	870

The impedance of a 0.1-μF surface mount capacitor reaches a minimum value of under 100 mΩ at around 10 MHz and remains below 1 Ω from approximately 1 MHz to 100 MHz. This explains why 0.1-μF capacitors have been popular as bypass capacitors for so long: many digital systems have switching frequencies below 100 MHz. Above 100 MHz, 0.01-μF capacitors in 0603 packages become attractive because of their lower impedance at higher frequencies. It gets harder to reduce very high-frequency noise, because the inductance of surface mount bypass capacitors declines only to a certain point.

Having discussed the basic issues of power distribution, attention can be turned back to the example in Fig. 17.16. Distributing the regulated 5-, 3.3-, and 2.5-V logic-level supplies in a manner that ensures high-frequency electrical integrity requires minimal impedance between the regulator and the load. The consideration goes beyond DC resistance to include inductance, which has a more substantial impact on the conductor's impedance at high frequency. As the regulator and load are separated by higher impedance, the regulator's ability to respond to fluctuations in load current is degraded. Low-inductance distribution is achieved by using complete planes or very wide copper paths to connect the regulator outputs to the various ICs and components that they serve.

Power plane design is directly related to the electrical integrity of other signals in the system and will be covered in more detail later. The ideal situation is to devote entire PCB layers to serve as power planes for each separate voltage. This eliminates power plane cuts that can cause other signal integrity problems. Unfortunately, not all systems can afford the cost or, in some cases, the physical size of many power planes. In a situation like this, multiple voltages must share the same PCB layer. Figure 17.17 shows a hypothetical single power plane structure for the preceding example that requires distribution of 12, 5, 3.3, and 2.5 V. The shaded regions represent continuous copper areas. A ground return plane is required but not shown, because it occupies a second layer and is continuous across all power plane regions. Each system has its own unique power distribution flow governed by the grouping of components that require different supply voltages. This example assumes the com-

* Jeffrey Cain, *Parasitic Inductance of Multilayer Ceramic Capacitors*, AVX Corporation, p. 3.

mon situation in which most of the system runs at 3.3 V, but the inner core logic of certain ICs (e.g., a microprocessor) runs at 2.5 V. The remainder of the system voltages are used for peripheral and I/O functions. In many cases, the components cannot be cleanly separated into groups that use only one or two voltages. These situations may demand multiple power planes.

Figure 17.17 also shows the placement of 47-μF bulk bypass capacitors in each power section. Their exact placement is arbitrary, but they should be distributed across the board. Not shown are the high-frequency bypass capacitors, because their placement is a direct function of where the ICs are located. There are also additional capacitors that would be located within the bounds of the voltage regulators, because each regulator has its own recommendations for input and output capacitors.

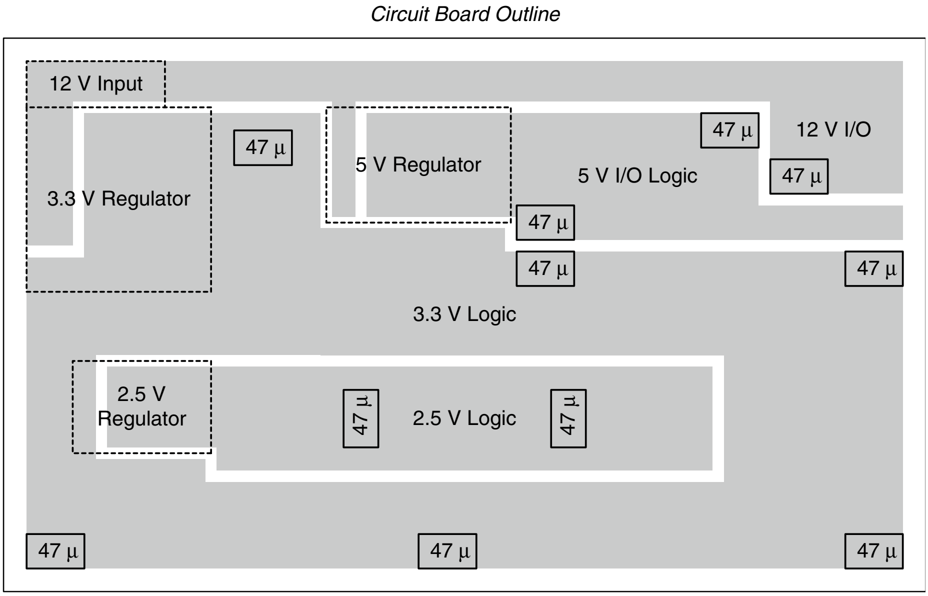

FIGURE 17.17 Multivoltage cut power plane.