The Changing World of Power Resistors

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09/14/05

Breakthrough *HPC* SMD Power Resistors
Boast 12 Watts, Small Footprint, Low cost

Power resistors have been around as long as the automobile, the telephone and the light bulb. With ratings from a few watts up to thousands of watts, these devices have continued to be an integral part for any electronic designer, as the industry has transitioned from vacuum tubes to transistors to integrated circuits and finally to today's complex surface mount assemblies.

Like many age-old technologies, however, the power resistor is increasingly being challenged to re-invent itself to keep up with newer systems, filled with intelligence, exhibiting high density and demanding more sophisticated thermal management principles.

The flagship product of the power resistor industry would be the wirewound type. It might be encapsulated or coated in some way but the basics remain the same - a number of turns of a wire made of a highly resistive material such as nichrome or tungsten alloy. With applied power, the wire can get very hot. Historically, the power resistor was simply positioned on a chassis circuit board in such a way that its substantial heat did not adversely affect other nearby components. All of this has been just fine as long as size was no object.

However, as circuitry gets smaller and smaller and every possible effort is made to eliminate reliability-related heat issues in systems, the historical approaches to power and dissipation management become less and less workable. There are historical analogies. Vacuum tubes, like many power resistors, by design, got very hot during normal operation. When power transistors replaced them, the power transistors in theory could also get very hot. However, they were newly packaged in a manner allowing more creative ways for heat removal. A vacuum tube was not characterized for any heat removal other than giving it a lot of surrounding space. A power transistor, on the other hand, is characterized so that it can be attached to a heat sink and its heat subsequently removed in an extremely predictable and efficient manner. A power transistor chip, which by itself might fail with applied power of more than one watt, might handle 100 watts when mounted properly. A vacuum tube had no such option to allow it to be reduced in size yet retain its power capability.

This kind of problem, as well as the possible solutions, has crept into the power resistor industry as well. A few decades ago SMD wirewound power resistors with compliant terminations took their place as readily available commercial components. In recent years thick and thin film resistors in power transistor packages such as TO-220 have become available from multiple sources, providing more options in higher power specialty applications.

While these new higher power options have been reasonably well received, the advent of surface mounting has added another dimension to the problem faced by power resistor makers. It has become no longer adequate to simply shrink the power resistor and characterize it for more systematic heat removal as is done with power transistors. There is also a demand, virtually non existent 15 years ago, that it be surface mountable by conventional pick-and-place techniques and that it perform its function in such SMD applications without attachment of any heat sinking.

This is particularly an issue in the 1 to 10 watt range where complexity, high density, and high production rates are widely found and surface mounting is the dominant component mounting method. It is less of a problem in the 20 watt-and-above specialty or low production-rate applications normally associated with wirewound power resistors, but still can exist.

While the majority of components in a complex SMD assembly require very little power, there is more often than not a need for some power resistors to deliver, regulate or monitor the power for the majority of components. As the components get smaller and smaller, and high PCB power density becomes a competitive yardstick, the ability to use SMD power resistors at higher and higher wattages becomes a challenge. It has been a common practice in some power management applications, like power supplies or DC converters, to put lower power SMD parts on one side of a PC board and reserve the other side for the large though-hole components, particularly those which dissipate power. Such an approach is becoming less and less acceptable as manufacturers drive toward circuit boards that use 100% surface mount components. Fifteen years ago, when surface mount assembly was becoming widespread, it was not uncommon to see through-hole vendors forming leads to allow them to be surface mounted. Such lead forming is today frowned upon for a variety of manufacturing and reliability reasons since it is generally incompatible with pick and place equipment.

In recognition of these limitations, power resistor vendors have made surface mounted devices available for well over a dozen years in pick-and-place friendly J-lead package styles (which are also commonly found today with producers of small PCB mounted inductors). That is, wirewound resistors are now available in industry standard packages with ratings up to 4 or 5 watts.

Patterned after earlier power resistors, these components can theoretically be operated at very high temperatures. Unlike semiconductors, resistive wire elements can easily operate at 200-250C without harm and therefore can more easily handle power without regard to temperature elevation. Unfortunately, while the resistor will survive, the PC board under it, or the adjacent components, may not, or if they do, the conditions are likely to violate acceptable safety agency limits for PC board temperature rise. This means that a popular-case 3 watt SMD power resistor is likely to require derating to half that power (1.5 watts) under real-world conditions, in order to ensure that the PCB does not get above 105 C directly under the resistor hot spot (a typical 3-watt SMD power resistor will reach that PCB hot spot temperature at about 50% of its rating—a 5 watt SMD resistor at a similar percentage.)

The resistor industry also offers thick film chip resistors in the very popular 2512 size with ratings up to two watts. These can loosely be viewed as power resistors although they, like the 3-watt wirewounds, also require substantial derating to meet safety agency criteria and if reliable performance is expected. It is important to note that virtually all

SMD resistors depend almost exclusively on the metallic contact between their contact pads and the PCB pads for heat removal and this factor becomes a significant limitation in power capability, in light of the derating criteria just mentioned
The challenge then, recognizing that there are a substantial number of high volume applications involving SMD and power issues above a few watts, is how to provide that power while not compromising the PC board integrity, SMD size benefits, or maximum power capability. Implicit in the challenge is the capability to get to even higher power levels. The answer is in borrowing a page from the power semiconductor industry. That is, the answer to significantly greater power in a small size is in the precise characterization of heat removal techniques and linking of those techniques with the way the product will ultimately be used. For example, a power semiconductor is able to coax a tiny ¼ watt silicon chip into handling 50 watts by precisely establishing a way to move heat a) from the PN junction in the chip to the header or tab—called "junction-to-case" thermal resistance b) from the tab(or case) to a heat sink—typically called case-to-heatsink thermal resistance, c) from the heat sink to the surrounding air—called heat sink-to-air thermal resistance and finally d) how that surrounding air performs the final step of heat removal within a multitude of ambient temperatures.

It is the precision of this process that lets engineers confidently use billions of semiconductor devices and be able to calculate exactly what will happen if anything about a, b, c or d changes. Those precise heat removal steps are defined in terms of "thermal resistance" and become an integral way the device is specified. This is routine for power semiconductors but not so for power resistors. Power resistors have historically been specified for operation in a given ambient without really telling the user exactly what is going on thermally---just as the light bulb user is indifferent to the filament temperature as long as the bulb seems to give off enough light.

A second very important factor, aside from thermal resistance characterization, comes into play. It would be a rare computer, communications system or industrial control system these days which consumes more than 100 watts but does not have a fan blowing air across its high-density surface mounted PC board. Reliability and performance can be seriously compromised if integrated circuits are continually run above 75C or higher. The rule of thumb for semiconductors is that reliability drops 50% for every 10 degree C increase in temperature.

Consequently, in a large, complex, densely packed computer or telecom system, it is a given that PC boards will have convection cooling, with the air moving at 200 linear feet per minute or higher.

The new ***HPC*** surface mount resistor technology was developed to respond to these emerging needs by combining established thermal management practices from the power semiconductor industry (device-level cooling) with such practices common in SMD board level products (system-level cooling). The result is a newly configured, cost-effective SMD power resistor which can handle many times more continuous-power as compared to presently available SMD power resistors, and exhibit extraordinary short-duration, peak-power handling in repetitive pulse applications.

Design Principles

The new patent pending **HPC** power resistor is unlike existing 1,3 and 5 watt SMD wirewounds, in that it employs a conventional thick film resistive element deposited on alumina substrate. The substrate is bonded to the flat surface of a subminiature proprietary aluminum extruded housing. The area of resistive element, area and thickness of the alumina, and method of bonding of the resistor to the aluminum surface is such that a very low thermal resistance is achieved between the resistive element and the aluminum. The design of the aluminum housing is such that heat is efficiently transferred from that initial resistor/aluminum interface to all other parts of the aluminum structure. The total surface area of the aluminum housing, because of the extruded details is such that it will present substantial surface area and precise but minimized thermal resistance to air moving over that complete surface area.
The result of the **HPC** extruded structure and controlled thermal resistance paths is that the final package can handle as much as 12 watts in the normally existing 400 LFM air flow, independent of X-Y device positioning, in a package occupying a volume of no more than a tenth of a cubic inch and a footprint of only 0.5” by 0.5”. This is more than triple the power the of any available SMD wirewound under <u>real</u> operating conditions on a PC board which requires safety agency approval (as do virtually all computer/telecom/industrial control boards. Moreover, the **HPC** resistor is non inductive as a result of its thick film resistive method.

It was earlier mentioned that a conventional SMD resistor, power type or not, almost exclusively depends on its pads for heat removal. The **HPC** series differs markedly in this respect. While the housing has integral J-lead type pads, the design of the housing is such that it transmits a only a fraction of overall resistor-generated heat to the PCB, That is, while at maximum power the resistive element can be at 150 C, the PCB solder pads will remain well under 105C.
This control of heat movement away from the PCB but in a way to better reach moving air is achieved by careful selection of aluminum cross-section, heat travel path lengths and overall surface area of the housing.

Because the **HPC** resistor is so closely patterned after a power semiconductor, it also exhibits that same excellent transient thermal resistance characteristic. That is, while the steady state power rating is determined to a great deal by the combination total surface area of the aluminum structure and the related air velocity, the momentary, or short duration power capability is to a great extent based on the <u>mass</u>, rather than surface area of the thermal conductive package-material-- in this case aluminum. That means, for up to a second or two, even on a repetitive basis, the device acts as if there is a very large heat sink, and it can handle easily up to **100 watts!** The **HPC** series is specifically characterized for how much power can be handled and for how long under such surge or repetitive high power conditions.

The design of the **HPC** device is available in resistance as low 25 milliohms. The package design makes Kelvin connections essentially an integral capability whenever low value types for current sensing are required. The package footprint allows plenty of room for large current traces from the outside of the device, and the voltage sense traces to be placed under the device itself.

CONCLUSION

The ***HPC*** surface-mount power resistor is unique in its manner of capitalizing on semiconductor techniques. In so doing, it can provide many times the power capability in the same space, at similar cost, as existing surface-mount alternatives, with superior overload performance characterization. In other words, it is the industry's first true surface-mounted power resistor, opening up a whole new range of creative possibilities for system designers.