SUPPLEMENT TO

ELECTRONIC DESIGN

FOR ENGINEERS AND ENGINEERING MANAGERS - WORLDWIDE

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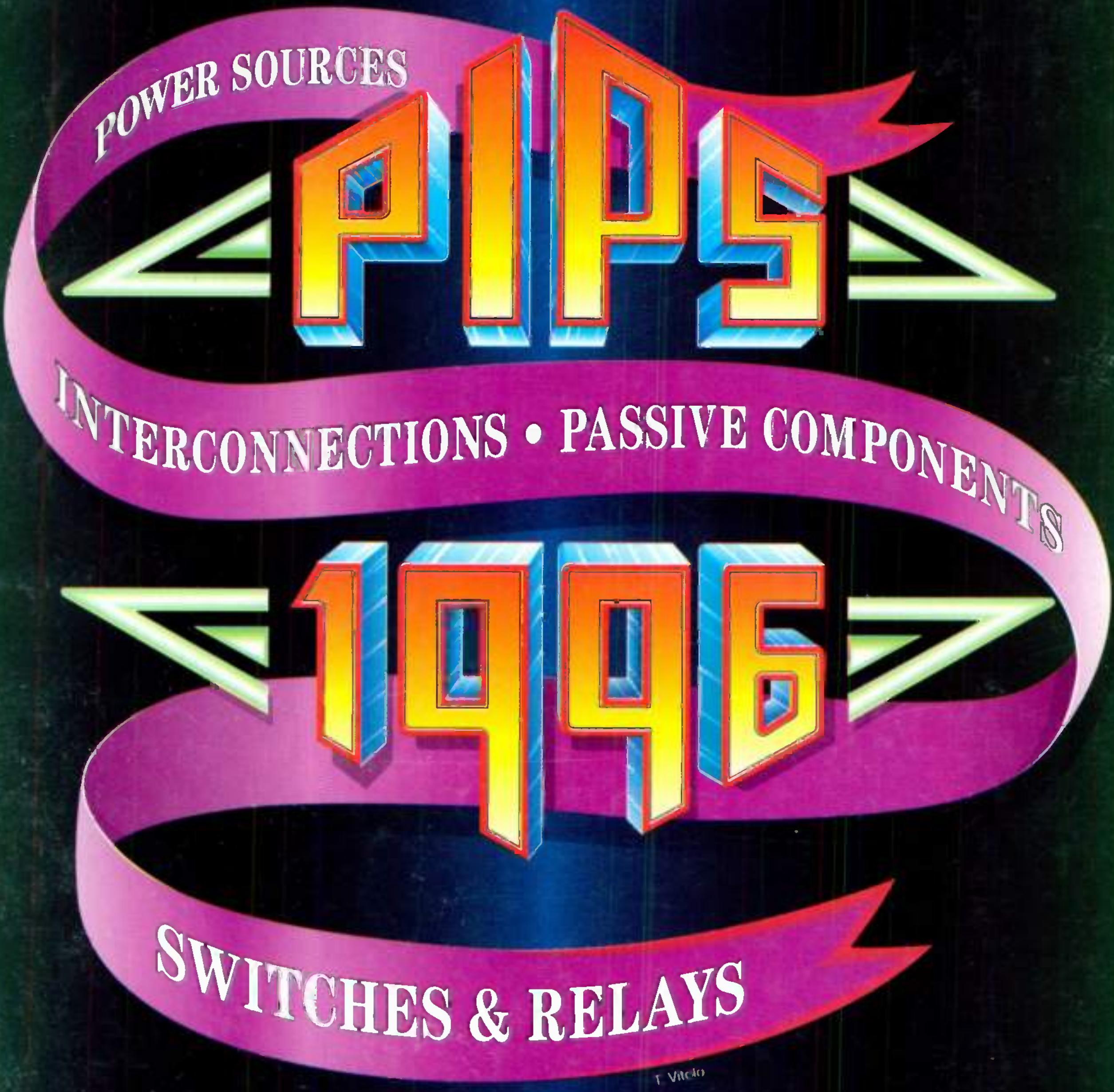

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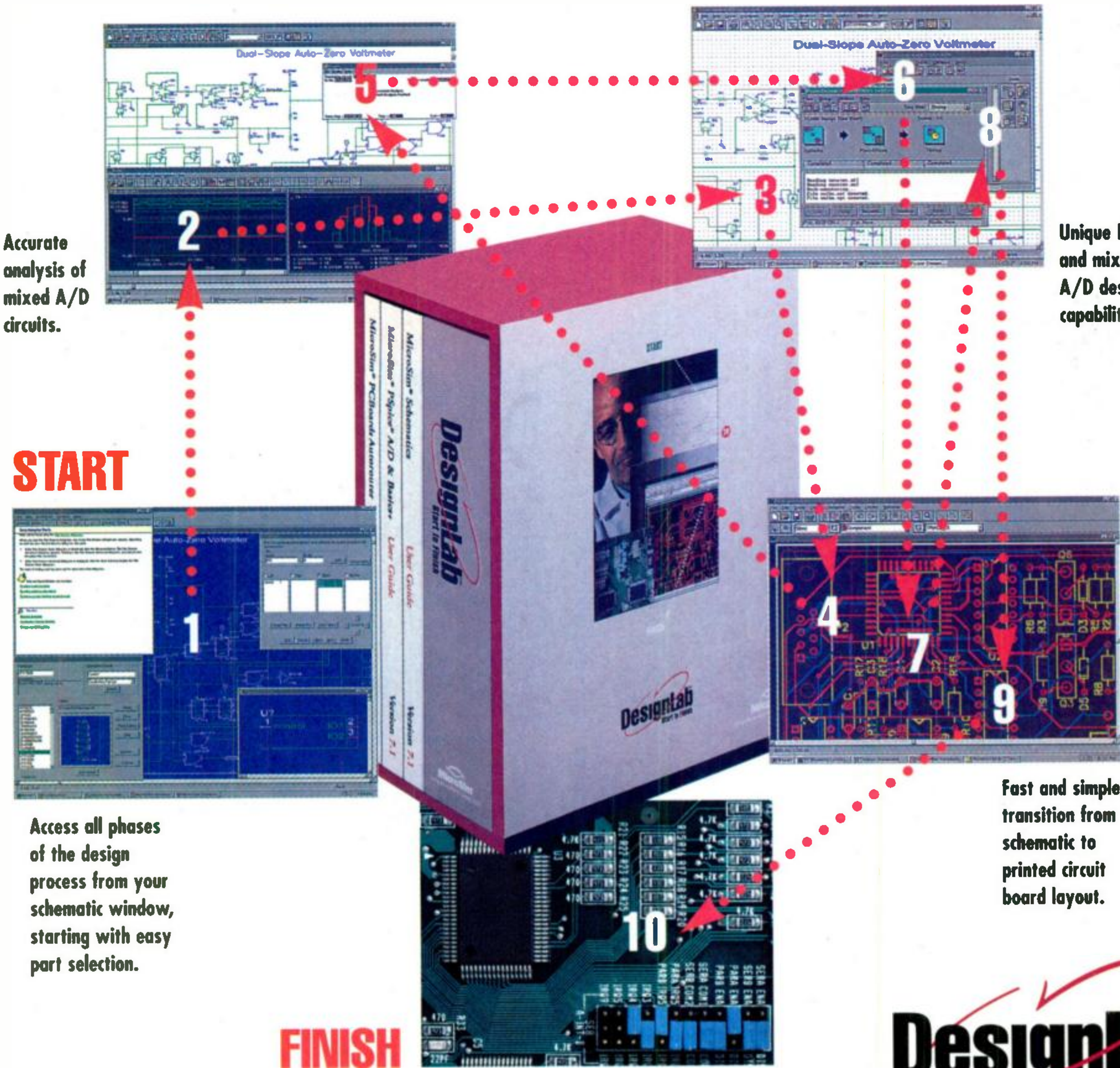

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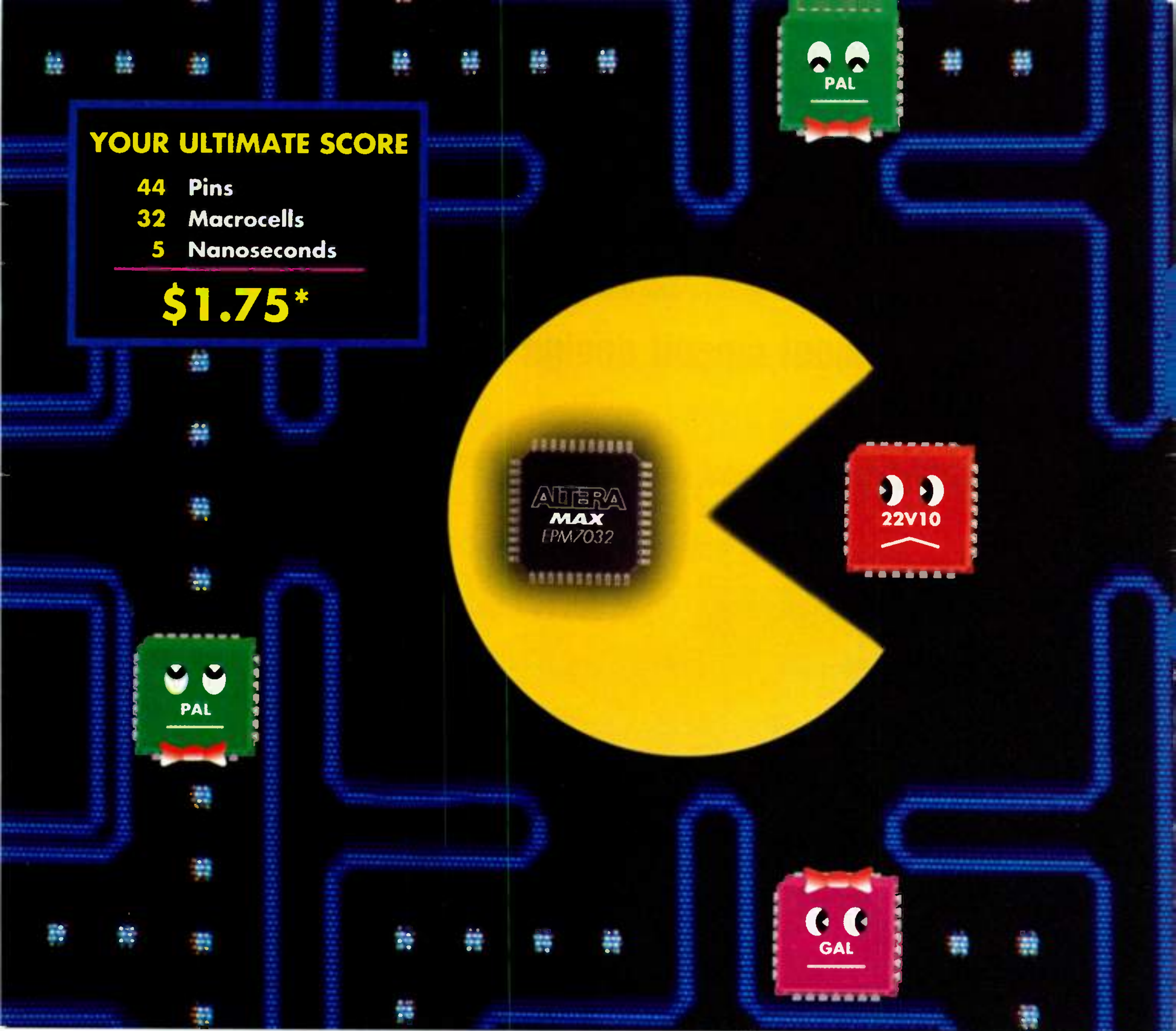
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ELECTRONIC DESIGN
FOR ENGINEERS AND ENGINEERING MANAGERS-WORLDWIDE

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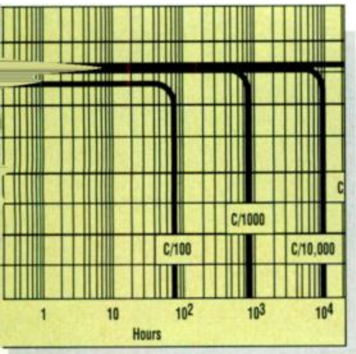

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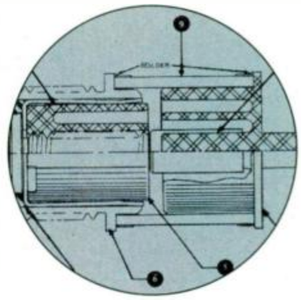
MANUFACTURERS LISTINGS



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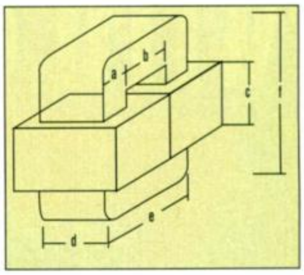

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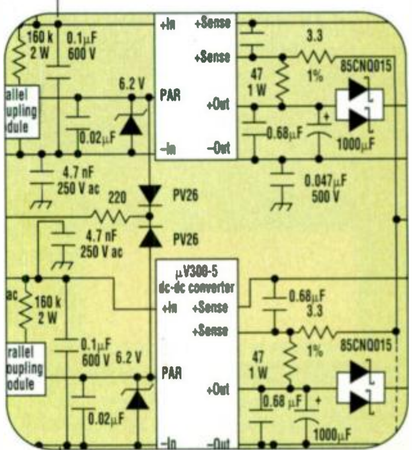

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In 1990, Electronic Design kicked off a new special section that focused on the basic technologies and products of electronic systems: Power supplies, interconnections, passive components, and switches and relays. We dubbed the section "PIPS" for the initial letters of each of the product areas covered. In that first year, PIPS appeared quarterly, but as the section's popularity grew, we increased the frequency of publication from four times a year to six times and then to its current frequency of 12 times a year, with a regular slot in the first issue of each month. Each installment gives special focus to a particular product area, while also covering new products in all four PIPS areas.

PIPS grew out of a realization that we were having little difficulty in finding more than enough material to fill an issue with news of all the developments in the hot new technologies--semiconductors, electronic design automation, software, computers, etc.—but it had become too easy to overlook developments in the more mature technologies, which were not as dramatic, but were nonetheless vitally important to total system design. Recognizing this, we made a commitment to regularly cover these fundamental electronic technologies, which are the backbone of most electronic systems. The result is the more than 50 PIPS special sections that have been published since 1990.

A commitment to cover the mature technologies, which are the backbone of every new system design.

In this supplement, we have collected many of the PIPS sections published in Electronic Design during the past year. Each monthly installment consists of a technical article and a large table listing specifications for a particular product type, along with the manufacturers' addresses and telephone numbers. Because of the timeliness factor, we have opted not to republish the extensive new product sections that also are a part of each PIPS installment.

Needless to say, we will continue publishing the PIPS sections, and also to strive to improve and make the section more relevant to the needs of our readers. Looking ahead to next year, here's the list of topics that will be covered with a special focus in the monthly PIPS sections in Electronic Design for 1997:

January: Power Converters
February: Board-Level Interconnects
March: Optoelectronics
April: Switches
May: Batteries
June: Enclosures
July: Power Supplies
August: Interconnects
September: Passive Components
October: Relays
November: Power Semiconductors
December: Packaging

It takes a strong commitment to our readers and a recognition of the importance of these technologies to consistently publish useful, new information on them. If you have special information needs in any of these areas, please let us know so that we can include them in our plans for future issues.

STEPHEN E. SCRUPSKI
Editorial Director

Choosing Lithium Primary-Cell Types

BY MARK SCHIMPF
Power Conversion Inc., 495 Boulevard, Elmwood Park, NJ 07407; (201) 796-4800.

Although they share common attributes, each of the various chemistries for lithium cells lends itself to different uses.

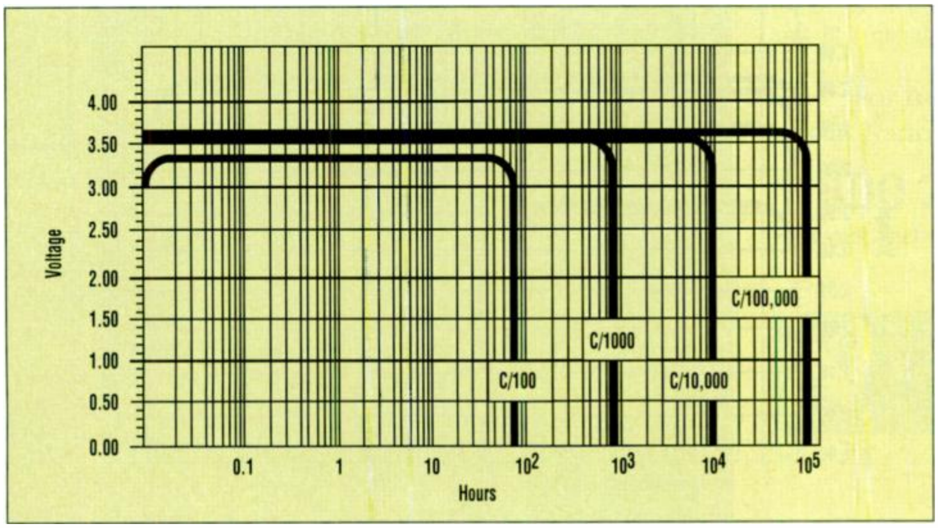
During the past decade, nonrechargeable (primary) lithium chemistries have established themselves as outstanding alternatives to carbon zinc, alkaline, and other commercial batteries typically used for primary and backup power sources. Lithium batteries—whether lithium thionyl chloride, lithium sulfur dioxide, or lithium manganese dioxide—provide uniquely broad operating characteristics. These characteristics make lithium chemistries particularly useful for a large veriety of applications that require years of dependable standby power at low discharge rates.

Lithium cells are also a good fit for applications that demand moderate or high continuous power or widely varying intermediate pulses, call for high per-cell operating voltages, and benefit from flat discharge profiles. If you need exceptional energy density, need to operate over a wide temperature range, and are now experiencing a high maintenance cost for replacing batteries, then lithium cells are probably a good choice for your particular application environment.

Despite their common virtues, each particular lithium chemistry has unique characteristics making it more suitable for certain classes of applications than others. Design engineers need to ask themselves several key questions before selecting a particular lithium battery for their application. Some of these questions are:

- What is the current load on the battery?
- What storage- and operating-temperature ranges do the application impose?
- What is the operating-voltage range for the application?
- What are the application's safety concerns? Is the battery accessible to consumers? What is the potential for abuse?
- What size and space constraints are imposed on the battery by the application?

Among the three lithium chemistries to be discussed, lithium thionyl chloride batteries offer the highest energy density and voltage and widest operating temperature range. Lithium thionyl chloride cells have a number of redeeming characteristics (*Fig. 1*). Among them is their safe construction. Their bobbin design is very safe under abuse conditions, but has limited current-delivery capability (typically much less than 100 mA for small cells and up to several hundred mA for large cells). They also offer the highest voltage in a lithium primary cell: Their open-circuit voltage is 3.65 V and operating voltage is from 3.0 to 3.6 V.



1. The discharge-characteristic curve for lithium thionyl chloride batteries shows essentially flat characteristics at all discharge rates with a sharp knee. Lithium thionyl offers the highest energy density of the three lithium primary chemistries. These discharge curves assume an operating temperature of 23° C.

energy density, high operating voltage, and a relatively wide operating-temperature range. Another extremely desirable attribute they have in common is a low self-discharge rate—typically less than 1% per year at room temperature. In lithium thionyl chloride and lithium sulfur dioxide systems, this characteristic is caused by the formation of a film on the lithium anode that inhibits self-discharge reactions.

This film, or passivation layer, can also cause a voltage sag upon initial application of a load, especially after months of storage. The magnitude of the voltage sag depends on temperature, current load, and the conditions the battery was subjected to while in storage. Voltage sag also is reduced, but not eliminated, in applications that have a low-drain continuous load on the battery.

The passivation layer causing this voltage sag begins to break down immediately after a load is applied, and operating voltage usually returns to a normal range within seconds. If the load is removed, the passivation layer will reform. Lithium manganese dioxide cells do not exhibit this voltage-sag characteristic caused by anode passivation.

All three lithium technologies have been designed for safety, even in conditions of abuse. All spiral designs, and the bobbin designs of some manufacturers, incorporate a one-time-use vent to release internal pressure.

Bobbin-design lithium thionyl chloride cells will not generate enough short-circuit current to raise the temperature to a level where the cell will vent. If the cell is somehow punctured, thionyl chloride, a corrosive liquid, is released.

Spiral-design sulfur dioxide and manganese dioxide cells can generate enough short-circuit current, especially in large cells, to cause sufficient temperature rise for the cell to vent. Sulfur dioxide is a respiratory irritant. But the amount contained in a single cell dissipates immediately in a ventilated room. The electrolyte contained in manganese dioxide cells is an organic liquid. It's flammable, but not corrosive or particularly irritating to breathe. Many design versions of all three chemistries have received the approval of Underwriters Laboratories and other safety agencies.

The decision to use a particular lithium chemistry generally hinges on some factor other than cost. On a dollar per watt-hour basis, the three technologies do not vary widely.

Small lithium thionyl chloride cells can range $0.35/Wh to

CONTINUED ON PAGE 16

The decision to use a particular lithium chemistry generally hinges on some factor other than cost.

MANUFACTURERS OF HIGH-DENSITY DC-DC CONVERTERS

Manufacturers	Output-power range (W)	Number of outputs	Input-voltage range (V dc)	Output-voltage range (V dc)	Output-current range (A)	Output ripple and noise	Line/load regulation	Power density (W/in.^{3})	Isolation-voltage range (V dc min)	EMI/RFI shielding?
AT&T Microelectronics Power Systems Div. Mesquite, TX (214) 284-8260 **CIRCLE 451**	20 to 300	Single or dual	18 to 36; 36 to 75	1.5 to 28	4 to 60	0.6 to 2% at 5 V	±0.01% to ±0.05%/ ±0.05% to ±0.1%	13 to 55	500 to 1000	Available as external circuitry or module
Absopulse Electronics Carp, Ontario, Canada (613) 836-3511 **CIRCLE 452**	25 W to 5 kW	Up to 4	12 to 260	5 to 260	0.1 to 100	1% of nominal output voltage	±1.5% combined	5	500 or 2750, depending on model	Yes
Advanced High Voltage Co. Tucson, AZ (800) 494-2424 **CIRCLE 453**	3 to 500	Single	12, 15, or 28	200 V to 30 kV	1 mA to 1 A	0.05% p-p of nominal	0.01% per ±10%	2 to 4.2	10 kV (DVM Series)	Yes
Astec America Inc. Carlsbad, CA (619) 757-1880 WWW: astec.com **CIRCLE 454**	50 to 500	Single and dual	5 to 300 (nominal)	2.2 to 48	3.3 to 70	1%	0.02%/0.1%	Up to 90	1500 to 2200	Yes
Conversion Devices Inc. Brockton, MA (508) 559-0880 **CIRCLE 455**	50 to 300	Single and dual	18 to 36; 36 to 72; 180 to 400	2.2, 3.3, 5, 12, and 15	Up to 60 A	2% p-p	±0.1%	24 to 54	2100 and 2700	No
Converter Concepts Pardeeville, WI (608) 429-3000 **CIRCLE 456**	10 to 350	Up to 4 standard; up to 7 custom	10 to 40; 20 to 60; 100 to 350	90 to 264	<1 to 20	1% max. ripple; 2% p-p noise	0.3%/ 1 to 1.5%	Varies with product line	250	Yes
Custom Power Systems Ronkonkoma, NY (516) 467-5328, ext. 500 **CIRCLE 457**	Custom	Custom	Custom	Custom	Custom	Custom	Custom	Custom	Custom	Yes
Digital Power Corp. Fremont, CA (510) 657-2635 **CIRCLE 458**	100 to 500	Single	18 to 420	1.2 to 48	6.7 to 60	100 mV at ≤5 V out; 2% at >5 V out	0.1%/0.2%	36 to 91	2700 V (300 V in); 2100 V (48 V in)	Built in with baseplate grounded
Electronic Measurements Neptune, NJ (908) 922-9300 emiapps@injersey.com **CIRCLE 459**	200	Single	12, 24, 48, 150, 300	3.3, 5, 12, 15, 24, 28, 48	2 to 40	3% p-p	0.5%	36	1500 (12 to 48 V in); 4300 (150 to 300 V in)	No
Engineered Magnetics Inc. Rancho Dominquez, CA (310) 635-9555 **CIRCLE 460**	5 W to 2 kW	Up to 4 typical, up to 12 custom	8 to 400	3.3 to 400	0.1 to 100	1%/1%	1%/1%	20	50 to 4242	Yes
Gamma High Voltage Research Ormond Beach, FL (904) 677-7070 **CIRCLE 461**	1 to 100	Up to 3	6 to 24	100 V to 100 kV	Zero to 100 mA	1.0 to 0.001%	20 to 0.001%	N.S.	1000 V to 20 kV	Yes
International Power Sources Ashland, MA (508) 881-7434 **CIRCLE 462**	60 to 200	Up to 3	10 to 400	3.3 to 48	2.5 to 40	3% of voltage output	0.5%/ 0.5 to 6%	6 to 21	1500	Yes
Interpoint Corp. Power Products Div. Redmond, WA (206) 882-3100 power@intp.com **CIRCLE 463**	1.5 to 200	Up to 4	4 to 400 or 16 to 40 typical	3.3 to 28 (various options in-between)	0.167 to 30	30 to 50 mV p-p typical (as low as 5 mV p-p)	<1% typical	Up to 80 W/in.^{3}	500 V dc (maximum)	Yes

MANUFACTURERS OF HIGH-DENSITY DC-DC CONVERTERS

Manufacturers	Output-power range (W)	Number of outputs	Input-voltage range (V dc)	Output-voltage range (V dc)	Output-current range (A)	Output ripple and noise	Line/load regulation	Power density (W/in.^{3})	Isolation-voltage range (V dc min)	EMI/RFI shielding?
Jeta Power Systems Signal Hill, CA (310) 427-0095 jeta@jeta.com **CIRCLE 464**	400 or 600	Up to 5	42 to 64 V or 120 V	3 to 5, 12, 15, 24, 48	Up to 120	50 mV p-p or 1%	±0.2%	>5 (fully functional, no additions required)	4242	Yes
KGS Electronics Arcadia, CA (818) 574-1175 **CIRCLE 465**	20 to 600	Up to 6	8 to 48	Zero to 36	1 to 30	>50 mV p-p	2% line and load	4 to 8	N.S.	Yes
Kepco Inc. Flushing, NY (718) 461-7000 kepcopower@aol.com **CIRCLE 466**	10 to 150	Single and dual	12, 24, 48, 18 to 36, 36 to 72, 100, 150	5, 12, 15, 24, ±12, ±15	Up to 30 (at 5 V)	100 to 150 mV p-p	0.05% typical, 0.2% maximum	Up to 18	500	No
Lambda Electronics Inc. Melville, NY (516) 694-4200 **CIRCLE 467**	1.5 to 2000	Up to 3	5 to 400	2 to 48	<1 to 80	5 mV p-p and up	0.1% and up	From 31 and up	Up to 3000 V ac	No
Lambda Novatronics Inc. Pompano Beach, FL (800) 952-6909 **CIRCLE 468**	1000 (standard parallelable modules)	Single	28 or 270	5 to 270	3.7 to 120	<1% ripple; <2% noise	±0.5% for both	10	2800 V input to output	Yes (to MIL-STD-461)
Logitek Inc. Ronkonkoma, NY (516) 467-4200 logitek@lgtk.com **CIRCLE 469**	15 to 150	Up to 4	16 to 40	5 to 48	0.5 to 30	50 mV p-p typical	0.1%	10 to 50	500 to 1000	Yes
Modular Devices Inc. Shirley, NY (516) 345-3100 **CIRCLE 470**	4 to 80	Up to 4	16 to 50; 86 to 158; 200 to 335	2 to 28 (plus specials)	50 mA to 50 A	15 to 50 mV p-p	10 mV typ./ 20 mV typ.	15	500 to 1000	Yes (to MIL-STD-461)
Pioneer Magnetics Inc. Santa Monica, CA (310) 998—5628 **CIRCLE 471**	500 to 1000	Up to 5	42 to 56	2 to 60	Zero to 150	1% or 50 mV	±0.25%	2.85	2500	Yes
Power General Canton, MA (617) 828-6215 powergeneral@nidecpg.com **CIRCLE 472**	15 to 75	Up to 3	9 to 72	2 to 15	1 to 15	50 to 75 mV p-p	0.3 to 1%	7 to 38	Uninsulated to 1500 V	Yes
RO Associates Inc. Sunnyvale, CA (408) 744-1450 102565.1441 @compuserve.com **CIRCLE 473**	50 to 250	Up to 3	20 to 32; 36 to 72; 220 to 400	2.1 to 28	4 to 60	1% typ., 3% max.	0.2%	40 to 58	1000 to 4500	No
ST Keltec Corp. Ft. Walton Beach, FL (904) 244-0043 www.sigtec.com **CIRCLE 474**	25 to 200	Up to 5	22 to 32; 220 to 320	3, 5, 12, 15, 28	15 to 20	20 to 100 mV	1%	10 to 40	100 V for 28-V input; 500 V for 270-V input	Yes
Shindengen America Inc. Westlake Village, CA (805) 373-1130 **CIRCLE 475**	1.5 to 300	Up to 3	4 to 7.2; 8 to 16.5; 16 to 32; 18 to 36; 20 to 60; 36 to 72	5, 12, 15, 24 (all ±10%)	0.06 to 60	5 V: 2% >5 V: 1% (with 50-MHz bandwidth)	±5% (total error band)	3.4 to 54.8	500	No
Sierra West Power Systems Inc. Las Cruces, NM (505) 522-8828 **CIRCLE 476**	25 to 150	Up to 3	10 to 400	3.3 to 48	1 to 45	50 mV p-p	±0.1%	15 to 20	1500	Yes

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more than $0.75/Wh; large thionyl chloride cells can range down to $0.20/Wh (as can large sulfur dioxide cells).

Small manganese dioxide cells typically range from $0.40/Wh to over $1.00/Wh.

Large manganese dioxide cells can range down to $0.35/Wh.

MARK SCHIMPF is Power Conversion Inc.'s director of lithium industrial sales. Schimpf received his bachelor's degree in chemistry from Lehigh University, Bethlehem, Pa., and an MBA from Fairleigh Dickinson University, Rutherford, N.J. He has worked in the battery industry for over 12 years.

Originally published in the January 8, 1996 issue of Electronic Design.

MANUFACTURERS OF HIGH-DENSITY DC-DC CONVERTERS

Manufacturers	Output-power range (W)	Number of outputs	Input-voltage range (V dc)	Output-voltage range (V dc)	Output-current range (A)	Output ripple and noise	Line/load regulation	Power density (W/in.^{3})	Isolation-voltage range (V dc min)	EMI/RFI shielding?
Tektris Electro Corp. La Mesa, CA (619) 589-0444 powerla@realm.net **CIRCLE 477**	200 W maximum	One	10 to 400	3 to 48	30 A maximum	1% maximum	0.05% maximum	18.2	3750	No
Transistor Devices Inc. Cedar Knolls, NJ (201) 267-1900 zeman_r @mailer.transdevices **CIRCLE 478**	200 W to 1 kW	Up to 5	24, 48, 120, 270	5 to 270	5 to 200	150 mV at 24 V out	1%	2 to 5	1200	Yes
VARO Garland, TX (214) 840-5293 **CIRCLE 479**	60 to 300	Up to 6	16 to 440	2.2 to 175	100 mA to 60 A	10 mV to 150 mV (ripple and noise)	<0.1% for both	5 to 50	1500 (military); 5000 (comm.)	Yes
Vicor Corp. Andover, MA (800) 735-6200 www.vicr.com **CIRCLE 480**	10 W to kilowatts	Depends on number of modules used	10 to 400	1 to 95	N.S.	0.75 to 2%	0.05%	Up to 50	4300 to 5600	Yes
Wall Industries Inc., Exeter, NH (603) 778-2300 http://www.conres.com/ wtop.htm **CIRCLE 481**	0.75 to 1800	Up to 5	4.5 to 400 (ranges of ±10%, 2:1, 4:1, and 5:1)	3.3 to 3000	1 mA to 60 A	50 mV p-p or 1% of output	±0.1%/ ±0.5%	3 to 26	Uninsulated to 5303	Yes

N.S. = not specified

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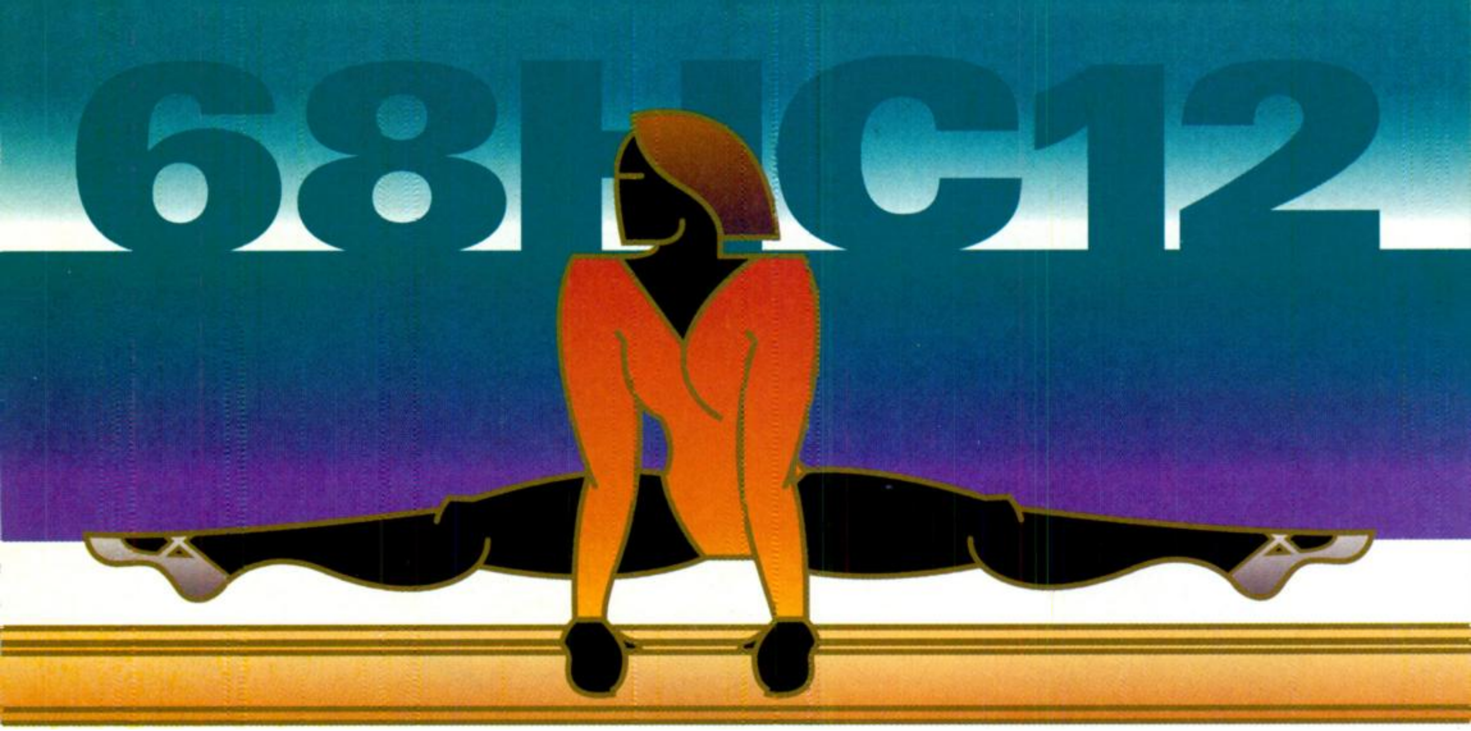
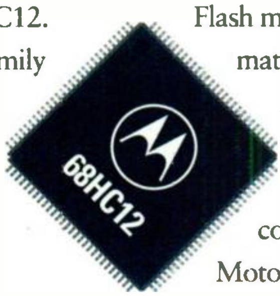


PERFECT BALANCE

The Competitive Edge of Motorola's New 16-Bit Microcontroller.

On a scale of one to ten, it's a 12. The 68HC12.

This new cost-effective microcontroller family offers the perfect balance of low power consumption and high performance. With a CPU12 core that runs at 8 MHz from 2.7 to 5.5 volts, the 68HC12 will launch next-generation designs for portable consumer, automotive, wireless communications, and industrial control products.



A perfect score. The 68HC12 is a highly integrated 16-bit architecture that is completely source-code compatible with Motorola's industry-standard 8-bit 68HC11 microcontrollers. Customers who need increased performance can now migrate designs directly up to the 68HC12 without sacrificing valuable investments in software.

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Trimmer Capacitors Still Make Sense

BY RICHARD J. NEWMAN
Voltronics Corp., 100-10 Ford Rd., Denville, NJ 07834; (201) 586-8585.

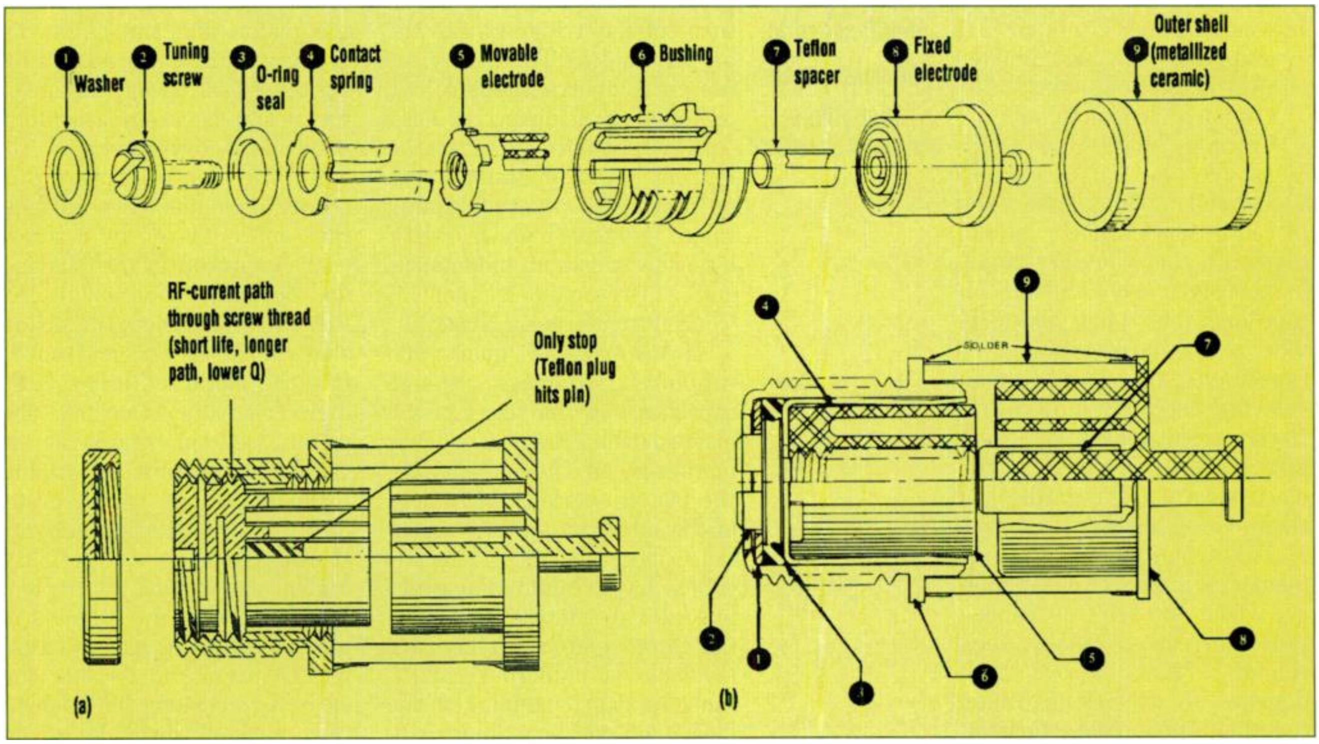
Mundane perhaps, but trimmer capacitors offer a number of unique capabilities for circuit designers.

Many designers consider trimmer capacitors to be mundane, perhaps archaic, and certainly well understood. But the volume of inquiries received at Voltronics year after year concerning fundamental characteristics of trimmer capacitors has not diminished. So it's certainly not mundane to review their basic properties, especially with the appearance of new applications in wireless personal-communications devices.

The trimmer capacitor is one of those components that every designer would rather do without. In an ideal world, in which the exact values of each component is known and is perfectly matched to the requirements of the circuit, trimmers would quickly become extinct.

That day has not come, however, and isn't likely to any time soon, because there is always some variability among components, and that must be compensated for. Trimmer capacitors are still the best way. For instance, after burn-in and temperature cycling, crystals can drift and can be returned to the exact frequency with trimmers.

Trimmers have also taken their share of knocks over the years on several counts. First, because the traditional trimmer is not a sealed device, dirt and other contaminants can enter it, causing degradation of performance and possible failure. In addition, because the trimmer is a mechanical device, it seems out of place in today's



1. The concentric-ring air trimmer is configured with either a rotating concentric ring (a) or non-rotating concentric ring (b). As the rings mesh, capacitance increases.

ubiquitous silicon, surface-mount environment.

While there is some justification for these complaints, today's best trimmers are every bit as reliable as their semiconductor counterparts on the circuit board. They'll deliver repeatable performance for the life of the host product and are in fact available in surface-mount configurations.

In short, while no designer likes to consider that the design will need adjustment in order to make it meet customer specifications, they almost always require some "tweaking." The bright side is that trimmers provide a way to make this a simple, accurate, and ultimately, less expensive task.

There are a variety of trimmer types available. What's important is choosing the right one for each application. Each of these trimmer types has its positive and negative aspects, and some are better suited to particular circuits than others.

Trimmer types include:

Half-turn:

•Ceramic through-hole and chip SMT

•Film, mica, paper

Multi-turn:

•Glass or quartz tubular

•Sapphire-dielectric tubular

•Air-dielectric tubular

•Teflon-dielectric tubular

Ceramic single-turn trimmers are the most common types, and millions have been placed in service. Their advantages are that they are small, inexpensive, and available on tape and reel. They also provide a significant amount of capacitance (up to 40 pF) considering their tiny footprint. These characteristics have assured them a place in the electronics world, regardless of their shortcomings.

These shortcomings include mediocre temperature stability, which worsens as capacitance increases. Finally, they cannot be tuned with a great degree of precision. Taken together, these characteristics make ceramic trimmers unsuitable for applications where precision is a paramount concern.

TRIMMER CAPACITOR COMPARISON

Device	Advantages	Disadvantages
Half-turn ceramic	Low cost Small size	Low resolution High capacitance drift Low voltage Unsealed (most styles) High temperature coefficient Low Q
Multi-turn (all dielectrics)	High resolution for fine tuning Many different mountings Low temperature coefficients Low capacitance drift Sealed Stable under shock and vibration	Higher cost Larger size
Multi-turn (glass and quartz dielectrics)	Capacitance ranges to 180 pF	Maximum frequency 500 MHz
Multi-turn (air dielectric)	Usable to 1.5 GHz High Q Capacitance to 30 pF	Maximum voltage 500 VDC
Multi-turn (Teflon dielectric)	Voltage ranges to 15 kV Most stable and reliable	Higher price

Each of these trimmer types has its positive and negative aspects, and some are better suited to particular circuits than others.

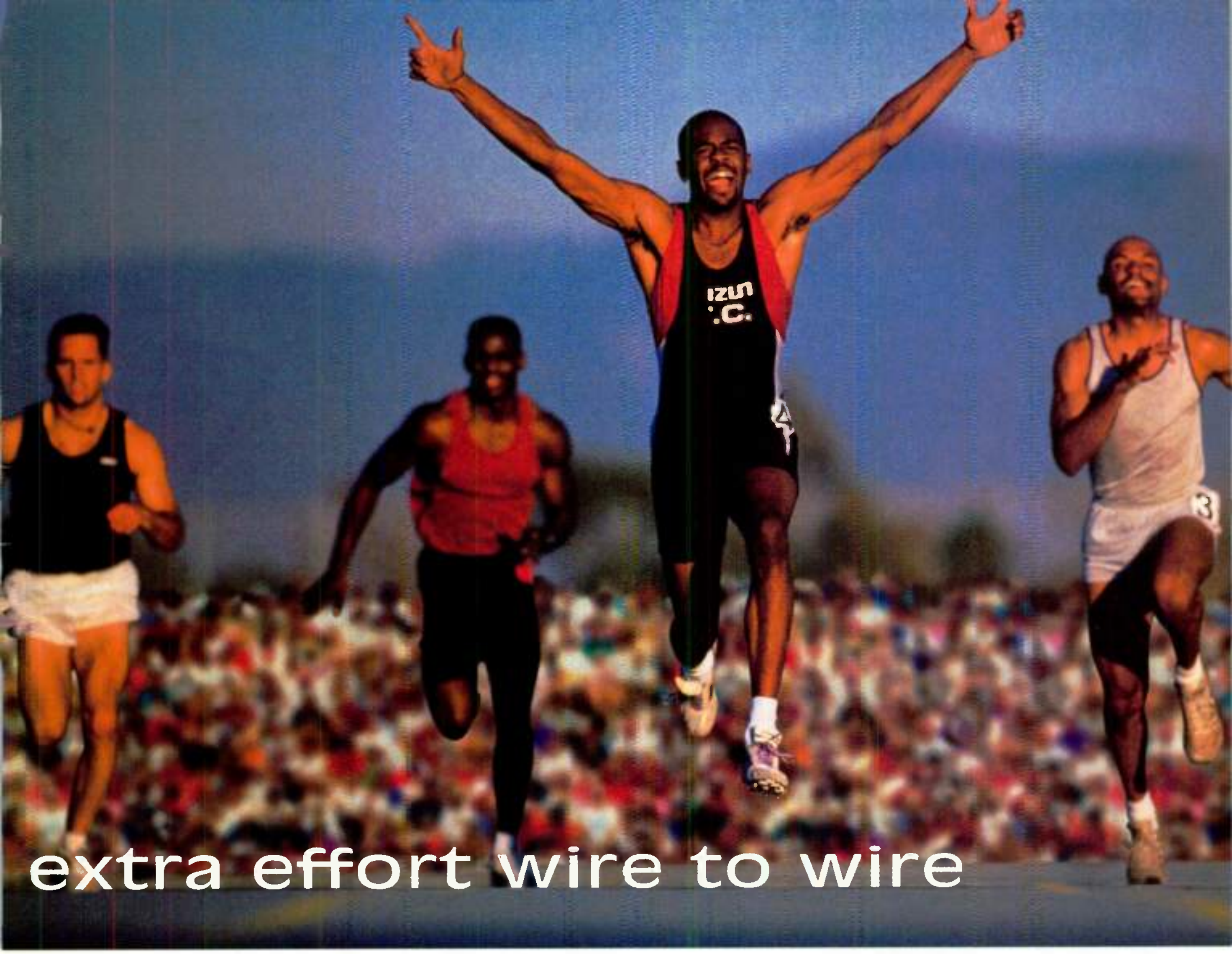
However, they are well suited to applications in which low cost and small size are the overriding concerns. The Q of these devices is about 1500 at 1 MHz, temperature coefficient is –200 to –1200 ppm/ °C, and capacitance drift ranges from ±1% to ±5%. Maximum voltage is generally less than 100 V dc.

When higher levels of performance are required, multi-turn tubular trimmers are the better choice. These devices use glass, quartz, sapphire, air, or Teflon as the dielectric. They can be made to provide extremely linear tuning with no reversals in the tuning range, and have high Q, low RF loss, low constant inductance, and self-resonant frequencies (SRFs) as high as 10 GHz.

Multi-turn glass, quartz and sapphire trimmers change capacitance by moving a piston inside a dielectric tube, which is metalized on the outside. As the piston overlaps with more of the metalization, the capacitance increases. The dielectric tubes have inner diameters precise to ±0.0002 in. with matching pistons. They are available in numerous capacitance ranges, depending on the dielectric, with maximum values of 16 pF for quartz, 180 pF for glass, and 8 pF for sapphire.

There are two types of tuning mechanisms used: rotating and non-rotating piston. In the rotating style, the piston is permanently attached to the adjustment screw. As the screw-piston assembly is turned into a threaded bushing, the piston is engaged into the metalized part of the dielectric tube. One problem with this design is that when the piston rotates, the air gap between the piston and the glass can change, which can result in tuning reversals. The advantage of this design is ease of assembly, resulting in lower cost.

In the non-rotating style, the piston is placed on bushing rails and is driven by a screw that's captured in the bushing and does not move axially. As the screw is turned, the piston slides along the rails and moves into the metalized area of the dielectric tube. Because the piston does not rotate, the air gap stays constant and tuning is linear within ±1% versus ±10% on the rotating version. It also assures better stability under shock and vibration. Because the screw remains in place, it provides easier access for the user. And because the current runs along the bushing rails rather than along the



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screw, the non-rotating styles have lower inductance and higher self-resonant frequencies.

At higher frequencies, the multi-turn trimmer with air, Teflon or sapphire dielectrics provides the best solution. In the air trimmer, capacitance is created by a movable set of concentric metal rings fitted into a fixed set of parallel rings *(see the figure)*. As the rings mesh, capacitance increases. A fine-thread screw provides many turns of resolution in terms of the exact value.

Like their solid-dielectric counterparts, air-dielectric trimmers can be designed in two ways—rotating or non-rotating. The primary difference between the two types is the method of sealing. The rotating design uses a removable cap to seal the unit. The non-rotating design uses an internal O-ring seal.

Sapphire is well suited to use in trimmers: its dielectric constant does not change with frequency, and its low-loss constant is extremely stable (less than 0.0003 to 10 GHz). Sapphire is chemically inert, totally moisture resistant, and mechanically strong. The Q of sapphire trimmers can be more than 4,000, capacitance ranges up to 8 pF, and temperature coefficient is ±50 ppm/ °C.

Another type of concentric-ring trimmer that was recently introduced uses Teflon as the dielectric. Teflon is an excellent dielectric material, and makes the trimmers built with it well suited to high-voltage and high-reliability applications. The Teflon dielectric prevents ionization, which plagues trimmers in high-altitude, space, and other high-voltage applications.

In addition, this type of trimmer is designed to eliminate all potential microphonics under the most adverse conditions and to have a temperature coefficient below ±100 ppm/ °C. Capacitance of this type of Teflon dielectric trimmer is up to 50 pF with voltage ratings as high as 2000 V dc.

For even higher-voltage applications (up to 15 kV), there is a larger Teflon-dielectric trimmer. These are available in capacitance values from 1 to 10 pF up to 100 to 1000 pF. The higher voltage requires larger sizes. These parts are more expensive than the standard low-voltage trimmers.

When it comes to choosing a trimmer, there is a wide variety of trimmer types available today, which makes picking the right one for a given application a challenge *(see the table)*. When deciding on a trimmer, designers must consider all of their requirements, such as capacitance range, package style, resolution, SRF, and Q. They then must look for the most cost-effective solution for their application.

To begin the selection process, the first decision is half- or multi-turn. How important is tuning resolution? If a half-turn is all that is required, then stick with the low-cost half-turn trimmers. If accuracy is critical, then the multi-turn trimmer capacitor is the way to go.

Capacitance range is next. Always choose a trimmer with enough range to meet any possible tolerance variations in your circuit. Then consider size, Q, and mounting, always trying to find the lowest cost solution.

In short, trimmers may not be the most glamorous electronic components in the designer's stable, but they are some of the most versatile. They allow a range of circuit-tuning adjustments to be made during production as well as after the product has been manufactured. This characteristic makes trimmers unique among circuit-tuning methods, including laser trimming. It also can reduce manufacturing costs. There is a wide variety of trimmers available today, from high-voltage types to tiny SMT devices for compact products. The designer's task is to choose the best one for the application.

RICHARD NEWMAN is chairman of Voltronics Corp., which he founded in 1963. After receiving his BEE from Cornell University, he worked at General Electric as head of the Radar Control Section of the Aeronautic & Marine Engineering Department. Mr. Newman moved on to be Chief Engineer of the Daven Co., in Livingston, N.J., before starting Voltronics.

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MANUFACTURERS OF ELECTROLYTIC CAPACITORS

Manufacturer	Capacitor types	Capacitance ranges (µF)	Rated voltages (WV dc)	Operating temperature range(s)	Capacitance tolerances	Load life (hours)	Maximum ESR (Ω@25 C, 120 Hz)	Maximum ripple (mA@25 C, 120 Hz)
Aerovox Inc., Aero M Group El Paso, TX (915) 771-7300 CIRCLE 510	Aluminum, radial, axial, snap-mount	5 µF to 1 F	6.3 to 500	To 105ÉC	±20% (standard)	1000 to 2500	Less than 1.5 times specified limit	Consult factory
Globtek Inc., Northvale, NJ (201) 784-1000 http://gramercy.ios.com/globtek/ CIRCLE 511	Aluminum, axial, snap-mount	0.35 to 65 µF	240 to 3500 V ac	-40 to 90 C	±5, ±6, and ±10%	60,000 minimum	N.S.	N.S.
NEC Electronics Inc. Mountain View, CA (415) 965-6495 CIRCLE 512	Tantalum SMT (R Series), electric double-layer (Supercaps)	0.047 to 220 µF (R Series); 0.01 F to 2.2 F (Supercaps)	2.5 to 50 V (R Series); 3.5 to 6.5 V (Supercaps)	-55 to 125 C (R Series); -40 to 85 C and -25 to 70 C (Supercaps)	±10 and ±20% (R Series)	1000@85 C (R Series); 1000@70 C (Supercaps)	Contact technical support	Contact technical support
Nichicon America Schaumburg, IL (708) 843-7500 CIRCLE 513	Aluminum, tantalum	0.1 to 470,000 µF	2.5 to 450 V	-55 to 125 C	10 and 20%	1000 to 20,000	Low ESR	High ripple current
Panasonic Industrial Co. Secaucus, NJ (201) 271-3173 CIRCLE 514	Aluminum/ tantalum radial, axial and snap-mount; electric double-layer	0.022 to 68,000 µF (overall)	2.5 to 450 V (overall)	-55 to 125 C (overall)	±20%	1000 and 2000@85, 105, or 125 C (depends on type)	Depends on type	Depends on capacitance value and dielectric type
Tecate Industries El Cajon, CA (619) 448-4811 CIRCLE 515	Aluminum (radial, axial, SMT, snap-in); tantalum (radial, axial, SMT)	0.1 to 68,000 µF (aluminum); 0.1 to 330 µF (tantalum)	6.3 to 450 V	-40 to 85 C to -55 to 105 C	5% (special); 10%, 20% (standard)	2000	N.S.	N.S.
Thomson Passive Components Charlotte, NC (704) 597-0766 CIRCLE 516	Aluminum	0.1 to 68,000 µF	6.3 to 450 V	-40 to 85 C to -55 to 105 C	±10, ±20, ±30, -10/+30, -10/+50, and -10/+100	1000, 2000, and 3000	0.1 to 10 (depending on value and voltage)	Dependent on value and voltage rating
Vishay International Sprague Div., Sanford, ME (207) 490-7224 CIRCLE 517	Tantalum (SMT, axial) solid and wet	0.1 to 330 µF	4 to 50	-55 to 85 C (125 C with derating)	5, 10, and 20%	Depends on product	Depends on product	Depends on product
Vishay Sprague Tantalum Div. Sanford, ME (207) 324-4140 CIRCLE 518	Tantalum (axial, radial, SMT)	0.0047 to 680 µF	3 to 125	-55 to 125 C	5, 10, and 20%	2000	Depends on product	Depends on product

N.S. = not specified

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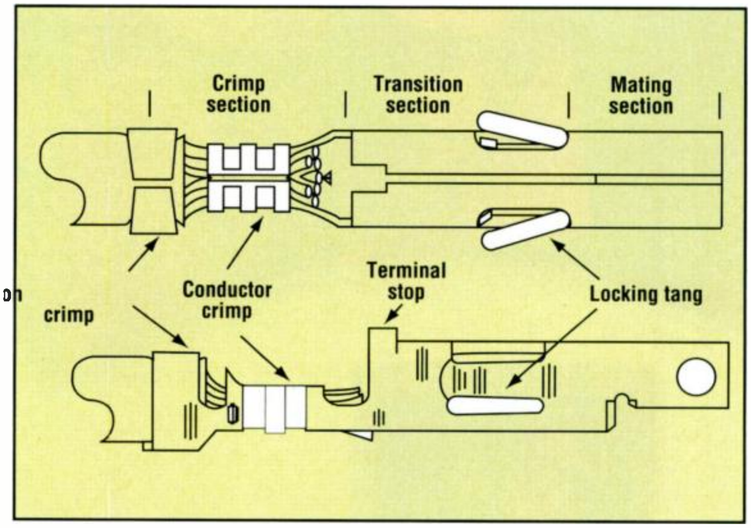
Good Crimps And How To Recognize Them

BY RANDY KEMPF
Molex Inc., 2222 Wellington Ct., Lisle, IL 60532; (708) 527-4234.

Here's how not to fall victim to the 13 most common ways to botch a crimp termination.

You've waded through all of the connector catalogs and found the connector that meets all your design criteria and is just right for your application. It has the right current rating, voltage rating, circuit size, engagement force, wire-size capabilities, configurations, and termination method. It has all of the safety features you need: positive locks, fully-isolated contacts, polarization, and agency certifications. It is, in short, the perfect connector.

But don't let out a huge sigh of relief quite yet—especially if the connector you've chosen uses a crimp-termination system. Crimps can be one of the fastest, most reliable, and rugged termination methods. But if the terminal isn't crimped onto the wire correctly, it'll wipe out all of the hard work you put into selecting the right connector. And, although there are 13 common crimping problems that can reduce the reliability of your product, these problems are easy to avoid with a little knowledge and advance planning (*see "A guide to crimping problems," below*).



1. There are three major sections to a crimp termination: the mating section, the transition section, and the crimping section. Any deformation of the mating section, especially during the crimping process, will reduce the connector's performance.

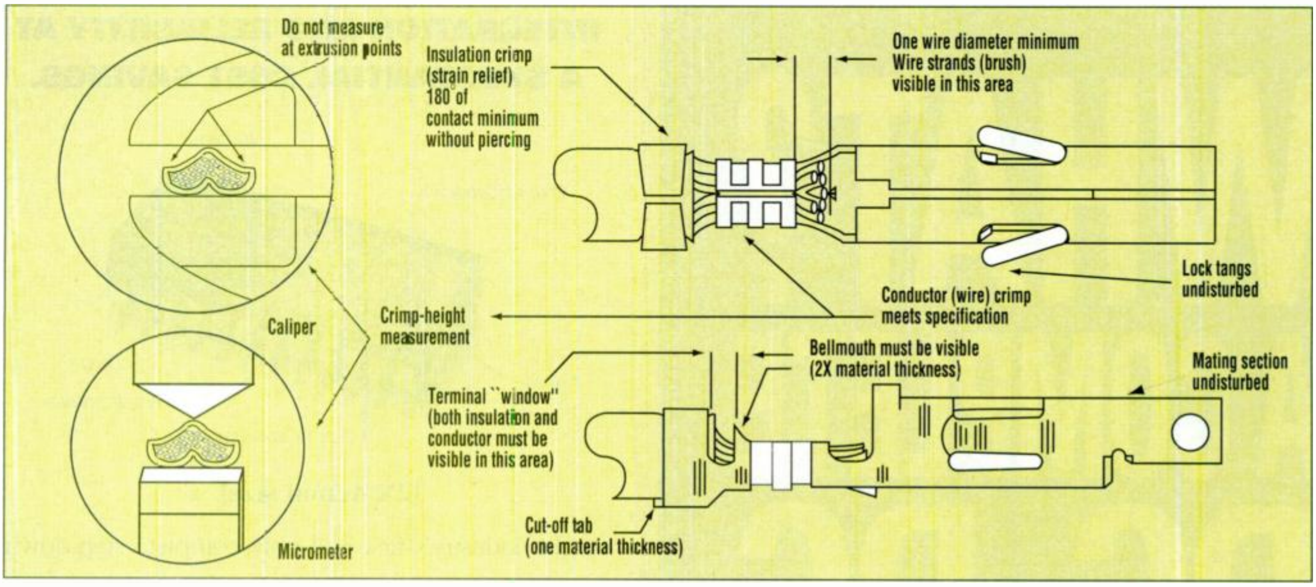
To begin with, it helps to understand that a terminal has three major sections: mating, transition, and crimping (*Fig. 1*). The mating section, as the name implies, is the section of the terminal that mates, or becomes the interface, with the other half of the connection. This section was designed to mate with a terminal of the opposite gender and to perform in a certain manner by the connector's designer. Anything that you do that deforms the mating section, especially during the crimping process, will only reduce the connector's performance.

The transition section also is designed so that it wouldn't be affected by the crimping process. Here again, anything you do that changes the position of the locking tangs or terminal stop affects the connector's performance.

The crimp section is the only section that's designed to be affected by the crimping process. Using termination equipment recommended by the connector manufacturer, the crimp section is deformed so it can be securely attached to a wire.

A Guide To Crimping Problems

Because most problems reported to connector manufacturers relate to one of 13 crimping problems, Molex offers an easy-to-use guide to help you avoid problems or recognize them quickly enough so that you make only good crimps. To order this guide (which comes in a poster format), please fax a copy of your business card to Advertising, (708) 512-8627. Or write to Molex Inc., 2222 Wellington Ct., Lisle, IL 60532; attn.: Good Crimp Drawings.



Let's look at an example of a properly performed crimp (*Fig. 2*). The insulation crimp compresses the insulation without piercing. The wire strands (or brush) protrude through the front of the conductor crimp section by at least the diameter of the wire's conductor. For example, an 18 AWG wire would protrude at least 0.040 in. Both the insulation and conductor are visible in the area between the insulation and the conductor's crimp section. The crimp section shows a bellmouth shape in the leading and trailing ends, while the transition and mating sections remain exactly as they were before the crimping process.

2. A number of attributes come together to make up a good crimp connection. If your crimps don't look like these, it may be a result of something amiss in the crimping process.

If your crimped terminal doesn't look like the terminal in Figure 2, it may be that something went wrong during the crimping process. Here are 13 of the most common problems that may occur during the crimping process and how to avoid them.

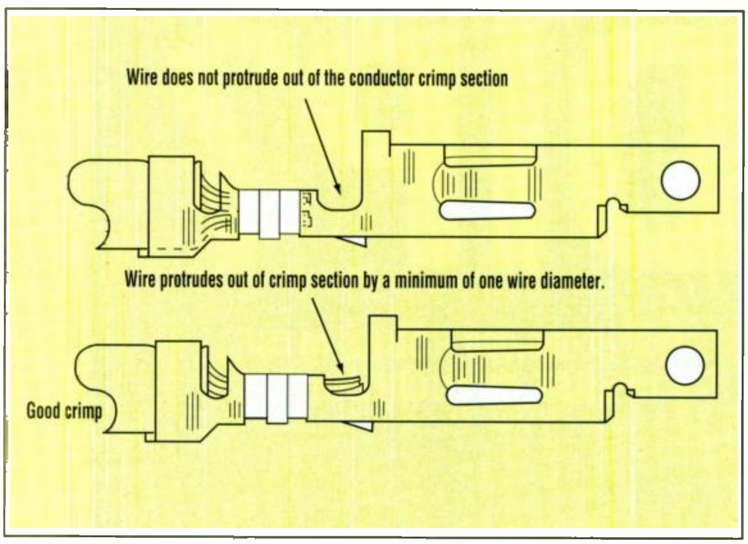
Crimp height is too small: The crimp height, which is the cross-sectional height of the conductor's crimp section after it's been crimped, is the most important characteristic of a good crimp. The connector manufacturer provides the crimp height for each wire size for which the terminal was designed. The correct crimp-height range or tolerance for a given wire may be as small as 0.002 in. With a specification this tight, verifying that the press is set up correctly is very important for achieving a good crimp.

A crimp height that's either too small or too large won't provide the specified crimp strength (terminal retention to the wire), will reduce the wire pull-out force and current rating, and may generally cause the crimp to underperform in otherwise normal operating conditions. A crimp height that's too small also may cut strands of the wire or fracture the metal of the conductor crimp section.

Crimp height is too large: A crimp height that's too large won't compress the wire strands properly. The result is excessive voids in the crimp section because of a lack of metal-to-metal contact between the wire strands and the metal of the terminal.

The solution to crimp-height problems is very simple: Adjust the conductor crimp height on the crimp press. Using a caliper or micrometer as shown in Figure 2, verify that the crimp height is within specification when the press is first used for a production run. Then re-check it as needed.

Insulation crimp is too



3. If the strip length is too short or if a wire isn't fully inserted into the conductor crimp section, the termination may not meet the specified pull force. The solution is simple: Increase the strip length of the wire-stripping equipment as specified for that specific terminal.

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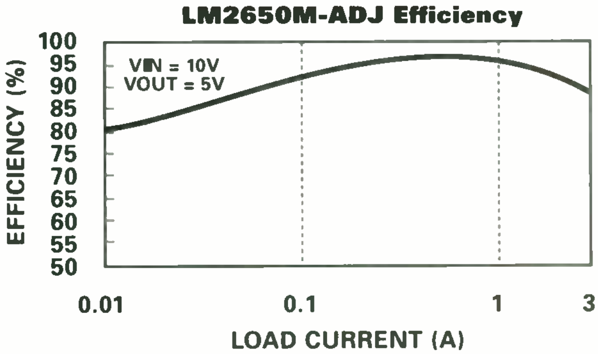

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small or too large: Connector manufacturers don't typically supply a crimp height for the insulation because of the variety of insulation types and thicknesses. The insulation crimp provides a strain relief for the conductor crimp section so that as the wire flexes, the wire strands don't break. An insulation crimp section that's too small may overstress and weaken the metal in the insulation crimp section.

Most types of crimp tooling allow the insulation crimp height to be adjusted independently of the conductor crimp height. The correct adjustment allows the terminal to grip the insulation for at least 180° without piercing the insulation. An insulation displacement, or compression where the outside diameter (OD) of the terminal's insulation crimp and the OD of the insulation are about the same, is ideal.

Loose wire strands: This is another common cause of crimping problems. If all of the wire strands aren't fully enclosed in the conductor crimp section, both the strength of the crimp and its current-carrying capability may be greatly reduced. To get a good crimp, you need to meet the crimp height specified by the connector's manufacturer. If all of the strands aren't contributing to that crimp height and therefore, crimp strength, then the crimp won't perform to specifications.

Generally, the problem of loose wire strands is very easy to solve by simply gathering the wires back into a bunch before inserting them into the terminal to be crimped. The strands may have been inadvertently separated during the handling or bundling process if stripping the insulation from the wire is done separately. Using a "strip-and-retain" process for insulation removal, in which the insulation slug isn't fully removed from the wire until just before a terminal is crimped onto the wire, helps minimize the problem.

Strip length is too short: If the strip length is too short or if a wire isn't fully inserted into the conductor crimp section, the termination may not meet the specified pull force because the metal-to-metal contact between the wire and the terminal is reduced. As shown in an figure, the strip length of the wire is too short (note that the insulation is in its proper position), not allowing the required one-wire-OD extension in front of the conductor crimp section (*Fig. 3*). The solution is simple: increase the strip length.

Wire is inserted too far: Another crimping problem that relates to a too-short strip length occurs when the wire is inserted too far into the crimp sections. As a result, the insulation is too far forward of the insulation crimp section and the conductors protrude into the transition section. This may cause as many as three failure modes in the actual application. Two relate to a reduced current rating and/or wire pull-out force because of reduced metal-to-metal contact in the conductor crimp section. A metal-to-plastic contact isn't as strong as a metal-to-metal contact. And even more importantly, it doesn't conduct electricity!

The third failure mode may occur when the connectors are mated. If the wire protrudes so far into the transition section that the tip of the male terminal hits the wire, it may prevent the connectors from fully seating or it may bend the male or female terminals. This condition is known as "terminal butting."

In extreme cases, the terminal may be pushed out the back of the housing, even though it was fully seated in the housing. To solve this problem, the wire must not be inserted into the press with so much force that it overcomes the wire stop on the press. You should also adjust the position of the wire stop so that it places the stripped wire into the correct axial position.

"Banana" (excessive bending) terminals: One of the most descriptive crimping problems is known as a "banana" crimp, because the crimped terminal takes on a banana shape (*Fig. 4*). This makes it difficult to insert the terminal into the housing and may cause terminal butting. The problem is easy to solve by adjusting

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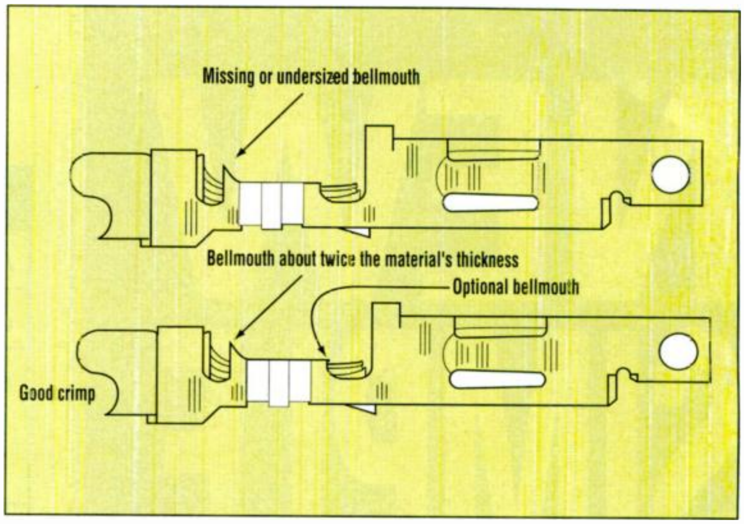
the position of the hold-down pin on the crimp press. This small pin is located in the crimp press and contacts the terminal in the mating section while the crimp sections are being crimped onto the wire. During crimping, a significant amount of metal on one end of the terminal (in the crimp section) moves. These high forces tend to force the front of the terminal upwards, unless it's held down by the aptly named "hold-down" pin.

Crimp is too far forward: One of the more obvious crimping problems is when part of the transition section is damaged. The front end of the transition section has an upwardly protruding tab called a "terminal stop." The stop's function is to prevent the terminal from being inserted too deeply into the housing. If the stop is severely damaged, the terminal can actually be pushed all the way through the housing.

The solution is relatively simple. The problem occurs when the terminal and carrier strip, which is the band or strip of metal the terminals are attached to when you receive them from the manufacturer, isn't properly located with respect to the press. To solve this, loosen the baseplate of the interchangeable tooling and realign it to the press.

Undersized bellmouth: The correct size for a bellmouth is about twice the thickness of the terminal material (*Fig. 5*). For example, if the terminal is made from material that's 0.008 in. thick, the bellmouth should be about 0.016 in. While a few thousands of an inch won't materially affect the terminal's performance, if the bellmouth is missing or if it's less than one material thickness, there's a risk of cutting the wire strands. The fewer strands that remain, the lower the termination strength. To correct the problem, make sure the punch and anvil on the crimping equipment are properly aligned.



5. The correct size for a bellmouth is about twice the thickness of the terminal material. If the bellmouth is missing or if it's less than one material thickness, there's a risk of cutting the wire strands. To correct the problem, make sure the punch and anvil on the crimping equipment are properly aligned.

Oversized bellmouth: There's also a problem if the bellmouth is oversized; this reduces the total contact area between the crimp section of the terminal and the wire. With decreased area in the wire-to-terminal interface, wire pull-out force drops. If the crimp height is correct, then the likely cause is worn tooling.

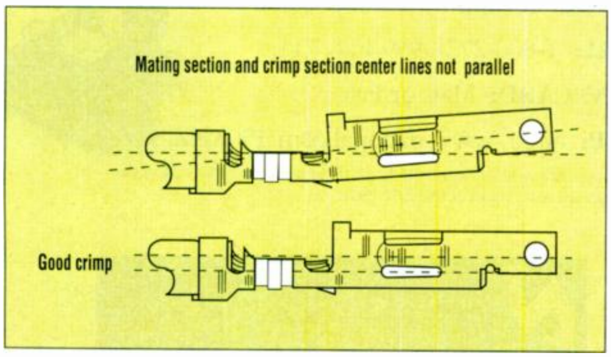
Carrier cutoff is too long: The carrier strip is cut off the terminal during crimping . If the remaining cutoff is too long, problems can occur. The extra metal may protrude out of the rear of the connector when the terminal is inserted into the housing, causing the connector to arc between adjacent contacts when higher voltages are applied. If the carrier cutoff at the front of the terminal is too long, the extra length may interfere with connector mating and result in "terminal butting."

To correct the problem, the baseplate on the press should be adjusted so that the terminal is centered properly in the crimp press. Another indication that the terminal isn't centered correctly is that the bellmouth is formed improperly. This occurs because the tooling for the bellmouth and the carrier cutoff are spatially related.

Bent locking tangs: Although bent locking tangs aren't necessarily the result of a poor crimping process, the connector can fail just the same. Locking tangs may be bent either in or out too far, which affects the terminal's ability to completely lock into the shelf in the housing designed for this purpose. The tangs may be damaged as the terminals are unwound from the reel if the friction wheel on the crimp press's reel holder is too tight. Or, it can be caused by handling after the terminals are crimped onto the wires.

Typically, terminated wires are gathered into a bundle and inventoried or transported to another location in the plant. During the bundling, or as each terminated wire is removed from the bundle, the locking tangs may be bent. If the damage occurs at the crimping press, then the friction wheel must be adjusted so it's just tight enough to keep the reel of terminals from being unwound

CONTINUED ON PAGE 36



4. In a "banana" crimp, the crimped terminal takes on a banana shape, making it difficult to insert the terminal into the housing. The problem is solved by adjusting the position of the hold-down pin on the crimp press.

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MANUFACTURERS OF PRINTED-CIRCUIT-BOARD CONNECTORS

Manufacturer	Connector styles (see key below)	Contact/row spacing (in. or mm)	Maximum pin density (contacts per linear inch)	Modular?	Number of contact rows	Functions in addition to signal (see key below)	Maximum insertion/ minimum withdrawal forces	Termination techniques (backplane/ daughter-board)
AirBorn Inc., Georgetown, TX (512) 863-5585 CIRCLE 482	PS, CE, SMT, FM	0.050, 0.075, and 0.100 in.	80	No	Up to 6	ST, PO, GP, IO, CO	4 oz/ 0.5 oz	Solder
AMP Inc., Harrisburg, PA (800) 522-6752 http://www.amp.com CIRCLE 483	CE, HD, HS	0.0635 to 6.50 mm	39.8 contacts per millimeter	Yes (depending on type)	Up to 8	ST, PO, GP, CO, FO, MI, SH	85 grams/ 30 grams	Pressfit, solder, and SMT
Aries Electronics Inc. Frenchtown, NJ (908) 996-6841 http://www.arieselec.com CIRCLE 484	CE, IDC PS,SMT	0.100 in., 2 mm, 1.27 mm	30	No	Up to 3	GP, LA, ST	Varies by product group	Pressfit and solder
Beau Interconnect, Laconia, NH (603) 524-5102 CIRCLE 485	TB	3.5 mm	7.25	Yes	Single	PO	N.A.	Solder
Comm Con Connectors Inc. Duarte, CA (818) 301-4200 CIRCLE 486	PS, SMT, TH	0.100 in., 0.050 in., 2 mm, 1 mm	25	Yes	Up to 4	ST	Depends on application	Solder
CW Industries Southampton, PA (215) 355-7080 CIRCLE 487	CE, PS	0.050 in., 0.100 in., 0.200 in., 2 mm	40	No	2 or 3	GP, IO, PO, SH	2 to 8 ozs	Solder
Elastomeric Technologies Hatboro, PA (215) 672-0787 CIRCLE 488	SMT, SO	Custom (starting at 0.040 in.)	25	Yes	Up to 3	ST	Zero	Compression
ELCO Corp., Huntingdon, PA (814) 643-0700 CIRCLE 489	FM, SMT, TH	0.5 mm, 0.8 mm, 1.0 mm, 1.25 mm, 0.050 in., 2 mm, 0.100 in., 0.200 in.	52	No	Up to 5	CO, GP, IO, PO	Varies with connector series	Pressfit, solder, SMT, wirewrap
ERNI Components Inc. Chester, VA (804) 530-5012 CIRCLE 490	CE, SMT, TH	Many	20	Yes	Up to 7	CO, FO, GP, IO, PO, ST	100 N/40 N	Pressfit, solder
Fujitsu Microelectronics Inc. San Jose, CA (408) 922-9000 CIRCLE 491	CE, PC, PS, SMT	2 mm, 0.05 in., 0.075 in., 0.635 in.	69	No	4 to 8	EL, GP, IO, ST	N.A.	Solder
HARTING Elektronik Inc. Hoffman Estates, IL (708) 519-7700 CIRCLE 492	PS, SMT	2.5 mm	48	Yes	Up to 5	CO, FO, GP, IO, PO, ST	102 grams	Pressfit
Hypertronics Corp., Hudson, MA (508) 568-0451 CIRCLE 493	PS, SMT, TH	0.075 to 0.200 in.	13	No	Up to 6	CM, CO, FO, GP, PO, ST	1.5 oz./ 1.2 oz.	Pressfit, solder
LZR Electronics Inc., Olney, MD (301) 921-4600 CIRCLE 494	CE, PS	N.A.	N.A.	Yes	N.A.	CO, IO, PO	N.A.	Solder
Methode Electronics Rolling Meadows, IL (708) 392-3500 http://www.methode.com CIRCLE 495	CE, PS, SMT, TH	0.200 in. to 1.0 mm	1-mm spacing between contacts	No	1 or 2	GP, PO, ST	Varies with connectors	Solder
Micro Plastics Inc. Chatsworth, CA (818) 882-0244 CIRCLE 496	CE	0.100, 0.125, 0.150, and 0.156 in.	Up to 70 positions	No	1 or 2	GP	Per MIL-C-21097 requirements or custom	Solder
Mill-Max Mfg. Corp. Oyster Bay, NY (516) 922-6000 http://www.mill-max.com CIRCLE 497	PS, SMT	0.050, 0.100, 0.070 in. and 2 mm	20	No	1 or 2	IO, ST	200 grams/ 5 grams (per position)	Pressfit

CONTINUED FROM PAGE 32

by their own weight. If the problem occurs during bundling , smaller bundles or improved handling procedures need to be implemented. While there are 13 problems that may be caused during crimping , there are just four simple rules that will help ensure success:

1. Choose the right connector for your application requirements.
2. Use the crimp tooling specified by the terminal manufacturer.
3. Properly adjust the crimp tooling and maintain it in good working order.
4. Periodically replace the parts that displace metal (conductor and insulation punches, anvils, and terminal cutters).

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MANUFACTURERS OF PRINTED-CIRCUIT-BOARD CONNECTORS

Manufacturer	Connector styles (see key below)	Contact/row spacing (in. or mm)	Maximum pin density (contacts per linear inch)	Modular?	Number of contact rows	Functions in addition to signal (see key below)	Maximum insertion/ minimum withdrawal forces	Termination techniques (backplane/ daughter-board)
ODU USA, Camarillo, CA (805) 484-0540 http://www.odu-usa.com CIRCLE 498	CE, PS, SMT	0.05, 0.1 in.	20+	Depends on connector	2 or more	FO, PO	N.S.	Pressfit, solder
Oupiin America Inc. Santa Clarita, CA (805) 252-4760 CIRCLE 499	PS, HD, SMT	N.S.	24	N.S.	Fixed by connector style	PO, ST	N.S.	Pressfit, solder
Panduit Corp., Tinley Park, IL (708) 532-1800 http://www.panduit.com/panduit CIRCLE 500	FR, IDC	0.100 and 0.156 in.	10 (0.100-in. centerline)	Depends on style	Up to 4 (depending on series)	CO, GP, PO	Varies with connector types	Pressfit, solder
Power Dynamics Inc. West Orange, NJ (201) 736-5722 CIRCLE 501	CE, PS, SMT	2.54, 2.0, 1.27 mm	N.S.	Yes	Up to 3	PO, ST	N.S.	Solder
RIA electronic, Eatontown, NJ (908) 389-1300 CIRCLE 502	TB	3.5, 5.0, 5.08, 7.5, 7.62 mm	7	Yes	1 or 2	GP, PO	4 N/2 N	Solder
Samtec Inc., New Albany, IN (800) SAMTEC-9 http://www.samtec.com CIRCLE 503	PS, SMT	0.100 in., 2 mm, 0.050 in., 1 mm	Up to 80	No	Up to 4	GP, IO, PO, ST	5 oz avg./ 1.6 oz avg. (depends on design)	Solder
Shogyo International Corp. Plainview, NY (516) 349-5200 CIRCLE 504	Many	Many options	N.A.	Yes (except for terminal blocks)	1 or 2	IO	0.5 to 3.0 kg for most styles	Solder (in most cases)
Specialty Electronics Landrum, SC (803) 457-3824 CIRCLE 505	PS, SMT, TH	0.100 in., 0.050 in., 2 mm, 1 mm	50	Yes	1 or 2	GP, IO, ST	225 to 20 grams	Solder
TEKA Interconnection Systems Providence, RI (401) 785-4110 SZGH88A@prodigy.com CIRCLE 506	CE, HD, PC, PS, SMT	From 0.200 in. to 1 mm	80	N.S.	Up to 4	FD, GP, SH, ST	180 grams (0.200 in)/ 10 grams (0.050 in.)	Pressfit, solder, solder-bearing leads
Thomas & Betts, Memphis, TN (901) 682-8221 CIRCLE 507	CE, HS, IDC	Centers: 0.156, 0.100, 0.050 in.	Up to 40	Yes	Up to 4	IO, ST	0.8 oz	Pressfit, solder
Trompeter Electronics Inc. Westlake Village, CA (800) 982-COAX CIRCLE 508	CJ	N.S.	N.S.	No	N.A.	CO	N.S	Solder
Viking Electronics Chatsworth, CA (818) 341-4330 CIRCLE 509	CE, SMT	0.050, 0.100, 0.125, 0.156 in.	N.S.	Some types	Custom	CM, GP, PO, ST	Variable	Pressfit, solder

Key to connector styles: CE = card edge; CJ = coaxial jacks; FM = flex mount; FR = flat ribbon; HD = high density; HS = high speed; IDC = insulation-displacement connector; PC= PCMCIA; PS = pin and socket; SMT = surface mount; SO = solderless; TB = terminal blocks; TH = through hole
Key to functions: CM= compliant; CO = coaxial; EL = ejection/locking mechanism; FD = I/O filtering and decoupling; FO = fiber optic; GP = guidance/polarization; IO = I/O and cable connections; LA = latching; MI = matched impedance; PO = power; SH = shielding; SO = standoffs; ST = stacking
N.A. = not applicable; N.S. = not specified

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READER SERVICE 132

1601A

Make The Right Battery Choice For Portables

BY PNINA DAN
Tadiran Electronic Industries Inc., 2 Seaview Blvd., Suite 102. Port Washington, NY 11050; (516) 621-4980.

Be sure to closely examine all the trade-offs before settling on a battery technology.

As portable systems gain market prominence, the reliability and energy capacity of batteries has become a critical issue. System power consumption and rechargeable-battery capacity—which translate into run time—are competitive factors that must be designed into a product at the outset. On top of that, today's six-to-nine-month product life cycles and a feverishly competitive environment create heavy price pressures on computer, cell-phone and portable-instrumentation makers.

The bottom line is that system designers must seek out or develop the most cost-effective power-management, secondary-battery, and charging technologies available to differentiate their products and keep them competitive. There's also the increase of public and governmental concern regarding environmental issues. New legislation has focused the attention of battery makers and users on battery chemistries, user accessibility, and cell disposal.

One of the major challenges the battery industry continually faces is the disparity in the nature and rate of technological advance in batteries and in portable-equipment markets. New battery-operated devices come out every six months or so, but truly new rechargeable-battery technologies can take years to develop and perfect for commercial use.

While it can be said that "familiarity breeds contempt," in the case of secondary (rechargeable) battery technology choices for portable applications, familiarity often breeds reluctance to change. In the past, when designers of portable systems had few reasonable choices available, this wasn't much of an issue. However, there are now many choices, and the decision to go with one battery technology rather than another can have serious impact on a product's success.

In the cellular-phone market, for example, primary consumer care-abouts in terms of product characteristics are audio clarity, range, reliability, "features," size, weight, and talk/standby time between battery recharges. Of these, the latter three are directly affected by the choice of battery technology and they can be critical end-product differentiators. If one eliminates the communications-specific requirements from the above list, the remaining care-abouts, especially size, weight, and time between recharges, apply to all portable electronic systems. Some polls have shown that longer battery life was the most desirable feature in future portable computers, with lower weight in third place.

In general, designers and

TABLE 1: COMPARING RECHARGEABLE TECHNOLOGIES

Characteristic	Types/chemistries				
	Sealed lead-acid	Nickel cadmium*	Nickel metal hydride*	Lithium ion*	Lithium metal*
Average operating voltage (V)	2	1.20	1.25	3.6	3.0
Energy density (Wh/kg)	35	45	55	100	140
Volumetric efficiency (Wh/l)	85	150	180	225	300
Cost ($/Wh)	0.25 to 0.50	0.75 to 1.5	1.5 to 3.0	2.5 to 3.5	1.4 to 3.0
Memory effect?	No	Yes	No	No	No
Self-discharge rate (%/month)	5 to 10	25	20 to 25	8	1 to 2
Temperature range (°C)	Zero to +50	-10 to +50	-10 to +50	-10 to +50	-30 to +55
Environmental concerns?	Yes	Yes	No	No	No

* = based on AA-size cell

end users want battery packs with the lowest possible weight and highest possible capacity crammed into the smallest possible volume at the lowest possible cost. These characteristics are especially important as the trend to miniaturization in portable products accelerates. While no single rechargeable battery type can optimize all of these factors, there are some obvious trade-offs among available technologies. In examining the secondary-battery technologies available for use in portable systems, it's useful to compare them with an eye toward the factors that affect size, weight, and time between recharges. This comparison can be easily translated to a bevy of end-use products (*Table 1*).

At the low end of the cost spectrum is the sealed lead-acid (SLA) battery. This chemistry is mature and reliable, but it's also at the low ends of the scales for volumetric efficiency (energy per unit volume) and energy density (energy per unit weight). You can expect an average of 85 Wh/l and 35 Wh/kg, respectively. Sealed lead-acid batteries were used in early hand-held systems but aren't widely used in smaller types. Most lead-acid batteries cannot be rapidly recharged (in, say, less than three hours) because of possible thermal damage, although special rapid-charge lead-acid types are available. Lead, of course, is a well-known pollutant and lead-acid batteries must be recycled.

Still near the lower end of the cost range but significantly better than lead acid in volumetric efficiency and energy density (120 Wh/l and 36 Wh/kg) is the "standard" sintered-metal-electrode nickel cadmium (NiCd) cell. With the introduction a few years ago of sponge-metal electrode technology, the volumetric efficiency of NiCd cells jumped to 150 Wh/l and energy density rose to 50 Wh/kg.

An important parameter for rechargeable batteries is their self-discharge rate, which is the rate at which the battery loses charge while not in use. Self-discharge rate can become an issue for end users who use a particular portable system infrequently, yet want to be able to rely on it when necessary. Self-discharge for NiCd batteries is moderate compared to other types.

TABLE 2: COMPOSITION OF 6-V CELL-PHONE BATTERY PACKS IN VARIOUS BATTERY TECHNOLOGIES

Characteristic	Nickel cadmium	Nickel metal hydride	Lithium ion	Lithium metal	Lithium metal
Number of cells	5	5	4	4	2
Voltage (V)	6	6	7.2	6	6
Capacity (Ah)	1.0	1.2	0.8	1.6	0.8
Weight (g)	104	104	72	68	34
Volume (ml)	40	40	32	32	16

Although NiCd cells are popular and well-understood, they have some drawbacks.

Nickel cadmium is the most familiar secondary-battery technology and is therefore widely used. Charging circuits are relatively simple and charging is relatively rapid, but take care to avoid extended periods at high temperatures during charging.

Although NiCd cells are popular and well-understood, they have some drawbacks. First, most batteries of this type available today exhibit "memory effect," which is a loss of capacity that results when the battery is recharged before it is fully discharged. Second, these batteries contain cadmium, a hazardous substance, and must be recycled in most areas.

Another common rechargeable alternative is nickel metal hydride (NiMH) batteries. NiMH cells offer increased volumetric efficiency (190 WH/l) over even the most advanced NiCd types. Energy density is also better than that of NiCd, at 55 Wh/kg. Open-circuit voltage for NiMH cells is 1.25 V, which is identical to that of NiCd cells. As a result, some designers have used NiMH batteries as drop-in replacements for NiCd packs. However, NiMH cells cost significantly more than NiCd cells (up to twice as much, depending on form factor) and require special charging circuits that are substantially different than the relatively simple ones used for NiCd. For NiMH, charging time, rate, and temperature must be accurately controlled. NiMH batteries also have the highest self-discharge rate of any of the types discussed here, making their use in some types of portable systems of questionable value.

Because NiMH cells contain no hazardous substances, disposal is not an issue. They also do not exhibit the memory effect associated with NiCd types, but their longevity is directly related to depth of discharge.

A third rechargeable option is lithium-based battery systems, which have always been considered attractive because of their high level of electrochemical performance. On the other hand, safety and environmental considerations originally required complex and costly construction techniques and safety systems. These factors raised costs and restricted early lithium batteries to critical military applications. Newer lithium-based systems have overcome the safety and environmental obstacles and are, in general, the most efficient types available.

The two lithium-based systems available today are lithium ion and lithium metal. While both types exhibit the overall advantages of lithium-

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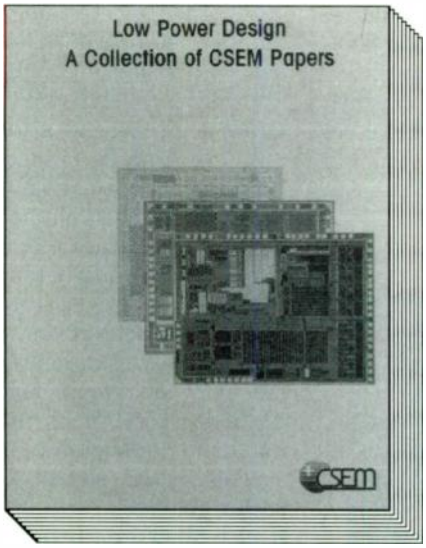

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Phone ____________ Fax ____________ E-mail ____________ based systems, they differ in some important respects specifically related to portable applications.

Lithium-ion rechargeable batteries were first used in small video camcorders and are now seeing some use in other portable applications. The relatively high voltage (3.6 V) of the lithium-ion cell offers the advantage of fewer cells being required to achieve a given voltage.

One major drawback to lithium-ion technology is its relatively high cost/performance ratio. The cost per watt-hour of a lithium-ion cell is significantly higher than that of other types, but some performance figures are not in proportion (*Table 1, again*). For example, the volumetric efficiency of a lithium-ion cell is significantly less than that of a lithium-metal cell and only slightly better than that of a nickel-cadmium cell. Energy density is about 64% better than NiMH, but at a potentially greater cost penalty. Energy density is also 36% below that of lithium metal.

Another shortcoming of the lithium-ion system is its primarily nonlinear discharge characteristic. Typically, an AA-sized lithium-ion battery, discharged at a rate of 250 mA, will drop in voltage from 4.3 V (fully charged) to about 3 V in about 90 minutes. The voltage will remain at 3 V for the next 90 minutes and then drop off rapidly to 2 V, at which point the battery is considered discharged. Depending on the design of the system, this discharge characteristic can be troublesome in some portable applications that require a minimum voltage for operation.

The more recently developed rechargeable lithium-metal (Li/Li_xMnO_2) batteries offer energy density and volumetric efficiency unmatched by any other battery type. Lithium metal cells, exemplified by Tadiran's In-Charge AA-size cells, sport energy density of 140 Wh/kg and volumetric efficiency of 300 Wh/l. The cells are totally safe and are immune to practically all types of physical or electrical abuse conditions. The increased safety factor is due primarily to a Tadiran-patented fail-safe, self-quenching electrochemical system and a built-in safety vent.

Lithium-metal batteries have no memory effect and have the lowest self-discharge rate of all rechargeables. A typical lithium-metal battery stored at room temperature (70° F, 20° C) retains 85% of its capacity after one year. A portable system powered by a charged lithium-metal battery will always be available for use regardless of how long it sits idle. Operating temperature range (-30° C to +55° C) is also greater than other battery types.

The discharge curve of a lithium-metal cell is practically flat. At a 250-mA discharge rate, after a brief (about 10-minute) drop from the fully charged voltage of 3.4 V, the voltage remains at 2.8 V for the remainder of more than three hours, dropping off to 2 V (the "discharged" point) after that. This also means that when two

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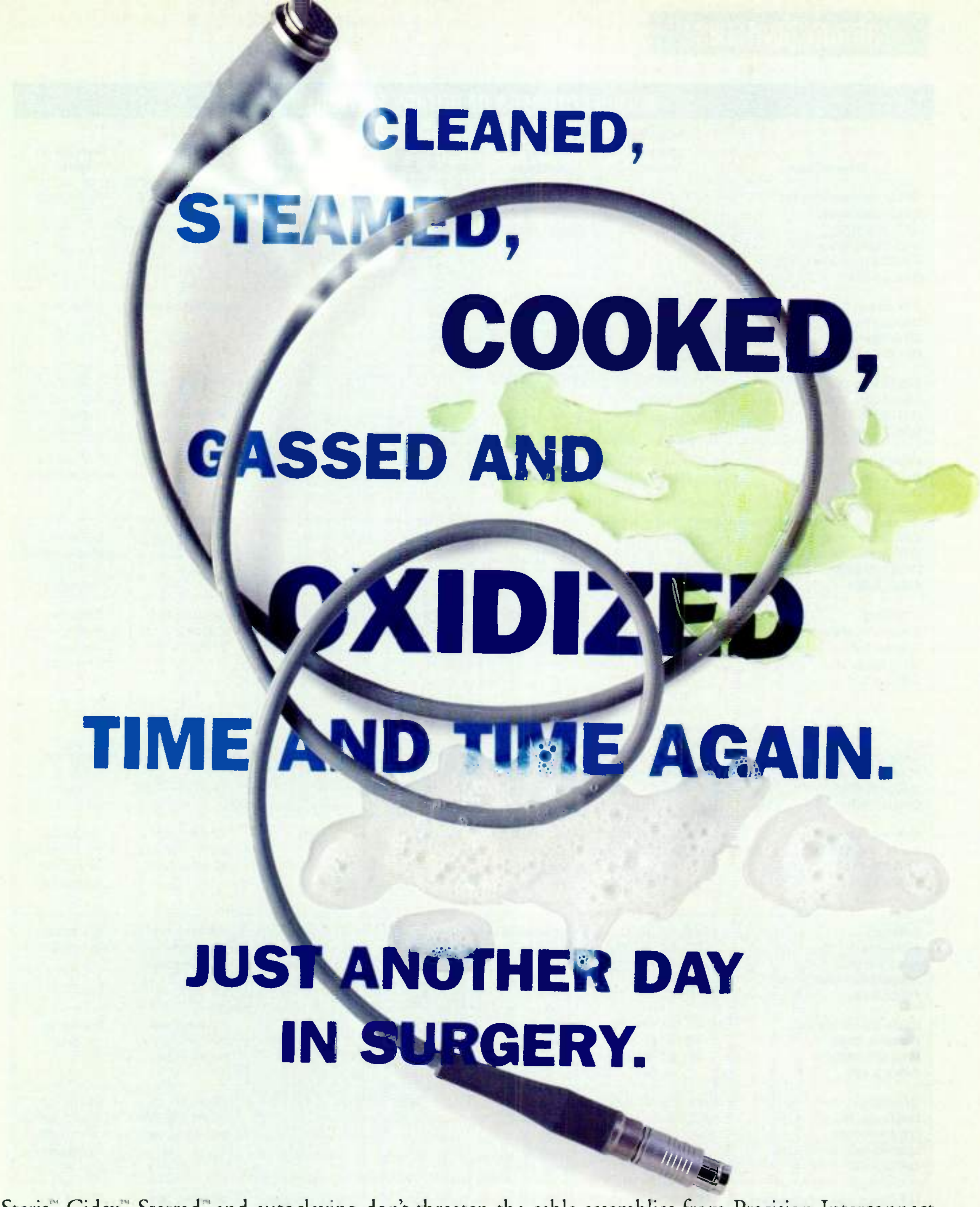

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READER SERVICE 137

MANUFACTURERS OF ROTARY SWITCHES

Manufacturer	Features (see key below)	Angles of throw/ number of positions	Maximum number of decks	Maximum number of poles/deck	Shorting or non-shorting contacts?	Termination styles
APEM Components Inc. Wakefield, Mass. (617) 246-1007 http://www.apem.com e-mail: info@apem.com CIRCLE 519	CO, LL, PC, SC, DIP packages	22.5°/16°, 30°/12, 36°/8, 45°/8, 60°/6, 90°/4	N.A.	N.A.	Non-shorting only	Pc-mounted
Arcolectric Corp. Canoga Park, Calif. (818) 700-1933 CIRCLE 520	IS, LL, SS, UC	250°/2	1	2	Non-shorting only	Solder lug; 0.187-in. quick connect
Ark-Les Corp. Watertown, Mass. (617) 924-2330 CIRCLE 521	CO, HC, HT, IS, LL, PC, SC, SS, PL, SR, UC	45°/8, 60°/6, 90°/4	1	6	Shorting and non-shorting; can be intermixed	Solder lug; pc-mount; wiring; wiring with connector
Bourns Inc. Riverside, Calif. (909) 781-5500 CIRCLE 522	CO, HT, IS, LL, PC, SC, SS	2, 5, or 10 positions	1	1	Non-shorting only	Pc-mounted; surface-mount
C&K Components Inc. Watertown, Mass. (617) 926-6400 CIRCLE 523	AS, CO, HC, IS, LL, PC, SC, SP, SS, PL, UC	30°/12, 36°/10, 45°/8, 60°/6, 90°/4	1	4	Shorting and non-shorting	Solder lug; pc-mount; wiring; wiring with connector
CTS Corp. Electrocomponents Div. Elkhart, Ind. (219) 296-6700 CIRCLE 524	AS, CO, CN, HC, HT, IS, IT, LL, PC, SC, SP, SS, PL, SR, UC (Also can incorporate potentiometers or special switches)	30°/12, 45°/8, 60°/6, 90°/4	Limited only by bar-stock length	Standard is 12 @ 30É, but others are available depending on angle	Shorting and non-shorting; can be intermixed	Solder lug; pc-mount; wiring; wiring with connector
Carlingswitch Inc. Plainville, Conn. (860) 793-9281 CIRCLE 525	SS, PL, UC, repeating action	45°/8, 90°/4	1	2	Non-shorting only	Solder lug; wiring; tabs
Cole Instrument Corp. Santa Ana, Calif. 714) 556-3100 CIRCLE 526	AS, CO, CN, HC, HT, IS, IT, LL, MQ, PC, RF, SC, SP, SS, PL, SH	10°/36, 11.25°/32, 15°/24, 18°/20, 22.5°/16, 30°/12, 36°/10, 45°/8, 60°/6, 90°/4	15	24	Shorting and non-shorting; can be intermixed	Solder lug; pc-mount; wiring; wiring with connector
E-Switch Minneapolis, Minn. (612) 375-9639 http://www.e-switch.com CIRCLE 527	AS, CN, IS, LL, PC, SC, SS, PL	30°/12, 60°/6, 90°/4	12	4	Shorting and non-shorting; can be intermixed	Solder lug; pc-mount
ELMA Electronic Inc. Fremont, Calif. (510) 656-3400 CIRCLE 528	AS, CO, CN, CK, HC, IS, LL, PC, RF, SC, SP, SS, PL, SR	15°/24, 30°/12, 36°/10, 60°/6	Up to 20	6	Shorting and non-shorting; can be intermixed	Solder lug; pc-mount
Grayhill Inc. LaGrange, Ill. (708) 354-1040 http://www.grayhill.com CIRCLE 529	AS, CO, CN, CK, HC, HT, IS, IT, LL, MQ, PC, RF, SC, SP, SS, PL, SR, UC	10°/36, 11.25°/32, 15°/24, 18°/20, 22.5°/16, 30°/12, 36°/10, 45°/8, 60°/6, 90°/4	12	12	Shorting and non-shorting; can be intermixed	Solder lug; pc-mount; wiring; wiring with connector
ITT Cannon Switch Products Eden Prarie, Minn. (612) 934-4400 CIRCLE 530	AS, CO, CN, HT, IS, LL, PC, SC, SP, SS, PL	10°/36, 15°/24, 22.5°/16, 30°/12, 36°/10	10	4/12 positions	Shorting and non-shorting	Solder lug; pc-mount
ITW Switches Chicago, Ill. (312) 282-4040 CIRCLE 531	IS, LL, PC, SC, SS	45°/8	1	2	Non-shorting only	Pc-mount

CONTINUED FROM PAGE 42

cells are used in series (to create a battery with a nominal voltage of 6 V) the voltage remains above 4 V for the entire discharge cycle. That 4-V level is the minimum operating voltage for many portable systems, including many cellular phones.

Lithium-metal batteries can deliver up to 2 A of current under continuous or pulse demand. The latter is especially important in cellular phones, where in a typical 600-mW unit, current demands can jump from a standby current of 40 mA to a 0.6-ms talk pulse of 1.4 A with a 200-mA floor between pulses.

Under these conditions, the mean talking current is 333 mA. A 4-cell (AA cells) lithium-metal battery pack, with a capacity of 1600 mAh, can provide nearly four hours of talk time with over 13 hours of standby time between recharges. This is accomplished in a four-cell battery pack that weighs only 68 g (2.4 oz.), which is 70% of the weight of an equivalent 6-V NiHM pack and about 60% of a lithium-ion pack. It can be useful to make a comparison of rechargeable-battery technologies (with the exception of sealed lead acid) and how they stack up in 6-volt packs for cell phones (*Table 2*).

The cost of lithium-metal batteries per watt-hour is nearly equal to that of NiMH batteries, making them the closest thing available today to "the lowest possible weight and highest possible capacity crammed into the smallest possible volume at the lowest possible cost."

Dr. PNINA DAN is director of research and development for rechargeable lithium batteries at Tadiran Battery Division, Rehovoth, Israel. She received her PhD in chemistry from the Weitzman Institute For Science, Rehovoth.

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MANUFACTURERS OF ROTARY SWITCHES

Manufacturer	Features (see key below)	Angles of throw/ numbers of positions	Maximum number of decks	Maximum number of poles/deck	Shorting or non-shorting contacts?	Termination styles
Janco Corp. **Burbank, Calif.** **(818) 846-1800** **CIRCLE 532**	AS, CO, CN, CK, HC, HT, IS, IT, LL, MQ, PC, RF, SC, SP, SS, PL, SR	11.25°/32, 15°/24, 18°/20, 22.5°/16, 30°/12, 36°/10, 45°/8, 60°/6, 90°/4	12	6	Shorting and non-shorting; can be intermixed	Solder lug; pc-mount; wiring; wiring with connector
NKK Switches **Scottsdale, Ariz.** **(602) 991-0942** **CIRCLE 533**	AS, CO, HT, IS, LL, PC, SC, SP, SS, UC	30°/12	6	11	Shorting and non-shorting	Solder lug; pc-mount
Oak Controls **OakGrigsby Div.** **Sugar Grove, Ill.** **(708) 556-4200** **CIRCLE 534**	AS, CO, CN, HC, HT, IS, IT, LL, PC, SC, SP, SS, PL, SR, UC	10°/36, 11.25°/32, 15°/24, 18°/20, 22.5°/16, 30°/12, 36°/10, 45°/8, 60°/6, 90°/4	8	12	Shorting and non-shorting; can be intermixed	Solder lug; pc-mount; wiring; wiring with connector
Omega Engineering Inc. **Stamford, Conn.** **(203) 359-1660** **http://www.omega.com** **CIRCLE 535**	CK, LL, SS (also thermocouple and RTD switching)	10°/36, 11.25°/32, 15°/24, 18°/20, 22.5°/16, 30°/12, 36°/10, 45°/8, 60°/6, 90°/4	4	1 (up to 40 throws or contacts)	Shorting and non-shorting	Wiring
Schurter Inc. **Petaluma, Calif.** **(707) 778-6311** **e-mail: 73024.2314@compuserve.com** **http://www.schurterinc.com** **CIRCLE 536**	AS, CK, HC, IS, IT, LL, SC, UC	60°/6	1	6	N.S.	Solder lug; pc-mount; quick-connect
Tech Laboratories Inc. **North Haledon, N.J.** **(201) 427-5333** **CIRCLE 537**	AS, CO, CK, HC, IS, IT, LL, MQ, SC, SP, SS, PL, UC	10°/36, 11.25°/32, 15°/24, 18°/20, 22.5°/16, 30°/12, 36°/10, 45°/8, 60°/6, 90°/4	12	2 to 8	Shorting and non-shorting; can be intermixed	Solder lug; wiring; wiring with connector

Key to features: AS = adjustable stops; CO = coded outputs; CN = concentric shafts; CK = custom knobs; HC = harness/cable assembly; HT = high-temperature operation; IS = industrial/standard grade; IT = isolated stops (push/pull to turn); LL = low-level switching; MQ = MIL-qualified grade; PC = flux-proof design; RF = RFI/EMI shielding; SC = screwdriver-slotted shafts; SP = shaft/panel seals; SS = single shafts; PL = special plating; SR = spring return (momentary); UC = UL/CSA recognition.
N.A. = not applicable; N.S. = not specified

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READER SERVICE 13

Downsizing PFC Inductors In Switchers

BY J.W. McCLEAN
AlliedSignal, 6 Eastmans Rd., Parsippany, NJ 07064; (201) 581-7653.

Here's how to design C-cores that will fit the needs of shrinking portable electronics.

Thanks in no small part to the boom in portable electronics, the demand for ever-smaller and -lighter high-frequency switched-mode power supplies (SMPS) is increasing dramatically. At the same time, with an eye toward reduced extraneous line noise in off-line equipment, limitations on the amount of harmonic currents are being imposed by standards organizations in Europe. It's anticipated that similar restrictions will be enacted in the U.S. as early as this year. Reducing these harmonic currents in power supplies requires an inductive component for power-factor correction.

Until now, providing power-factor correction in switched-mode supplies has been problematic for power-supply manufacturers. Several topologies for the inductor design have provided the required harmonic-current limitation, the most notable being the continuous-mode boost pre-regulator.

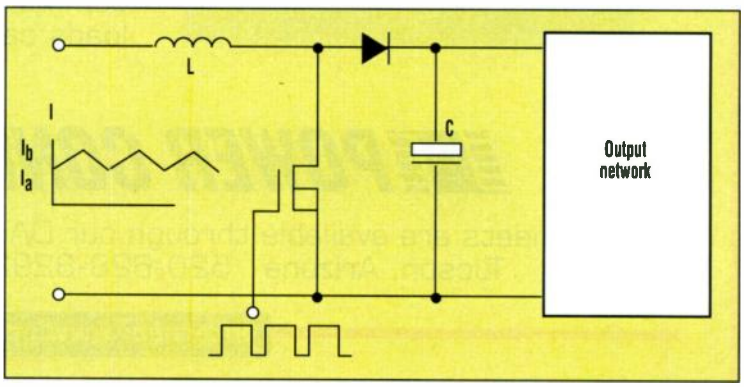
But no matter which topology is used, the inductive circuit adds size, weight, and cost to the overall power supply. Indeed, when made of ferrite, molypermalloy-powder (MPP), or powdered-iron materials, for example, the inductor represents a significant proportion of the additional cost, size, and weight of the overall power-factor-correction circuit.

Use of amorphous-metal alloy in the inductor is one way to meet the emerging operating standards for reduced harmonic currents while dramatically cutting the size, weight, and cost of the inductor. In many cases, using C-cores of amorphous-metal alloys resolves the size, weight, and cost problems that would not yield to previous power-factor-correction topologies. Because of the high saturation-flux density and low frequency-dependent losses of amorphous alloy, the inductive component can be made smaller and lighter than before. Indeed, core losses can be reduced by as much as 70%, while size can be reduced by as much as 40%.

Today, for a given performance level, amorphous alloy is likely to provide the low-cost solution at power levels above the range of 800 to 1000 W. It's expected in the near future that the threshold power level at which amorphous-alloy inductors result in an acceptably low-cost solution will fall to the lower end of that range.

The balance of this article will outline a basic procedure enabling designers to fully exploit amorphous-metal technology. This procedure will apply directly to the design of the inductive element of a continuous-mode boost pre-regulator.

Let's start with a look at the basic operation of the boost pre-regulator. An ideal boost switch-mode power converter is shown (*Fig. 1*). During the switch's on-time, the inductor current ramps upwards from its initial value I_a and reaches its final value I_b just before the switch turns off. After the switch turns off, the energy

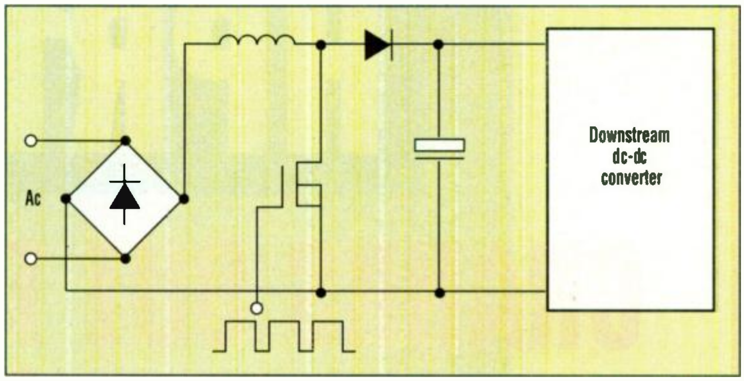


1. In an ideal boost switch-mode power converter, the inductor current ramps upward from its initial value I_a during the switch's on-time. It reaches its final value I_b just before the switch turns off. After the switch turns off, the energy stored in the inductor during the on-time of the switch is delivered to the output network, and the inductor current ramps downwards from I_b.

stored in the inductor is delivered to the output network, and the inductor current ramps downwards from I_b. If the converter is operating in the continuous mode, the current ramps down to a value greater than zero.

Many of the properties of the boost converter can be determined by examining the schematic. The output voltage must be higher than the input voltage. If this were not true, the inductor would not pass current to the output network of the converter. In the continuous mode, the value of the ripple current in the inductor can be made arbitrarily small by increasing the value of the inductance.

If we modify the dc-dc boost converter by including a bridge rectifier at the input, we obtain a somewhat different circuit (*Fig. 2*). This is the typical power train for a high-power-factor boost pre-regulator. Through proper control of the switch's duty cycle, this converter draws a sinusoidal current from an ac source that's in phase with the ac source voltage, thereby creating a converter with a unity power factor.



2. Modifying the dc-dc boost converter to include a bridge rectifier at the input yields this circuit, which is the typical power train for a high-power-factor boost pre-regulator. Through proper control of the switch's duty cycle, this converter draws a sinusoidal current from an ac source that's in phase with the ac source voltage, thereby creating a converter with a unity power factor.

As mentioned previously, the output voltage of the boost converter must be higher than the input voltage. If we choose an output voltage that's higher than the peak ac-line voltage, the converter will operate over the full input-voltage range (from zero volts to the ac-line peak of about 380 V). This enables universal input to the converter without the need for additional range-switching circuitry.

For the inductor current to be continuous, the ripple current ΔI in the inductor should not exceed twice the minimum input peak current. The inductance value which guarantees this condition is the critical inductance L_{crit}, and is given by the expression in Equation 1 (*see "Equation Listings" box*).

Having calculated the inductance to maintain the required ΔI, the peak current that the inductor must conduct without saturating can be calculated using:

$$I_{in(rms)\,max} = P_{in\,max} / V_{in(rms)\,min} = P_{out\,max} / (V_{in(rms)\,min} \eta_{PREG}) \quad (2$$

Therefore, with a sinusoidal input current, the expression is given as:

$$I_{in\,pk} = \sqrt{2}(I_{in(rms)\,max}) + \Delta I / 2 \quad (3)$$

Overload current conditions should be taken into account.

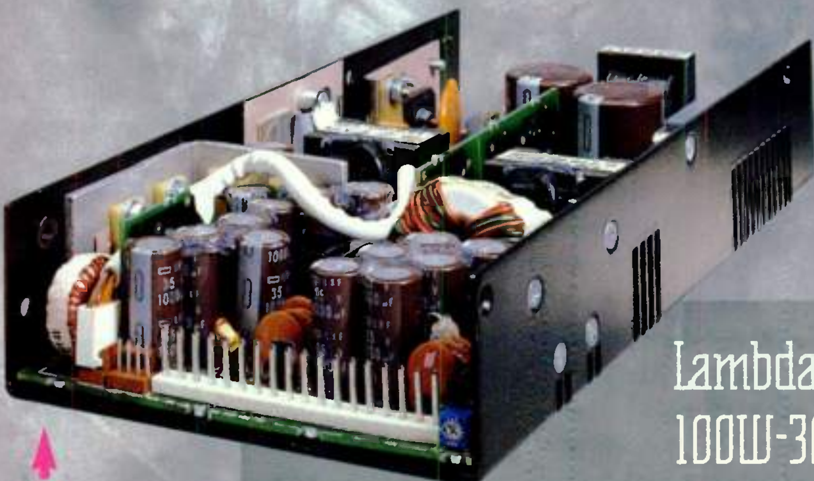
Now that the necessary inductor parameters L_{crit} and $I_{in\,pk}$ have been calculated, we can continue with the design procedure for the power-factor-correction inductor.

TABLE 1: APPROXIMATE POWER DISSIPATION OF AMORPHOUS-METAL C-CORES IN WATTS FOR A GIVEN TEMPERATURE RISE IN °C

Core	SA cm^2	20°C	25°C	30°C	35°C	40°C	45°C	50°C
AMCC-6.3	103.4	3.8	4.9	6.1	7.4	8.7	10.0	11.3
AMCC-8	115.9	4.2	5.5	6.9	8.3	9.7	11.2	12.7
AMCC-10	132.1	4.8	6.3	7.8	9.4	11.0	12.7	14.5
AMCC-16A	143.1	5.2	6.8	8.5	10.2	12.0	13.8	15.7
AMCC-16B	160.3	5.8	7.6	9.5	11.4	13.4	15.5	17.6
AMCC-20	172.3	6.3	8.2	10.2	12.3	14.4	16.6	18.9
AMCC-25	202.2	7.4	9.6	12.0	14.4	16.9	19.5	22.2
AMCC-32	216.0	7.9	10.3	12.8	15.4	18.1	20.8	23.7
AMCC-40	230.0	8.4	11.0	13.6	16.4	19.3	22.2	25.2
AMCC-50	303.5	11.1	14.5	18.0	21.7	25.4	29.3	33.2
AMCC-63	321.0	11.7	15.3	19.0	22.9	26.9	31.0	35.1
AMCC-80	356.0	13.0	17.0	21.1	25.4	29.8	34.3	39.0
AMCC-100	373.0	13.6	17.8	22.1	26.6	31.3	36.0	41.0
AMCC-125	464.0	16.9	22.1	27.5	33.1	38.9	44.8	51.0
AMCC-160	485.0	17.7	23.1	28.8	34.6	40.6	46.8	53.0
AMCC-200	526.0	19.2	25.1	31.2	37.5	44.0	51.0	57.0
AMCC-250	592.0	21.6	28.2	35.1	42.3	49.6	57.1	65.0
AMCC-320	707.0	25.8	33.7	41.9	50.5	59.2	68.2	77.5
AMCC-400	780.0	28.4	37.2	46.3	55.7	65.4	75.3	85.5
AMCC-500	854.5	31.2	40.7	50.7	61.0	71.6	82.5	93.6
AMCC-630	934.0	34.1	44.5	55.4	66.7	78.3	90.2	102.0
AMCC-800A	1013	36.9	48.3	60.1	72.3	84.9	97.8	111.0
AMCC-800B	1171	42.7	55.8	69.5	83.6	98.1	113.0	128.0
AMCC-1000	1292	47.1	61.6	76.6	92.2	108.3	124.7	142.0

PFC or No PFC?

That is the question.



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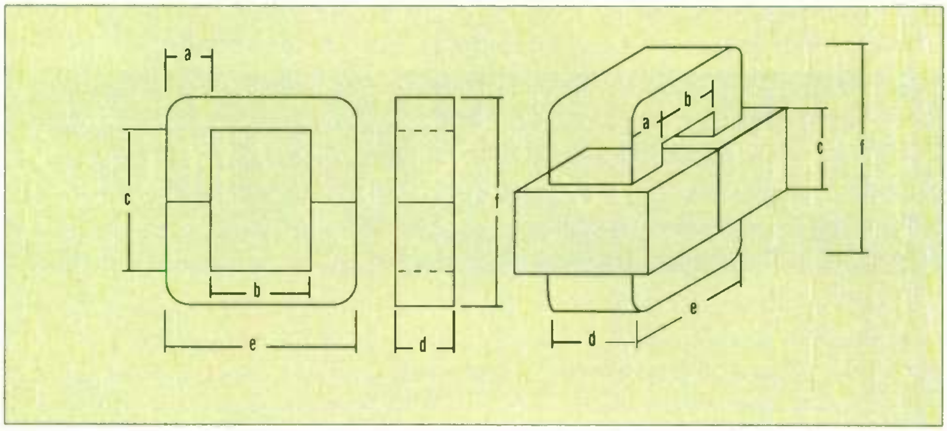
The first step is to determine the input data. Assume the following for the continuous-mode boost pre-regulator in question:

- Output power (overload), Pout = 2.2 kW
- Switching frequency, f_{SW} = 50 kHz
- Output dc voltage, V_{out} = 380 V
- Minimum ac-input voltage, Vin(rms) min = 90 V
- Maximum ac-input voltage, Vin(rms) max = 260 V
- Maximum temperature above ambient, °C = 50° C
- Inductor efficiency, η_L = 99% (preferred/optimal value is sufficient)
- Pre-regulator efficiency, η_{PREG} = 95% (preferred/optimal value is sufficient)

In the second step, we estimate the ripple current ΔI and critical inductance L_{crit}. Assuming the inductor efficiency is 99%, use the following:



3. This dimensional diagram of a C-Core is used to estimate the amount of fringing flux, F. The ratio of the air cross section to the physical cross section of the core is approximated using Equation 19.

$$P_{tot} = (1-\eta_L)(P_{out}/\eta_{preg}) = (1-0.99)(2200/0.95) = 23.16\text{ W} \quad (4)$$

For a theoretically optimized design, the core and copper losses are calculated using:

$$P_{core} = P_{cu} = P_{tot}/2 = 23.16/2 = 11.58\text{ W} \quad (5)$$

Next, select a core based on total losses dissipated and the required maximum ΔT °C (*for data on power dissipation, see Table 1*). Dissipating 22 W in an amorphous-metal C-core AMCC -25 will give rise to ΔT= 50° C.

Next, calculate the power loss for a core with weight wt using:

TABLE 2: AMORPHOUS-METAL C-CORE PRODUCT LISTING

Core	a (cm)	b (cm)	c (cm)	d (cm)	e (cm)	f (cm)	l_m (cm)	A_c (cm^2)	wt (kg)	W_aA_c (cm^4)	SA (cm^2)
AMCC-6.3	1.0±0.05	1.1	3.3	2.0+0.05	3.1+0.1	5.3+0.2	13.1	1.6	0.150	5.8	103.4
AMCC-8	1.1±0.08	1.3	3.0	2.0+0.05	3.5+0.1	5.2+0.2	13.2	1.8	0.170	7.0	115.9
AMCC-10	1.1±0.08	1.3	4.0	2.0+0.05	3.5+0.1	6.2+0.2	15.4	1.8	0.200	9.4	132.1
AMCC-16A	1.1±0.08	1.3	4.0	2.5+0.05	3.5+0.1	6.2+0.2	15.1	2.3	0.250	12.0	143.1
AMCC-16B	1.1±0.08	1.3	5.0	2.5+0.05	3.5+0.1	7.2+0.2	16.9	2.3	0.280	14.9	160.3
AMCC-20	1.1±0.08	1.3	5.0	3.0+0.05	3.5+0.1	7.2+0.2	17.5	2.7	0.340	17.5	172.3
AMCC-25	1.3±0.08	1.5	5.6	2.5+0.05	4.1+0.1	8.2+0.2	19.6	2.7	0.380	22.7	202.2
AMCC-32	1.3±0.08	1.5	5.6	3.0+0.05	4.1+0.1	8.2+0.2	20.0	3.2	0.460	26.9	216.0
AMCC-40	1.3±0.08	1.5	5.6	3.5+0.05	4.1+0.1	8.2+0.2	19.9	3.7	0.530	31.1	230.0
AMCC-50	1.6±0.1	2.0	7.0	2.5+0.05	5.2+0.1	10.2+0.3	24.9	3.3	0.590	46.2	303.5
AMCC-63	1.6±0.1	2.0	7.0	3.0+0.05	5.2+0.1	10.2+0.3	25.3	3.9	0.710	54.6	321.0
AMCC-80	1.6±0.1	2.0	7.0	4.0+0.1	5.2+0.1	10.2+0.3	25.4	5.2	0.950	72.8	356.0
AMCC-100	1.6±0.1	2.0	7.0	4.5+0.1	5.2+0.1	10.2+0.3	25.0	5.9	1.060	82.6	373.0
AMCC-125	1.9±0.1	2.5	8.3	3.5+0.1	6.3+0.1	12.1+0.3	30.2	5.4	1.170	112.0	464.0
AMCC-160	1.9±0.1	2.5	8.3	4.0+0.1	6.3+0.1	12.1+0.3	28.5	6.5	1.330	134.9	485.0
AMCC-200	1.9±0.1	2.5	8.3	5.0+0.1	6.3+0.1	12.1+0.3	29.8	7.8	1.670	161.8	526.0
AMCC-250	1.9±0.1	2.5	9.0	6.0+0.1	6.3+0.1	12.8+0.3	31.4	9.3	2.100	209.2	592.0
AMCC-320	2.2+0.1	3.5	8.5	5.0+0.1	7.9+0.1	12.9+0.4	32.5	9.0	2.170	267.7	707.0
AMCC-400	2.2±0.1	3.5	8.5	6.5+0.1	7.9+0.1	12.9+0.4	33.6	11.7	2.820	348.1	780 0
AMCC-500	2.5±0.1	4.0	8.5	5.5+0.1	9.0+0.1	13.5+0.4	35.6	11.3	2.900	384.2	854 5
AMCC-630	2.5±0.1	4.0	8.5	7.0+0.1	9.0+0.1	13.5+0.4	35.6	14.3	3.670	486.2	934 0
AMCC-800A	2.5±0.1	4.0	8.5	8.5±0.15	9.0+0.1	13.5+0.4	35.6	17.4	4.450	591.6	1013
AMCC-800B	3.0±0.1	4.0	9.5	8.5±0.15	10.0+0.1	15.5+0.4	39.3	21.0	5.930	798.0	1171
AMCC-1000	3.3±0.1	4.0	10.5	8.3±0.15	10.6+0.1	17.1+0.5	42.7	23.0	7.060	966.0	1292

$$P = P_{tot}/(2wt) = 23.16/[2(0.38)] = 30.47\ \text{W/kg} \quad (6)$$

Then, determine the ac flux, B_{ac}, that will give rise to P at the switching frequency f_{SW}. For AlliedSignal POWERLITE C-cores, we use the following equations:

$$P = 6.5 f_{sw}^{1.51} B_{ac}^{1.74}\ \text{W/kg} \quad (7)$$

$$B_{ac} = \left[P/(6.5 f_{sw}^{1.51})\right]^{1/1.74} = \left[30.47/((6.5)50^{1.51})\right]^{1/1.74} = 0.0815\ \text{T} \quad (8)$$

$$\Delta B = 2B_{ac} = 2(0.0815) = 0.163\ \text{T} \quad (9)$$

Note that f_{SW} is given in kilohertz.

Assuming the peak line-frequency current corresponds to about 1.4 Tesla, the ripple current is calculated using Equation 10. We can then calculate the critical inductance based on ΔI using Equation 11 (see box "Equation Listings").

The third step is to calculate the energy-storage requirement, E. Having already calculated L_{crit} and $I_{in\ pk}$, we can now calculate the energy-storage requirement of the inductor using Equation 12 (see box "Equation Listings").

In the fourth step, we calculate the required core-area product, W_aA_c, using Equation 13. The result should agree to within one size of the core selected in the second step.

The fifth step requires us to select a core. Choose one with a W_aA_c value that's greater than that calculated in the previous step (Table 2). This W_aA_c corresponds to amorphous-metal C-core AMCC-25.

The sixth step is to calculate the number of turns required, N. This is accomplished by using:

$$N = \frac{L_{crit} I_{inpk}(10^4)}{B_{max} A_c} = \frac{(400\times 10^{-6})(38.5)(10^4)}{(1.4)(2.7)} = 41\ \text{turns} \quad (14)$$

$$\frac{NA_c}{L} = \frac{I_{inpk}(10^{-4})}{B_{max}} \quad (17)$$

Step seven is to calculate the air gap required, l_g, using Equations 15 and 16 (see box "Equation Listings"). From step six, we have:

Therefore, the final air-gap equation given in Equation 18 (see box "Equation Listings").

In step eight, the goal is to estimate the amount of fringing flux, F. The physical core cross section dimensions are given by a and d (*Fig. 3*). The ratio of the air cross section to the physical cross section of the core is approximated by using:

$$F = \frac{(a + l_g)(d + l_g)}{ad} \quad (19)$$

F is sometimes known as the fringing factor. The fringing flux has the effect of reducing the reluctance of the gap by a factor of F, which in turn increases the inductance of the component also by a factor of F.

Step nine requires us to calculate the corrected turns to give the required inductance value. From Equation 15 in step seven, we derive:

$$L = \frac{0.4\pi N^2 A_c(10^{-8})}{l_g + (l_m/\mu\Delta)}\ \text{Henry} \quad (20)$$

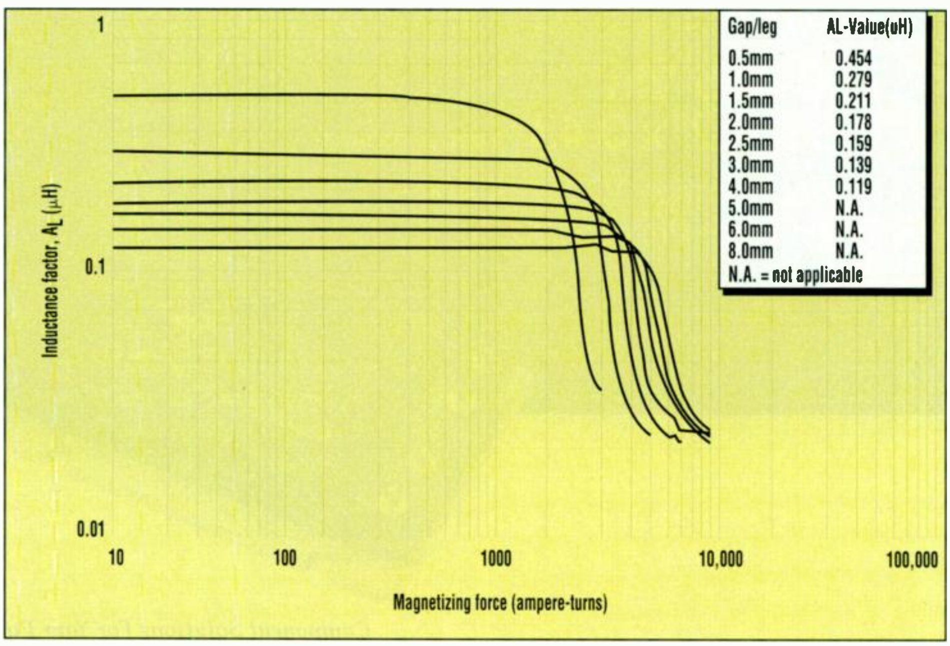
Because of the fringing flux, A_c is increased by the fringing factor F. Therefore, the number of turns N is calculated using Equation 21 (see box "Equation Listings").

In step 10, we calculate the conductor area, A_X. If the conductor has a circular cross section, then it is a reasonable assumption that a window-utilization factor of 0.4 can be used. If the conductor has a rectangular cross section, it's reasonable to assume that a window-utilization factor of up to 0.6 can be used. Both of these window-utilization factors will leave enough space for a bobbin and insulation between windings.

The C-core window area is given by the dimensions b and c (*Fig. 3*). The cross-sectional area of the conductor is given by:

$$A_x = \frac{bcK}{N} = \frac{(1.5)(5.6)(0.4)}{39} = 0.086\ \text{cm}^2 \quad (22)$$

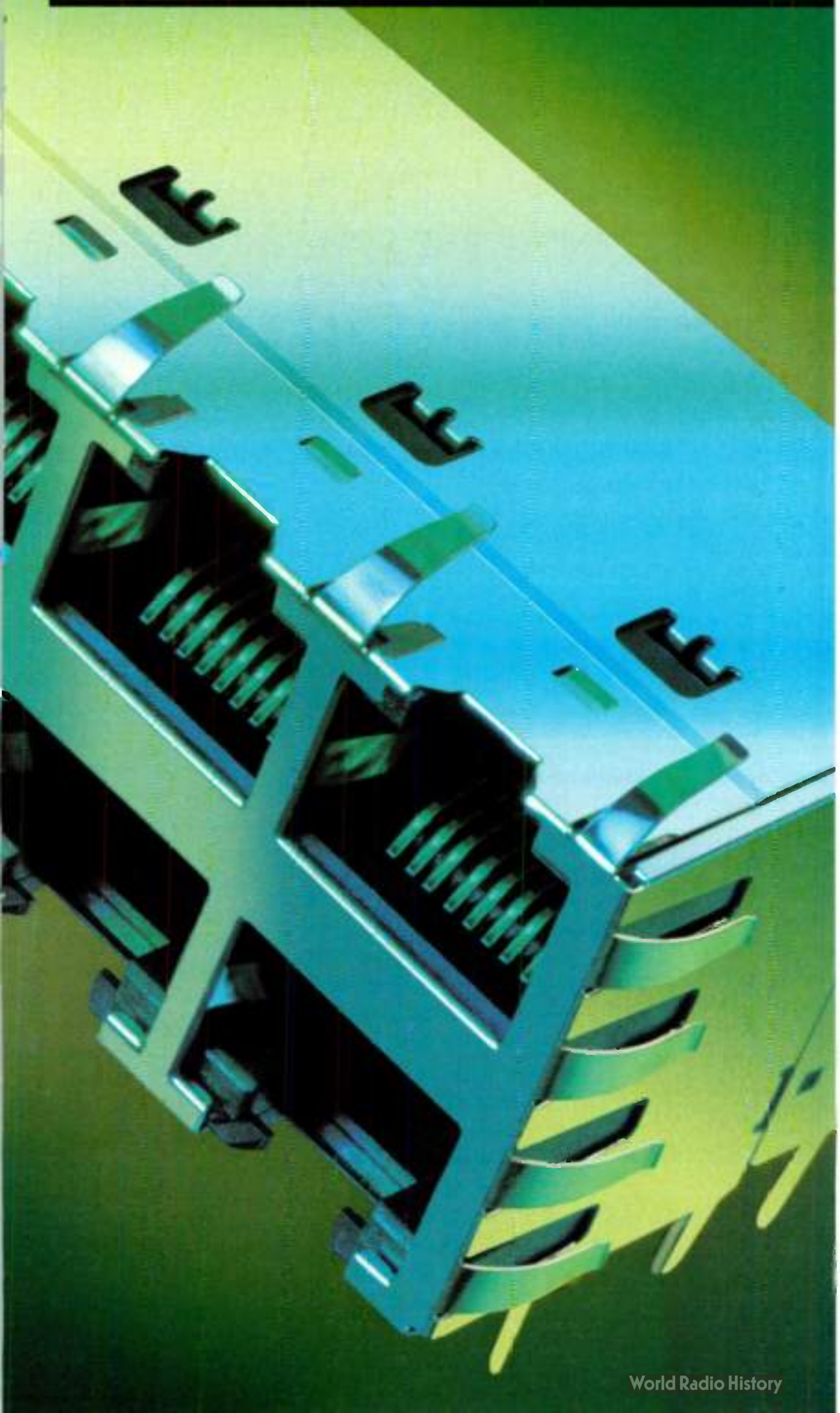
At this point we can also calculate the resistance per unit length for the calculated cross section. For copper at a given temperature, T, the resistivity is given by Equation 23 (see



4. As the magnetizing force increases, the inductance of an amorphous-metal C-Core decreases as the core moves further into saturation. For the particular core and gap size chosen, we can check the value of inductance under peak magnetizing condition, modifying the design where necessary.

No Modular Connector Keeps Better Tabs on EMI than StackJack™

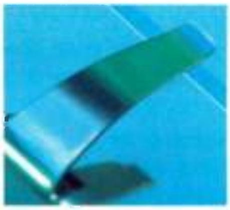
Enhanced Tab Design Delivers Superior Shielding



Performance is everything.

That's why we designed our shielded StackJack™ harmonica jacks using enhanced, spring-action tabs to provide the best shielding available. Better shielding translates into interference-free, high-speed networks that outperform the competition.

The spring-action feature provides better, more tolerant contact with the panel to allow easier installation, lower assembly costs, and greater long-term reliability.



The spring-action of the StackJack enhanced tabs provides superior shielding, producing fast, interference-free network performance.

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Thanks to the only selectively gold-plated, wire-formed contacts in the industry, you get constant normal force, low-contact resistance and no memory problems. All this adds up to high performance with 1000-mating-cycle reliability. And if you're looking for higher hub density, specify StackJack in the industry's lowest profile, with up to 16 ports in a two-row configuration. And if you don't need shielding, try our unshielded StackJack modular connectors.

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Stewart Connector Systems, Inc.
Insilco Technologies Group

RD2 Old Trail
Glen Rock, PA 17327
Phone: 717-235-7512
Fax: 717-235-7954

READER SERVICE 158

box "Equation Listings").

If we assume that the maximum ambient temperature is 50° C, and the losses in the component create an additional temperature rise of 30° C, then we should use a value of 80° C when calculating the resistivity of copper. This corresponds to:

$$\rho = 2.16\,\mu\Omega\text{-cm} \quad (24)$$

The resistance per unit length of conductor is given by:

$$R_{unit} = \rho / A_x \quad (25)$$

$$R_{unit} = \frac{2.16N}{bcK} = \frac{(2.16)(39)(10^{-6})}{(1.5)(5.6)(0.4)} = 25.0\,\mu\Omega\text{-cm} \quad (26)$$

Step 11 calls for calculation of the copper losses, P_{cu}. The mean turn length (MTL) of a C-core is approximated using:

$$MTL = (2)(a + 2b + d) = (2)[1.3 + (2)(1.5) + 2.5] = 13.6\text{ cm} \quad (27)$$

The total resistance for the winding is given by:

$$\Omega_{tot} = R_{unit}\,MTL\,N = (25.0 \times 10^{-6})(13.6)(39) = 13.26\text{ m}\Omega \quad (28)$$

If the current has a significant high-frequency component, then the resistance of the winding will increase due to the skin effect. The skin effect in high-frequency designs can be minimized by using Litz or foil windings.

The copper losses can now be calculated:

$$P_{cu} = I^2_{rms}\Omega_{tot} = (26)^2(13.26)(10^{-3}) = 8.96\text{ W} \quad (29)$$

Step 12 is to calculate the ac flux in the gap (and core). Use the following:

$$B_{ac} = \frac{0.4\pi N(\Delta I / 2)(10^{-4})}{\ell_g} = \frac{0.4\pi 39(4.23/2)(10^{-4})}{0.12} = 0.086\text{T} \quad (30)$$

EQUATION LISTINGS

$$L_{crit} = \frac{V_{in\,min}(1 - V_{in\,min} / V_{out})}{\Delta I f_{sw}} \quad (1)$$

where L_{crit} = *critical* inductance (H).

$V_{in\,min}$ = minimum dc-input voltage (V).

V_{out} = dc output voltage (V).

ΔI = ripple current (I).

f_{sw} = switching frequency (kHz).

and where $V_{in(dc)min} = \sqrt{2}(V_{in(ac)min})$

$$\Delta I = \Delta B / B\left[\sqrt{2}(P_{out}) / (\eta_{preg} V_{in(ac)min})\right] = (0.163/1.4)\left[\sqrt{2}(2200) / ((0.95)(90))\right] = 4.23\text{ A}_{p\text{-}p} \quad (10)$$

$$L_{crit} = \frac{\sqrt{2}V_{in(ac)min}\left[1 - ((\sqrt{2}V_{in(ac)min}) / V_{out})\right]}{\Delta I f_{sw}} = \frac{\sqrt{2}(90)\left[1 - (\sqrt{2}(90/380))\right]}{(4.23)(50{,}000)} = 400\,\mu\text{H} \quad (11)$$

$$E = 0.5(L_{crit} I_{inpk}^2) = 0.5(400 \times 10^{-6})(38.5)^2 = 0.296\text{ Joules} \quad (12)$$

where $I_{in\,pk} = \sqrt{2}P_{out} / (\eta_{PREG} V_{in(ac)min}) + \Delta I / 2$ Amps

$$W_a A_c = \frac{2E(10^4)}{B_{max} JK} = \frac{(2)(0.296)(10^4)}{(1.4)(500)(0.4)} = 21.17\text{ cm}^4 \quad (13)$$

where E = energy (Joules).

B_{max} = maximum peak flux density (Tesla).

J = current density (A / cm^2).

and K = window-utilization factor

$$L = \frac{0.4\pi N^2 A_c (10^{-8})}{\ell_g + (\ell_m / \mu\Delta)}\text{ Henry} \quad (15)$$

where ℓ_g = total air gap (cm).

ℓ_m = magnetic-path length of core (cm).

and $\mu\Delta$ = incremental permeability at operating point on B-H loop = 1000

$$\ell_g = \frac{0.4\pi N^2 A_c (10^{-8})}{L} - \frac{\ell_m}{\mu\Delta}\text{ centimeters} \quad (16)$$

$$\ell_g = \frac{0.4\pi N I_{inpk}(10^{-4})}{B_{max}} - \frac{\ell_m}{\mu\Delta} = \frac{0.4\pi(41)(38.5)(10^{-4})}{1.4} - \frac{19.6}{1000} = 0.12\text{ cm} = 0.06\text{ cm / leg} \quad (18)$$

$$N = \sqrt{\frac{L\left[\ell_g + (\ell_m / \mu\Delta)\right](10^8)}{0.4\pi A_c F}} = \sqrt{\frac{(400 \times 10^{-6})[0.12 + (19.6/1000)](10^8)}{(0.4)\pi(2.7)(1.07)}} = 39\text{ turns} \quad (21)$$

$$\rho = 1.724\left[1 + 0.0042(T - 20)\right](10^{-6})\ \Omega\text{-cm} \quad (23)$$

$$SA = 2f(b + d) + 2(b + d)(b + e) + 2f(b + e) = 2(8.2)(1.5 + 2.5) + 2(1.5 + 2.5)(1.5 + 4.1) + 2(8.2)(1.5 + 4.1) = 202.2\text{ cm}^2 \quad (33)$$

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DCP010512	5V	12V	Single
DCP010515	5V	15V	Single
DCP010505D	5V	±5V	Dual
DCP010512D	5V	±12V	Dual
DCP010515D	5V	±15V	Dual

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- Isolation (rated) 1000Vrms
- Switching 400kHz
- Temperature Range . . . . –40°C/+100°C
- Package . . . . 14-pin DIP

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Calculation of the core losses comprises step 13. For AlliedSignal POWERLITE C-cores, recall that losses are given by the expressions:

$$P_{core} = 6.5 f_{sw}^{1.51} B_{ac}^{1.74}\ \mathrm{W/kg} \quad (31)$$

$$P_{core} = 6.5 f_{sw}^{1.51} B_{ac}^{1.74} wt = 6.5(50)^{1.51}(0.086)^{1.74}(0.38) = 12.71\ \mathrm{W} \quad (32)$$

Note that f_S is expressed in kHz.

The 14th step is to estimate the convective surface area. Painstaking accuracy can be used to calculate the actual surface area of the wound component. However, the boundary layer associated with natural convection in air tends to round off the surface contours, and so the effective convective surface area is approximated by the surface area of a box barely enclosing the wound component. This area is calculated using dimensional diagrams (*Fig. 3, again*) and Equation 33 (see box "Equation Listings").

In step 15, we calculate the approximate temperature rise of the wound component using:

$$P_{tot} = P_{core} + P_{cu} = 8.96 + 12.71 = 21.67\ \mathrm{W} \quad (34)$$

$$\Delta T = (P_{tot} / SA)^{0.833} = (21670 / 202.2)^{0.833} = 49°\mathrm{C} \quad (35)$$

Efforts should be made to make $P_{core} \approx P_{cu}$ to optimize the design. Note that P_{tot} is expressed in milliwatts.

Step 16 is to determine the effect of the dc bias on the value of inductance. The procedure so far has assumed that there will be no appreciable drop in inductance factor A_L with increasing magnetizing force, H (Amps-turns). However, as the magnetizing force increases, the inductance will decrease as the core moves further into saturation. For the particular core and gap size chosen, we can check the value of inductance under peak magnetizing condition from the characteristic graphs in AlliedSignal's POWERLITE C-core Technical Bulletin, modifying the design where necessary.

Referring to the graph of inductance factor A_L versus magnetizing force H for the particluar C-Core model AMCC-25 (*Fig. 4*), we see that for the above design:

L (0 Amps) = 375 μH

L (38.5 A) = 320 μH (85% L_{INIT}).

As the deadline for implementing power-factor correction approaches, design engineers are faced with the task of designing power-factor-correction circuits that are small, light, efficient, reliable, and, most importantly, cost effective.

The preceding design procedures and examples demonstrate that there are no differences between designing magnetic components using AlliedSignal's POWERLITE

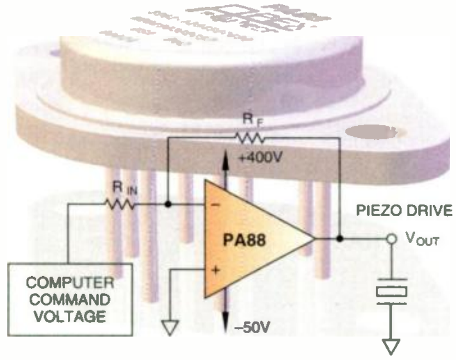
CONTINUED ON PAGE 62

For High Voltage Amplifiers, Why Look Anywhere Else?

KEY PRODUCT SPECIFICATIONS				
Part #	Supply	$I_{OUT\ PEAK}$	$I_{STANDBY}$	Slew Rate
PA08	30V-300V	200mA	8.5mA	30V/µs
PA41	100V-350V	120mA	2mA	40V/µs
PA42	100V-350V	120mA	2mA	40V/µs
PA43	30V-450V	120mA	2mA	40V/µs
PA85	30V-450V	350mA	25mA	1000V/µs
PA87	100-450V	200mA	3.8mA	20V/µs
PA88	30V-450V	200mA	2mA	30V/µs
PA89	150V-1200V	100mA	6mA	16V/µs

The Power Miser

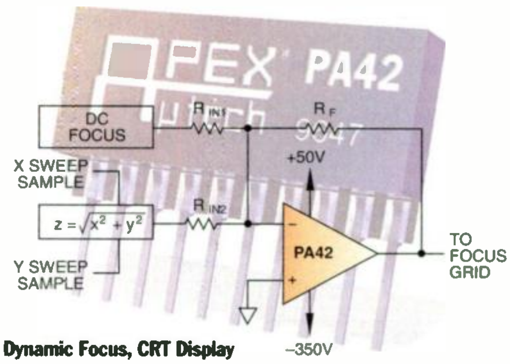
When concerned about system power supply drain or heat buildup, the **PA88** offers cool running with only 2mA max standby current. With a total supply rating of 450V and an output capability of 200mA peak, the **PA88** is up to your design challenges. The **PA88M** is the military screened version



Low Power Micro Positioning

The Penny Pincher

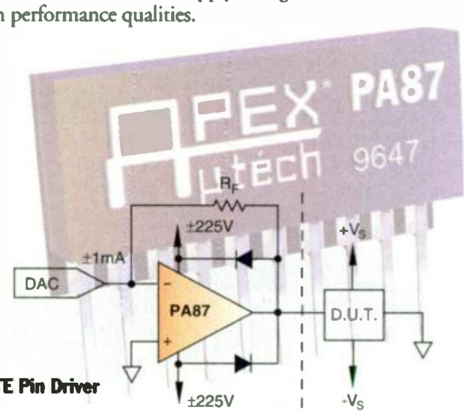
Monolithic technology makes the **PA42**'s $17.90 price tag in 10K pieces mighty attractive. With a footprint of less than one fourth that of a TO-3 package, the **PA42** is THE choice for high density applications. Its 2mA maximum standby current is also consistent with high density, and remember, this monolithic is rated up to 350V total supply and 120mA output.



Dynamic Focus, CRT Display

The Power Punch

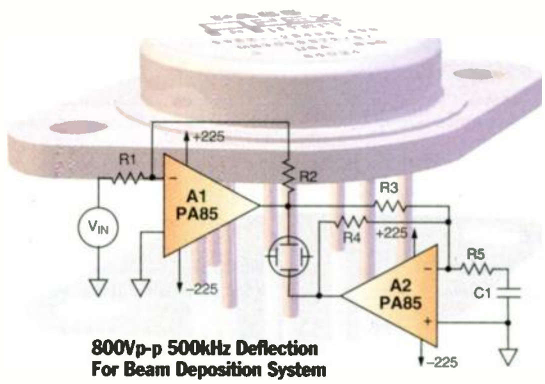
If you're looking for high output capabilities, then the **PA87** can drive continuous output currents up to 200mA, and pulse currents up to 300mA into capacitive loads. The **PA87's** space-saving single inline package is perfect to conserve board real estate and its $57.15 price in 10K quantities is equally impressive. A standby current rating of 3.8mA and a total supply rating of 450V adds to the **PA87's** high performance qualities.



ATE Pin Driver

The Speed Demon

If it's speed you need, the **PA85** is the fastest high voltage op amp you can buy. A slew rate of 1000V/µs, a total supply capability of 450V and peak currents to 350mA, the **PA85** is well suited to high speed drives for PZTs, optical switches and other capacitive loads. The gain bandwidth product of 100MHz insures AC fidelity. It's also available in a military screened version, the **PA85M**.



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MANUFACTURERS OF UNINTERRUPTIBLE POWER SUPPLIES

Manufacturer	List prices	System topologies	Capacities (VA)	Run times (minutes)	Surge let-through (% of peak load)	RMS-voltage regulation (V ac)	Software features (see key below)	SNMP hardware interface?
Acme Electric Corp. **Cuba, N.Y.** **(716) 968-2400** **CIRCLE 538**	From $139 to $1299	Line-interactive; stand-by	250 to 1400	3 to 150	Less than 5%	N.A.	SD, WB, NM, SNMP (all optional)	External
American Power Conversion **West Kingston, R.I.** **(800) 877-4080** **CIRCLE 539**	From $119 (Back-UPS series) to $5199 (Matrix series)	Line-interactive; stand-by	200 to 5000	Up to 17 at full load (Matrix Series)	As low as <0.3%	Varies with product lines	SD, WB (in PowerChute Plus package), NM, SNMP	Internal and external
BEST Power **A unit of General Signal** **Necedah, Wisc.** **(608) 565-7200; (800) 356-5794** **CIRCLE 540**	From $129 to $17,324+	On-line; line-interactive; stand-by; ferroresonant	280 VA to 220 kVA	5 to 30 at full load (without extended runtime options)	0.03 to 1.4 (all units pass ANSI/IEEE C62.41)	Depends on load	SD, WB, NM, SNMP (all optional)	External
Clary Corp. **Monrovia, Calif.** **(800) 442-5279** **http://www.clary.com\onguard** **CIRCLE 541**	From $477 to $9421	On-line; line-interactive	450 to 5000	5 to 45 (unlimited with runtime options)	200%	±2%	SD, WB, NM, SNMP (all optional)	External
Computer Power Inc. **High Bridge, N.J.** **(800) 526-5088** **CIRCLE 542**	From $149 to $35,000	On-line; line-interactive; stand-by; ferroresonant	300 VA to 350 kVA	5 minutes to 24 hours	Less than 1%	±2%	SD, WB, NM, SNMP (all optional)	External
Custom Power Systems **Ronkonkoma, N.Y.** **(516) 467-5328** **http://www.custompower.com** **CIRCLE 543**	Based on custom design	On-line (ac-dc UPS)	Per customer requirements	Per customer requirements	N.A.	N.A.	None	None
Deltec Electronics Corp. **San Diego, Calif.** **(619) 291-4211** **http://www.deltecpower.com** **e-mail: info@deltecpower.com** **CIRCLE 544**	Starts at $119	On-line; line-interactive; stand-by	220 VA to 60 kVA	5 minutes to 10 hours	N.S.	N.S.	SD, WB, NM (included), SNMP (optional)	External
EPE Technologies Inc. **Division of Square D** **Costa Mesa, Calif.** **(714) 557-1637** **CIRCLE 545**	From $139 to $6290	On-line; line-interactive; stand-by	250 VA to 10 kVA (single-phase); 12 kVA to 750 kVA (three-phase)	7 to 15 standard	Below 400 to 500% (on-line mode)	±2%, ±3%, ±5%	SD, WB, NM, SNMP (all optional)	Internal
Elgar Corp. **San Diego, Calif.** **(619) 458-0085** **e-mail: sales@elgar.com** **CIRCLE 546**	From $4185 to $9445	On-line	1 kVA to 3 kVA	5 to 15 (longer with extended battery capacity)	Tested to IEC 801-2	±2% over full range of line/load regulation, stability, and accuracy	SD (RS-232) included	Proprietary RS-232
Exide Electronics Group Inc. **Raleigh, N.C.** **(919) 870-3239** **http://www.exide.com\exide** **e-mail: info@exide.com** **CIRCLE 547**	Start at $139	On-line; line-interactive; stand-by	250 VA to 1000 kVA	Varies per application	Varies per application	±3%	SD, WB, NM, SNMP (all optional)	External
Hewlett-Packard Co. **New Jersey Div.** **Rockaway, N.J.** **(201) 586-5888** **http://www.hp.com\go\netserver** **CIRCLE 548**	From $319 to $1179	On-line; line-interactive	600 to 2100	6 to 11 at full load	On-line: <0.3%; Line-interactive: <0.8%	On-line: 120 V ac (±3%); Line-interactive: 120 V ac (±5%)	SD, WB, NM, SNMP (all included)	Internal (optional in on-line models)
Liebert Corp. **Columbus, Ohio** **(800) 877-9222, (614) 888-0246** **http://www.liebert.com** **e-mail:** **pulsed@smtpgw.liebert.com** **CIRCLE 549**	From $173 to $7164	On-line; line-interactive; stand-by	250 VA to 18 kVA	5 to 160+	Sustains all input surges	±5%	SD, WB, NM (all optional) SNMP included in some models, optional in others	N.S.

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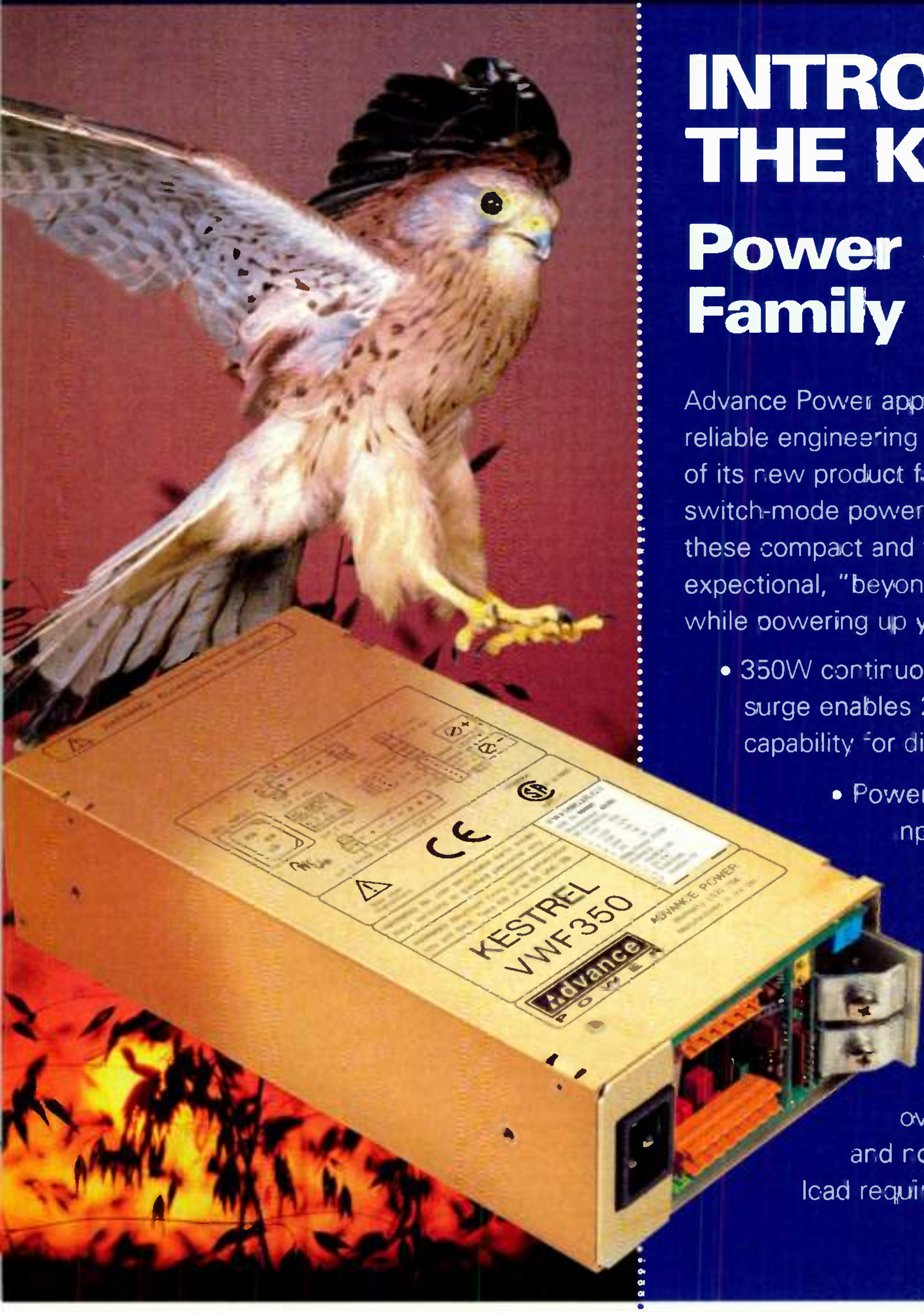

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CONTINUED FROM PAGE 58
C-cores and the more conventional ferrite and MPP products. On the contrary, because of the high saturation-flux density and the low frequency-dependent losses, size reductions of up to 40% and weight reductions of up to 50% can be achieved while maintaining the same or greater end-product reliability.

JOSEPH W. McCLEAN is Senior European Applications Development Manager at Allied Signal Amorphous Metals. McClean previously worked for Theo. Benning Ireland GmbH, Wexford, Ireland, as an R&D engineer. He holds a BA in experimental physics from Trinity College, University of Dublin.

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MANUFACTURERS OF UNINTERRUPTIBLE POWER SUPPLIES

Manufacturer	List prices	System topologies	Capacities (VA)	Run times (minutes)	Surge let through (% of peak load)	RMS-voltage regulation (V ac)	Software features (see key below)	SNMP hardware interface?
Lortec Power Systems Inc. **Garland, Texas** **(800) 927-5051** **CIRCLE 550**	From $600 to $100,000	On-line	600 VA to 30 kVA	Selectable	N.S.	From 1% to 3%	N.S.	External
Para Systems Inc. **Minuteman-UPS Div.** **Carrollton, Texas** **(214) 446-7363** **http://www.minuteman-ups.com** **CIRCLE 551**	From $99 to $9999	On-line; line-interactive; stand-by	200 VA to 10 kVA	5 to 2,880	<0.2%	92 to 267 V	SD, WB, NM, SNMP (all optional)	External (optional)
SL Waber Inc. **Mt. Laurel, N.J.** **(609) 866-8888** **CIRCLE 552**	PH250: $119 PH500: $229 Upstart: $249	PH: Stand-by Upstart: Line-interactive	250 to 500	5 to 15	±5%	±5%	PH: None Upstart: SD, WB, SNMP included	PH: None Upstart: Internal
Solidstate Controls Inc. **Columbus, Ohio** **(800) 635-7300** **CIRCLE 553**	From $2,000 to $150,000	On-line; stand-by	400 VA to 150 kVA	5 minutes to 8 hours	N.S.	±2%	None	None
Superior Electric **Bristol, Ct.** **(860) 585-4500** **CIRCLE 554**	From $135 to $1875	On-line; line-interactive; stand-by	200 to 2200	5 to 10 at full load	Meets UL 1449 (330)	Depends on model	SD, WB, NM, SNMP (all optional)	None
Tektris Electro Corp. **La Mesa, Calif.** **(619) 589-0444** **CIRCLE 555**	N.S.	Stand-by	Up to 1 kVA	Up to 120	N.S.	60 V ±2%	SD (included)	None
Transistor Devices Inc. **Cedar Knolls, N.J.** **(201) 267-1900** **e-mail:** **zeman_r@mailer.transdev.com** **CIRCLE 556**	From $3000 to $50,000	On-line	1.25, 2.5, 6, and 10 kVA (single- and three-phase)	5 to 30	Zero	0.1% voltage and 0.1% frequency	SD (included)	None
Tripp Lite **Chicago, Ill.** **(312) 755-5401** **http://tripplite.com** **e-mail:** **info%tripplite@mcimail.com** **CIRCLE 557**	From $119 to $4199	On-line; line-interactive; stand-by	200 VA to 5 kVA	10 minutes to unlimited time	150%	87 to 140 V ac (to ANSI C84.1)	SD (included), WB and NM (included or optional), SNMP (optional)	External
ViewSonic **Walnut, Calif.** **(800) 688-6688; (714) 545-1338** **http://viewsonic.com** **CIRCLE 558**	From $139 to $699	Line-interactive	280 to 1400	4 to 6 (full load), 8 to 12 (half-load)	1%	Input voltage of 87 to 149 V ac	None	External
Wilmore Electronics Co. **Hillsborough, N.C.** **(919) 732-9351** **CIRCLE 559**	From $345.50 to $1640 (qty. 10)	On-line; stand-by	50 VA to 1 kVA	Depends on user-supplied batteries	N.A.	±3% for regulated units vs. dc-input line and output load	None	None

Key to software features: SD = shutdown; WB = Windows-based client management; NM = network-management application; SNMP = SNMP software agent. N.A. = not applicable; N.S. = not specified

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READER SERVICE 119

Approaching Packaging As A System

BY GEORGE CORREIRA
Rittal Corp., One Rittal Pl., Springfield, OH 45504; (513) 399-0500.

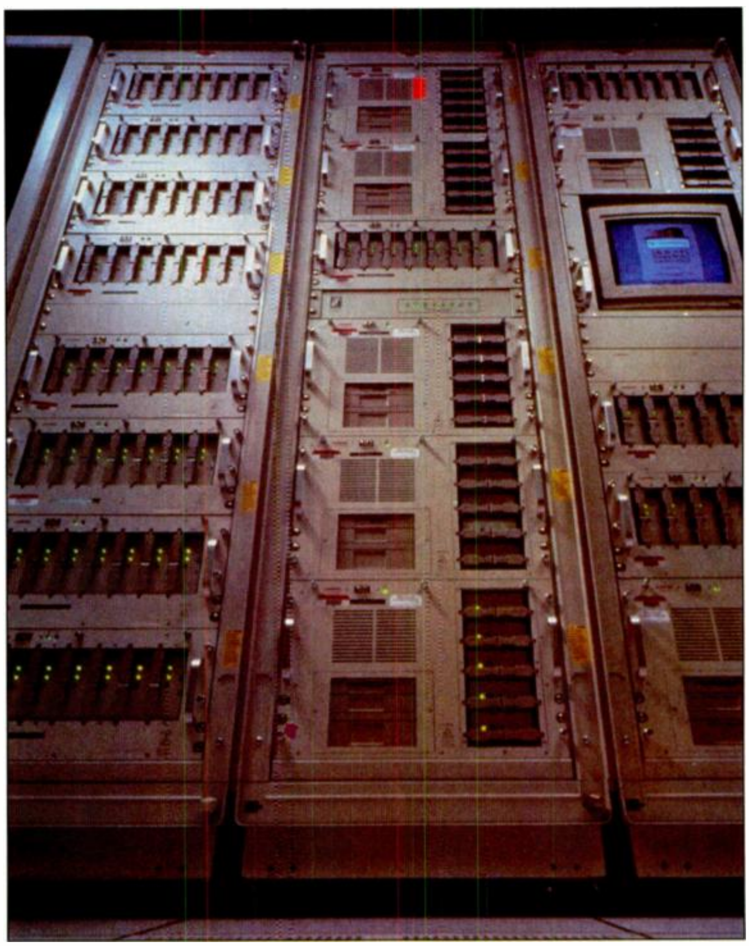
It pays to think "enclosures" early in the design cycle. doing so will result in a more effective system housing.

Today's trend in designing network equipment is to strive for compatibility with 19-in. racks. This format allows for vertical orientation of equipment in standard cabinets and racks. Although the 19-in. standard has been used for over 50 years, only recently has it come into play in configuring network equipment. Computer-server products now are being manufactured and developed for future use in so-called "rack-and-stack" configurations, as are most other peripheral products, such as switches, routers, and hubs. The rack-and-stack configuration allows all of the necessary hardware, cabling, and other accessories to be properly stored, maintained, and accessed in a convenient, complete housing.

As more technological developments occur in network computing, the client-server network is reaching the point where many business applications are being developed on computer servers that integrate complete, all-in-one network equipment. A typical roster of equipment for a network could include such components as computer servers, bridges, routers, hubs, switches, repeaters, 19-in. enclosures, cable-management accessories, climate-control devices, electromagnetic-compatibility (EMC) materials, monitors, keyboards, uninterruptible-power-supply (UPS) systems, patch panels, telecommunication equipment, and mass-storage devices.

With such a wide range of hardware and accessories being integrated, system designers face a host of new packaging requirements that haven't been seen in past years. The most critical aspects include:

• Enhanced security measures, because computer equip-



1. A rack-mounted server system combines powerful computing with stackable, space-saving convenience. It also provides a highly functional enclosure. (Photo courtesy of Compaq Corp.)

ment is no longer limited to the secured environment.

•Enough integration capability to enable equipment to be packaged with other peripheral equipment in the same physical location.

•The ability to package equipment into a central, well-managed, and often relatively small space.

•Good cable-management provisions.

•An easy means of providing expansion capabilities.

•Climate control.

Because of these diverse needs, enclosures play an important role in the design and manufacture of electronics. The systems used in the network incorporate products that range from a host of standard and modified components that form the basis of completed designs. A complete range of subracks and chassis, desktop and rack-mount enclosures, open data racks, and 19-in. cabinets and cases are used to integrate the electronics into the system hardware (*see the figure*).

To meet these challenges, computer-equipment designers and OEMs are forming partnerships with packaging experts early in the design process. While each project is unique in terms of internal mounting requirements, weight capacity, and cooling needs, companies that produce modular, standardized packaging offer an effective option. Months and sometimes years of development time are spent designing and testing the right combination of components, printed-circuit boards, electromagnetic-compatibility components, and climate-control devices to deliver a finished, quality product to the market. In addition, considerable time and engineering effort is dedicated to designing an effective, value-rich enclosure for the end-user's network system.

In this process of concurrent engineering, the emphasis is on incorporating all disciplines into the complete product-development process, from concept to production. Participants in this product-development discussion include a number of areas, including electrical, electronic, mechanical, and software engineering, as well as purchasing, quality, finance, and marketing. However, it's imperative that manufacturer and vendor work together to integrate design and manufacturing at initiation of the design process—instead of as an afterthought.

Benefits of concurrent engineering can range from faster product development and cost-effective manufacturing to a more efficient, superior design and reduced costs.

Benefits of concurrent engineering can range from faster product development and cost-effective manufacturing to a more efficient, superior design and reduced costs. With concurrent design, the equipment and the enclosure are literally made for each other. Therefore, it's truly in the best interest of both parties to think about the system packaging upfront.

Network infrastructures entail a wide variety of complex system-hardware components that are integrated for client-server/enterprise network applications. For system engineers, determining system requirements revolves around solving many tasks at the same time. To build and design the correct product, it's important to follow a logical step-by-step process. Some of the system requirements can be enumerated in the form of a checklist. A list of this sort can be a helpful aid (*see the table*).

SYSTEM-PACKAGING CHECKLIST REVIEW

1. Site planning:	
• Room size	• Cabling (under and over flooring)
• Climate control	• Remote-site applications
• Environmental considerations	• EMC requirements
• Future expansion possibilities	• Service
• Logistics	
2. Internal product definition:	
• Total maximum system weight	• Climate-control factors/heat dissipation
• Packaging for transportation	• Cable-management system
• Telescope slide arrangements	• Cable-entry system
• EMC compliance	• Internal mounting dimensions
• Electronic network products and systems, i.e. servers, UPSs, switch box, monitor, keyboard, and more	
3. External product definition:	
• Enclosure	• Required external-size dimensions
• Usable rack space	• Aesthetic issues
• Base and stabilization methods	• Ventilation patterns
• Special testing parameters	• Shock and vibration requirements
• Standard accessories, i.e. shelves, slides, system chassis, cable management, and more	• Security

The first step for system design is to plan the hardware implementation, including integration of the various system elements. Not only must engineers incorporate the numerous server components, but they must consider the additional peripheral elements in their design. So to begin implementation of the system, the design must include all of the system components.

From there, planning of the network system must consist of site planning for space allocation—a crucial second step. Because space for these installations is at a premium, integrating the products vertically becomes both necessary and logical in order to maximize the density of products and integrated components.

Next, of increasing concern for server systems and other electronic components is the heat buildup in these powerful units. Server and peripheral manufacturers are well aware

that for every 20° F, or approximately 10° C, above a component's maximum operating temperature, the average life of semiconductors is cut in half. Thus, climate-control needs are of ultimate concern for designers.

Added steps would focus on planning for the wiring and cable infrastructure, future expandability, security, and network management. Designers also must address the need to protect the sensitive electronics from electromagnetic or radio-frequency interference (EMI/RFI). It's extremely imperative that EMI/RFI be considered as an integral part of product design to optimize the performance of the electronics and to minimize its interaction with other equipment.

The 19-in. configuration now in vogue provides the OEM with an option that incorporates the various system components as well as meets installation, maintenance, and service requirements. Therefore, the 19-in. enclosure becomes the logical choice to accomplish the "racking and stacking" of products and accessory items in a variety of environments.

It's also important to understand the essential relationship between enclosures and their uses for end-user applications. Let's look at how enclosure technology is employed in modern network environments.

Network infrastructures are installed in a host of diverse environments. One setting for a network installation could be the "glass house" of a corporate headquarters. This type of installation strictly dictates the space available for the installation of network equipment and controls. Because real estate is always at a premium, additional enclosures and equipment should be considered carefully. Such settings also mandate the use of aesthetically appealing enclosures. On top of providing improved manageability and easy serviceability, the integrated server package system cleans up the office—an important factor when the system is so visible as in this scenario.

Finally, the system requires installation in a climate-controlled area as well as high security with locked access. In many cases, the best approach is a modular enclosure that can house everything from servers to UPS and communications equipment—all readily inserted on stackable 19-in. racks and easily expanded by adding more modules.

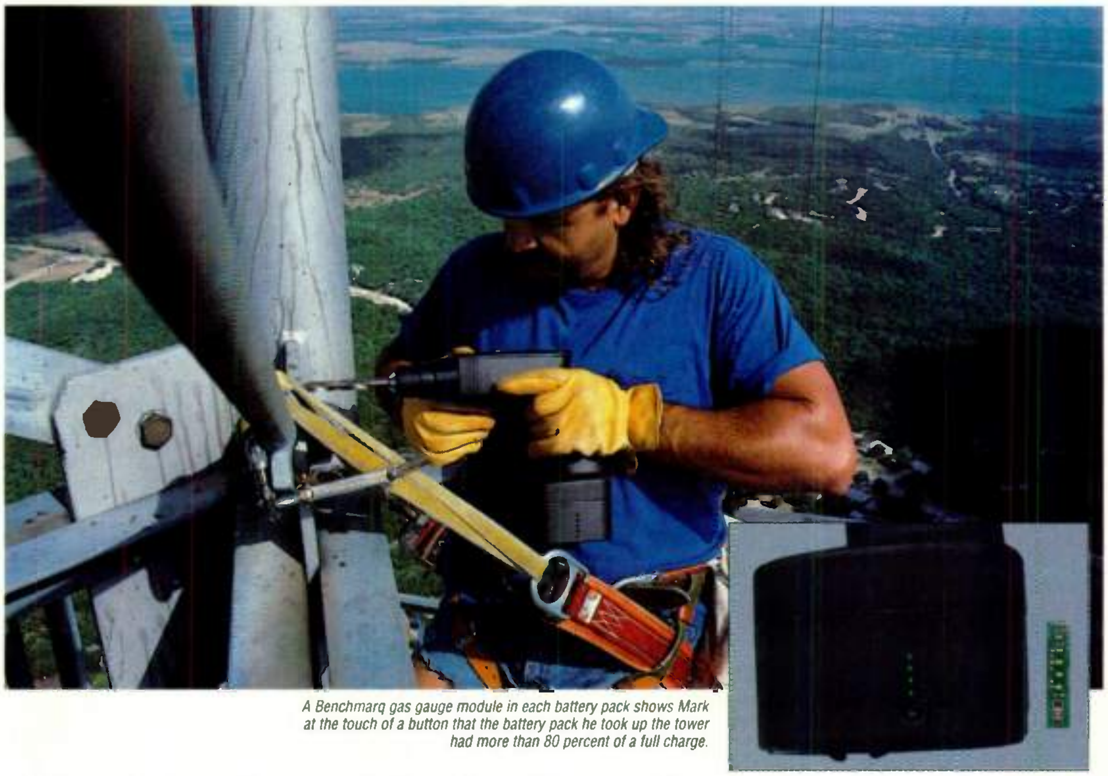
Equipment also can be located at remote sites that are connected to a central system. These locations can range from wiring closets to factory floors. In these kinds of installations, the enclosures must provide added security, adequate climate control, environmental protection, and measures for expansion. For equipment not designed for EMC emissions standards, it might be necessary to use enclosures that protect against unwanted EMC interference. It's easier and less costly to achieve

CONTINUED ON PAGE 76

Benchmarq makes the module that displays the charge

that's in the battery

that runs the drill...



A Benchmarq gas gauge module in each battery pack shows Mark at the touch of a button that the battery pack he took up the tower had more than 80 percent of a full charge.

that Mark carried 1,500 feet up the tower.

Thanks to the Benchmarq battery gas gauge designed into Mark's drill, Mark can finish his job with confidence, knowing his drill won't run out of power before the work is complete. Smart battery technology helps sell products. And Benchmarq makes it easy for you to make your battery packs intelligent.

At Benchmarq, we specialize in battery management technology. And our fully tested, ready-to-install battery capacity modules can save you time and money, and shorten your time to market.

Our engineers work directly with you to address your most challenging problems. We can customize our modules to accommodate your space and power requirements. And because all components are included on a small board, your buying and manufacturing processes are simple. You buy, inventory, and assemble a single part.

So call Benchmarq for a turn-key solution to your battery monitoring and charging needs. Because when you offer reliable smart power with your product, guys like Mark step up and buy.

Gas Gauge IC/Module Selection Guide

16-Pin IC Part No.	Description	Battery Technology	Module Part No.
bq2010	Gas Gauge IC	NiMH and NiCd	bq2110, bq2110L
bq2011/J	Gas Gauge IC for Power Tools	NiMH and NiCd	bq2111L
bq2012	Gas Gauge IC	NiMH and NiCd	bq2112, bq2112L
bq2014	Gas Gauge IC with Ext. Charge Control	NiMH and NiCd	bq2114, bq2114L, bq2164
bq2050	Power Gauge™ IC	Li-Ion	bq2150, bq2150L, bq2165
bq2090	SMBus v.95 Gas Gauge IC	NiMH, NiCd, Li-Ion	bq2190L

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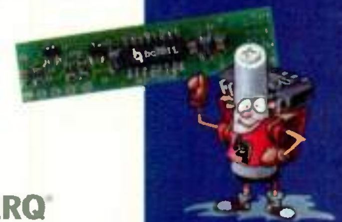

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READER SERVICE 111

MANUFACTURERS OF ENCLOSURES

Manufacturer	Enclosure configurations	Bus structures	Backplane sizes	System cooling options	Drive bays	Power-supply options	Is shielding available?
Altech Corp. **Flemington, N.J.** **(908) 806-9400** **http://www.altechcorp.com** **CIRCLE 560**	Industrial, DIN, and others in many configurations	N.A.	From 2.5 by 2.5 in. to 14 by 10 in.	N.A.	N.A.	N.A.	Yes (plastic enclosures with copper-based shielding)
Ango Electronics Corp. **N. Arlington, N.J.** **(201) 955-0800** **http://www.ango.com** **CIRCLE 561**	Rackmount, metal desktop types	PCIbus	N.A.	Fan	Four double-density (two exposed; two buried)	Standard PC supply	Yes, to FCC specifications
Buckeye Stamping Co. **Columbus, Ohio** **(800) 728-0776** **CIRCLE 562**	Desktop, rackmount, portable, front-loading, wedge consoles	Eurocard, VME, VXI, Multibus II	3U to 6U, VXI 9U and 12U	Cluster-punch ventilation	N.A.	N.A.	EMI and RFI shielding available
Bud Industries Inc. **Willoughby, Ohio** **(216) 946-3200** **CIRCLE 563**	Cabinet racks, relay racks, desktop, rackmount, portable instrument cases	None	None	Blowers, fan trays, exhaust fans	N.A.	N.A.	Yes (per customer request)
Bustronic Corp. **Fremont, Calif.** **(510) 490-7388** **http://www.bustronic.com** **CIRCLE 564**	Desktop, rackmount, tower, portable tower	VME64, VME, VXI, ISA, PCI/ISA, and custom	Any, depending on bus or custom design	Ac and dc fans, water cooling	One to 12 or more	150 W to 1.5 kW (+5 V or ±12 V standard; other voltages optional)	Yes, to levels 1 and 2
Calmark Corp. **San Gabriel, Calif.** **(818) 287-0451** **CIRCLE 565**	PC-board enclosures (card cages, subracks)	VME	None	Individual ac or dc axial fans or fan-tray assemblies	Custom	Custom	Custom
Dawn VME Products **Fremont, Calif.** **(510) 657-4444** **e-mail: dawnsales@aol.com** **CIRCLE 566**	Desktop, rackmount, tower	VME, VXI, Sbus	Two to 21 slots; 3U, 6U, 9U, custom, MIL-spec	Positive pressure, evacuation, custom	As many 3.5 and 5.25 in. as required	Up to 2 kW	Yes, to FCC Class B
Electronic Solutions **Div. of Zero Corp.** **San Diego, CA** **(619) 452-9333** **e-mail: sales@elsol.com** **CIRCLE 567**	Desktop, rackmount, tower	VME, Multibus, Multibus II, VXI, Sun, VSB	VME (2 to 21 slots), Multibus (4 to 26), Multibus II (3 to 20), VXI (3 to 13), VSB (2 to 6)	Various	Various	175 to 1500 W	Yes, to FCC Class A and B; VDE, CISPR
Electrorack Products Co. **Anaheim, Calif.** **(714) 776-5420** **CIRCLE 568**	Desktop, sloped, vertical, RFI/EMI, seismic, NEMA-rated, crash-tested	None	None	Blowers, fans, vents	None	None	Yes: FCC through Tempest
Electro Space Fabricators **Topton, Pa.** **(610) 682-7181** **CIRCLE 569**	Rackmount and desktop	VME, VXI, custom	3U, 6U, 9U, 12U, J1-J2	N.A.	N.A.	N.A.	Yes
Elma Electronic Inc. **Fremont, Calif.** **(510) 656-3400** **http://www.elma.com** **e-mail: sales@elma.com** **CIRCLE 570**	Desktop, rackmount, portable, tower, wallmount, MIL-spec	VME, VXI, Multibus II, ISA, PCI, Futurebus	VME (2 to 21 slots), VME64 (5, 7, 9, 12, 21 slots), VXI (B,C,D sizes), ISA, PCI/ISA	Convection, forced air, conduction	Many options and configurations	200, 250, 350, 500, 750 W	Yes, in all levels up to and including Tempest
Emcor Products/Crenlo Inc. **Rochester, Minn.** **(507) 289-3371** **CIRCLE 571**	19-, 24-, and 30-in. EIA modular rackmount and desktop types	N.A.	N.A.	Packaged blowers, fan trays, and fan panels	N.A.	N.A.	Yes: to commercial/FCC requirements and Tempest specifications

Toko Chip Inductors

TOKO Types		Typical Q	EIA Footprint	Quantity per Reel	Inductance Range (1nH – 10nH – 100nH – 1µH – 10µH – 100µH – 1mH)
LL1005-F "World's smallest" Ceramic nH		50@ 1900 MHz	0402 (1.0 x 0.5 mm)	10,000	5.6; 6.8 – 27 *; 3.3 – 27; 3.3 – 27
LL1608-F General purpose Ceramic nH		30@ 800 MHz	0603 (1.6 x 0.8 mm)	4,000	1.2 – 5.6; 22; 6.8; 3.3
LL1608-FH High current, High Q in micro size Ceramic nH		50@ 800 MHz	0603 (1.6 x 0.8 mm)	4,000	1.2 – 5.6; 6.8; 3.3
LL2012-F General purpose nH Ceramic nH		50@ 800 MHz	0805 (2.0 x 1.2 mm)	4,000 (3,000) ≥47nH	1.5 – 5.6; 6.8 – 470; 3.3 – 470; 3.3 – 470
FSLU2520 General purpose Ferrite nH and µH		40	1008 (2.5 x 2.0 mm)	2,000	220; 220; 820
32CS General purpose Ferrite nH and µH		30	1210 (3.2 x 2.7 mm)	1,500	220; 220; 8.2
33CS Air core high Q		85@ 150 MHz	1616 (4.0 x 4.0 mm)	2,000	6.8 – 22
36CS Air core high Q			2616 (6.4 x 4.0 mm)	2,000	22 – 50

*Available soon, please contact Toko for details.

Tolerances:

- C = ±0.2nH
- S = ±0.3nH
- T = 3%
- J = 5%
- K = 10%
- M = 20%

READER SERVICE 140

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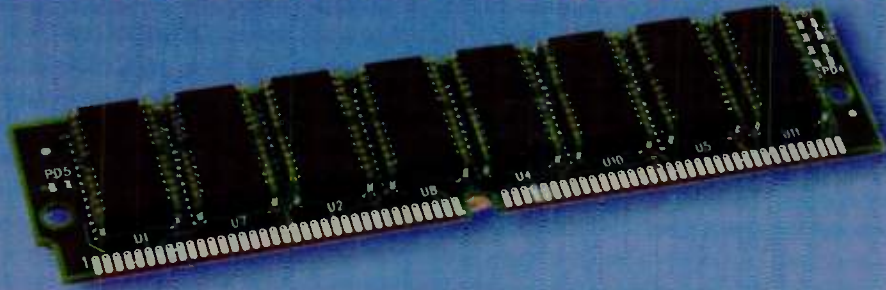
MANUFACTURERS OF ENCLOSURES

Manufacturer	Enclosure configurations	Bus structures	Backplane sizes	System cooling options	Drive bays	Power-supply options	Is shielding available?
Enclosure Technology Inc. **Ypsilanti, Mich.** **(313) 481-2200** **CIRCLE 572**	Desktop, rackmount, tower, keyboard tray, PC/104 cube, embeddable card cages, 1-to-5U enclosures	ISA, PCI, PC/104	3 to 14 slots	Various; depends on enclosure	Various; depends on enclosure	Various; depends on enclosure	Yes: all NEMA ratings, UL, FCC, CSA, TUV, CE mark
Equipto Electronics Corp. **Aurora, Ill.** **(708) 897-4691** **CIRCLE 573**	Racks, consoles, instrument cabinets (all modular to EIA RS-310 specifications)	N.A.	N.A.	Fans, blowers, air conditioners	N.S.	N.S.	FCC/VDE, Tempest, European Union EMC Directive
Extrusion Technology **Randolph, Mass.** **(617) 963-7200** **CIRCLE 574**	Desktop, cabinet	VME	N.A.	N.A.	N.A.	N.A.	Enclosures are of all aluminum (shielding is built in)
Carlo Gavazzi Inc. **Mupac Business Unit** **Brockton, Mass.** **(508) 588-6110** **e-mail: tedb@mupac.com** **CIRCLE 575**	Tower, desktop, rackmount, test station	VME, VXI, Multibus II, Futurebus+, Fibre Channel, PC-AT, Multibus I, custom	From 3-slot 3U (J2) to 21-slot J1/J2	Evacuation/ pressurization	From one to 16 bays in all configurations including hot pluggable	200 W to 2 kW	Yes, up to full MIL-spec if required
General Devices Co. Inc. **Indianapolis, Ind.** **(317) 897-7000** **CIRCLE 576**	Rackmount, tower, and seismic types meet EIA RS-310 specifications	N.A.	N.A.	Natural convection, fans, blowers	N.A.	Multi-outlet power-supply strips	Yes; to FCC or MIL specifications
Hoffman Engineering **Anoka, Minn.** **(612) 422-2194** **CIRCLE 577**	19-in. mini rack cabinets, electronic rack cabinets, lab racks, cases, rackmount/desktop cases	VME, VXI, Multibus II, Futurebus+	Wide range of high-speed, standard, and modified backplanes	Internal or top-mount fan trays with ratings from 88 to 612 cfm; other fan and air-conditioning options	N.A.	Full range of power-supply options hinging on system requirements	All available in shielded versions tested in accordance with MIL-STD-285
Hybricon Corp. **Ayer, Mass.** **(508) 772-5422** **http://www.hybricon.com** **CIRCLE 578**	Desktop, rackmount, tower	VME, Multibus II, Futurebus+, compact PCI	Slot sizes from 2 to 21	Blowers, tubeaxial fans, air-restriction kits	Choice of 1 to 4, either front-access or buried	From 80 W to 1350 W	Yes, per FCC Class B specifications
Industrial Computer Source **San Diego, Calif.** **(619) 677-0877** **http://industry.net/indcompsrc** **e-mail: industrial.computer@ industry.net** **CIRCLE 579**	Rack, bench, floor, panel/wall	ISA, EISA, PCI	4, 6, 10, 15, or 20 slots (passive backplane)	Fans with various airflow capacities	Many options, both front-access and internal	50 to 500 W; 120 V ac, 240 V ac, or 24/48 V dc	Yes, per FCC Class B specifications; EMC directive 89/336/EEC
Interlogic Industries **Melville, N.Y.** **(516) 420-8111** **http://www.infoview.com** **CIRCLE 580**	Desktop, rackmount, tower	ISA, EISA, VESA local bus, ISA/PCI	4 through 20 positions	Fans	4 through 12 bays, both 3.5 and 5.25 in.	200 W to 400 W ac and 250 W dc	No
JMR Electronics **Chatsworth, Calif.** **(818) 993-4801** **http://www.jmr.com** **e-mail: jmr-support@jmr.com** **CIRCLE 581**	RAID, CD-ROM, rack/cabinets, rackmount, desktop	SSI, SSA, SCA, and custom (Fibre Channel forthcoming)	None	Multiple, depending on enclosure size and devices supported	Many options	Standard and customer options	Yes, per FCC Class A or B specifications; CE, TUV, UL, CSA
Kinetic Computer Corp. **Cambridge, Mass.** **(617) 547-2424** **e-mail: vinit@kin.com** **CIRCLE 582**	Rugged PCs	STD 32, PC/104, ISA, compact PCI	4 to 24 slots	Conduction cooling	2.5-in. shock-mount HDD; PCMCIA HDD	Dc-dc (vehicle)	Yes, to MIL-STD-461; CE mark; FCC specifications
Knurr USA Inc. **Simi Valley, Calif.** **(805) 526-7733** **CIRCLE 583**	Desktop, rackmount, carry, tower	VME	N.A.	Fan cassettes and fan trays in various configurations	N.A.	N.A.	Yes, to DIN 41494 part 5

MANUFACTURERS OF ENCLOSURES

Manufacturer	Enclosure configurations	Bus structures	Backplane sizes	System cooling options	Drive bays	Power-supply options	Is shielding available?
Lowell Mfg. Co. **Pacific, Mo.** **(314) 257-3400** **CIRCLE 584**	Stand-alone, gangable rack frame, wall-mount, desktop, transportable	N.A.	N.A.	Rackmount fan panels and blowers	N.A.	Rackmount power-distribution panels, power strips, and sequential power switching	N.A.
Magnetic Shield Corp. **Bensenville, Ill** **(708) 766-7800** **CIRCLE 585**	Magnetically shielded enclosures for CRTs	N.A.	N.A.	N.A.	N.A.	N.A.	Magnetic shielding for CRTs, hard drives
PacTec, Div. of LaFrance Corp. **Philadelphia, Pa.** **(215) 884-9502** **CIRCLE 586**	Desktop, handheld, rackmount	N.A.	N.A.	Venting, heat sinks, fans	N.A.	N.A.	Yes (nickel acrylic)
Palo Alto Design Group **Palo Alto, Calif.** **(415) 327-9444** **e-mail: marcom@padg.com** **CIRCLE 587**	Desktop, mid-tower, slimline, server	VME, ISA, EISA, PCI, NuBUS (custom version available)	Standard chassis for baby-AT, LPX/LPM, ATX motherboards	One 80-mm fan inside power-supply unit; one or two additional fans	3, 4, or 16 (depending on model)	VDE B, 50,000-hr MTBF, European standards, fan control; redundant, hot-swap for server model	Yes, per FCC Class B specifications
Powerbox (USA) Inc. **Broomfield, Colo.** **(303) 439-7220** **CIRCLE 588**	Desktop, rackmount	N.A.	N.A.	Integrated heat sinks	N.A.	Wide selection of power supplies	Not specified, but shielding can be achieved
Radstone Technology Corp. **Montvale, N.J.** **(800) 368-2738** **http://www.radstone.com** **e-mail: radstone@radstone.com** **CIRCLE 589**	Rackmount, mini-tower, ATR	VME, VSB	3, 5, 8, 10, 15, and 20 slots	Forced air, conduction	One or two 5.25-in. drives	28 V dc, 100 to 240 V, 50/60 Hz; 115 V ac, 400 Hz	Yes, to MIL-STD-461C specifications
Rangeley Mill Inc., Case Div. **Rangeley, Me.** **(800) 227-1415** **CIRCLE 590**	Custom fabrication; all types	Custom fabrication; all types	Custom fabrication; all types	Venting	Custom fabrication; all types	N.A.	Yes; per customer specification
Rittal Corp. **Springfield, Ohio** **(513) 399-0500** **http://www.industry.net/rittal** **e-mail: rittal@industry.net** **CIRCLE 591**	Rackmount, wall-mount, panel-mount	VME64, VME64 Extension, Multibus II, compact PCI	Large array of sizes for VME64; 9-, 20-, and 21-slot unbused types; VME/VSB plug-on types (3 to 6 slots)	1U rackmount fan assemblies; 3-, 6-, and 9-fan assemblies for subrack mounting	19-in. housings for up to 12 3.5-in. drives or 6 5.25-in. drives	VME supplies rated 130, 200, 400, 500, 750, and 1000 W	Yes, to European EMC standards
Rose & Bopla Enclosures **Div. of Phoenix Mecano** **Frederick, Md.** **(301) 696-9800** **CIRCLE 592**	Rackmount, desktop, wall-mount, panel-mount, electronic	VME	None	None	None	None	RFI, vacuum seal
Schroff Inc. **Warwick, R.I.** **(401) 732-3770** **http://www.schroffus.com** **CIRCLE 593**	Desktop, rackmount, tower, wall-mount	VME, VXI, Futurebus, Multibus II	From 2 to 21 slots	Fans, blowers, air conditioners	Up to 35 drive bays (3.5- and 5.25-in. vertical or horizontal)	Shoebox-style 160, 250, 350, 500, and 750 W	Yes (22 dB at 1000 MHz)
Sescom Inc. **Henderson, Nev.** **(800) 634-3451** **CIRCLE 594**	Desktop, rackmount (generic boxes)	N.A.	N.A.	N.A.	N.A.	N.A.	No
Simco **Avon Park, Fla.** **(941) 452-9090** **CIRCLE 595**	Desktop, handheld	PC-card slides	1 in. through 11 in.	Various venting matrices available	N.A.	N.A.	Yes, EMI/RFI with ElectroDial 550 nickel acrylic

MEGA SIMMS



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CONTINUED FROM PAGE 68

EMC in the design stage than to address problems once the products are in the field.

When the time comes to expand networks, servers are easily added vertically to a 19-in. system without burning up more floor space. One answer might be to use wall-mounted enclosures for equipment when space is limited or that which is easily installable on a remote wall.

Overall, enclosure manufacturers are able to provide standardized solutions that offer numerous advantages to the end user. By teaming together and participating in concurrent engineering, a variety of benefits can be provided. These benefits can include both cost and time savings, both of which are crucial issues in today's competitive global market. In addition, by integrating design and manufacturing, the enclosure partner is able to provide a standardized product with an improved design and higher quality. Moreover, packaging experts will be able to help identify the various needs of the computer OEM or manufacturer and, in turn, design an enclosure that meets those specific needs.

The technological advances made in network equipment has brought about a need for a vertical integration of computer components. Designers are therefore utilizing the 19-in. rack-mount standard as they design and plan their system implementation. As these emerging technologies continue to drive the need for value-packaged solutions, enclosure manufacturers will serve as packaging partners to provide cost-effective, flexible solutions.

GEORGE CORREIRA, electronics product manager at Rittal Corp., has more than 13 years of experience with mechanical, electrical, and electronic packaging. He currently specializes in system-level packaging and EMC applications.

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MANUFACTURERS OF ENCLOSURES

Manufacturer	Enclosure configurations	Bus structures	Backplane sizes	System cooling options	Drive bays	Power-supply options	Is shielding available?
STRONGBOX **Culver City, Calif.** **(310) 305-8288** **CIRCLE 596**	Rackmount chassis (heavy-duty)	Configured by user to support bus structure of choice	N.A.	Convection or user-configured	N.A.	Configured and supplied by user	No (enclosures are shieldable by user)
TDJ Co. Inc. **San Diego, Calif.** **(619) 276-5920** **e-mail: order@tdj.com** **CIRCLE 597**	Desktop, rackmount (MIL-STD-189)	None	None	None	None	None	No
Tracewell Enclosures **Westerville, Ohio** **(614) 846-6175** **CIRCLE 598**	Desktop, rackmount, tower, ruggedized, COTS, test stands	VME, VXI, Multibus II, PCI, ISA, EISA, custom	Each bus structure has range of standard sizes and slots	Positive- and negative-pressure forced air	Up to 64 drives in custom units	Various OEM supplies and custom solutions with dc-dc converters	Yes, to FCC Class A and B
Vector Electronic Co. **Sylmar, Calif.** **(800) 467-3331** **http://www.vectorelect.com** **e-mail: inquire@vectorelect.com** **CIRCLE 599**	Desktop, rackmount, tower, custom	VME, VXI, PCI, CPSI, PC, Multibus II	3, 5, 7, 9, 10, 12, 14, 17, 20, 21 slots	Push, pull, and push/pull combination	From 1 to 5 in any configuration required	100, 250, 300, 400, 500, 750, 1000, 1200 W	Yes, to any level required
VERO Electronics Corp. **Hamden, Conn.** **(203) 288-8001** **http://www.vero-usa.com** **e-mail: vero@vero-usa.com** **CIRCLE 600**	Desktop, rackmount, tower, and custom models	VME, VXI, PCAT, STE, G96, G64, Multibus I/II	All possible variations from 1 to 21 slots	Standard and intelligent fan trays; custom systems	3.5 and 5.25 in. in both horizontal and vertical configurations	Any customer requirement can be met	Yes, typically 50 dB at 300 MHz and 30 to 40 dB at 1 GHz
Zoltech Corp. **Van Nuys, Calif.** **(818) 780-1800** **http://www.zoltech.com** **CIRCLE 601**	Desktop, rackmount, tower, and wall-mount on special order	VME, Q-bus, Multibus II, Sunbus, VXI	From 3 to 21 slots	Forced and/or filtered air	Up to 8 half-height or 4 full-height 5.25-in. (also 3.5 in.)	50 to 1000 W, 90 to 264 V ac, 40 to 440 Hz (also dc input)	No special shielding

N.A. = not applicable; N.S. = not specified

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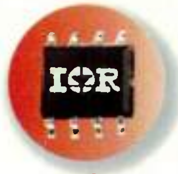

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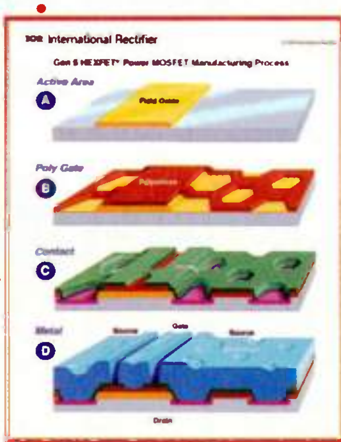

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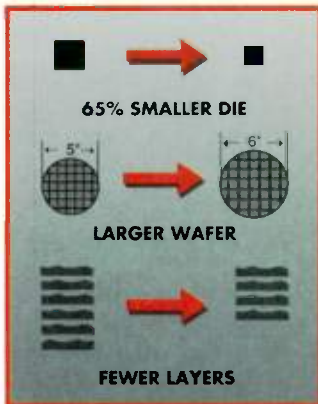

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IRFZ44	MTP50N05E	RFP45N06	STP40N05	IRFZ44N
IRFZ46	MTP50N06E			IRFZ46N
IRFZ48		RFP50N05	STVHD90	IRFZ48N
IRLZ24	MTP15N05EL	RFP14N05L		IRLZ24N
IRLZ34	MTP30N06EL	RFP25N05L	STP32N05L	IRLZ34N
IRLZ44	MTP50N05EL		STP50N05L	IRLZ44N
IRL520		RFP7N10LE		IRL520N
IRL530	MTP12N10EL	RFP12N10L		IRL530N
IRL540	MTP25N10EL			IRL540N
IRF1010	MTP60N06HD	RFP70N06		IRF1010N
IRL2203	MTP75N03HDL	RFP70N03		IRL2203N
IRL3705				IRF3705N
IRF520	MTP10N10E	BUZ72A		IRF520N
IRF530	MTP12N10E	BUZ20		IRF530N
IRF540	MTP25N10E			IRF540N
IRF1310	MTP33N10E	RFP40N10	STP40N10	IRF1310N
IRFR024	MTD10N05E	RFD14N05SM		IRFR024N
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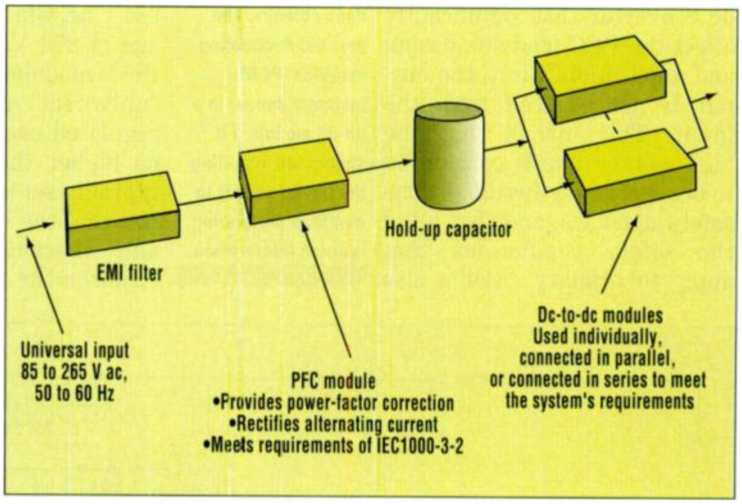
READER SERVICE 125

Configuring An Off-The-Shelf PFC Supply

BY RICHARD OKADA and STEVE KELLER
RO Associates Inc., 246 Caspian Dr., P.O. Box 61419, Sunnyvale, CA 94088; (408) 744-1450.

Here's how to design IEC-compliant compact supplies using readily available components.

Speeding up the design cycle has long been a crucial goal of design engineering, and configuring power supplies with proven, modular components can help. Power-supply design cycles are generally 75% to 85% shorter with modules than with the more traditional approach that uses discrete ICs, transistors, and magnetics. What's more, choosing modular components that already meet UL, CSA, and other agency standards makes certification of the supply as a whole a much quicker process.



1. The modular building-block approach to power-supply design enables designers to configure power supplies that meet the latest international specifications for power-factor correction. By using modules that have already been UL-approved, the design and qualification cycle is dramatically shortened.

Module-based power supplies offer a number of benefits that ultimately result in lower cost of ownership. For instance, the modules are already debugged, so field reliability is higher. Output-power capability, hot-plug-in capability, redundancy, and other features can be configured to the customer's exact needs (*Fig. 1*). Serviceability is enhanced and maintenance costs are reduced because modules can be readily replaced. And you can easily keep up with the shifting sands of IC operating voltages by substituting modules with alternate output voltages.

Another factor favoring the modular approach is the arrival of the IEC specifications that took effect last January. They place tight restrictions on the EMI and power-factor performance of power supplies sold in Europe. Many modular power-supply component suppliers, including RO Associates, offer power-factor-correction (PFC) modules and EMI-filter modules that enable designers to quickly meet the latest IEC regulations.

The following configuration suggestions were derived from the design of a 5-V power supply with PFC, N+1 redundancy, and current sharing. We'll begin by examining a schematic that shows one of the redundancy blocks for this supply (*Fig. 2*). This block is repeated N+1 times to obtain the required output power with redundancy. The design is based entirely on off-the-shelf modules, which are shown in the schematic with heavy outlines. As with most supplies, this design can be divided into two sections—an input stage and an output stage. The input stage converts the ac-input power into high-voltage dc power. The output stage then converts the high voltage dc power into isolated, low voltage output power.

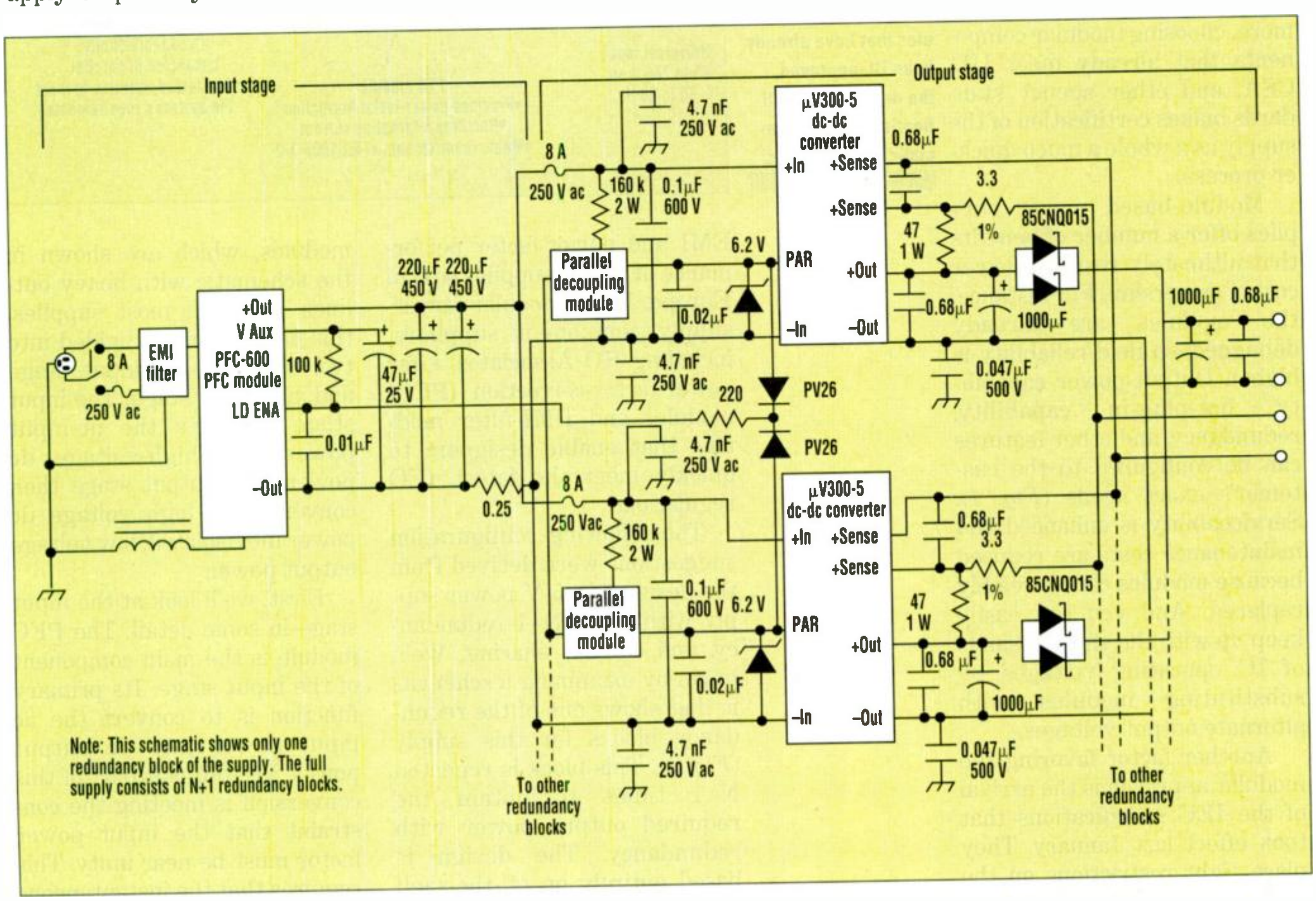
First, we'll look at the input stage in some detail. The PFC module is the main component of the input stage. Its primary function is to convert the ac input power into dc output power. The difficult part of this conversion is meeting the constraint that the input power factor must be near unity. This requires that the instantaneous input current be proportional to the instantaneous input voltage. In other words, the PFC module has to look like a resistive load to the ac power source. Power-factor regulations are set forth in the new IEC specification, IEC 1000-3-2. Most PFC modules contain a diode bridge to convert the bipolar input voltage into a unipolar, half-sine wave. They then convert the rectified voltage to a higher dc output voltage using a boost-topology dc-to-dc converter. A simplified diagram of this approach is shown (*Fig. 3*).

There are two characteristics of the boost-topology dc-to-dc converter that significantly affect the PFC module's design and application. First, the output is not isolated from the input. This means that the high-voltage bus is considered to be a "primary circuit" by the safety agencies, and that all of the safety regulations that apply to primary circuits also apply to the outputs and status signals of the PFC module.

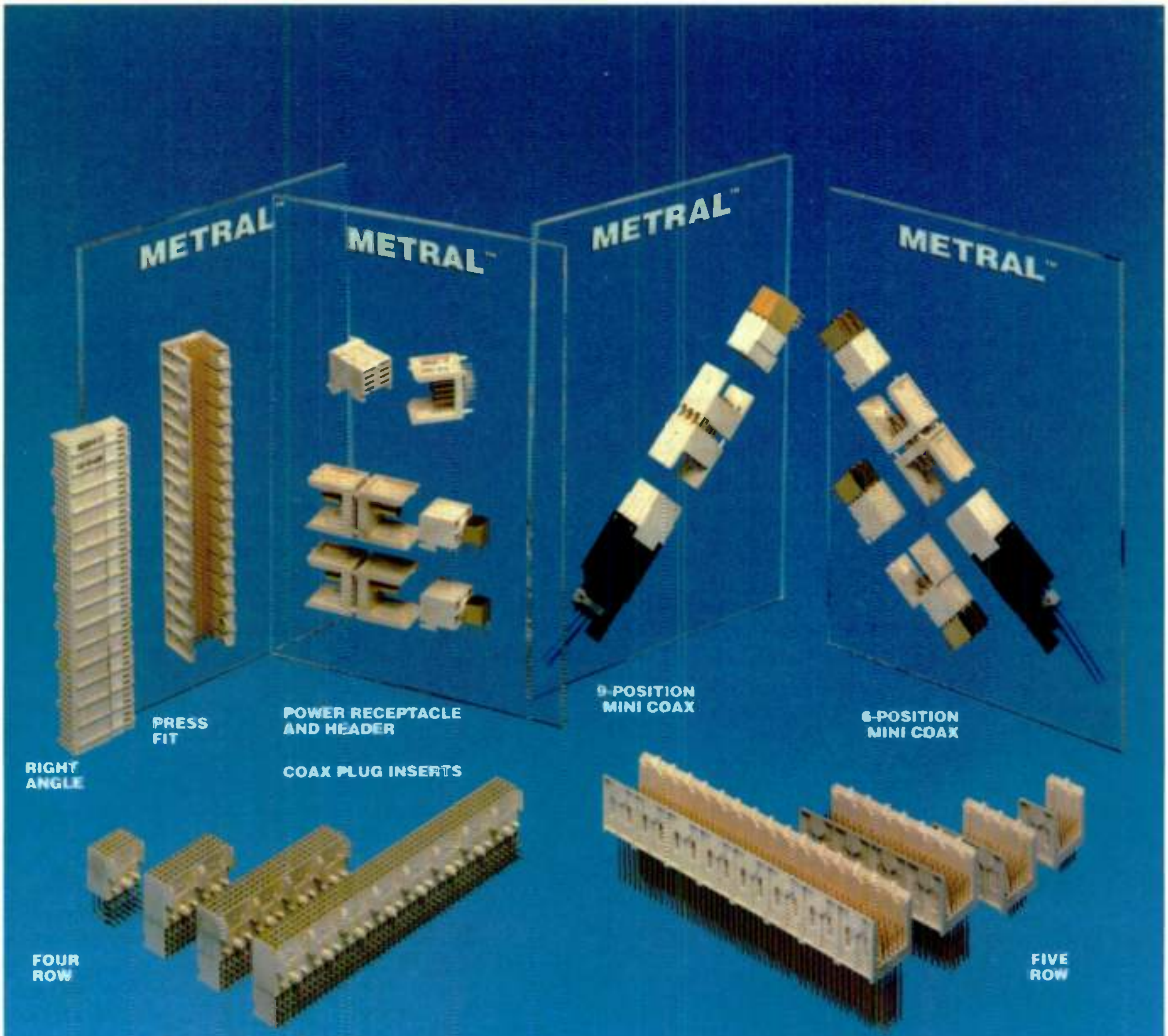
The second characteristic is that the output voltage *must always* be higher than the input voltage. This characteristic has two consequences in a PFC module: The output voltage must be very high to operate from a utility line, and the converter is not inherently protected against short circuits or current limited. A benefit of the first consequence is that if the output voltage is high enough to operate from the highest utility voltage, the module can then operate from any utility voltage. Currently, the highest utility voltage is 264 V ac, which has a peak voltage of 373 V. Therefore, for a PFC module to have a truly "universal" input range, the regulated output voltage must be higher than 373 V, and is typically set around 380 V. The fact that the boost converter is not short-circuit protected requires the module manufacturer to add a protection circuit. This is typically accomplished by placing a solid-state series switch in the output stage of the PFC module (*Fig. 3, again*).

Paralleling PFC modules for higher-power applications must be approached with great care. When PFC modules are paralleled, the internal bridge rectifiers will not share current equally between the modules. In some applications this may be acceptable as long as the total input current for the system doesn't exceed the current rating of one of the PFC rectifier diodes. High-power applications, however, require special techniques to parallel PFC modules.

There's a simple, cost effective way to force the paralleled rectifiers to properly share the return current (*Fig. 4*). This approach places a resistor (R_S) in series with the return pin of each PFC-module output. The resistor improves the current



2. This modular power supply can be easily expanded to provide more power by adding more redundancy blocks. The parallel decoupling modules (PDMs) instantly decouple a dc-dc module if it should fail, enabling the power supply to continue performing without interruption.



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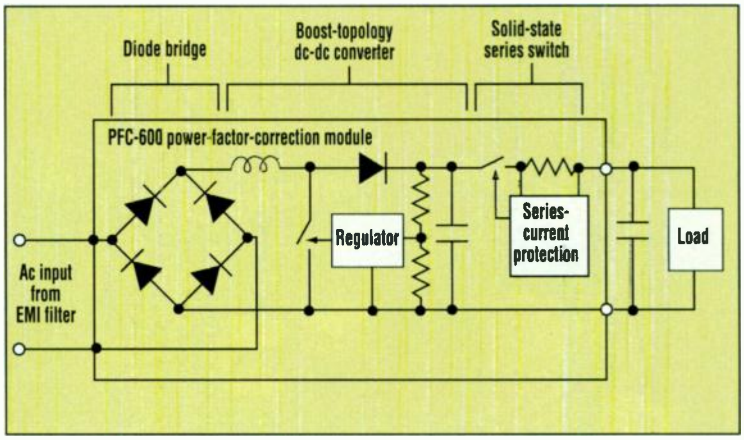
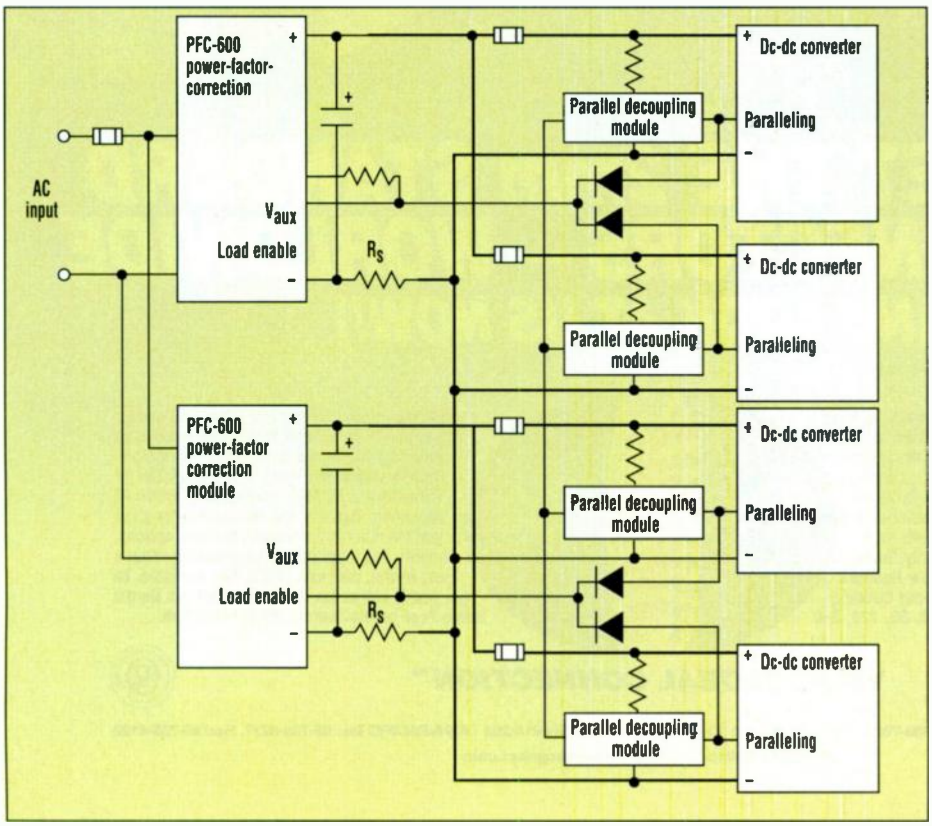
World-Wide Web Site: http://www.bergelect.com sharing by reducing the sensitivity of the return current to the voltage drop across the diode-resistor combination. Load sharing between the PFC modules is enhanced in this approach by using parallelable dc-to-dc converters. The approach shown in Figure 4 ensures PFC-module load sharing by connecting the same number of output modules to each PFC module. The fact that the output modules are sharing the load will force the PFC modules to do the same. This approach can even be extended to provide N+1 redundancy. Other approaches to load sharing use PFC modules that have built-in current-sharing provisions. These approaches are similar to those used to parallel dc-to-dc modules, which are discussed later in this article.

PFC modules require an input-EMI filter for proper operation. The filter performs two functions: It protects the external world from the switching noise generated by the PFC module, and it filters externally generated noise before it can reach and disturb the PFC module. The EMI filter should have one or more capacitors on its output (the PFC-module side) to ensure that it presents a low source impedance to the PFC module at the module's switching frequency. If the EMI filter doesn't have sufficient capacitance, or if the EMI filter is remotely located, an agency-recognized X capacitor[1] should be added across the line at the PFC module's input. Because a PFC module can generate significant amounts of high-frequency noise, it'll require a fairly large EMI filter. As a rough estimate, the volume of the filter will be two to three times the volume of the PFC module.



3. This simplified PFC-module diagram shows the basic structure of a PFC converter. Most PFC modules contain a diode bridge to convert the bipolar input voltage into a unipolar, half-sine wave.



4. A simple approach for paralleling PFC modules forces the diode bridges to share current by placing a small resistor (R_S) in the return path. Load sharing is enhanced by using current-sharing converters for the load.

For proper operation, PFC modules require holdup capacitors in addition to an EMI filter. The amount of holdup capacitance across the PFC module's output is based on the required holdup time. The holdup time is determined by the length of time that the supply must be capable of running without any input power. A typical range of holdup times is 20 ms to 50 ms. The required capacitance is calculated by balancing the energy lost by the capacitor with the energy used by the load (including the dc-to-dc converters) using:

$$C = 2PT_{hold}/(V_1^2 - V_2^2)$$

where C is the required holdup capacitance in farads, P is the load power (including the dc-to-dc converters) in watts, T_{hold} is the holdup time in seconds, V_1 is the output voltage of the PFC in volts, and V_2 is the minimum input voltage of the dc-to-dc converters in volts.

When selecting capacitors to provide the required holdup capacitance, pay attention to the capacitors' voltage and ripple-current ratings and to the minimum capacitance over the operating temperature range of the supply. Capacitors, espe-

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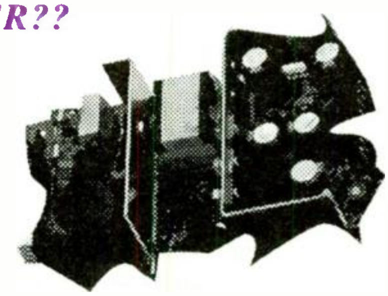

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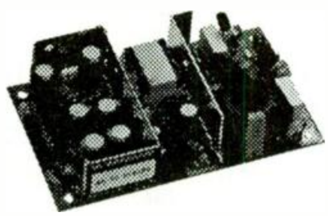

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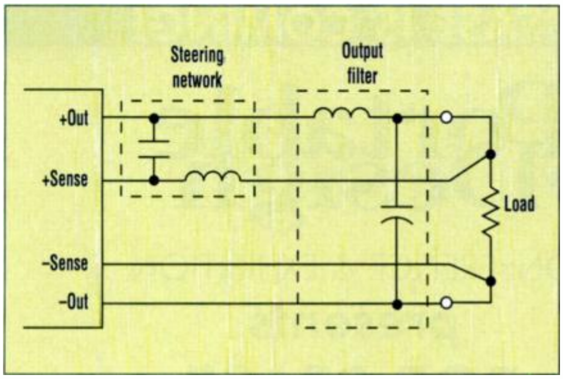


5. If both remote sensing and a low-frequency output filter are required, it may be necessary to use a frequency-selective steering network.

cially electrolytics, can lose a significant percentage of their capacity at low temperatures.

We'll now turn our attention to the supply's output stage, which is made up of one or more dc-to-dc modules that convert the high voltage from the PFC module into the desired output voltages. The first step in selecting the output modules is to determine the output voltage and current requirements. Once the designer has determined those parameters, the next step is to select the modules that will fulfill them from a supplier's catalog. Dual- and triple-output modules are more cost-effective than multiple single-output modules. The most important features to consider when selecting a module are: Cost, efficiency, footprint, agency approvals, reliability, and power density. Some other module features to consider are: Maximum operating temperature, thermal protection, parallelability, input and output overvoltage protection, short-circuit protection, and available status signals.

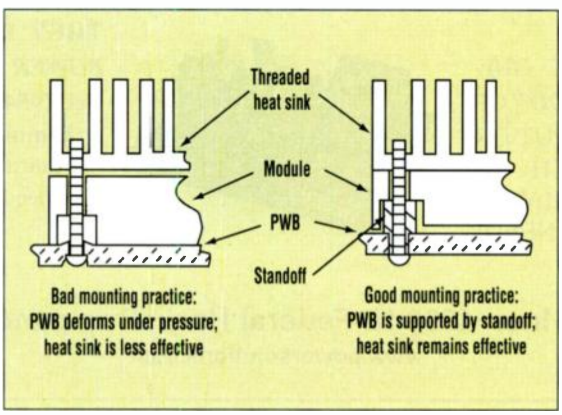
High-power systems can benefit from the advantages of modular components by connecting several dc-to-dc modules in parallel. The parallel connection allows a group of modules to achieve higher current levels than are available from a single unit. To ensure that all of the modules share the load current equally, it's necessary to connect a control signal to each module.

Output trimming allows the designer to make adjustments in the output voltage. Almost all modules that have an output-trim feature can be trimmed by ±10%. Some modules can be trimmed down by as much as 40%, albeit with slightly reduced output performance. The upper end of the adjustment range is usually limited by the overvoltage-protection circuit in the dc-to-dc module. The most common use of the trim feature is to obtain nonstandard output voltages. This allows designers to achieve nearly any output voltage while stocking only a few standard modules.

Other uses include distribution-loss compensation, voltage margining, and remote programming. When designing for an application requiring a trimmed module, the designer must observe both the maximum output power and the maximum output current ratings of the module. For example, a 200-W, 5-V, 40-A module trimmed to 4 V will only be capable of providing 160 W because of its maximum current rating.

Remote sensing moves the point of voltage regulation from the module's output to the load. This allows the module to compensate for voltage drops in the power-distribution system. The voltage drops are generally due to resistive losses in the PCB traces and connectors as well as voltage drops across ORing diodes. Most

6. Proper module mounting is essential to maintain performance over the life of the system.



modules can compensate up to 0.5 V or 10% of the nominal output voltage, whichever is greater. The limiting factor in how much drop can be compensated is the module's overvoltage-protection circuit.

Remote sensing is usually straightforward, but there are a few caveats to observe:

• The sense leads of the module must always be connected. If the design is such that the sense leads can fail open or can be left unplugged, then connect 100-Ω resistors from each sense pin to the corresponding output pin (such as from +SENSE to +OUT).

• Do not sense around a low-frequency output filter. Sensing around an output filter will place the filter in the module's feedback loop and can cause instability. Consider using trimming instead of remote sensing if your application requires an output filter whose corner frequency is near, or below, the loop-crossover frequency of the module. If both remote sensing and a low-frequency output filter are needed, it may be necessary to use a frequency-selective steering network (*Fig. 5*).

Protect the sense signals from noise sources by bypassing the sense signal at the load and shielding the sense lines. For best performance, the bypassing should consist of both an electrolytic (or tantalum) capacitor and a ceramic capacitor in parallel.

Shielding can be accomplished by using shielded twisted-pair or coax cable, or by burying the sense traces between ground planes in applications where they are routed through a PWB.

Fault tolerance is a power-supply feature that is being required much more often these days. In a fault-tolerant system, the outputs are unaffected by one or more component failures. The best way to achieve fault tolerance is to use N + M redundancy. It's here that the modular approach has the most advantages. In this scheme, N is the number of modules required to provide full power to the load, and M is the number of extra modules used in the system. M typically ranges from 1 to 3. That way, if one of the modules fails, the system still can supply full power to the load until the damaged module can be replaced.

For this scheme to work, the failed module(s) must decouple from the input power, the output power, and the current-sharing control busses without any significant effects.

Input-bus protection is accomplished by placing a fuse in series with the +IN pin of each module. The fuse should have a current rating that's higher than required by the dc-to-dc module, but is lower than the output-current rating of the PFC module. This ensures that the fuse will open if the modules fail.

The output bus can be protected by placing an ORing diode in series with each module's output. Therefore, if a module fails with a short on its output, the diode will be back-biased and the output bus will be protected. Choose diodes that exhibit a very low forward-voltage drop such as Schottky diodes. One important thing to note about a diode is that the forward voltage decreases as the diode temperature rises. Therefore, to improve efficiency, it's better to allow the diode to run a little warm under normal operating conditions. A good compromise temperature is 70° C. This allows a low forward-voltage drop without degrading reliability.

Good pc-board layout practices are critical in realizing all of the benefits of using modular components. The three key factors governing the layout of a modular power supply are grounding, noise prevention and abatement, and component mounting and placement. Keeping these factors in mind when creating the layout will speed the overall design and debug cycle.

Good pc-board layout practices are critical in realizing all of the benefits of using modular components.

We recommend using a four-layer board to implement a good grounding strategy. Use the two outer layers for split power and ground planes, and the two inner layers for low-level signals. Where necessary, add extra planes to the inner layers to beef up the high-current paths. The top layer, located closest to the modules and components, should be divided into four sections.

The goals in providing all of these sections on the top layer are: (a) to minimize the loop area of any generated noise; (b) to shield the low-level signals from noise emitted by the modules; and (c) to provide a safe place on which to mount the modules and components. The remaining layers should be designed around the top layer. Note that there shouldn't be any traces or planes crossing the gaps between the sections of the top layer. If there are, then those signals may be quite noisy and could couple noise to other traces.

The four sections of the top layer are: (1) the chassis ground plane; (2) the dc-to-dc-converter input-return plane; (3) the dc-to-dc-converter case ground plane; and (4) the power-supply output-return plane(s). The chassis ground plane provides a ground path to the EMI filter as well as shielding for the PFC module. The PFC module's case should be connected to the chassis ground plane through an inductor or ferrite bead. The dc-to-dc-converter input-return plane shields any input-referenced control signals and provides a safe mounting point for the holdup capacitors.

The case ground plane for the dc-to-dc converters provides a safety ground and shielding for the converters. If all of the converters are from the same series of a given manufacturer, then use a single plane for all of the module cases and connect it to chassis ground. Otherwise, to prevent crosstalk between the modules, you may have to isolate the converter cases from each other with inductors or beads. The output return plane is the most difficult to design. If your grounding design calls for a common return from the load to the power supply, then the output return plane should be connected to it. Otherwise, you must choose the return plane(s) carefully to avoid ground loops. This is especially true if there are output-referenced control signals that are common to all of the modules.

Noise prevention and abatement also are important facets of board design. The most effective noise-prevention strategy is to keep signal traces short. Doing so is facilitated by using SMT components where possible to reduce spacing and lead inductance.

Careful planning in the placement of the modules and components can also reduce the trace length, as well as improve the routability of the board. Keep the loop areas of all signals, especially the high-current signals, as small as possible. Large loop areas will increase the magnetic coupling between traces. Magnetic coupling is difficult to counteract because magnetic shielding is usually required instead of copper shielding. Because a pc board only uses copper conductors, the traces and ground planes may be ineffective as shields against magnetic coupling.

Loop areas can be reduced by routing signal traces next to their return paths and by shortening the length of the traces. Loop areas can also be reduced by placing bypass capacitors as close to the noise source as possible.

When laying out the pc board, always leave provisions for as many noise-abatement capacitors as possible. Consider this as risk reduction for the debug phase of your design. The most effective noise-abatement capacitors are connected from the input pins to the case and from the output pins to the case. Also effective are capacitors between the sense lines in remote-sense applications and capacitors from the parallel pin to its return pin in paralleling applications.

Proper module mounting and placement is paramount to the reliability and performance of the power supply. Improper mounting techniques can strain the leads of the module or reduce the thermal coupling between the module and its heat sink.

The most common mounting method uses screws that pass through the heat sink, module, and board with either the heat sink or the board having built-in threads to secure the screw. When using this mounting method, be careful not to rely on unreinforced pc-board material to maintain the torque on the screw.

Another benefit of using standoffs is that their height can be selected to slightly raise the module off the board for cleaning.

While some modules have a flat surface on the side against the board, most have recessed mounting holes or slots to allow for more mounting versatility. Under compression, the board material will cold-flow into the recess, reducing the tension on the screw (*Fig. 6*).

The result will be a loss of thermal coupling between the module and the heat sink, leading to higher module temperatures and lower reliability. To avoid this scenario, a standoff should be placed between the pc board and the module. A swaged standoff is preferred because the barrel passes through the board and contacts the screw head. This completely removes the compression force from the board.

Another benefit of using standoffs is that their height can be selected to slightly raise the module off the board for cleaning.

Notes:

1. An X capacitor is a capacitor that is approved by US and foreign safety agencies for use from line to neutral or line to line in non-isolated applications.

RICHARD OKADA has for 22 years been vice-president of marketing at RO Associates. Okada received a B.S. in physics from the University of California, Berkeley, in 1970, and an MBA from the University of California, Los Angeles, in

CONTINUED ON PAGE 91

READER SERVICE 151

MANUFACTURERS OF OPEN-FRAME SWITCHING POWER SUPPLIES

Manufacturer	Output power (W)	Output voltages (V dc)	Number of outputs	Input range (V ac) (Type?)	EMI shielding available?	Power factor correction available?	Industry-standard footprints?	Cooling options
Absopulse Electronics Carp, Ontario, Canada (613) 836-3511 CIRCLE 652	10 to 5000	12 to 260	One to four	90 to 240 (autoselecting depending on model)	Yes	Yes	Yes	Fans, convection, conduction
Advanced Power Solutions Pleasanton, Calif. (510) 485-1280 http://www.advpower.com e-mail: msaps@aol.com CIRCLE 653	5 to 500	3.3, 5, 12, 15, 28, 36, 48	One to five	100 to 500 W autoselecting; 5 to 100 W universal	Yes	Yes (on supplies from 80 to 500 W)	Yes	Convection or fan
American Reliance Inc. Arcadia, Calif. (818) 303-6688 http://www.amrel.com e-mail: amrel@amrel.com CIRCLE 654	30 to 1050	5 to 250	One to three	115/230 V manual	No	No	Half- and full-rack styles	Fans supplied as standard
Applied Kilovolts Portslade, Sussex, U.K. (44) 1273 439440 CIRCLE 655	5 to 250	1 kV to 60 kV	Two	24 V and 110 V ac	Cover included	No	Yes	Convection or fan
Ascent Power Technologies Concord, Ontario, Canada (905) 660-9814 e-mail: harryt@ascent.com CIRCLE 656	10 W to 4 kW (custom)	1.5 V to 100 kV	Up to 20	85 to 260	Yes	Yes	Yes	Free convection or forced-air conduction
Astec America Inc. Carlsbad, Calif. (619) 757-1880 http://www.astec.com CIRCLE 657	25 to 350	5 to 60	One to four	85 to 264; autoselecting	Yes	Yes	Yes	Convection and fan
Astrodyne Corp. Taunton, Mass. (508) 823-8080 CIRCLE 658	15 to 300	5 to 24	One to four	85 to 264; autoselecting	Yes	No	Yes	Convection or fan
Bertan High Voltage Hicksville, N.Y. (516) 433-3110 http://www.bertan.com e-mail: info@bertan.com CIRCLE 659	1 kW	500 V to 125 kV	Four or more	120/240	Yes	No	No	Air
CEC Electronics Corp. Hauppauge, N.Y. (516) 582-4422 CIRCLE 660	10 W to 1 kW	3.33 to 48	One to five	110/220, 50/60 Hz; 208, 40 to 400 Hz	Yes	Yes (single- and three-phase active PFC available)	Yes (custom types also available)	Convection and conduction
Celestica Inc. North York, Ontario, Canada (416) 448-4524 CIRCLE 661	300 W to 2 kW	5 to 48	One to eight	90 to 264, autoselecting	Yes	Yes (standard)	Yes	Fans are optional
Computer Products South Boston, Mass. (617) 464-6656 CIRCLE 662	25 W to 1 kW	3.3 to 48	One to five	85 to 264, autoselecting	Yes	Yes	Yes	Optional fan or convection cooling
Condor DC Power Supplies Oxnard, Calif. (805) 486-4565 e-mail: condordc@condorpower.com CIRCLE 663	20 to 400	3.3, 5, 12, 15, 24, 48	Up to five	85 to 264, universal input	Yes	Yes (on 350-W units)	Yes	Convection or fan
Conversion Equipment Corp. Orange, Calif. (714) 637-2970 CIRCLE 664	85 W to 1 kW	2 to 250	Up to seven	85 to 265, autoselecting or universal inputs available	Yes	Yes	Yes	Convection (no fan), fan-cooled, and conduction
Converter Concepts Inc. Pardeeville, Wisc. (608) 429-3000 CIRCLE 665	10 to 350	5 to 48	One to four standard (more on custom basis)	90 to 264, universal	Yes	Yes (on select models)	Many models have standard footprints	Fans (optional)

MANUFACTURERS OF OPEN-FRAME SWITCHING POWER SUPPLIES

Manufacturer	Output power (W)	Output voltages (V dc)	Number of outputs	Input range (V ac (Type?)	EMI shielding available?	Power factor correction available?	Industry-standard footprints?	Cooling options
Custom Power Ronkonkoma, N.Y. (516) 467-5328 http://www.custompower.com e-mail: sales@cps.mhs.compuserve.com CIRCLE 666	Custom	Custom	Custom	24 to 310, autoselect is optional	Yes	Yes	Yes (custom types also available)	Convection, conduction, liquid
Deltron Inc. North Wales, Pa. (215) 699-9261 CIRCLE 667	40 W to 2 kW	5 to 48	One to seven	115/230; optional autoranging from 90 to 264 V	Yes	Yes	Yes	Fan standard/ optional
Digital Power Corp. Fremont, Calif. (510) 657-2635 CIRCLE 668	50 to 750	±2 to ±60	One to four	90 to 132 or 180 to 264 (some units autoselecting; others true universal input	Yes	Yes	Yes	Convection and internal or external fan
ETA-USA San Jose, Calif. (800) 382-7697 CIRCLE 669	10 W to 4 kW	2 to 52	One to five	85 to 254, autoranging	Yes	Yes	Yes	Convection or forced air
GlobTek Inc. Northvale, N.J. (201) 784-1000 http://gramercy.ios.com/~globtek e-mail: globtek1@chelsea.ios.com CIRCLE 670	10 W to 1 kW	3 to 48	One to five	90 to 260; autoselecting	Yes	Yes	Yes	Convection and forced air
Integrated Power Designs Wilkes-Barre, Pa. (717) 824-4666 CIRCLE 671	45 to 300	2 to 48	One to five	85 to 264	Yes	Yes	Yes	Convection
International Power Sources Inc. Ashland, Mass. (508) 881-7434 CIRCLE 672	15 to 200	5 to 48	One to four	85 to 264; universal	Yes	No	Yes	Fan or optional cover with fan on unit
Jerome Industries Corp. Elizabeth, N.J. (908) 353-5700 e-mail: jeromeIND@aol.com CIRCLE 673	Up to 250	5 to 48 (plus multiple outputs)	Up to seven	85 to 264; autoselecting	Yes	Yes	Yes	Convection and fan
Keltron Power Systems Waltham, Mass. (617) 894-8700 e-mail: keltron@tiac.com CIRCLE 674	10 to 600	5 V to 50 kV	One to four	Autoranging ac or dc inputs	Yes	Yes	Yes	Convection or air flow
Kepco Inc. Flushing, N.Y. (718) 461-7000 http://www.kepcopower.com e-mail: hq@kepcopower.com CIRCLE 675	3 to 1500	3 to 48	Up to four	85 to 264, wide range	Yes	Yes	Yes	<300 W: convection; >300 W: forced air
LZR Electronics Gaithersburg, Md. (301) 921-4600 CIRCLE 676	1 to 500	1 to 200	One to four	90 to 265, autoselecting	Yes	Yes	Yes	N.S
Lambda Electronics Inc. Melville, N.Y. (516) 694-4200 http://www.lambdapower.com CIRCLE 677	10 to 450	2 to 48	One to four	85 to 264, autoselecting	Yes	Yes	Yes	Convection or forced air
Lutze Inc. Charlotte, N.C. (704) 357-8835 e-mail: info@lutze.com CIRCLE 678	0.04 to 50 A	24 V dc	15	24 to 575	Yes	No	Yes	N.S

MANUFACTURERS OF OPEN-FRAME SWITCHING POWER SUPPLIES

Manufacturer	Output power (W)	Output voltages (V dc)	Number of outputs	Input range (V ac) (Type?)	EMI shielding available?	Power-factor correction available?	Industry-standard footprints?	Cooling options
Modular Devices Inc. Scotts Valley, Calif. (408) 335-3562 e-mail: tommdi@aol.com CIRCLE 679	150 W to 4 kW	1.2 to 400	As required	Autoselecting	Yes	Yes	Yes (select models)	As required
Multicomp Beaverton, Ore. (503) 626-4200 CIRCLE 680	3 to 600	5 to 75	Up to six	90 to 264, autoselecting	Yes	Yes	No	Convection and forced air
Oryx Power Products Mt. Prospect, Ill. (847) 635-6222 CIRCLE 681	30 to 400	±5 to ±24	One, three, or four	90 to 264, N.S.	Yes	Yes	Yes	Convection and forced air
Phihong USA Milpitas, Calif. (408) 946-7888 http://www.phihongusa.com CIRCLE 682	10 to 200	+5 to +24, -15 to -5	Up to four	90 to 264 universal; 90 to132/ 180 to 264 autoranging	No	No	Yes	Convection or 20- or 30-cfm fans
Pico Electronics Power Supply Div. Mt. Vernon, N.Y. (914) 699-5514 e-mail: HLSC73@prodigy.com CIRCLE 683	30 to 200	5 to 24	Up to four	85 to 264, autoranging	No	Yes	Yes	Fan
Power General Canton, Mass. (617) 828-6216 e-mail: powergeneral@ nidecpg.com CIRCLE 684	20 to 250	3.3 to 28	Up to four	85 to 265, universal; 90 to 265, autoranging	Yes	Yes	Yes	Convection and forced air
Power-One Camarillo, Calif. (805) 987-8741 http://www.power-one.com CIRCLE 685	30 W to 4 kW	2 to 120	Up to 21	85 to 264, N.S.	Yes	On some products	Yes	Fan or convection
Power Solutions Inc. Pompano Beach, Fla. (954) 943-4110 CIRCLE 686	15 to 350	±2 to ±60	One to four	85 to 264, universal	Yes	350-W models only	Yes	Fan optional on most models
Power Switch Corp. Lodi, N.J. (201) 478-0800 e-mail: pwrswitch@aol.com CIRCLE 687	10 to 400	3.3 to 48	One to five	85 to 264, N.S.	Custom	Yes	Yes	Convection and forced air
Rantec Microwave & Electronics Inc. Power Systems Div. Los Osos, Calif. (805) 528-5858 CIRCLE 688	10 W to 1 kW	5 to 28	Multiple on custom models; three on standard products	85 to 270	Yes (on HDM high-density modules)	Yes	Yes	Baseplate cooling
Shindengen America Rolling Meadows, Ill. (708) 593-8585 CIRCLE 689	5 to 130	5 to 48	One to four	85 to 264, N.S.	Yes	Yes	Yes	Convection
Sierra West Power Systems Las Cruces, N.M. (505) 522-9928 CIRCLE 690	5 W to 3 kW	2 to 300	One to five	90 to 135, 180 to 270, autoselecting	Yes	Yes	Yes	Conduction or convection
Switching Power Inc. Ronkonkoma, N.Y. (516) 981-7231 http://www.switchpwr.com e-mail: sales@switchpwr.com CIRCLE 691	100 to 800	2 to 48	Five	90 to 264, selectable or autoselecting	Yes	Yes	Yes	Side fan, top fan, or customer cooling options

CONTINUED FROM PAGE 86

1972. Before joining RO Associates, Okada worked at Hughes Aircraft as a member of the technical staff.

STEVE KELLER develops power-supply products and supports customer applications for RO Associates. Keller earned a BSEE from Arizona State University, Tempe, in 1986, and an MSEE from Santa Clara University in 1993. Before joining RO Associates, Keller spent nine years at Kaiser Electronics designing analog and power circuitry for military airborne display systems.

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MANUFACTURERS OF OPEN-FRAME SWITCHING POWER SUPPLIES

Manufacturer	Output power (W)	Output voltages (V dc)	Number of outputs	Input range (V ac) (Type?)	EMI shielding available?	Power factor correction available?	Industry-standard footprints?	Cooling options
Tamura Corp. Temecula, Calif. (909) 694-8350 CIRCLE 692	10 to 500	3.2 to 48	One to four	85 to 264, N.S.	No	Yes	Yes	Convection, forced air
Tectrol Inc. Downsview, Ontario, Canada (416) 630-8108 CIRCLE 693	5 W to 4 kW	2 to 400	One to 15	85 to 265, autoselecting	Yes	Yes	Yes	Natural convection and fan cooling
Technology Dynamics Bergenfield, N.J. (201) 385-0500 CIRCLE 694	25 to 600	3 to 500	Four	90 to 264, autoselecting	Yes	No	Yes (on select models)	Forced air, hard mounting
Tektris Electro Corp. La Mesa, Calif. (619) 593-5000 http://www.tektris.com CIRCLE 695	5 to 600	2 to 300	One to five	85 to 265, autoselecting	Yes	Yes	Yes	Convection, fans
Todd Products Corp. Brentwood, N.Y. (516) 231-3366 CIRCLE 696	150 to 1500	2 to 60	Up to four	90 to 264, universal	Yes	Yes	Yes	Self or external
Transistor Devices Inc. Cedar Knolls, N.J. (201) 267-1900 http://www.transdev.com e-mail: info@mailer.transdev.com CIRCLE 697	500 and up	2 to 56	One to five	85 to 265, autoselecting	Yes	Yes	N.S.	Free air or fan
Tri-Mag Inc. Visalia, Calif. (209) 651-2222 CIRCLE 698	10 to 350	2.7 to 350	One to six	85 to 265, autoselecting or universal	Yes	Yes	Yes	Convection or forced air
Tri Source Inc. Shelton, Conn. (203) 924-7030 CIRCLE 699	50 W to 1 kW	3.3 V to 4 kV	Five	90 to 130, 180 to 264, autoselecting	Yes	Yes	Yes	Convection or internal fan
Unipower Corp. Coral Springs, Fla. (954) 346-2442 CIRCLE 700	150 to 500	2 to 48	One to five	90 to 132, 180 to 264, jumper or autoselecting; also 90 to 264, universal	Yes (cover includes fan)	Yes (to 0.99)	No	Open frame with forced air or cover with fan
Wilmore Electronics Co. Hillsborough, N.C. (919) 732-9351 CIRCLE 701	5 to 700	5 to 130	One to five	86 to 264, wide range	Yes (offer both open-frame and enclosed units)	Yes	Standard and custom	Convection
Xentek Power Systems San Marcos, Calif. (619) 471-4001 CIRCLE 702	Up to 500	5; 4.5 to 8; 8 to 16; 16 to 28; 5, 12, 15, or 24	Up to seven	90 to 264, autoselecting	Yes	No	Yes	Fan

N.A. = not applicable; N.S. = not specified

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SCSI Connectors Close The EMI/RFI Gap

BOB THORNTON
Fujitsu Takamisawa America Inc., 250 E. Caribbean Dr., Sunnyvale, CA 94086; (800) 380-0059.

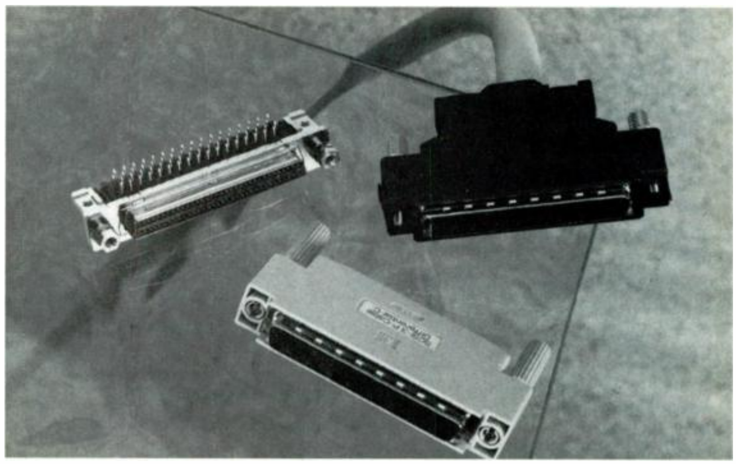
Enhanced SCSI connectors help snuff out radiated emissions in high-speed systems.

Due to SCSI's escalating popularity and its enhanced performance, system designers face a new cadre of challenges, some of which can be met by using novel SCSI-connector designs. The challenges include EMI/RFI in high-speed workstations, weight considerations in laptop computers, and support for plug-and-play peripherals.

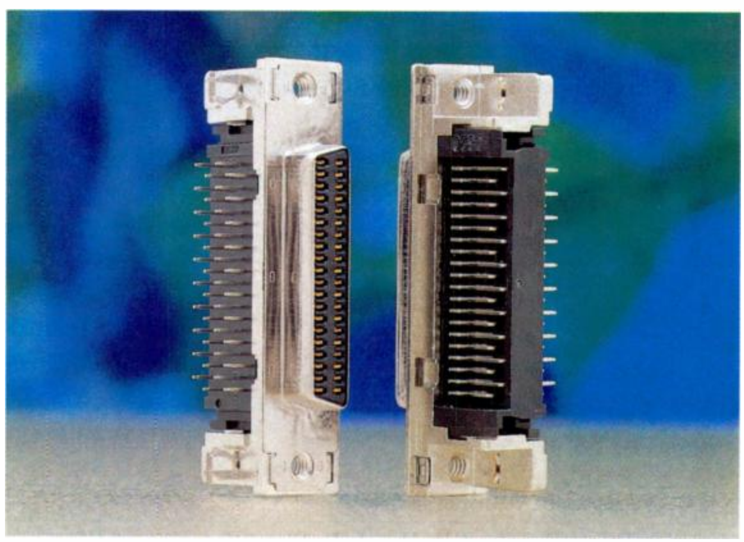
In these three instances, applying simple, yet profound, engineering ideas to SCSI connectors achieves design goals that could otherwise have been far more costly to attain. And in the case of the plug-and-play connector, the Fujitsu design may become an open industry standard.

Designers have long been challenges by the effects of EMI/RFI. SCSI-3 is a high-performance interface typically used in high-speed workstations. Pentium Pro systems run at clock speeds of 150 MHz, for example, and some RISC-based workstations operate at speeds exceeding 200 MHz. Such high-speed signals can radiate through the smallest aperture in the workstation's case, creating EMI/RFI for nearby equipment.

Conventional SCSI connectors have slight gaps where the stamped part of the connector shell (sometimes referred to as the connector's "nose") attaches to the die-cast connector frame (*Fig. 1*). In earlier generations of SCSI-equipped workstations, these gaps posed no problems because they were smaller than the wavelength of the fastest clocks generated inside the workstation case. Now, however, the wave-



1. In conventional SCSI connectors, small gaps from the tabs (which attach the stamped part of the connector shell to the die-cast body) allow EMI and RFI to escape from workstations with extremely high clock speeds.



2. By redesigning the SCSI-3 connector, the stamped nose of the connector extends over the die-cast body. This moves the gaps from the attachment tabs to the far ends of the connector. The workstation's chassis overlaps the gaps and blocks the escape of EMI/RFI. The design also provides a continuous ground plane for ESD from the SCSI cable.

lengths are short enough to allow electromagnetic interference to escape through the gaps. This situation makes it difficult for systems manufacturers to meet FCC regulations.

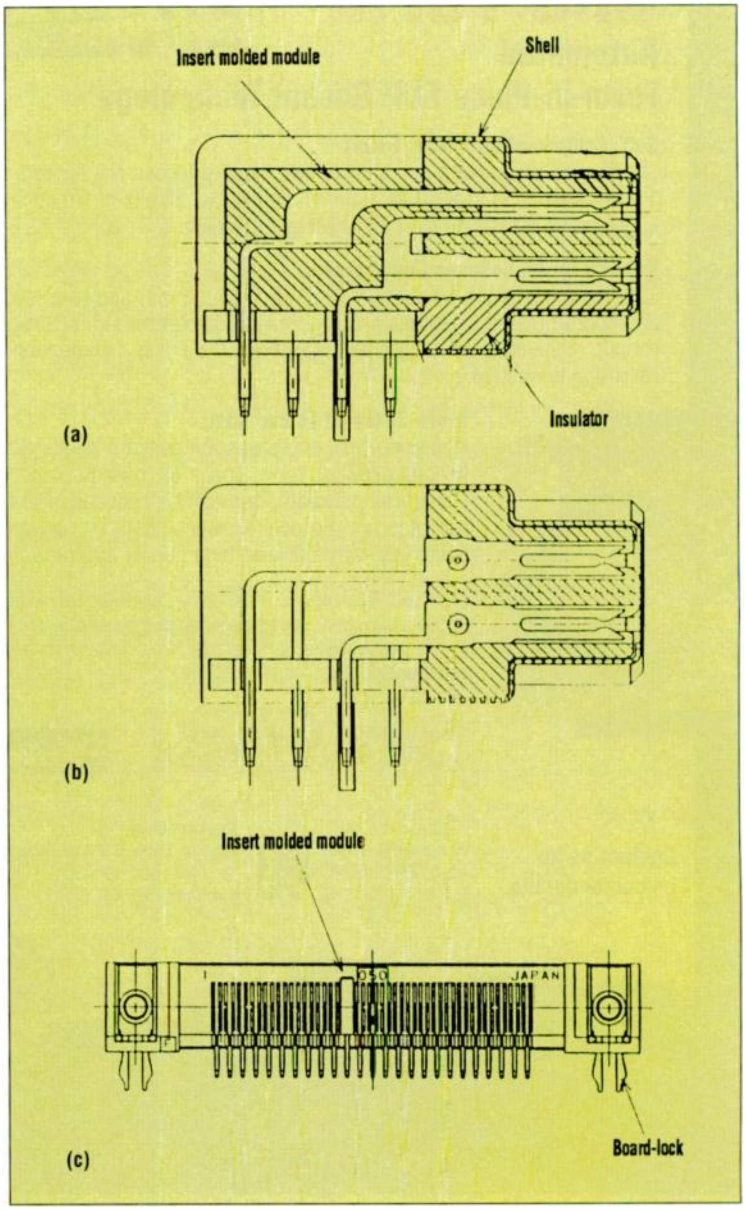
Eliminating this problem required a rethinking of connector design. All high-performance connectors are made with a stamped nose and a die-cast body, which blocks EMI from passing through the connector. The stamped nose has to fasten onto the body somehow, and doing that with the conventional tabs leaves inevitable gaps. Making radical changes to this tried-and-true design could push connector costs up prohibitively.

The elegant solution is to extend the stamped part of the SCSI-3 connector shell over the die-cast body so that the attachment holes are at the extreme ends of the connector (Fig. 2). The workstation's chassis thus overlaps the gaps, blocking the propagation of any EMI from the connector body. The design also provides a continuous ground plane, which ensures that any electrostatic discharge from the SCSI cable is grounded.

Benefits stemming from this design change aren't confined to SCSI-3, of course. Any connector for high-speed applications can take advantage of the same method. In addition to SCSI-3, for example, Fujitsu is using this connector configuration for 40-pin Media Independent Interface (MII) connectors.

Another challenge facing system designers involves weight considerations in laptop computers and other portable devices. The increasing popularity of SCSI peripherals gives laptop computer makers a reason to integrate a SCSI connector into their products. Conventional SCSI-2 connectors are fairly heavy, however, because of their die-cast construction. The manufacturing

3. Using a molded rather than die-cast construction for SCSI-2 connectors reduces the weight and cost of the connector for applications such as laptop computers, desktop PCs, and removable disk and tape drives.



4. A SCSI-2 connector that enables plug-and-play operation for peripherals employs a tiny molded module that has a split pin (a). When a mating connector is plugged in, the split pin is shorted, indicating to the system that a peripheral was added. The molded part of the module is on the left, and it inserts into a standard connector body just like any typical pin (b). A view of the entire connector shows how the module is inserted among the other pins (c).

process used to fabricate die-cast parts also makes these connectors more expensive than cost-conscious laptop computer makers would like.

Fortunately, because today's laptop computers run at lower speeds than those of high-performance workstations, EMI isn't as much of a problem. Therefore, it's possible to reduce the weight of the SCSI-2 connector by using a molded construction instead of a die-cast one (*Fig. 3*). This connector weighs far less than die-cast versions and is more economical, while delivering the same level of performance as conventional SCSI-2 connectors.

The lower cost of the molded SCSI-2 connector offers benefits for any type of system, whether weight is an issue or not. Desktop systems, especially for cost-sensitive consumer applications, are prime candidates for these connectors. Removable disk and tape drives also can take advantage of both the lightweight and low-cost characteristics.

Yet another challenge that is gaining popularity is support for plug-and-play peripherals. In this instance, a large peripherals manufacturer wanted a SCSI-2 connector that would allow the system to know when a peripheral was plugged in. If a PC has a way to detect when a CD-ROM is plugged into the SCSI port, for example, the system can tell when to begin automatic transactions to set up the CD-ROM's operation. This capability would allow manufacturers to extend the PC's internal plug-and-play feature to peripherals outside the PC.

One way to detect the presence of a new peripheral (or have the peripheral itself detect when it's plugged in) is to have a pin in the male SCSI connector short together two contacts in the female connector. When the peripheral is plugged in, the shorted pins allow the peripheral to detect the event.

The challenge in this application was to come up with a solution that had minimum impact on the existing connector design. All SCSI-2 peripherals need to be able to use the same connectors, on the same daisy-chained cables, whether enabled for plug-and-play operation or not. Adding new pins to the connector or otherwise changing the connector's configuration was not an option.

Besides, changing the basic SCSI-2 connector too much would lead to excessive cost increases. As with the EMI-blocking SCSI-3 connector (and most other engineering challenges), designing an expensive solution would have been straightforward. Creating a design that would minimize costs required more creativity.

Another difficulty in creating the new design was the need to make the solution robust enough for day-to-day use. The contacts in a female SCSI connector are quite small. Ordinarily, they would be fragile if divided, Therefore, they could short together when a pin from the mating connector is inserted.

The way to meet this challenge is to create a modular insert that replaces two sets of contacts in an otherwise conventional SCSI-2 connector (*Figs. 4a, 4b, and 4c*). One set of contacts is divided in half so that the mating pin can short the halves together, yet the contacts are solidly encased in the module and connector body for added strength.

As shown, pins 11 and 36 in the module short together when mated with a male connector (*Fig. 4*). Both of these pins are usually connected to ground. Without changing the normal functions of these pins, therefore, the connector allows the system to detect when the pins are shorted together.

This technique also allows a SCSI system to be self-terminating. If a peripheral detects that neither a terminator nor another peripheral is plugged into the second SCSI port, the peripheral knows it's at the end of the daisy chain and should terminate the SCSI lines. This arrangement ensures that proper termination is used and simplifies SCSI use for consumers, who have little desire to keep track of SCSI technical requirements.

From a manufacturing perspective, the molded module suppresses costs because it has a minimal impact on the existing SCSI-2 connector design. The module simply replaces two of the female pins that would typically occupy slots in the connector's shell. The other parts of the new connector remain identical to the existing design. The only new expense is in stamping out the pins for the module, injection-molding it, and then substituting it for the existing pins in the connector assembly process.

All three of the connectors described here make SCSI easier to design into various types of systems. The EMI-blocking design opens the way for any connector to function in high-speed applications, where noise could be a problem. The light-weight molded design offers a breakthrough for both weight- and cost-sensitive applications. And the insertion-detecting design enables the first true plug-and-play functionality for peripherals. With relatively modest changes, these connector designs give new capabilities to designers.

BOB THORNTON, product marketing manager of interconnect products at Fujitsu Takamisawa America Inc., is responsible for new-product development, pricing, planning, and technical marketing. Thornton is a graduate of San Jose State University.

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MANUFACTURERS OF PCMCIA (PC CARD) CONNECTORS

Manufacturer	Connector offerings	Available types	Mounting style	Ejection mechanisms	Are *card.bus* versions offered?	Are they keyed to accept 3 or 5 V?	Elevated versions?
AMP Inc. Harrisburg, Pa. (800) 522-6752 http://www.amp.com CIRCLE 602	Single- and dual-slot types	Through-hole and SMT	Inverse-mountable (separate port)	Right- and left-hand; with EMI ground clips	Yes	3 and 5 V	Yes; both through-hole and SMT
Berg Electronics Camp Hill, Pa. (717) 730-4702 http://www.bergelect.com CIRCLE 603	Single- and dual-slot types	Through-hole and SMT	Inverse-mountable	Right- and left-hand; with EMI ground clips	Yes	3 and 5 V	Yes; both through-hole and SMT
Fujitsu Takamisawa America Sunnyvale, Calif. (408) 745-4900 http://www.fujitsufta.com CIRCLE 604	Single- and dual-slot types	Through-hole and SMT	Inverse-mountable	Right- and left-hand; with EMI ground clips	Yes	3 and 5 V	Yes; both through-hole and SMT
Hirose Electric Simi Valley, Calif. (805) 522-7958 e-mail: box%725-9483 @mcimail.com CIRCLE 605	Single- and dual-slot types	Through-hole and SMT	Top-mount only	Right- and left-hand; with EMI ground clips	Yes	3 and 5 V	Yes; both through-hole and SMT
JST Corp. Waukegan, Ill. (847) 473-1957 CIRCLE 606	Single- and dual-slot types	Through-hole and SMT	Top-mount only	Right- and left-hand; with EMI ground clips	Yes	5 V only	Yes; both through-hole and SMT
Methode Electronics Inc. Chicago, Ill. (708) 867-9600 CIRCLE 607	Single- and dual-slot types	Through-hole types	Top-mount only	Left-hand only	No	5 V only	No
Robinson Nugent New Albany, Ind. (812) 941-3576 e-mail: rnmktg@iglou.com CIRCLE 608	Single- and dual-slot types	Through-hole and SMT	Inverse-mountable and top-mountable	Right- and left-hand; with EMI ground clips	In development	3 and 5 V	Yes; through-hole only

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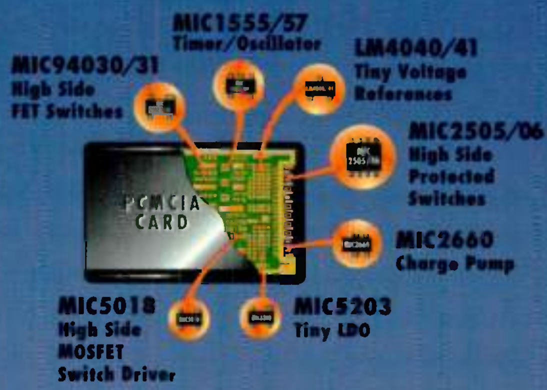

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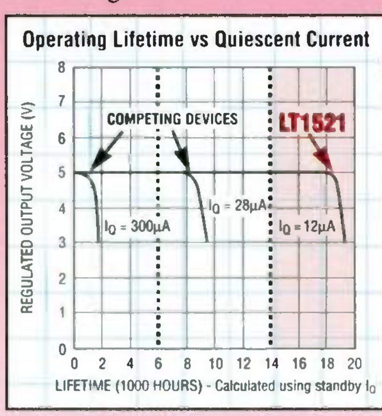
LT1521: 300mA Output 12µA I_Q
LT1529: 3A Output 50µA I_Q

Squeeze even more life out of your batteries with the LT1521 micropower low dropout regulator. The LT1521's ultralow quiescent current, low dropout, and intelligent protection features will maximize useful battery life in your portable product. The LT1521 supplies up to 300mA of output current and operates with a quiescent current of just 12µA. The dropout voltage is only 0.5V at 300mA output current. The LT1521CS8 includes a shutdown feature which drops quiescent current down to 6µA. This is below the self-discharge current of most batteries.



For protection features you can't beat the LT1521. It has built-in protection against reverse input voltages up to 20V and no reverse voltage will appear at the output. The LT1521 also has reverse output current protection. If the output is held higher than the input by a backup battery or other voltage source, no reverse current will flow from the output back to the input; and only 6µA will flow from the output to ground. These protection features eliminate the need for protection diodes.

Current limiting and thermal limiting give complete overload protection.

The LT1521 saves board space by using 1.5µF surface mount ceramic capacitors. The LT1521 is supplied in 8-lead SO and 3-lead SOT-223 packages. Fixed output voltages of 3.0V, 3.3V and 5V are available, as well as an adjustable version with an output range of 3.75V to 20V. For higher current applications or applications requiring high surge currents, the LT1529 can be used. The LT1529 can supply 1.5A of output current with a dropout voltage of just 0.4V and a quiescent current of just 50µA. Dropout at 3A increases to only 0.6V. The LT1529 has the same protection features as the LT1521. Pricing begins at $2.10 in 1000 piece quantities.

For more details, contact Linear Technology Corporation, 1630 McCarthy Blvd., Milpitas, CA 95035. 408-432-1900. Fax: 408-434-6441. For literature only, call **1-800-4-LINEAR.**

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