Demystify Current Ratings for Connector Selection

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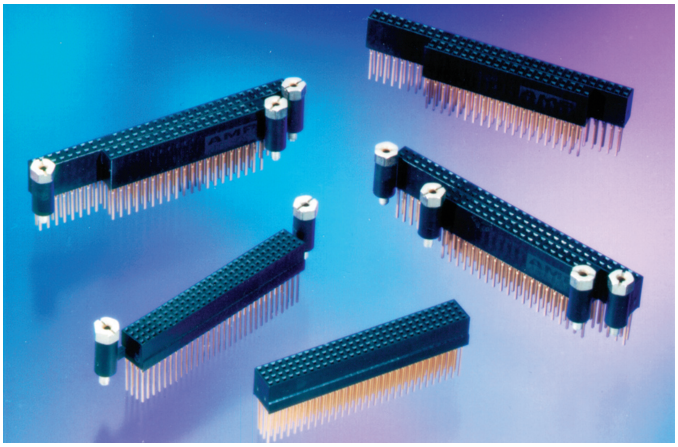
Connectors that handle both signal and power require the designers to have knowledge of the contact's current capacity, space requirements, derating factors, heating considerations, and assembly techniques.

Most electronic systems have mixed power requirements where the same connector handles signals and power. However, when module plugability is required, designers often use connectors designed primarily for signal-level duty. While the **photo**, below, shows connectors specifically designed for solder-free, press fit applications, the primary selection criterion often revolves around available board space. Yet, taking the mystery out of the combination of space requirements, current rating value, derating factors, heating considerations, and assembly techniques is essential for proper connector selection.



PC/104 connectors employ compliant pin contacts for solder-free, press fit installations. In cases where power is distributed through PC/104 connectors, multiple parallel contacts are used.

Using signal contacts for power requires knowledge of how current ratings are determined. No standards body sets the methodology for determining these ratings. The **figure**, on page 39, shows a system that uses a multitude of connectors and cables.

Contact Current Rating

By one common definition, a power connector contact is any contact used at or near its rated current capacity. Thus, a signal contact rated at 2A is actually a power contact when it delivers power from the module to a p.c. board.

Separable connector contacts generally consist of a male pin mated with a receptacle that contains one or more spring contact "fingers." The current carrying capacity of a connector's mated contact pair depends mainly on:

- Contact material.
- Geometry.
- Spring force between the pin and receptacle contacts.

These three variables determine the magnitude and stability of the resistance across the contact interface.

The current rating of a contact is defined as the current level that creates a certain temperature rise of the contact spring—usually 20°C or 30°C. Both electrical and thermal factors govern the heat created by the current. The temperature rise of the contact spring depends on its bulk resistance, the current level—and on heat dissipation to the surroundings. The bulk resistance and thermal conductivity of the contact spring will be a function of a particular connector under consideration. But the heat dissipation will depend on heat sinking effects of the contact's surroundings and the size of the wire or nature of the printed circuit board terminated to the contact.

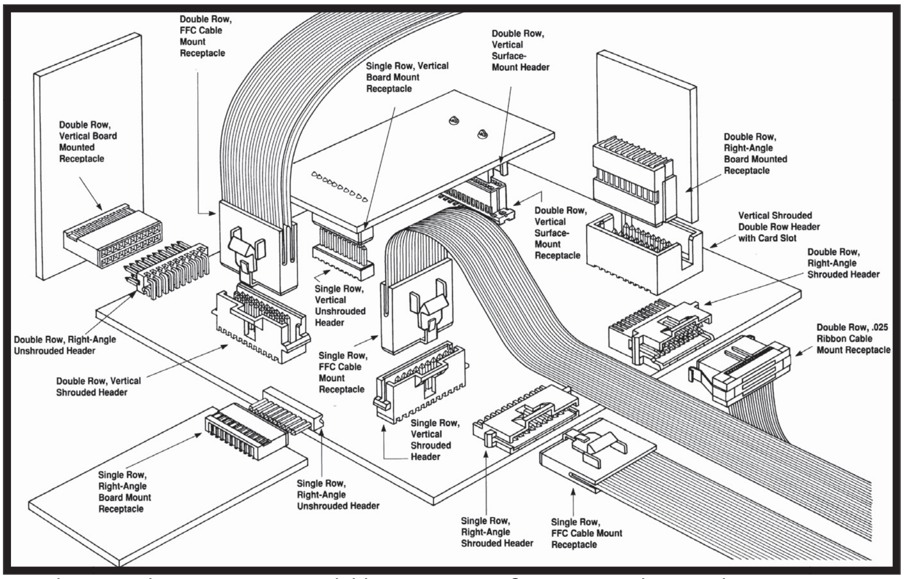
Derating Contacts

Published current ratings in catalogs are often for a single contact pair isolated in ambient air. This is an ideal and artificial situation. The presence of a housing around a contact pair will inhibit the convective and radiation cooling mechanisms to such an extent that conduction cooling predominates. Conductive cooling includes that of the wire or board terminated to the contacts.

The size of the wire terminated to the contact significantly affects current carrying capacity. Larger wires allow a higher current for the same temperature rise. Another important factor is the heat generated from several power contacts grouped together in a plastic housing. This heat accumulates, reducing heat dissipation and requiring the derating of individual contacts. In addition, contact aging and the number of mating connect/disconnect cycles a connector has experienced adversely affect the contact current carrying capacity.

Consider the following example: Suppose 5A causes a 30° temperature rise in a single contact spring connected to an 18-AWG wire in ambient air (no housing). However, in the actual application, the multiple contacts are in a connector housing—50% of them will carry the 5A, and they're terminated to a smaller 20-AWG wire. From **Table 1**, on page 40, for contacts connected to 20-AWG wire and 50% loaded within a plastic housing, the derating factor is 0.68. The specific current rating for this application is 5 × 0.68 or 3.4A. This rating applies for contacts independently energized; that is, each contact is in a separate circuit (not connected in parallel).

The number of mating cycles a contact mated pair undergoes also affects its power rating over time. On a microscopic level, the contact interface actually consists of the mating of



Board-mounted connectors are available in various configurations with many designs accommodating SMT processing. Cable-end connectors terminate to FFC, ribbon cable, and discrete wire.

Loading	18 AWG	20 AWG	22 AWG	24 AWG	26 AWG
Single	1	0.83	0.69	0.59	0.50
30%	0.97	0.80	0.66	0.57	0.49
50%	0.83	0.68	0.57	0.48	0.42
70%	0.65	0.53	0.45	0.38	0.33
100%	0.55	0.45	0.38	0.32	0.28

Table 1. *Derating factors (%) for power contact loading in a housing vs. wire size termination.*

many small hills and valleys, called asperities. High currents through these small asperities create high-localized temperatures—high enough to produce microwelding of the contacts at these points. These microwelds can cause interface wear in subsequent mating/unmating cycles.

Different contact platings have different melting points, affecting their response to these high asperity temperatures. But for the contacts discussed here, signal contacts carrying power generally have gold plating. As voltage levels drop, connector contact performance must be more like a signal connector, despite the power function. Gold offers both a high melting point (minimizing wear with use) and low resistance (minimizing voltage drops). This makes gold the best choice for these applications.

Parallel Contact Applications

The designer can choose to spread high current from the power supply module over several contacts. These parallel contact applications interact electrically and thermally in a housing. If a contact in a parallel circuit develops a high resistance relative to the other contacts, then a significant amount of its current load shifts to the remaining contacts in the circuit. This increases the electrical and thermal stress on those other contacts.

While the high-resistance contact operates at a lower current than the others, its operating temperature will not necessarily be reduced. This is the result of its higher resistance and its thermal interaction with the remaining contacts. Thermally driven failure mechanisms may become important, and the connector may experience thermal runaway. A design strategy must provide enough contacts in the parallel circuit such that, in spite of unequal current distribution, none of the contacts will exceed their individual current rating.

If the connector is to be mated or unmated while the circuits are live, other power considerations come into play. For example, the application may require a connector with ground pins. Thus, the designer should consider connectors that incorporate a set of longer pins designated as ground pins. This means that during mating and unmating, the ground contacts will make first and break last within the connector, aiding the electrical stability of the circuit.

Assembly Techniques

For board-mounted connectors, termination configurations are traditional post-and-hole, surface mount, and press fit.

Power contacts fit all three types, so the criteria for choosing the termination depends more on the application and applied cost.

Typically, board construction determines the termination technique. For a board of standard thickness, the most common connector choice is the post-and-hole termination. Thin, small boards and boards with a bottom heatsink tend toward surface mount, especially if other components are surface mounted. A thick, multilayer board will tend to use press fit connectors because soldering becomes more difficult for such boards.

Connector costs tend to rise as terminations move from post-and-hole to surface mount, to press fit. In general, post-and-hole connectors are the least expensive. The wave solder process for terminating these connectors is the most common and familiar. Surface-mount connectors tend to have higher performance plastic housings, raising their cost slightly. They also tend to have lower power ratings. Board designers should check that the connector manufacturer did not adversely change the contact geometry (from a power point of view) to achieve a surface-mount version within the same modular connector family. The press fit connectors require specialized compliant contact designs that increase costs again.

Applied cost is another matter. The surface-mount connectors simplify the soldering process and lend themselves to automated assembly techniques. Press fit connectors eliminate the need for soldering. Assembly equipment is available to check and document each press fit connector installation for proper insertion forces.

In the case of wire-to-board connectors, the alternative terminations are crimp, solder, or insulation displacement. High-speed assembly machines are available for crimp and insulation displacement techniques.

To minimize voltage drops in systems with little voltage margin, the power connectors must have contacts and wire sizes as large as possible. This is especially true if the designer uses parallel contacts to spread the power load. In such cases, the number of positions must be on the high side to improve reliability. Often, however, the connector is the last consideration in the design, leaving minimal or insufficient space for the connector.

Another problem with using signal connectors for power applications is that the catalogs rarely offer derating tables and data regarding power performance. For large connector volumes, designers have the leverage to require tests that document power performance of connectors terminated to a variety of wire sizes and with different percentages of loading. Otherwise, designers have to choose connectors conservatively, keeping in mind the principles. **PETech**

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