

## SPOTLIGHT

# Linear PSUs—still a cost-effective solution

A number of changes have been seen by the power supply industry over the last few years. One reason for this is that as the IC industry has developed, other associated industries have had to meet the demands imposed upon them by this growth.

This *Spotlight* feature looks at these advances together with the impact that the "new" IC technology has made on the power supply industry.

### High spec at low cost

The main advantage of linear power supplies is their excellent specification for low cost. The linear power supply available now is the result of many years' experience in design and build. These are shown clearly in the latest generation in the form of reductions in both cost and size whilst a very high specification is maintained. It must be stated, however, that as a result of their design, linear power supplies are notoriously inefficient; the most efficient return figures of approximately 30%.

The high overall specification of linear units (efficiency aside) is necessary for the unit to survive. The large demand for very low ripple, very stable and reliable power sources has resulted in the linear power supply maintaining its position in the market in spite of the ever increasing range of switch mode PSUs.

The large number of control ICs for both switch mode and linear PSU applications is evidence of the considerable effort that IC and instrument manufacturers are required to make to keep up with the power supply industry itself, which is continually seeking to lower the cost per Watt of PSUs, whilst improving reliability.

### Optimised for lower power applications

It is at the lower power end of the market that the linear PSU is most

competitive in terms of both price and specification. The result of this is that the under 25W market is totally dominated by this type of device, in its many shapes and forms. At higher power, the switch mode supply tends to dominate due to its high efficiency (typically around 70%) and low weight, unless other parameters take precedence (eg, low ripple and noise).

The move to encapsulation over the past ten years has resulted in the emergence of a new breed of linear PSU which is very rugged and reliable. The 'fit and forget' philosophy is at the

heart of the power supply industry. This has been realised by relying on tried and tested products thus making use of cost effective solutions to PSU problems.

Another advantage of linear PSUs is their versatility: they may be adapted to cope with customers' special requirements in terms of voltage, current and overload characteristics. This also means that they make ideal components for programmable power supplies, available with output voltage and current programmable by resistance or voltage. There are now

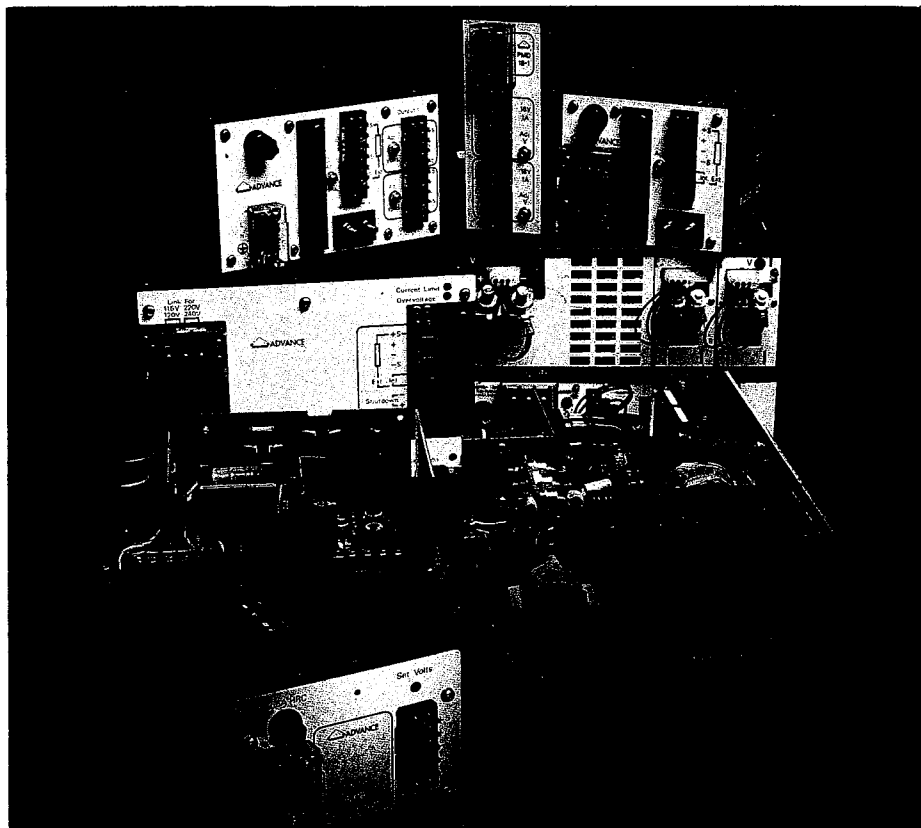
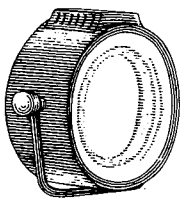


Fig. 1 A selection of products from Advance Power Supplies showing both modular and open frame power supplies



## SPOTLIGHT 2

interfaces available to connect power supplies to the IEEE488 bus.

### Construction determines cost

The majority of power supply specifications require that relatively low voltage DC outputs (usually stabilised) be derived from 50 or 60Hz ac inputs. Conventionally this means that a linear regulator is heavy, bulky and ineffectual. The minimum possible cost is determined by the sheer bulk of raw materials used in its construction. These are predominantly iron or steel (in the input transformer and chassis), copper (in the transformer windings and wiring) and aluminium (in the electrolytic capacitors and heatsinks—required to cool the power dissipating components).

In the case of the conventional linear regulator, approximately 80% of the bulk of the unit is accounted for by transformers, reservoir electrolytic capacitors and heatsinks.

### Standards favour indigenous manufacture

Standards relevant to power supplies are in existence but not one of these is *specifically* designed to apply to power supplies, and therefore many irrelevancies complicate the picture. The accompanying box stories aim to clarify the jungle of cross-related standards.

The most permanent standards in Europe are VDE 0871 for rfi and VDE 0806 for isolation. The problem is that typically it costs a PSU manufacturer £5k to put a particular model through total VDE approval. Thereafter the item requires re-submission following any change—even a change in resistor value—which seriously limits the manufacturer's flexibility. In consequence, the expression "meets VDE" or (more accurately) "designed to meet VDE" appears in data sheets much more often than "approved to". This does not necessarily imply that the PSU is in any way inferior to a fully approved item, just that there are no independent guarantees on safety/rfi.

In the USA, the situation is somewhat different. Much as BS9000 offers a 'blanket' approval of production/QA lines, FCC and UL have schemes to endorse manufacturers in-house test facilities. With UL in effect providing fire insurance and FCC radio interference specs now mandatory, the US standards obviously favour indigenous manufacturers in the same way that BT approval (TG26) does in the UK.

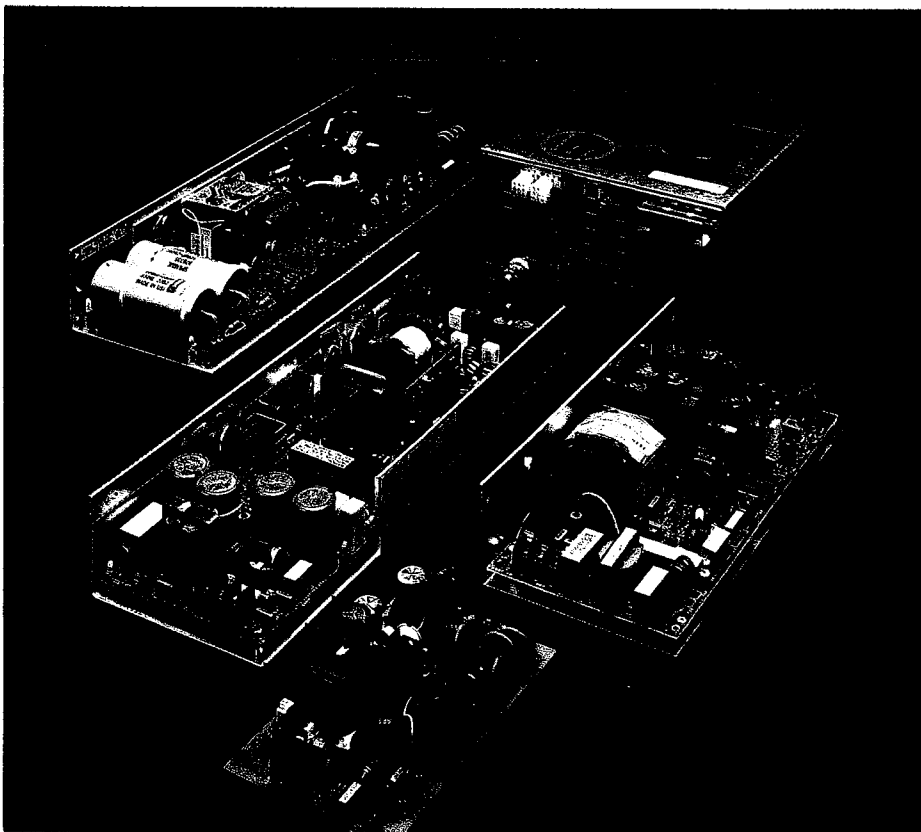


Fig. 2 SMPSs are available from many power supply manufacturers, these are examples from Boschert

These factors contribute to an understanding of the unusually pronounced influence of local manufacture in the power supply business, compared to other electronic sub-assemblies.

It is of course, the end equipment which must finally meet the relevant VDE (etc) standard. While the power supply obviously has a major influence on the safety/rfi of the final equipment, this can be seriously affected by mis-application of a PSU, either by insufficient cooling or by the incorrect installation of the PSU. Some of the wiser PSU manufacturers make the cautionary statement that their SMPSs meet VDE (etc) *when correctly installed*.

### The switch mode philosophy

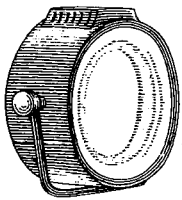
In a conventional PSU, the energy reservoir is normally at a voltage only a little above the required dc output voltage. If this energy can be stored at a much higher voltage, for example the input voltage, the size of the required capacitor will reduce dramatically. The size of the capacitor required to produce a given degree of filtering is inversely proportional to the ripple

frequency, therefore if the operating frequency can be increased, the capacitor will be smaller. Filtering can also be achieved by means of inductors which show the same characteristic of reduction in size as frequency increases. This requirement for high frequency operation is compatible with the requirements for optimum transformer size.

If a system were devised in which the two factors, storage and filtering, could be divorced, the solution would allow energy to be stored at high voltage and high frequency.

Mechanically the bulk of the heat sinks is determined by the efficiency of the regulating system. In a conventional series-regulated type of supply, the main sources of dissipated power are in the series-pass transistors and in the main rectifiers.

The obvious way to remove most of the series transistors' dissipation is to adopt a switching technique. With regard to rectifier losses, the only obvious improvements possible are in the choice of rectifier system and the type used. For example a push-pull



## SPOTLIGHT 3

system consumes less power than a full wave bridge rectifier system and Schottky barrier rectifiers are more efficient than the normal silicon junction type.

The ideal system should offer the following:

- 1) Voltage conversion and isolation at as high a frequency as possible.
- 2) Energy storage at as high a voltage as possible.
- 3) Rectification at as high a frequency as possible to minimise requirements for filter capacitors and/or inductors.
- 4) A switching mode of output regulation to minimise dissipation and hence heatsink bulk.

There are various systems which can show advantages in one or more of these areas. A thyristor- or triac-controlled system has some advantages (energy storage at high voltage for instance), and it is a switching system. However, thyristors and triacs are not capable of operating at a high

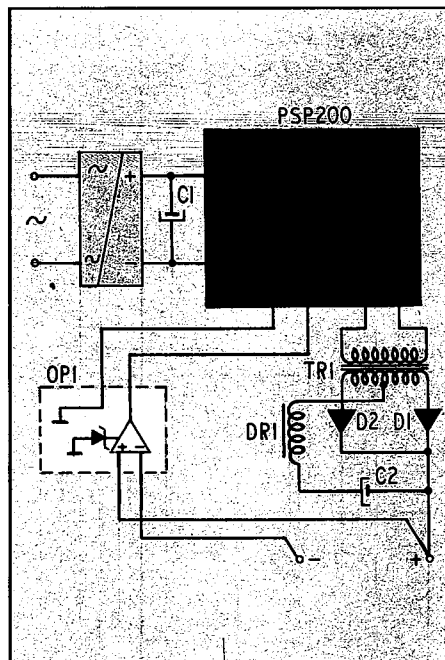


Fig. 3 PSP 100 and PSP 200 from Lindmark Electric AB are primary switched power supply modules which require no special expertise for manufacture. The module enables a functional switch power unit to be provided easily and quickly. The module has an efficiency rating of 95%, it needs no cooling, and will not interfere with radio transmission

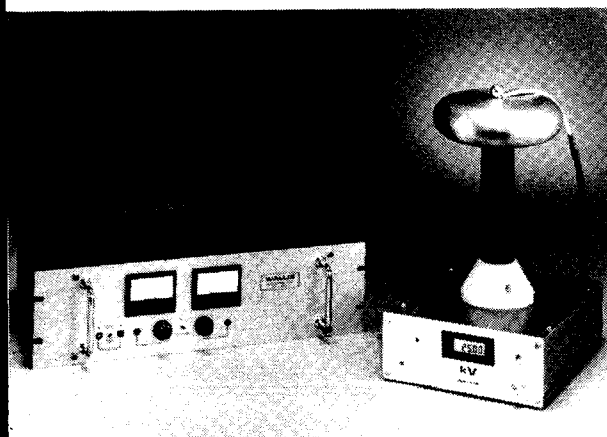
enough frequency for full benefit to be obtained in the miniaturising of transformers and filter components.

A low voltage switching regulator, on the other hand, gives the advantages of high frequency transformers and has low voltage energy storage.

The only system that achieves all these required features is a 'direct-off-line' switching converter employing a closed loop technique to achieve a regulated output. This system has been known for many years but it is only recently that technology has caught up with theory to a sufficient degree to make the implementation of such a system a viable proposition. This has

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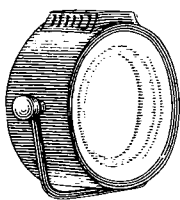
Illustrated The 30kV VCS303/1 is being checked using the digital 100kV dc Voltmeter.

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## SPOTLIGHT 4

resulted in the possibility of miniature power supplies becoming a reality.

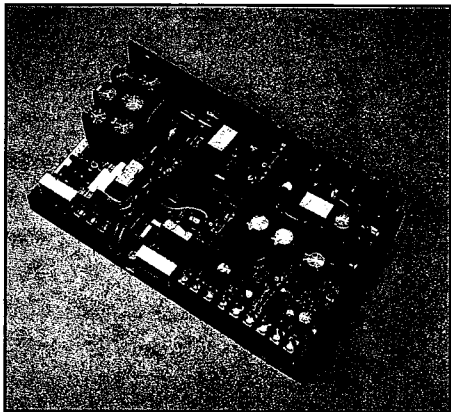


Fig. 4 A switching power supply model, HSS 100; from Weir, with five outputs, three of which are fully regulated

### A modular approach to power

At this time it seems that there is only one company who can offer a truly

modular approach to a power supply, although a second company, Advance, plan to release a modular unit later this year. The AMPSS from Astec combines hybrid technology and power supply design.

The primary circuit is an unregulated half-bridge bulk power converter with over-current protection. Operating at 40-50kHz, it provides a single output voltage of approx 30V at nominal input voltage.

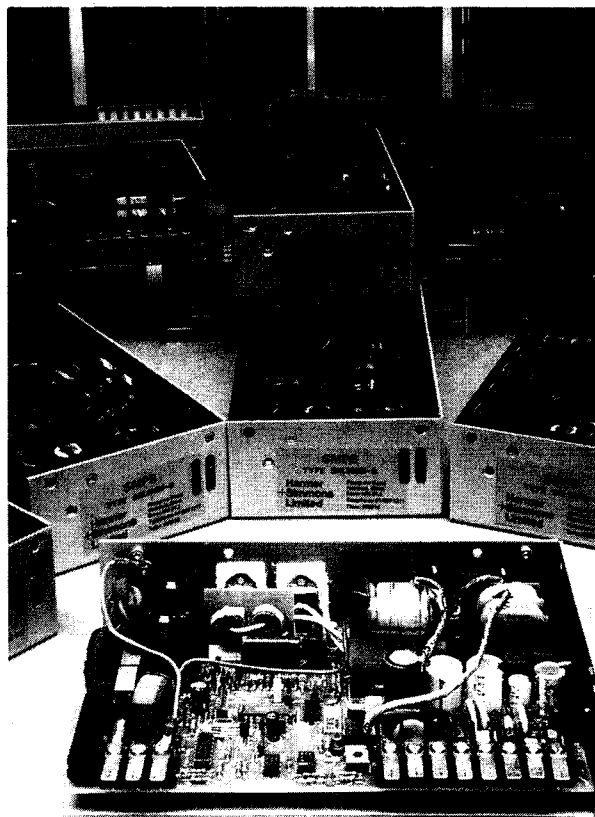
Individual outputs are obtained by the use of a combination of dc/dc regulators. This combination may be pre-determined by the customer's requirement. The dc/dc converters for positive voltage outputs are 'buck' regulators which use power FETs as the switching devices, operating at 500kHz. Negative outputs are achieved using the same basic technology but using either flyback or feed-forward techniques for the main conversion.

A control IC will primarily be used to

provide various control functions in the output regulators.

The AMPSS units take three basic forms:

- 1) A 500kHz switching regulator which may be used in many situations. These include off-line isolated, unregulated, distributed power supply systems, specific output regulation in unregulated power systems and other dc/dc converter applications.
- 2) An unregulated Hall bridge converter. As the use of hybrid technology make this module relatively small, it is suited to applications such as wall mounted transformers, although its primary function will be to power a complete AMPSS system (see 3).
- 3) A combination of a dc/dc regulator and power conversion modules, or AMPSS. This is tailored to low volume custom and semi-custom power supply requirements. It also has applications where unusual mechanical configurations are required.



## SWITCH MODE POWER SUPPLIES

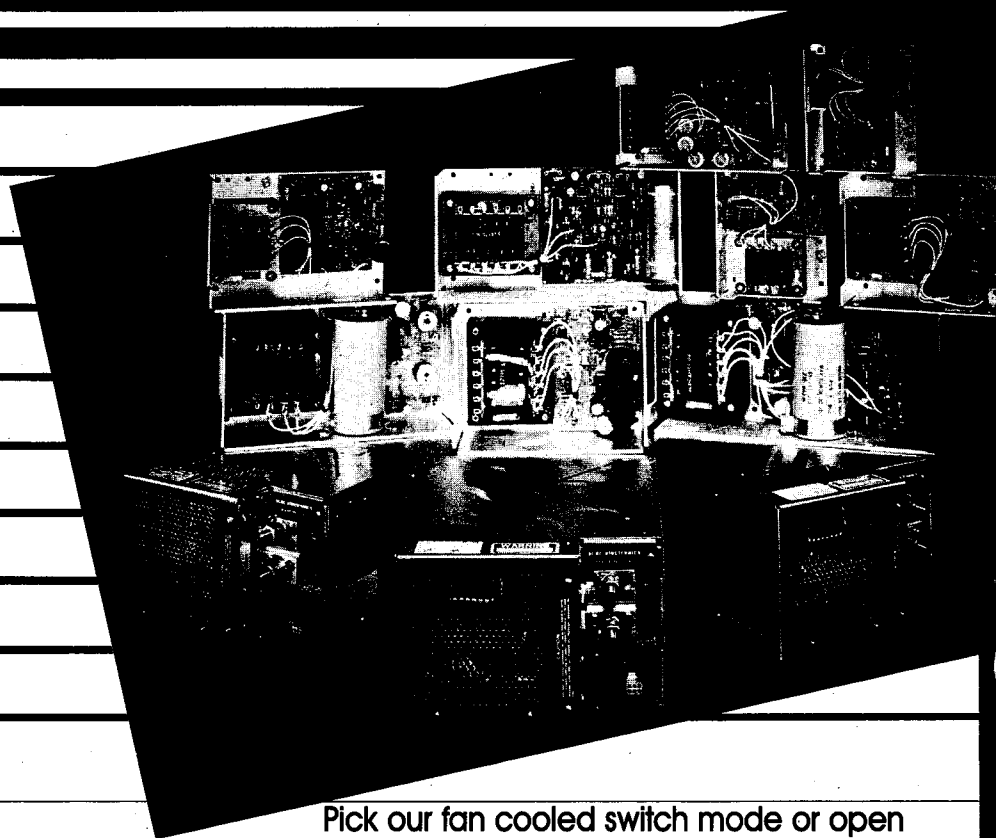
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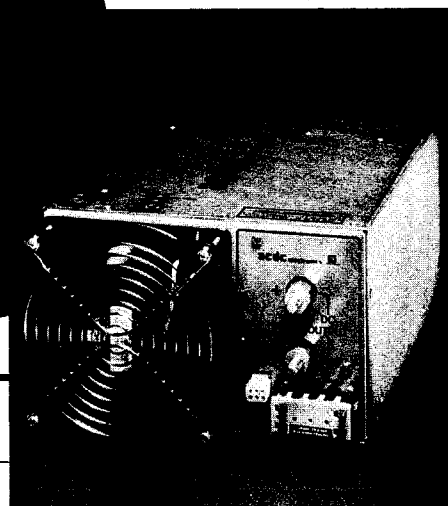
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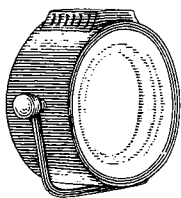
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# SPOTLIGHT 5

**Table 1. Recent multiple-output open-frame SMPSPs**

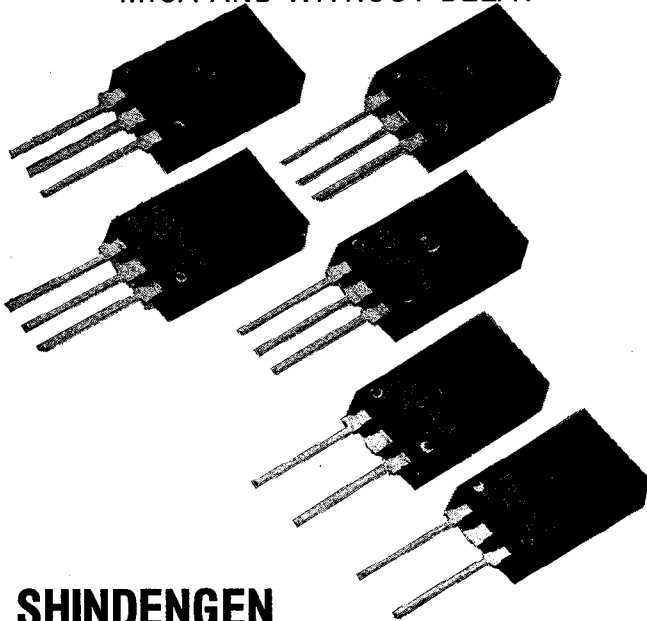
Manufacturer (Agent)	Power rating (at 40°C convection cooled)	Main output				Secondary outputs				Size in cm	PSU standards	Model No.	Price (25+)
		VI rating max	Regulation ( $\pm 15\%$ line change)	Load (load varies $\pm 20\%$ )	Noise (% of $V_{out}$ ) lf hf	VI rating	Regulation line load						
<b>Advance Power Supplies</b> (formerly Gould) (0279 55155)	350W	5V 50A	0,5%	0,1%	1%	1%	2x (10 to 15V) 5A 24V 5A -5V 2A	0,5%	0,5%	7x19x30	UL CSA BT VDE	P350	from £260
	130W	5V 15A	0,1%	0,1%	1%	1%	-5V 1A (12V 4A + 12V 2A) or (2x15V 4A)	4%	4%	6x13x27	UL CSA VDE	OF482 or 480	from £120
<b>ACDC Electronics</b> (Amplicon Electronics) (0273 608331)	224W	5V 25A	0,2%	0,2%	0,2%	1%	5V 1,5A 2x12V 3A 15V 3A	0,5%	0,5%	12x36x8	UL478 UL114 CSA22.2 VDE0804 VDE0806 VDE	RM224	£280
	164W	5V 20A	0,2%	0,2%	0,2%	1%	15V 2,5A 2x12V 2A 5V 1,5A	0,5%	0,5%	12x36x6		RM164	£260
	84W	5V 10A	0,2%	0,2%	0,2%	1%	2x12V 1A 5V 1A	0,5%	1%	12x27x6		RM84	£198
<b>Astec</b> (0734 509411) (Thame 084421 4561)	150W	5V 13A	3%	3%	1%	1%	2x12V 1,5A +24V 1,7A -12V 0,2A	5% 10% 5%	5% 10% 5%	15x16x6	VDE0804 IEC435 UL1012	AC9664	£88
	165W	5V 11A	0,2%	3%	1%	1%	-12V 11A +12V 6A +12V 2A	0,2% 0,2% 0,2%	5% 5% 5%	14x28x7		AC9731	£156
	40W	5V 3A	0,2%	1%	1%	1%	12V 2,5A -12V 0,1A	0,2% 0,2%	2% 2%	10x16x5		AC8151	£33
<b>Automation &amp; Power Systems</b> (0273 420196)	50W	5V 3A	0,2%	0,2%	0,1%	0,5%	2x12V 1A +24V 1A	0,4% 0,4%	6% 6%	20x12x6	BS204, BT 5850, 800 IEC380 VDE0804, 0871, 0875	050-series (Eurocard)	from £48
	250W	5V 15A	0,1%	0,25%	0,1%	0,6%	2x12V 3A 1x24V 1A	0,4% 0,4%	6% 6%	27x15x8		010-046 (Slimline)	£178
<b>Belix</b> (01-397 0921)	40W	5V 5 or 2A	5%	5%	1%	1%	+12V 1 or 2,5A -12V 0,5% A	5%	5%	5x16x10	UL approved IEC 380, 435 ECMA57 CEE-10 Pt 2 CSA22.2/143 CSA 22.2/154 VDE 0730, 0804, 0806 BSI 5850	KFD40	£44
	60W	5V 6 or 3½A	5%	5%	1%	1%	+12V 2 or 3A -12V 0,5A	5%	5%	5x20x11		KFD60	£60
	80W	5V 6A	5%	5%	1%	1%	+12/15V 2A -12/15V 0,5A -5/12/+24V 0,5A	5%	5%	5x23x13		KFD80	£74
	100W	5V 10A	0,5%	1%	3%	3%	±12/15V 1,5A -5V/+24V 0,5A	0,5% 0,5%	5% 2%	6x23x11	UL approved	KS100	£110
	200W	5V 25A	0,5%	1%	3%	3%	±12/15V 4A -5V 0,75A/24V 2A +24V 4A	0,5% 0,5% 0,5%	5% 5% 5%	6x33x11		KS200	£216
	250W	5V 20A	0,5%	1%	3%	3%	±12/15V 4A ±15/+24V 4A -5V 1A/24V 4A	0,5% 0,5% 0,5%	5% 5% 5%	10x30x19		KL306	£237

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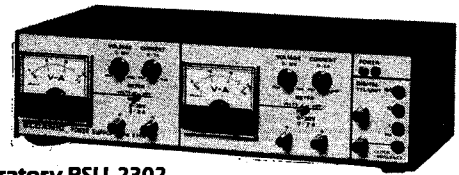
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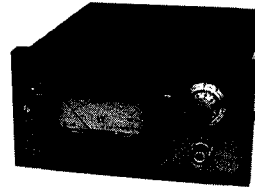
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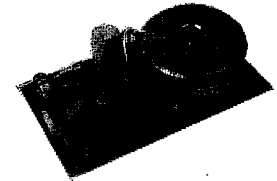


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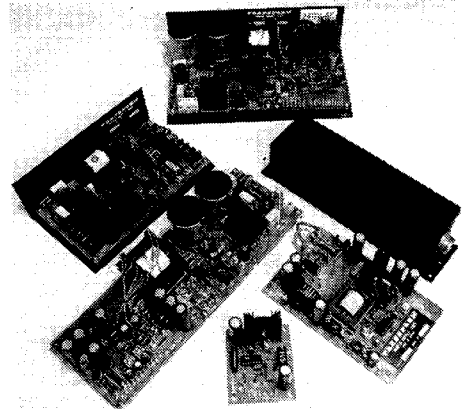
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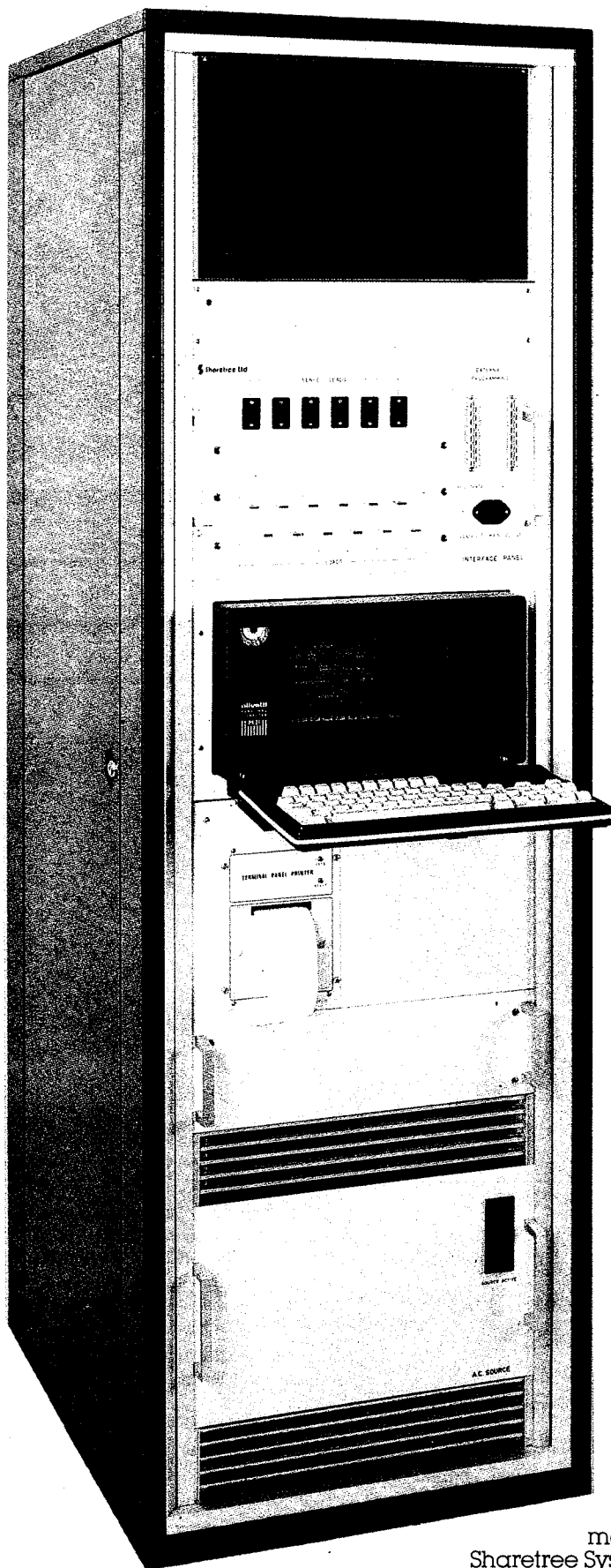
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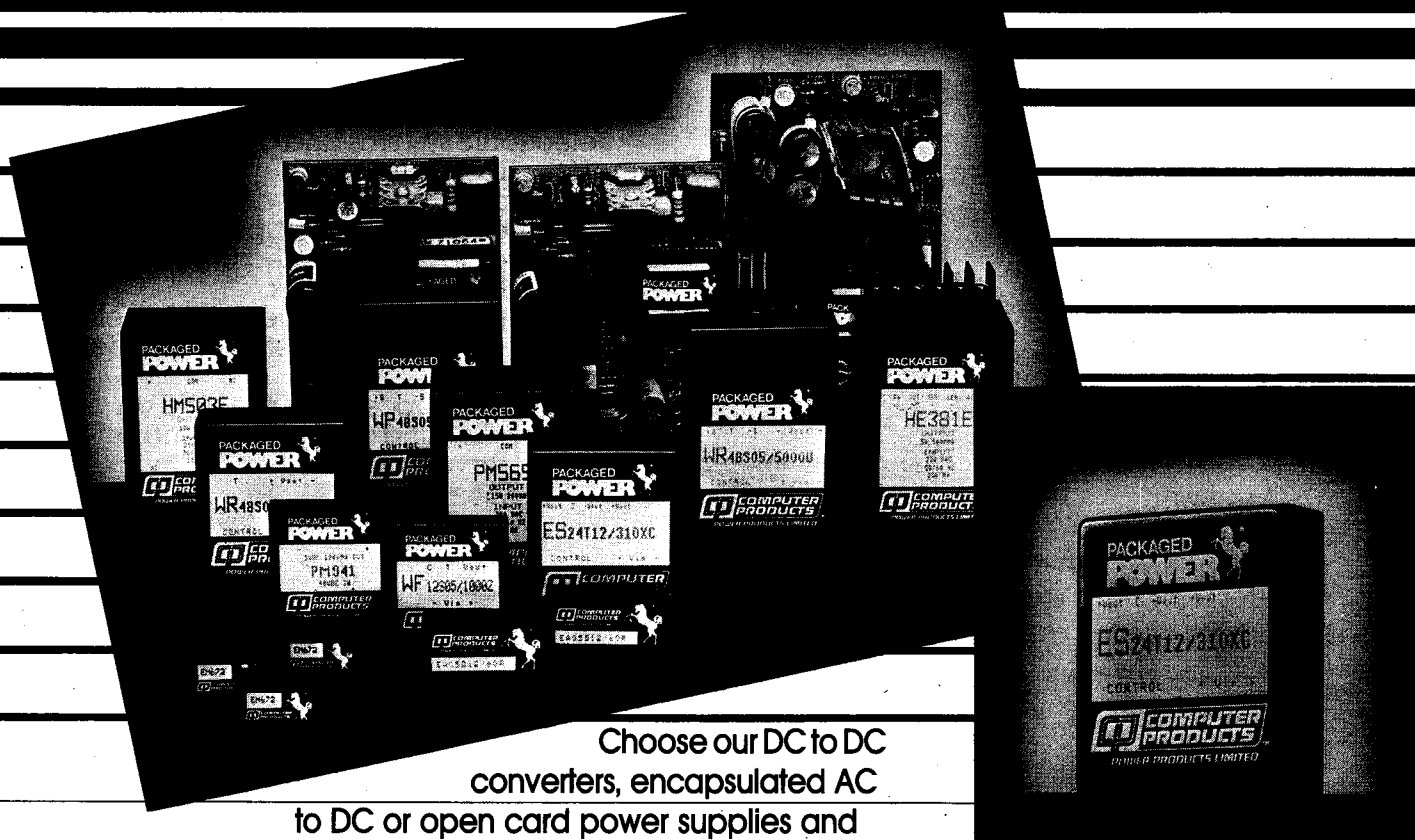
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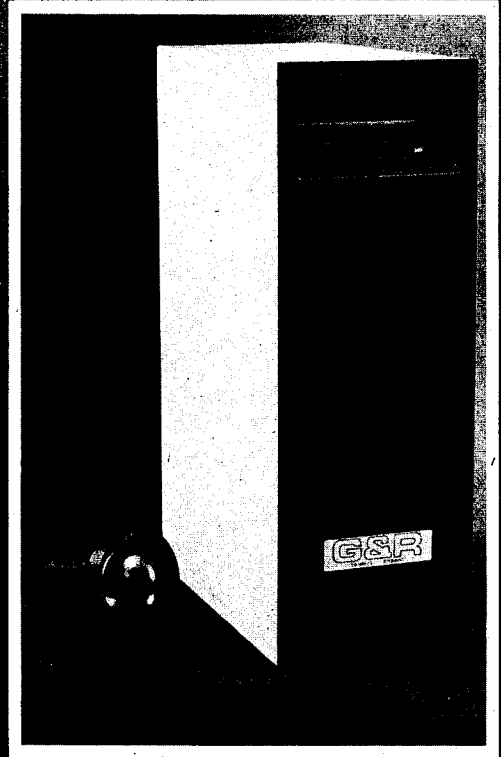
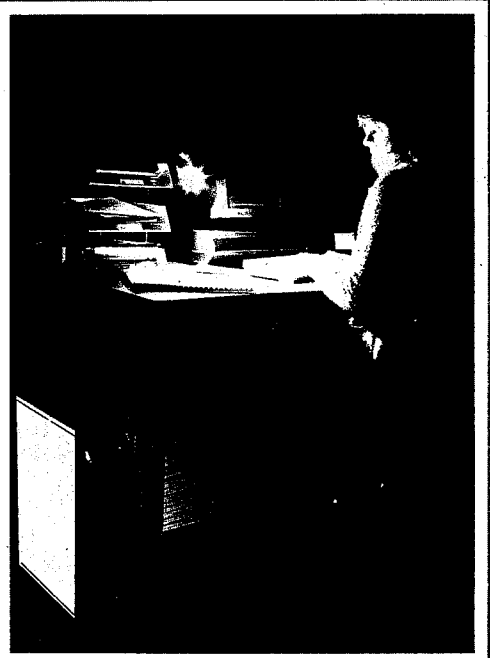
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# A light in the darkness



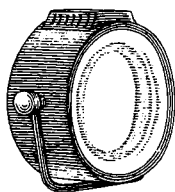
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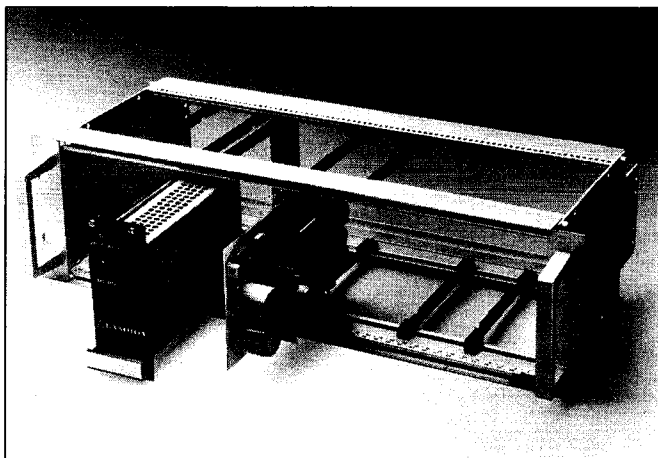
# SPOTLIGHT 7

**Table 1. (continued): Recent multiple-output open-frame SMPs**

Manufacturer (Agent)	Power rating (at 40°C convection cooled)	Main output				Secondary outputs				Size in cm	PSU standards	Model No.	Price (£5+)
		VI rating max	Regulation Line (± 15% line change)	Load (load varies ± 20%)	Noise (% of V <sub>out</sub> ) lf hf	VI rating	Regulation line	load					
<b>KRP/Hitron</b> (Kingslo 0635 32585)	40W	5V 3,5A	0,5%	0,5%	1%	1%	+12V 1,5A -12V 0,2A	0,5%	5%	10×16×5	UL, VDE CSA, BT	<i>KHSG</i> 40-32	£36
	125W	5V 7A	0,5%	0,5%	1%	1%	+12V 2A -12V 0,8A +12V 1,5A +24V 1,5A	0,5%	5%	13×27×7		<i>KHSC</i> 125-50	£107
<b>Panasonic</b> (0753 73181)	40W	5V 4A	0,2%	0,3%	1%	1%	+12V 1A -12V 0,5A -5V 0,5A	0,6%	1%	18×11×5	BS585 VDE0806 IEC380 CSA UL144/478	<i>MJ</i>	£45
	200W	5V 12A	0,2%	0,6%	1%	1%	2×12V 1A -5V 1A 2×24V 1A	0,6% or 1%	1% or 5%	39×13×6		<i>MG</i>	£180
<b>Philips</b> (Pye Unicam 0223 258866)	200W	5V 20A	0,1%	0,15%	2%	2%	12V 2A 12V 4A 24V 2A -5V 0,2A	0,5% 0,5% 0,5% —	1,5% 2,5% 4% 0,5%	9×23×17	IEC, UL VDE0871	<i>PE1203/20</i>	£319
<b>Power Concepts</b> (0703 31567)	40W	5V 3A	0,5%	0,4%	1%	1%	+12V 2A -12V 0,5A	1%	5%	8×13×5 or 10×16×5	UL478 CSA22.2 IEC435 VDE0806	<i>3045</i>	£34
	60W	5V 6A	0,5%	0,4%	1%	1%	+12V 3A -12V 0,5A	1%	5%	10×13×5		<i>3055</i>	£50
	100W	5V 10A	0,5%	1%	1%	1%	2×12V 3A -12V 3A	1%	5%	10×20×5		<i>4110</i>	£85
<b>Power Products</b> (Amplicon 0273 608331)	90W	5V 7A	0,2%	0,2%	1%	1%	2×12V 1A 12V 2,5A (or 24V 1.25A)	0,05%	0,05%	21×12	VDE0806 UL, CSA	<i>80001</i>	£116
	40/50W	5 or 8V 5 or 3A	0,2%	0,2%	1%	1%	2×(12/15/16V) 1A -5V 0,25A	0,2%	0,5%	15×10	VDE0806	<i>80009/10</i>	£80
<b>Powerline</b> (0734 868567)	50W	5V 6A	0,1%	1%	1%	1%	2×12V 1A +24V 1A -5V 1A	0,1%	1%	18×11×5	IEC380 VDE0806 VDE0871A	<i>EP6003</i>	£58
	200W	5V 20A	0,02%	1%	1%	1%	-5V 4A 2×12V 4A +24V 4A	0,5%	2%	23×16×5 or 26×12×6	IEC380 VDE0804 VDE0871A	<i>ER200</i>	£170
	100W	5V 8A	0,1%	2%	1%	1%	+12V 4A -12V 1A +12V 2A	0,1%	2%	20×11×6	VDE0806 IEC380 VDE0871A	<i>F200</i> <i>EP3503</i>	£93
<b>Powertron</b> (0223 67878)	300W	5V 40A	0,1%	0,1%	1%	1%	2×12V 7A	0,2%	5%	7×2×36	VDE, IEC CSA	<i>EAS/40-3</i>	£324
<b>Thorpe</b> (0284 69581)	50W	5V 6A	0,1%	0,2%	1%	1%	12V 3A -12V 0,2A	0,2%	5%	10×13×4	UL	<i>TP3050-6</i>	£60
	100W	5V 10A	0,1%	0,2%	1%	1%	2×12V 3A -5V 1A	0,2%	5%	10×20×4	UL	<i>TP410-03</i>	£110
<b>Waytronics</b> (0233 42227)	150W	5V 15A	0,5%	1%	0,2%	1%	2×12V 3A -12V 1A	0,1%	1%	28×10×7	BS5850 IEC380 VDE0804	<i>SL150</i>	£106
	50W	5V 5A	0,2%	1%	0,2%	1%	12V 2A -12V 0,5A	0,1%	1%	19×12×6		<i>SSL50/3/b</i>	£54
<b>Weir</b> (0243 865991)	250W	5V 30A	0,25%	0,12%	0,2%	1%	24V 6A 2×12-15V 6A 5-15V 3A	0,5%	1%	30×19×7	IEC380 VDE0806 VDE0871 BT2 & 26 UL478	<i>SMM250</i>	£195
	200W	5V 30A	0,25%	0,12%	0,2%	1%	2×12-15V 6A	0,5%	1%	30×7×7		<i>SMM200</i>	£165
	100W	5V 10A	0,5%	0,25%	0,5%	1%	12V 1A 12V 1A -5V 0,6A 24V 1,5A	1,5% 0,5%	0,5%	26×12×7		<i>SMM100S</i>	£80

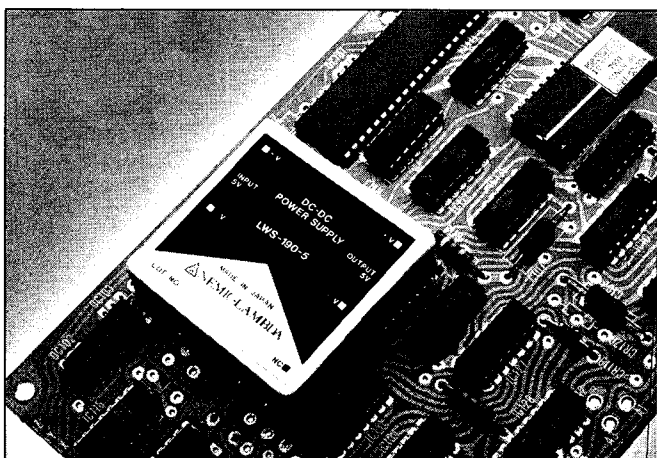
# POWER SUPPLIES FOR 1985

## New Modular LI Series for Europe



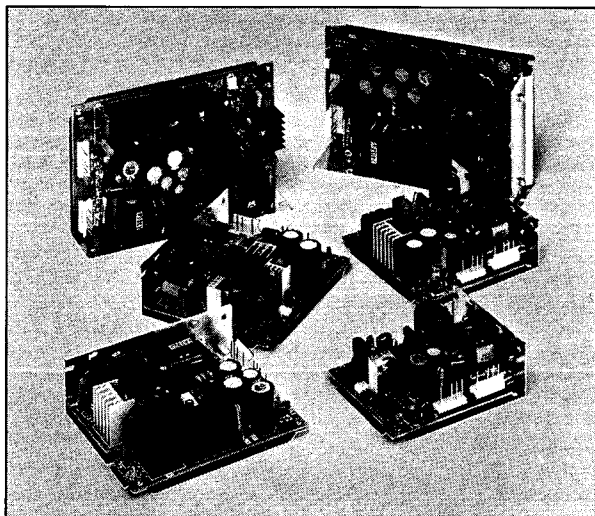
Eurocard/VME Sizing  
Designed to meet IEC & VDE requirements  
Connectors: DIN type H15  
Soft start: Inrush current limited  
Overload protected – characteristic allows parallel operation  
10 Models – Enclosed with front panel  
10 Models – Open card style  
Output range 5V to 28V fixed output (adjustable  $\pm 5\%$ )  
15W & 30W ratings  
User selectable dual input

## Isolated DC to DC Switching in Miniature



26 models to your exact requirements  
Inputs: 4.5V to 6.0V dc      4.5V to 10.0V dc  
         10.0V to 15V dc      10.0V to 30.0V dc  
         20.0V to 30V dc      20.0V to 60.0V dc  
Outputs: Fixed and variable 2.5W to 48W  
PCB mounting with all outputs isolated  
Overload protected  
High efficiency conversion  
Four package sizes  
The LW Series will solve your space problems

## Low Cost Commercial/OEM Switching



LV Series – Lambda quality at the right price!  
30 models including triple output options  
A.C. input with 5 to 48 Volts output  
10 Watts sized 1.4" x 3.8" x 4.5" up to  
50 Watts sized 1.4" x 3.8" x 6.3"  
All single outputs are  $\pm 5\%$  adjustable  
5V $\pm$ 12V; 5V $\pm$ 15V; 12V–12V–5V fixed o/p triples  
Convection cooling up to 60°C with overload protection  
Overvoltage protection standard on higher wattages  
Molex input and output connections for every OEM unit  
Indicator lamp to verify output voltage  
UL and CSA approvals applied for



**LAMBDA ELECTRONICS** Abbey Barn Road, High Wycombe, Bucks., HP11 1RW  
Telephone: High Wycombe (0494) 36386 (6 lines) Telex: 837153

## Probably the most reliable power supply available today

The new LR Series power supplies have 50% lower parts count in a 25% smaller package with a 5 year guarantee.

### High Power Density Packing

1.4W/inch<sup>3</sup> for LRS 54V models

1.65W/inch<sup>3</sup> for LRS 55V models

### Very High Efficiency

75% minimum for 5V models

82% minimum for 12 to 15V models

84% minimum for 20 to 48V models

### Designed to meet UL CSA VDE & IEC specs

#### Specification & Ratings

Fixed output voltage (adjustable  $\pm 5\%$ ) over range 3V to 48V from 9 models in each range

Input 187V to 265V 41-440Hz

LRS 54V, 200W to 280W depending on output voltage at 40°C rating

LRS 55V, 300W to 400W depending on output voltage at 40°C rating

Soft start

Current limited and thermally protected

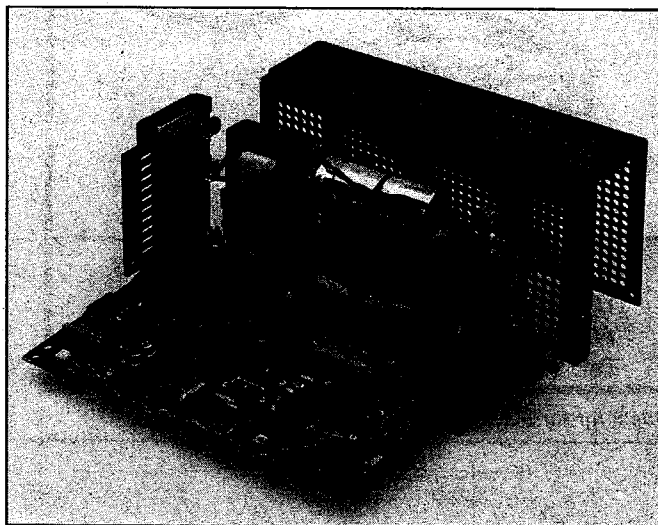
OV as standard and Remote Shutdown

Operating Range:  $-10^{\circ}\text{C}$  to  $+71^{\circ}\text{C}$  (derate from 40°C)

EMI (conducted) conforms to VDE 0871 Class A

MTBF: 55000 hours proven

MTBR: Two part chassis allows easy access for repair as illustrated



### LY Series

#### Input 42V to 60V dc

LYS K-D Range 350W to 500W

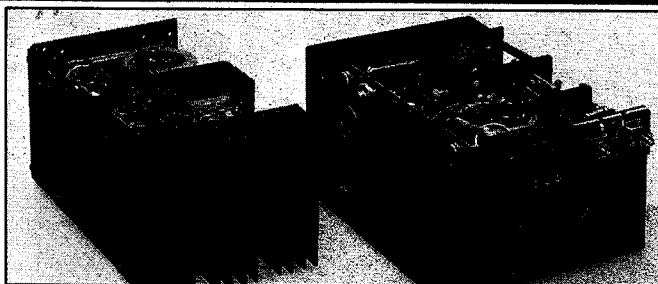
LYS D-D Range 600W to 770W

DC output voltage 5V to 28V – fixed output

High reliability: 55000 hours proven

Efficiency: 70% minimum

OV standard on all models



### LYS – EE Models

5V to 28V fixed output (adjustable  $\pm 5\%$ )

Rating: 1125W to 1400W depending on output voltage

Efficiency: 78% min for 5V

80% min for 12V – 15V

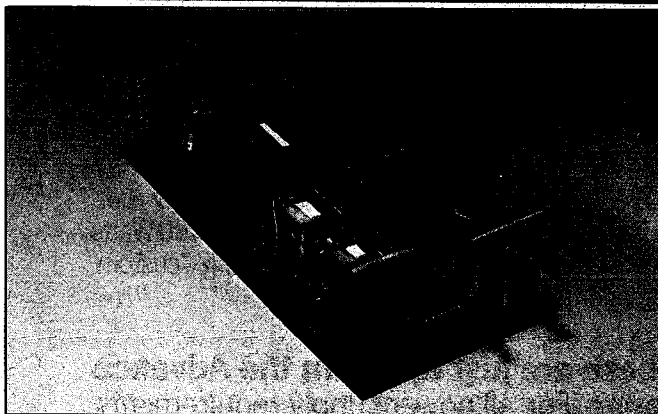
82% min for 70V – 98V

Soft start and Remote Sensing

Designed to meet UL, CSA & VDE 0806

High reliability: 55000 hours minimum

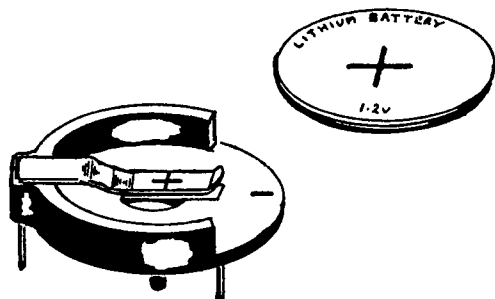
OV standard on all models



**LAMBDA ELECTRONICS** Abbey Barn Road, High Wycombe, Bucks., HP11 1RW  
Telephone: High Wycombe (0494) 36386 (6 lines) Telex: 837153

Circle 42 for further information

**NEW RANGE OF PC  
COIN CELL BATTERY  
HOLDERS**  
*from SPEARETTE*



**SPEAR ENGINEERING CO LTD**  
TITAN WORKS, LIMPSFIELD ROAD,  
WARLINGHAM CR3 9HA  
Tel: 08832-2774 Telex: 8813831

Circle 8 for further information

**DC-DC CONVERTERS**

**NEW!**

**L M Series - Single/Dual Outputs**



**Metal  
Cased**

**P.C.B.  
mounting**

- \* OUTPUTS OF UP TO 15W
- \* HIGH PERFORMANCE REGULATED O/P'S
- \* INDUSTRY STANDARD SIZE
- \* THERMAL PROTECTION & S/C PROOF
- \* MANUFACTURED IN THE UK.

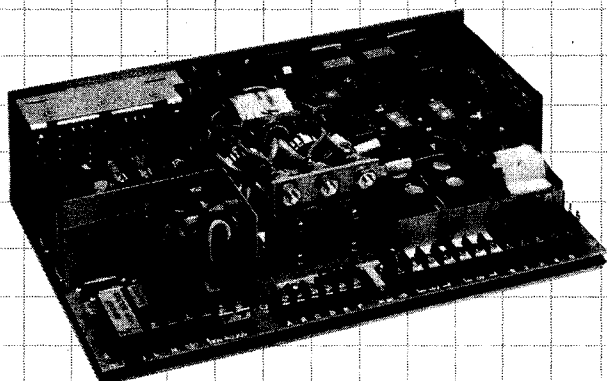
**The Converter Specialists**



**K.E. DEVELOPMENTS LTD.**  
The Mount, Toft, Cambridge, CB3 7RL  
Tel. Comberton (022026) 3532

Circle 49 for further information

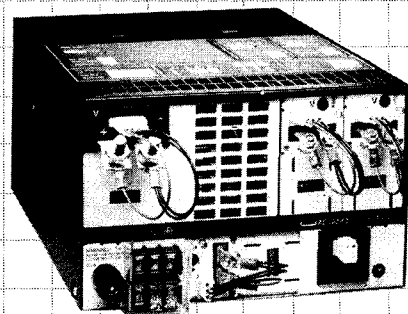
# ADVANCE IN WATTS



**POWERFLEX-P350**—● 5 outputs. ● Any permutation of volts/amps up to 350Watts. ● 450Watts peak.—The 'catalogue' product meeting 'custom' demand

**These are just two from the Advance range.** For all power supply requirements contact us first.

Circle 38 for further information

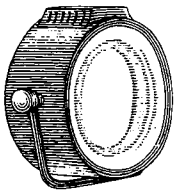


11106

**HIFLEX**—● 6 outputs plus signals/sequencing. ● Up to 750 Watts total power with over 3000 output permutations. ● BT, UL, and CSA approved. ● Compact—only 8" x 5" x 11"!—Sophisticated modularity, the simple answer to complex power needs.



Advance Power Supplies Ltd.,  
Raynham Road, Bishop's Stortford,  
Herts. CM23 5PF, England.  
Tel: (0279) 55155. Telex: 81510.



## SPOTLIGHT 8

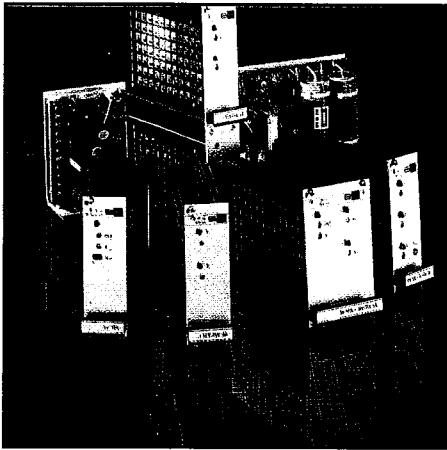


Fig. 5 Examples of the BICC-Vero range of 19in rack mount power supplies

### Open frame SMPS— Eurocard set to become the standard?

The many different package styles that are available today for SMPSS can

### Comparison between linear and switching PSUs

prove a headache to anybody specifying a unit which is to be second sourced. The obvious answer to this is a standard package. The consensus of opinion from most power supply manufacturers is that the 19 inch rack style will become the standard.

BICC-Vero have recently introduced a range of power supplies which fit into a 19 inch rack system and incorporates a front panel which is identical to those of other instruments housed within the rack to keep a uniform style. Another manufacturer who has developed a

range of power supplies to complement their range of 19 inch racks is Schroff and we can expect all of the rack manufacturers to release a range of PSUs in the near future. Whether these prove to be original designs or simply a labelling deal remains to be seen.

### Special components for power supplies

The continual striving by manufacturers of SMPSS to improve their products has resulted in the birth of a

# DIRTY MAINS! a computers' worst enemy

## REGUVOLT-a computers' best friend!

A 'dirty' mains supply can often jeopardise the performance of your computer, causing data loss, system crashes and sometimes, damage to both hardware and software.

Raw power, direct from the mains, is prone to transients or voltage 'spikes', which are usually caused by the variation and switching of electrical loads in the vicinity of your computer (e.g. photocopiers, lifts, domestic appliances etc.).

These 'spikes' play havoc with the mains, and then your computer suffers!

A Reguvolt Mains Conditioner will solve the problem, by providing

complete electrical isolation between the mains and your computer system. Transients are suppressed, and a 'clean' and stable voltage supply is maintained.

Where *total* mains security is concerned, a Reguvolt really is your computers' *best* friend!

Please send for further details today.

Single and 3-phase  
models available,  
from  
120VA to  
60kVA.



**Cetronic Components Ltd.**

Hoddesdon Road, Stanstead Abbots,  
Ware, Herts SG12 8EJ, England.

Tel: Ware (0920) 871077 Telex: 817293

# The answer to all your needs.

*yes!* Delivery when you want it, as fast as you want it.  
Hamilton will give you a fast, flexible response. A rapid delivery in hours if that's what's demanded.

*yes!* A superlative range of equipment  
Hamilton stocks one of the most comprehensive ranges of microprocessor development systems. But more than that, the systems are carefully chosen from only the world's major manufacturers—like Intel, Hewlett-Packard, Motorola, Zilog and Micropross—the acknowledged leaders in their fields.

*yes!* Extremely flexible rental terms.  
Rent MDS from Hamilton for a day, a week, a month, for as long as you like. Always you'll find the terms highly competitive. Hamilton will tailor a flexible rental plan for you. And advise you when a long term project may mean that buying is the better option.

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Blue chip multinational companies and institutions wouldn't keep using Hamilton's MDS service if it wasn't highly reliable, flexible, skilled, fast. And the best!

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No matter what your project application, Hamilton's MDS Support Group is available for full on-site or telephone support on every item of equipment available for rental.

Note the MDS Hotline numbers and keep them handy. Hamilton. Where the answer to all your needs is always 'Yes'.

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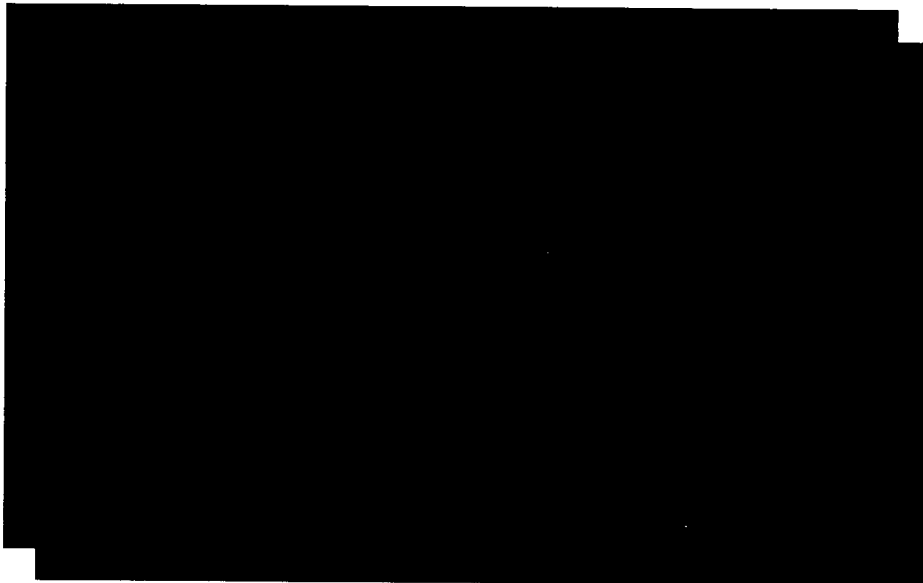
HAMILTON



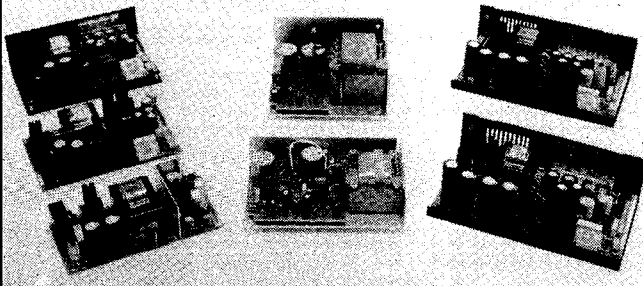


It must be realised that there is a wide variation in the degree of protection provided, and the PSUs reaction to overload—this ranges from just blowing fuses to fast power down with automatic (digitally timed) re-start attempts. There is resistance by the PSU manufacturers to adopt a standard general-purpose IC which would make all SMPSS very similar in performance. This resistance appears to have its roots based in the fact that all power supply manufacturers see themselves as individuals and like to

Concentrating on this area of activity,



# ARE YOUR OEM POWER SUPPLY PRICES RISING ?



## OURS ARE NOT!

**WE OFFER: STANDARD-SIZED**

- \* LINEARS \* SWITCH-MODE \* EUROCARD
- \* DC:DC \* MAINS ADAPTORS \* CUSTOM DESIGN

SEND OR CALL NOW

**POWERAIL**   
**ELECTRONICS**

6B PRINCES ST,  
DUNSTABLE, BEDS.  
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Circle 10 for further information

# BATTERIES and SYSTEMS

**Your problems solved.**

- Elpower Technacell Batteries. Maintenance free solid gel energy source for all your applications. Capacity range from 0.9AH to 38AH
- Nickel Cadmium Cells and Batteries. Single cells and packs including special batteries. Capacity range 150mAh to 7AH
- Altus Lithium Batteries. The range covers button and standard round cells.
- Battery Chargers, Adaptors and Stabilised Power Supplies to meet battery specifications. Maintenance free UPS to your requirements. Portable Power Packs for convenience and standby applications

*Other products in our range include*

- Quartz Crystals, TTL and CMOS Oscillators.
- Base Station and Mobile Antennas.
- Self supporting steel towers.
- Circulators and Isolators. Dummy Loads, Duplexers and Combiners. Filters and Multicouplers.
- Piezo Loudspeakers and Handsets.

*Please ask for further detailed information quoting quantities and specifications.*

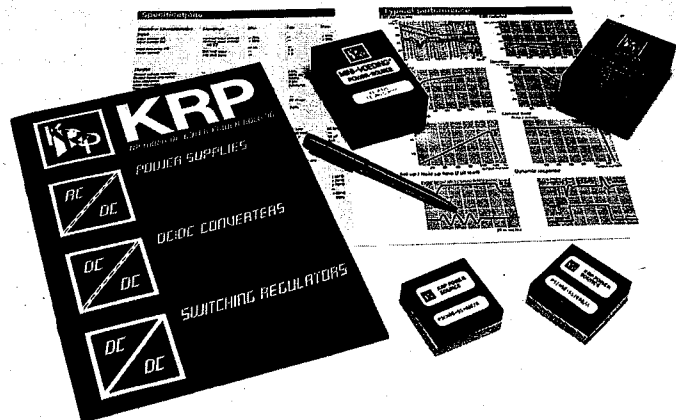
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Spracklen House, Dukes Place,  
Marlow, Bucks. SL7 2QH.  
Tel: 06284 74324/73555.

**PDL**

Circle 32 for further information

# D.C.-D.C. CONVERTERS/POWER SUPPLIES

- Linear/Switch Mode
- International 'Footprints'
- Single/Dual A.C. Input
- Up to 280volts D.C. input
- 5 volts — 250 volts D.C. output
- Single, Dual and Triple output
- Regulated — Unregulated
- Isolated — Non Isolated
- European Safety: V.D.E./C.E.E.  
3,750 Kv A.C. Isolation
- Output power to 40 Watts
- 2 Year Warranty



The KRP Power Source B.V. ranges of encapsulated AC-DC and DC-DC modules enables the user to specify the most cost effective solution to any application.

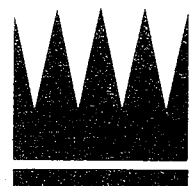
An exceptional choice of power sizes with single to triple outputs is available in both the AC and DC input modules.

Send now for full technical data or contact us direct with your requirements.

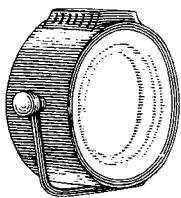
**KINGSLO LTD**

**A KRP POWER SOURCE (UK) CO**

8-10 West Mills, Newbury, Berks,  
RG14 5HJ. Tel: (0635) 32585  
Telex: 917654 KPOWER G



Circle 63 for further information



# SPOTLIGHT 10

Astec have used the latest surface-mounting techniques to produce their *Control module 2*, an SIL daughter board with two bare IC chips (and other chip components including a toroidal ferrite bead) mounted directly on the board. This design handles all the housekeeping (Vout adjust, short circuit protection and brown-out protection) plus supplying the basic drive to the main switching transistors.

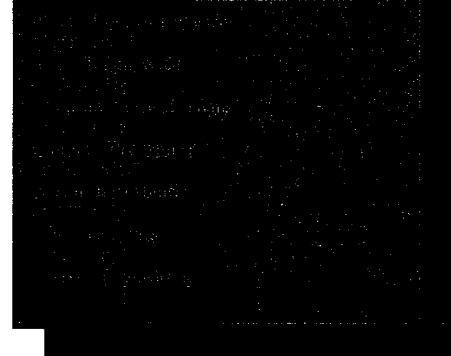
One of the problems associated with SMPSs can be switch-on surge. To help combat this problem, Advanced Power Components have introduced a range of products known as 'soft starts', claimed to be a cost-effective alternative to thyristor or resistor/relay protection circuits. The 'soft starts' are designed to suppress large current surges by varying their resistance during switch-on. The components are connected in series with the input supply to the circuit being protected (the connection can be made on either the ac or dc side). The units become 'transparent' during nor-

mal operation and also have the advantage of improving overload protection — fuse ratings can be reduced due to the absence of high starting currents.

## Uninterruptible power supplies

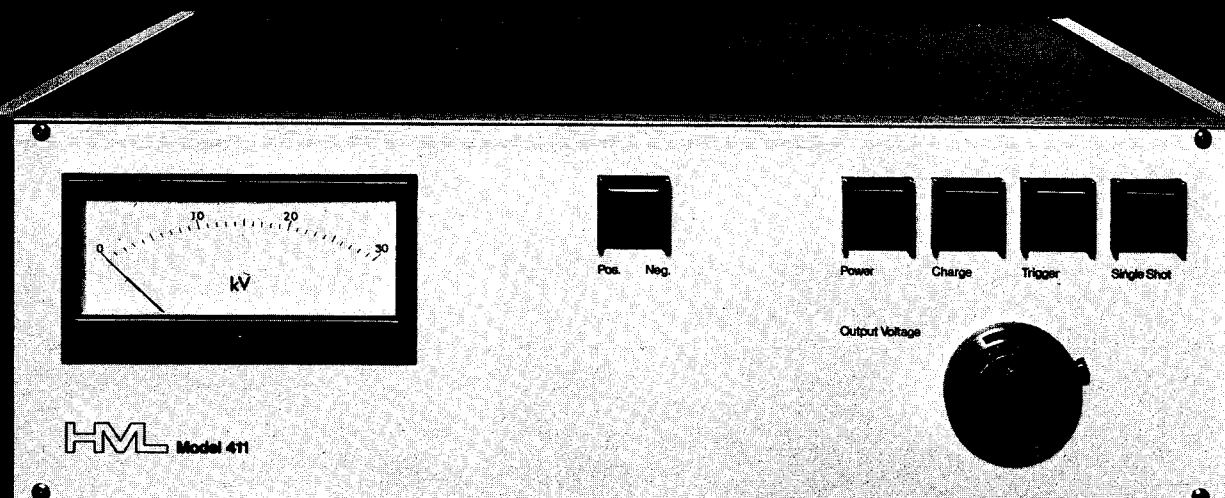
Pieces of equipment which provide a continuous dc supply are commonly referred to as Uninterruptible Power Supplies (UPS). Developed originally for the petrochemical industry to provide secure supplies for critical process control applications, they are now playing a prominent role in powering computer and computer-based systems. Acting as a buffer between the mains and the critical load, they protect against all forms of disturbance, including total power failure. Continuous development means that current equipment bears little resemblance to the early designs. Ferroresonant inverters have now largely disappeared, and pulse width modulation or waveform synthesis are the preferred techniques. Environmental

## Manufacturers of UPSs



considerations too have received considerable attention. Size and weight are constantly being reduced, and UPSs as large as 200KVA can now be housed in a single enclosure. At the other end of the scale, small UPSs are increasingly being conceived of as office products designed to blend in with word processing and similar micro systems.

# Our optional extras are standard.



## SAFER OPERATION

411 switched-mode HV supplies give accurate high performance in difficult applications

Precision voltage control is combined with remote operation and extensive safety features

Four model ranges 0-50 KV, 70-1000 J/S. And we're pleased to customise

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RG24 0BT  
Tel: (0256) 56695  
Telex: 858733

**SERIES 411  
HIGH VOLTAGE  
SUPPLIES**

**HARTLEY**



Circle 72 for further information

# FROM THE INNOVATORS

Greendale Electronics, leading manufacturers of standard and custom power supplies have now launched three new multi output switched mode power supply series.

U.K. designed and built, the new models increase the company's comprehensive range in the 45 to 120 watt market. All units are manufactured to International specifications, essential to meet the high performance requirements of today's advanced technology.



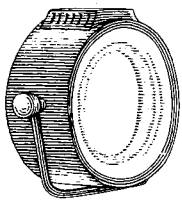
- GSM 45 - recently introduced range designed for low power applications, offers maximum power supply flexibility. Standard features - optional input filtering, trip/restart and full output protection.
- GSM 60 - Best selling model re-specified from popular 19A series. 8 model range offers quad output, 2 levels of auxiliary regulation and up to 60 watt continuous output.
- GSM 70 - A rugged high powered version of the GSM 60 for those applications where additional peripheral equipment requires higher continuous power supply capability.
- GSM120 - Latest design, 120 watt, 5 output high technology off-line switched mode power supply. Compact low profile unit in PCB, chassis or fully enclosed formats for Eurocard Mounting. Incorporates all facilities of counterparts with additional option to change main output from the 5V to the 24V output.

The high quality, competitively priced power supply range from Greendale Electronics - THE INNOVATORS.



## GREENDALE ELECTRONICS

Green Lane, Dronfield, Sheffield S18 6LL. Tel: (0246) 417661 Telex: 54649 GDELEC G.



# SPOTLIGHT 11

**Table 2. 19in rack-mounted hv power supplies**

Company	Range	Power	V <sub>out</sub> (for full spec)	I <sub>out</sub>	Price (1 +)	Weight	Regulation		Meters	Remote control
							Line (±10%)	Load (100%)		
<b>Alpha Repeater</b> (0273 597222)	<i>RHV 50</i>	50W	100V to 1kV-1kV to 100kV	50mA-0,5mA	£637-£1980	8kg-20kg	100ppm	100ppm	2	Yes
	<i>RHV 100</i>	100W	100V to 1kV-1kV to 100kV	100mA-1mA	£1078-£2475	12kg-30kg	100ppm	100ppm	2	Yes
	<i>RHV 300</i>	300W	500V to 5kV-1kV to 100kV	60mA-3mA	£3074-£4950	16kg-46kg	100ppm	100ppm	2	Yes
<b>Bertan</b> via Powerline (0734 868567)	<i>205A</i> (8 models)	~20W	0 to 1kV-0 to 50kV	30mA-0,3mA	£992-£2559	5½kg-11kg	10ppm	50ppm	1	Yes
	<i>210</i> (8 models)	~200W	0 to 1kV-0 to 50kV	225mA-2,5mA	£1744-£3583	15kg-21kg	10ppm	50ppm	1	Yes
<b>Brandenburg</b> (01-689 0441)	<i>Alpha II</i> (5 models)	25W	500V to 5kV-6kV to 60kV	5mA-0,4mA	£646-£1030	9kg-17kg	10ppm	20ppm	1	Yes
	<i>Gamma</i> (5 models)	100W	1kV to 10kV-10kV to 100kV	10mA-1mA	£1227-£2206	23kg-35kg	0,02%	0,05%	2	No
	<i>Photomult</i> <i>HV/HVV</i> (27 models)	10W 20W-6kV	10 to 2½kV 0 to 10kV	5mA 20mA-2A	£380 £585-£6200	6½kg 16kg-154kg	10ppm 0,1%	10ppm 0,2%	1 2	No No
	<i>410B</i> <i>415B</i>	100W 90W	0V to 10kV 0V to 3kV	10mA 30mA	£3795 £2387	27kg 27kg	10ppm 5ppm	10ppm 5ppm	1 1	No No
<b>Hartley</b> (0256 56695)	<i>425</i> (6 models)	200W	250V to 2½kV-400V to 40kV	80mA-5mA	£912-£1475	10kg-12kg	0,5%	0,5%	1	Yes
	<i>421</i> (48 models)	100W- 1500W	100V to 1kV-5kV to 50kV	100mA-30mA	£1210-£4999	10kg-35kg	0,1%	0,1%	2	Yes
<b>Hunting Hivolt</b> (07917 4511)	<i>250</i> (12 models)	250W	0V to 10kV-0V to 50kV	25mA-5mA	£1680-£1900	15kg-15kg	0,02%	0,05%	2	Yes
	<i>2000</i> (16 models)	2000W	0V to 25kV-0V to 200kV	80mA-10mA	£4200-£6800	75kg-85kg	0,02%	0,05%	2	Yes
	<i>4000</i> (6 models)	4000W	0 to 50kV-0 to 150kV	80mA-32mA	~£7000- ~£11000	150kg-170kg	0,02%	0,05%	2	Yes
	<i>VCS</i> (3 models)	30W	100V to 5kV-100V to 30kV	6mA-1mA	£745	15kg	100ppm	250ppm	2	+£95
<b>Wallis</b> (0903 211241)	<i>R</i> (5 models)	100W	500V to 5kV-10kV to 100kV	20mA-1mA	£1060-£2300	17kg-25kg	50ppm	100ppm	2	+£95
	<i>OL</i> (6 models)	500W	10V to 1kV-100V to 60kV	500mA-8mA	£1650-£2195	20kg-28kg	0,1%	0,1%	2	Yes
	<i>OL (1kW)</i> (6 models)	1000W	10V to 1kV-1kV to 60kV	1000mA- 16mA	£1800-£2950	20kg-28kg	0,1%	0,1%	2	Yes
	<i>OL (2,5kW)</i> (6 models)	2500W	20V to 1kV-500V to 30kV	2500mA- 80mA	£3500-£4050	37kg-40kg	0,1%	0,1%	2	Yes

Table 1 shows a selection of open-frame multiple-output SMPSs. The examples shown are the latest entries from each manufacturer (or where there are no new designs they have been chosen to illustrate broadly the power range covered). Prices are indicative only, and rounded to the nearest pound. Sizes are rounded to the nearest cm. Most of the standards shown are 'designed to meet' and not necessarily 'approved to'. The regulation specifications usually apply only within a range of loads; the minimum load is generally 10 to 20% of full load.

Comparison of the max power handling with the sum of quoted output V1 will illustrate the, now common, 'power-trading' concept, where the user can decide, within limits, how to allocate the output power amongst the secondaries:  $\pm V$  means  $+V$  and  $-V$ ;  $-12V + 15V$  means  $-12V$  or  $+15V$ .

Table 2 shows a selection of rack mounted high voltage power supplies from leading sources. An attempt has been made to indicate the general specifications, though variations in specifications may occur at the manufacturers' discretions.

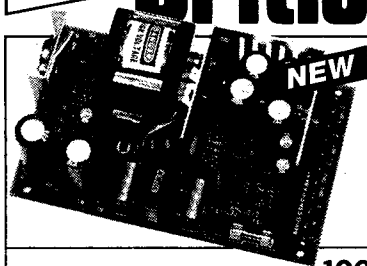
There are no mandatory rules for measuring a particular parameter; ie, the percentage line or load change for regulation, or the conditions of ripple and noise measurement. The data given above is therefore for guidance only, and Electronics Industry can accept no responsibility for any errors or omissions in these or any other tables.



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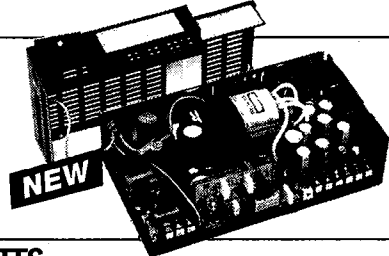
**MODEL AC94310**

OUTPUTS: +5V 10A, +12V 4A, -12V 0.5A, -5V 0.25A

**MODEL AC94311**

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**NOTE:** The two +12V 5A rails may be connected in series for  
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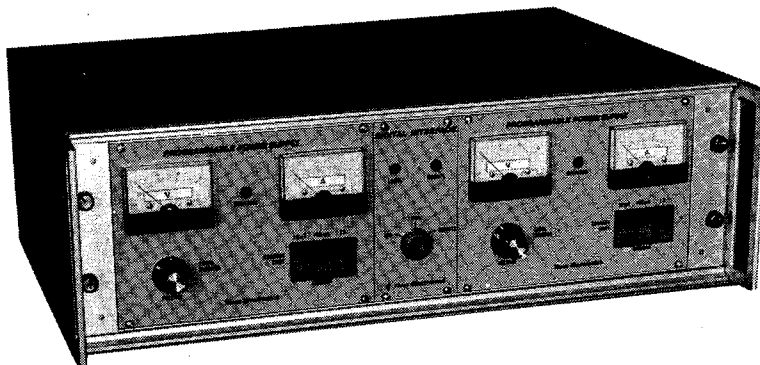
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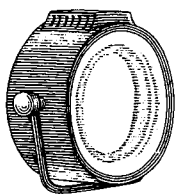


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## Voltage converters—dc/dc

A dc/dc converter is a dc-operated power source which performs two primary functions: isolating the primary dc input from external loading effects and providing output levels which differ from those of the primary dc input. Converters with input-to-output (I/O) isolations fill an additional need in permitting the establishment of independent grounding systems.

The excellent line and load regulation available from these devices makes them ideal for use as local dc distribution points in large scale systems. They can deliver well regulated dc power to circuit segments when operated from poorly regulated primary dc power rails. In this way they isolate the system from the deficiencies of the primary dc source.

A dc/dc converter designed to operate from a 12V automotive battery can deliver fixed single outputs which vary from  $\pm 5$  to  $\pm 50$ Vdc, depending on model. This feature is essential as the use of electronics by the automotive industry increases and is also seen in uninterruptible power supplies.

Converters with the I/O feature perform the same loop-breaking function as a 'Balun' transformer; ie, (ideally) no conductive path exists between input and output commons, tending to make the input and output terminal pairs independent of each other. It is for this reason that a high degree of isolation will exist between the input and output current loops. However, it must be realised that all dc/dc converters generate a certain amount of output ripple. Unlike line-operated series pass power supplies, all dc/dc converters utilise some form of switching. This is usually associated with a magnetic material changing state at the frequency rate. As this change takes place, losses occur. These losses manifest themselves as a quasi step function current source reflected toward the input and delivered to the output. Output ripple, commonly referred to as output noise current, cannot be readily filtered. Output filtering would increase the output independence of the converter,

making it extremely sensitive to load variation.

### Input protection

Some manufacturers of converters fit their units with reverse voltage protection. The most effective of several methods of this protection is a diode placed in series with the input. Another method of protection is to connect a power diode in parallel with the input, so that it is reverse biased under normal input conditions.

The series method is foolproof. The diode offers a very high impedance under reversed input polarity conditions, providing the input voltage is not greater than the reverse voltage breakdown of the series diode. The basic shortcoming of this method is that a significant amount of power is lost across the protection diode during normal operation, eg an additional 14–20% loss would exist for 5V input applications, due to the diode alone.

The reverse parallel method of protection dissipates very little power, but is seriously limited with respect to protection. To be effective, the diode must be capable of dissipating all of the available input power to the converter for extended periods of time. It would otherwise eventually become open circuited and hence ineffective. This type of reverse voltage protection can be readily and adequately effected by the user if required.

In relative terms, the manufacturers of dc/dc converters tend to offer a reasonable degree of conformity as regards rating, pin-out and mounting footprint. The industry standard for medium power units is set by the power

products division of Computer Products (incorporating Stevens Arnold) who are distributed in the UK by Amplicon. Other leaders are Semiconductor Circuits (via Powerline) followed by Reliability (via Thame Components) and Power General. Melcher (via FR Electronics and Thame Components) are also important in Europe, although to date it appears that there has been no effort made by Melcher to conform to these standard packages. Fabrimex (via Powerline) have also tended to go their own route but European manufacturers KRP (via Kingslo) second source standard items as well as producing their own package designs.

British suppliers (eg, Analog Devices, Burr Brown, Coutant, Dattel, Gould, Gresham) have used Computer Products to brand label for them in the past, and so they tend to match the standard quite closely with their encapsulated units.

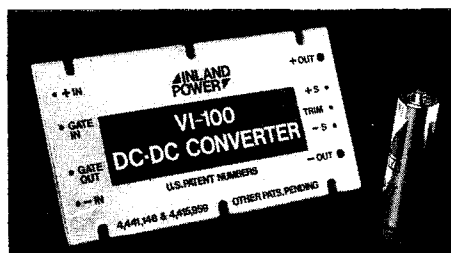


Fig. 6 A typical dc/dc converter layout

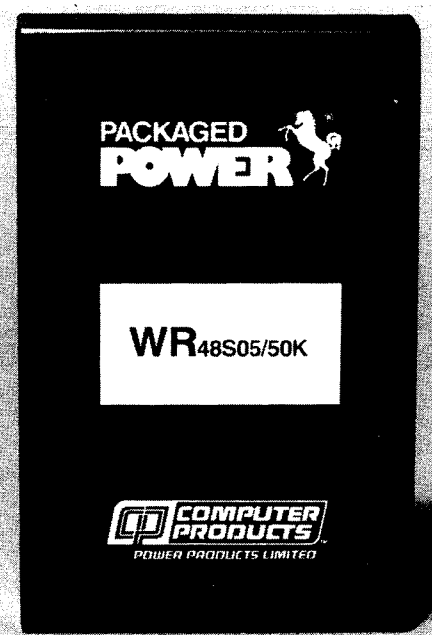
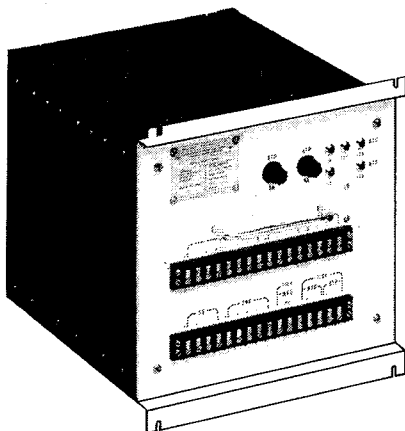


Fig. 6a One of the Computer Products' range of dc/dc converters. The same devices have been supplied by most of the leading power supply manufacturers in the past as a result of labelling deals

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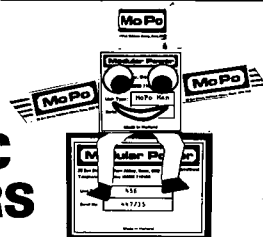


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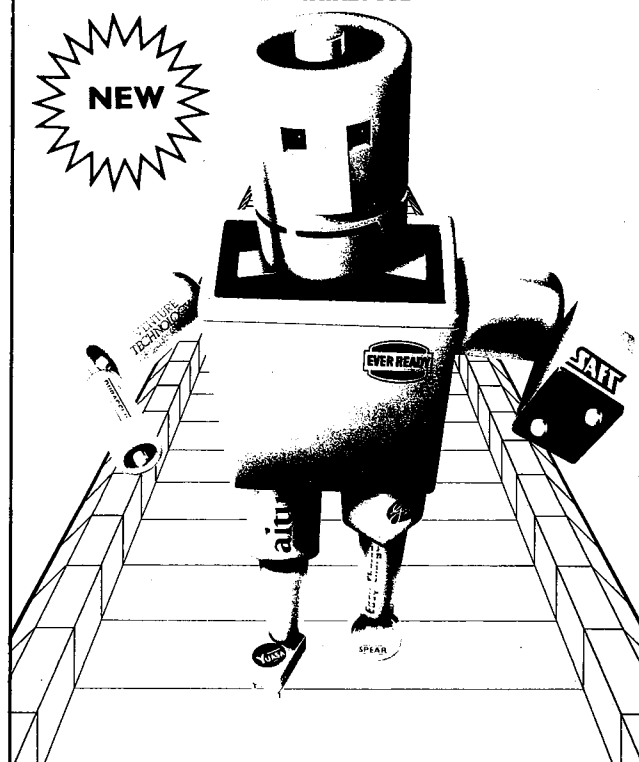
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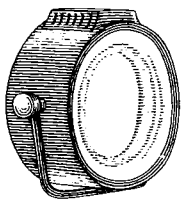
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## ALLBATTERIES

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## Batteries for OEM applications

**W**hilst for commercial applications the choice of battery to use is relatively straightforward—standard or long-life (notably Duracell)—for applications within the OEM electronics industry, the choice is critical.

In this section of *Spotlight*, we look at battery technology and the wide variety available.

### The Lithium alternative

Lithium primary cells in their various forms remain the most important recent development in battery technology. The benefits of most Lithium cell types are particularly relevant to designers of electronic equipment where the current drain is small. One of the obvious areas is that of memory back-up, but as CMOS becomes common in all areas of chip fabrication, supply requirements for many ICs are reducing radically making battery-power a viable possibility here for the first time.

The good shelf life of Lithium cells (generally 5–10 years), coupled with excellent temperature characteristics in low or occasional drain applications enables them to be treated as electronics components, soldered into a board. Even their MTBF is likely to be comparable with other components. The added cost and circuit complexity required for secondary cells is eliminated and many OEMs are now re-appraising rechargeable battery systems.

An indication of the battery capacity in amp-hours is given in table 3. The figures show the range of capacity commonly available, and exclude unusually large sizes.

Most cell technologies are available in the standard AA size and have relative capacity of constant 20mA drain. This level of discharge current suits some types better than others, but the general relationship holds good for most normal current levels.

### Common cell sizes

US	IEC	Diam × height
D	LR20	34,2 × 61,5mm
C	LR14	26,2 × 50mm
AA	LR6	14,5 × 50,5mm
AAA	LR03	10,5 × 44,5mm

*Despite efforts to establish the IEC nomenclature in the UK, the established US size code remains the most common*

### Cell efficiency

Power density gives only a rough indication of the relative volumetric efficiency of different cells because this figure usually also varies with the size of the cell considered.

It would be fair to assume that with smaller cells containing less active electrolyte, the Watt-hours/cc figure would decrease—as indeed it does with most button cells. Some cylindrical cells on the other hand (eg alkaline) use different constructions for smaller sizes and the volumetric efficiency actually increases.

The power density figures given in table 3 do nevertheless allow the prospective user with restrictions on space to gauge the most suitable battery technologies worth investigat-

ing. It is interesting to note that while silver cells are actually more efficient than some Lithium types in terms of volume, the light atomic weights of Lithium (7, just below the weights of Hydrogen and Helium: 1 and 4 respectively) makes it at least twice as good as any other type (including silver with an atomic weight of 107,868) when efficiency is assessed in terms of weight (Watt-hours/gram).

### Temperature range

As a result of their chemical basis, all cells will become more active as temperature increases and will be able to supply more current (due to a doubling in rate of the chemical reaction taking place within the cell for every 10°C rise in temperature). The upper limit depends not only on the chemical constituents of the cell but also on its construction.

Boasting an operating temperature of +150°C, Lithium copper oxide was developed specifically for use in applications requiring such high temperature operation. This type of cell has proven invaluable in (eg) medical apparatus which is steam-sterilized or remote geological transponders (in oil drilling, etc).

It is at the low end of the range that the ability to deliver useful current has

### Comparative performance of D size cells

Applications	IEC test conditions	SP	HP	PP	Alkaline
Portable lighting	5Ω for 30min/day	16hr	22hr	29hr	34hr
Portable lighting	4Ω for 4min/hr, 8hr/day	12hr	18hr	22hr	28hr
Tape recorders	3,9Ω for 1hr/day	5hr	11hr	16hr	21hr
Portable lighting	3,9Ω for 30min/day	11hr	18hr	21hr	27hr
Portable lighting	2,5Ω for 10min/day	8hr	12hr	13hr	14hr
Toys	2,2Ω for 5min/day	4hr	5hr	11hr	14hr
Razors and toothbrushes	2,2Ω for 5min/day	8hr	10hr	12hr	13hr

*The table shows the life expectancy in hours for four types of cell to an end point of 0,9V under standardised test conditions (and the typical consumer applications these aim to simulate). It can be seen that the advantage of the more expensive types differs according to the nature of the demand*

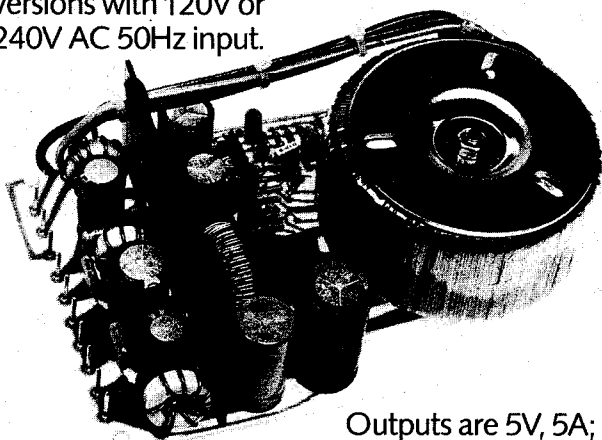
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# Secondary switching power supplies

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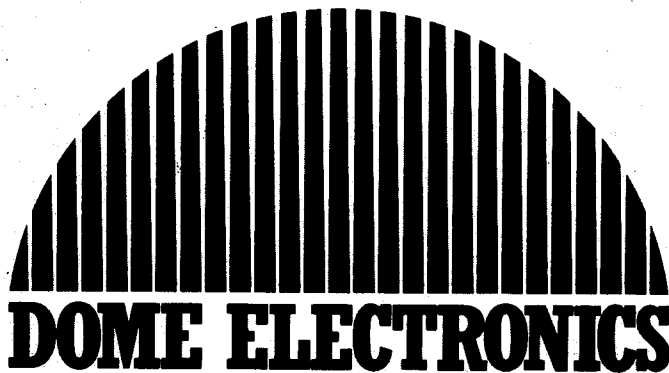
The Zeus series features 25W, 55W and 85W versions with 120V or 240V AC 50Hz input.



Outputs are 5V, 5A;  $\pm 12V$ , 1A. Single, dual, triple or quad options conform to BS6204 safety specifications, and a wide range of output connectors are available. Zeus series power supplies are ideal for all disc drive, printer, microcomputer and cassette applications, as well as for use in telecommunications and data processing systems.

## **Dome – British technology and capability.**

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### **Encapsulated Power Supplies**

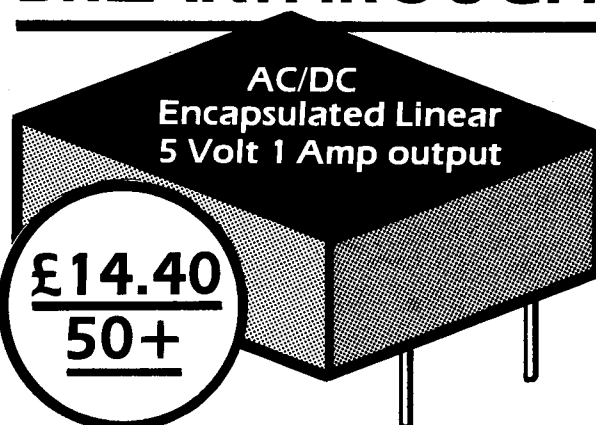
Calex designs, builds and tests quality into every encapsulated power supply and this quality is backed with a full 5-year warranty. Competitively priced, ex-stock delivery is offered on PCB Industry Standards, Chassis Mounts, and U.L. Medical Approvals. *To build the best you need the best, call Calex.*

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## Package styles

Popular cell sizes are  $\frac{1}{2}$ AA, AA and AAA cylindrical styles, and most cells are produced in these sizes. These styles allow readily-available battery connector clips to be used. Cells designed for long term, low drain applications (ie, memory back-up), such as LiCuO or LiMnO<sub>2</sub>, will have radial leads for ease of insertion into printed circuit boards. For space-restricted applications a wide range of button/coin cell shapes and sizes is available.

**Fig. 7 A representative selection of the Duracell range of batteries**

Offering the highest power density of any cell type and an impressive temperature performance of  $-20^{\circ}\text{C}$  to

### Table 3. Comparison of primary cell types

Primary Cell Type	EMF (V)	Current (mA)	Packaging	Capacity (mAh)	Temp. Range (°C)	Power Density (mW/cm²)	Price (¢/cell)	Manufacturer
Aluminum-air (Al/NaOH)	2.20-2.35	20-100 mA	Cylindrical	1-3 Ah	-55 to +140	0.75	42	Sanyo, Matsushita
Aluminum-iron disulfide (Al/FeS₂)	1.5	10 mA	AA, AAA, AA-A, AA-B, AA-C, AA-D, AA-E, AA-F, AA-G, AA-H, AA-I, AA-J, AA-K, AA-L, AA-M, AA-N, AA-O, AA-P, AA-Q, AA-R, AA-S, AA-T, AA-U, AA-V, AA-W, AA-X, AA-Y, AA-Z, AA-AA, AA-AB, AA-AC, AA-AD, AA-AE, AA-AF, AA-AG, AA-AH, AA-AI, AA-AJ, AA-AK, AA-AL, AA-AM, AA-AN, AA-AO, AA-AP, AA-AQ, AA-AR, AA-AS, AA-AT, AA-AU, AA-AV, AA-AW, AA-AX, AA-AY, AA-AZ, AA-BA, AA-BB, AA-BC, AA-BD, AA-BE, AA-BF, AA-BG, AA-BH, AA-BI, AA-BJ, AA-BK, AA-BL, AA-BM, AA-BN, AA-BO, AA-BP, AA-BQ, AA-BR, AA-BS, AA-BT, AA-BU, AA-BV, AA-BW, AA-BX, AA-BY, AA-BZ, AA-CA, AA-CB, AA-CC, AA-CD, AA-CE, AA-CF, AA-CG, AA-CH, AA-CI, AA-CJ, AA-CK, AA-CL, AA-CM, AA-CN, AA-CP, AA-CQ, AA-CR, AA-CS, AA-CT, AA-CU, AA-CV, AA-CW, AA-CX, AA-CY, AA-CZ, AA-DA, AA-DB, AA-DC, AA-DD, AA-DE, AA-DF, AA-DG, AA-DH, AA-DI, AA-DJ, AA-DK, AA-DL, AA-DM, AA-DN, AA-DO, AA-DP, AA-DQ, AA-DR, AA-DS, AA-DT, AA-DU, AA-DV, AA-DW, AA-DX, AA-DY, AA-DZ, AA-EA, AA-EB, AA-EC, AA-ED, AA-EE, AA-EF, AA-EG, AA-EH, AA-EI, AA-EJ, AA-EK, AA-EL, AA-EM, AA-EN, AA-EO, AA-EP, AA-EQ, AA-ER, AA-ES, AA-ET, AA-EU, AA-EV, AA-EW, AA-EX, AA-EY, AA-EZ, AA-FA, AA-FB, AA-FC, AA-FD, AA-FE, AA-FF, AA-FG, AA-FH, AA-FI, AA-FJ, AA-FK, AA-FL, AA-FM, AA-FN, AA-FO, AA-FP, AA-FQ, AA-FR, AA-FS, AA-FT, AA-FU, AA-FV, AA-FW, AA-FX, AA-FY, AA-FZ, AA-GA, AA-GB, AA-GC, AA-GD, AA-GE, AA-GF, AA-GG, AA-GH, AA-GI, AA-GJ, AA-GK, AA-GL, AA-GM, AA-GN, AA-GO, AA-GP, AA-GQ, AA-GR, AA-GS, AA-GT, AA-GU, AA-GV, AA-GW, AA-GX, AA-GY, AA-GZ, AA-HA, AA-HB, AA-HC, AA-HD, AA-HE, AA-HF, AA-HG, AA-HH, AA-HI, AA-HJ, AA-HK, AA-HL, AA-HM, AA-HN, AA-HO, AA-HP, AA-HQ, AA-HR, AA-HS, AA-HT, AA-HU, AA-HV, AA-HW, AA-HX, AA-HY, AA-HZ, AA-IA, AA-IB, AA-IC, AA-ID, AA-IE, AA-IF, AA-IG, AA-IH, AA-II, AA-IJ, AA-IK, AA-IL, AA-IM, AA-IN, AA-IO, AA-IP, AA-IQ, AA-IR, AA-IS, AA-IT, AA-IU, AA-IV, AA-IW, AA-IX, AA-IY, AA-IZ, AA-JA, AA-JB, AA-JC, AA-JD, AA-JE, AA-JF, AA-JG, AA-JH, AA-JI, AA-JJ, AA-JK, AA-JL, AA-JM, AA-JN, AA-JO, AA-JP, AA-JQ, AA-JR, AA-JS, AA-JT, AA-JU, AA-JV, AA-JW, AA-JX, AA-JY, AA-JZ, AA-KA, AA-KB, AA-KC, AA-KD, AA-KE, AA-KF, AA-KG, AA-KH, AA-KI, AA-KJ, AA-KK, AA-KL, AA-KM, AA-KN, AA-KO, AA-KP, AA-KQ, AA-KR, AA-KS, AA-KT, AA-KU, AA-KV, AA-KW, AA-KX, AA-KY, AA-KZ, AA-LA, AA-LB, AA-LC, AA-LD, AA-LE, AA-LF, AA-LG, AA-LH, AA-LI, AA-LJ, AA-LK, AA-LM, AA-LN, AA-LO, AA-LP, AA-LQ, AA-LR, AA-LS, AA-LT, AA-LU, AA-LV, AA-LW, AA-LX, AA-LY, AA-LZ, AA-MA, AA-MB, AA-MC, AA-MD, AA-ME, AA-MF, AA-MG, AA-MH, AA-MI, AA-MJ, AA-MK, AA-ML, AA-MM, AA-MN, AA-MO, AA-MP, AA-MQ, AA-MR, AA-MS, AA-MT, AA-MU, AA-MV, AA-MW, AA-MX, AA-MY, AA-MZ, AA-NA, AA-NB, AA-NC, AA-ND, AA-NE, AA-NF, AA-NG, AA-NH, AA-NI, AA-NJ, AA-NK, AA-NL, AA-NM, AA-NO, AA-NP, AA-NQ, AA-NR, AA-NS, AA-NT, AA-NU, AA-NV, AA-NW, AA-NX, AA-NY, AA-NZ, AA-OA, AA-OB, AA-OC, AA-OD, AA-OE, AA-OF, AA-OG, AA-OH, AA-OI, AA-OJ, AA-OK, AA-OL, AA-OM, AA-ON, AA-OO, AA-OP, AA-OQ, AA-OR, AA-OS, AA-OT, AA-OU, AA-OV, AA-OW, AA-OX, AA-OY, AA-OZ, AA-PA, AA-PB, AA-PC, AA-PD, AA-PE, AA-PF, AA-PG, AA-PH, AA-PI, AA-PJ, AA-PK, AA-PL, AA-PM, AA-PN, AA-PO, AA-PP, AA-PQ, AA-PR, AA-PS, AA-PT, AA-PU, AA-PV, AA-PW, AA-PX, AA-PY, AA-PZ, AA-QA, AA-QB, AA-QC, AA-QD, AA-QE, AA-QF, AA-QG, AA-QH, AA-QI, AA-QJ, AA-QK, AA-QL, AA-QM, AA-QN, AA-QO, AA-QP, AA-QQ, AA-QR, AA-QS, AA-QT, AA-QU, AA-QV, AA-QW, AA-QX, AA-QY, AA-QZ, AA-RA, AA-RB, AA-RC, AA-RD, AA-RE, AA-RF, AA-RG, AA-RH, AA-RI, AA-RJ, AA-RK, AA-RL, AA-RM, AA-RN, AA-RO, AA-RP, AA-RQ, AA-RR, AA-RS, AA-RT, AA-RU, AA-RV, AA-RW, AA-RX, AA-RY, AA-RZ, AA-SA, AA-SB, AA-SC, AA-SD, AA-SE, AA-SF, AA-SG, AA-SH, AA-SI, AA-SJ, AA-SK, AA-SL, AA-SM, AA-SN, AA-SO, AA-SP, AA-SQ, AA-SR, AA-SS, AA-ST, AA-SU, AA-SV, AA-SW, AA-SX, AA-SY, AA-SZ, AA-TA, AA-TB, AA-TC, AA-TD, AA-TE, AA-TF, AA-TG, AA-TH, AA-TI, AA-TJ, AA-TK, AA-TL, AA-TM, AA-TN, AA-TO, AA-TP, AA-TQ, AA-TR, AA-TS, AA-TT, AA-TU, AA-TV, AA-TW, AA-TX, AA-TY, AA-TZ, AA-UA, AA-UB, AA-UC, AA-UD, AA-UE, AA-UF, AA-UG, AA-UH, AA-UI, AA-UJ, AA-UK, AA-UL, AA-UM, AA-UN, AA-UO, AA-UP, AA-UQ, AA-UR, AA-US, AA-UT, AA-UY, AA-UZ, AA-VA, AA-VB, AA-VC, AA-VD, AA-VE, AA-VF, AA-VG, AA-VH, AA-VI, AA-VJ, AA-VK, AA-VL, AA-VM, AA-VN, AA-VO, AA-VP, AA-VQ, AA-VR, AA-VS, AA-VT, AA-VU, AA-VV, AA-VW, AA-VX, AA-VY, AA-VZ, AA-WA, AA-WB, AA-WC, AA-WD, AA-WE, AA-WF, AA-WG, AA-WH, AA-WI, AA-WJ, AA-WK, AA-WL, AA-WM, AA-WN, AA-WO, AA-WP, AA-WQ, AA-WR, AA-WS, AA-WT, AA-WU, AA-WV, AA-WX, AA-WY, AA-WZ, AA-XA, AA-XB, AA-XC, AA-XD, AA-XE, AA-XF, AA-XG, AA-XH, AA-XI, AA-XJ, AA-XK, AA-XL, AA-XM, AA-XN, AA-XO, AA-XP, AA-XQ, AA-XR, AA-XS, AA-XT, AA-XU, AA-XV, AA-XW, AA-XX, AA-XY, AA-XZ, AA-YA, AA-YB, AA-YC, AA-YD, AA-YE, AA-YF, AA-YG, AA-YH, AA-YI, AA-YJ, AA-YK, AA-YL, AA-YM, AA-YN, AA-YO, AA-YP, AA-YQ, AA-YR, AA-YS, AA-YT, AA-YU, AA-YV, AA-YW, AA-YX, AA-YY, AA-YZ, AA-ZA, AA-ZB, AA-ZC, AA-ZD, AA-ZE, AA-ZF, AA-ZG, AA-ZH, AA-ZI, AA-ZJ, AA-ZK, AA-ZL, AA-ZM, AA-ZN, AA-ZO, AA-ZP, AA-ZQ, AA-ZR, AA-ZS, AA-ZT, AA-ZU, AA-ZV, AA-ZW, AA-ZX, AA-ZY, AA-ZZ	20 to 100	AA, AAA, AA-A, AA-B, AA-C, AA-D, AA-E, AA-F, AA-G, AA-H, AA-I, AA-J, AA-K, AA-L, AA-M, AA-N, AA-O, AA-P, AA-Q, AA-R, AA-S, AA-T, AA-U, AA-V, AA-W, AA-X, AA-Y, AA-Z, AA-AA, AA-AB, AA-AC, AA-AD, AA-AE, AA-AF, AA-AG, AA-AH, AA-AI, AA-AJ, AA-AK, AA-AL, AA-AM, AA-AN, AA-AO, AA-AP, AA-AQ, AA-AR, AA-AS, AA-AT, AA-AU, AA-AV, AA-AW, AA-AX, AA-AY, AA-AZ, AA-BA, AA-BB, AA-BC, AA-BD, AA-BE, AA-BF, AA-BG, AA-BH, AA-BI, AA-BJ, AA-BK, AA-BL, AA-BM, AA-BN, AA-BO, AA-BP, AA-BQ, AA-BR, AA-BS, AA-BT, AA-BU, AA-BV, AA-BW, AA-BX, AA-BY, AA-BZ, AA-CA, AA-CB, AA-CC, AA-CD, AA-CE, AA-CF, AA-CG, AA-CH, AA-CI, AA-CJ, AA-CK, AA-CL, AA-CM, AA-CN, AA-CP, AA-CQ, AA-CR, AA-CS, AA-CT, AA-CU, AA-CV, AA-CW, AA-CX, AA-CY, AA-CZ, AA-DA, AA-DB, AA-DC, AA-DD, AA-DE, AA-DF, AA-DG, AA-DH, AA-DI, AA-DJ, AA-DK, AA-DL, AA-DM, AA-DN, AA-DO, AA-DP, AA-DQ, AA-DR, AA-DS, AA-DT, AA-DU, AA-DV, AA-DW, AA-DX, AA-DY, AA-DZ, AA-EA, AA-EB, AA-EC, AA-ED, AA-EE, AA-EF, AA-EG, AA-EH, AA-EI, AA-EJ, AA-EK, AA-EL, AA-EM, AA-EN, AA-EO, AA-EP, AA-EQ, AA-ER, AA-ES, AA-ET, AA-EU, AA-EV, AA-EW, AA-EX, AA-EY, AA-EZ, AA-FA, AA-FB, AA-FC, AA-FD, AA-FE, 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AA-QH, AA-QI, AA-QJ, AA-QK, AA-QL, AA-QM, AA-QN, AA-QO, AA-QP, AA-QQ, AA-QR, AA-QS, AA-QT, AA-QU, AA-QV, AA-QW, AA-QX, AA-QY, AA-QZ, AA-RA, AA-RB, AA-RC, AA-RD, AA-RE, AA-RF, AA-RG, AA-RH, AA-RI, AA-RJ, AA-RK, AA-RL, AA-RM, AA-RN, AA-RO, AA-RP, AA-RQ, AA-RR, AA-RS, AA-RT, AA-RU, AA-RV, AA-RW, AA-RX, AA-RY, AA-RZ, AA-SA, AA-SB, AA-SC, AA-SD, AA-SE, AA-SF, AA-SG, AA-SH, AA-SI, AA-SJ, AA-SK, AA-SL, AA-SM, AA-SN, AA-SO, AA-SP, AA-SQ, AA-SR, AA-SS, AA-ST, AA-SU, AA-SV, AA-SW, AA-SX, AA-SY, AA-SZ, AA-TA, AA-TB, AA-TC, AA-TD, AA-TE, AA-TF, AA-TG, AA-TH, AA-TI, AA-TJ, AA-TK, AA-TL, AA-TM, AA-TN, AA-TO, AA-TP, AA-TQ, AA-TR, AA-TS, AA-TT, AA-TU, AA-TV, AA-TW, AA-TX, AA-TY, AA-TZ, AA-UA, AA-UB, AA-UC, AA-UD, AA-UE, AA-UF, AA-UG, AA-UH, AA-UI, AA-UJ, AA-UK, AA-UL, AA-UM, AA-UN, AA-UO, AA-UP, AA-UQ, AA-UR, AA-US, AA-UT, AA-UY, AA-UZ, AA-VA, AA-VB, AA-VC, AA-VD, AA-VE, AA-VF, AA-VG, AA-VH, AA-VI, AA-VJ, AA-VK, AA-VL, AA-VM, AA-VN, AA-VO, AA-VP, AA-VQ, AA-VR, AA-VS, AA-VT, AA-VU, AA-VV, AA-VW, AA-VX, AA-VY, AA-VZ, AA-WA, AA-WB, AA-WC, AA-WD, AA-WE, AA-WF, AA-WG, AA-WH, AA-WI, AA-WJ, AA-WK, AA-WL, AA-WM, AA-WN, AA-WO, AA-WP, AA-WQ, AA-WR, AA-WS, AA-WT, AA-WU, AA-WV, AA-WX, AA-WY, AA-WZ, AA-XA, AA-XB, AA-XC, AA-XD, AA-XE, AA-XF, AA-XG, AA-XH, AA-XI, AA-XJ, AA-XK, AA-XL, AA-XM, AA-XN, AA-XO, AA-XP, AA-XQ, AA-XR, AA-XS, AA-XT, AA-XU, AA-XV, AA-XW, AA-XX, AA-XY, AA-XZ, AA-YA, AA-YB, AA-YC, AA-YD, AA-YE, AA-YF, AA-YG, AA-YH, AA-YI, AA-YJ, AA-YK, AA-YL, AA-YM, AA-YN, AA-YO, AA-YP, AA-YQ, AA-YR, AA-YS, AA-YT, AA-YU, AA-YV, AA-YW, AA-YX, AA-YY, AA-YZ, AA-ZA, AA-ZB, AA-ZC, AA-ZD, AA-ZE, AA-ZF, AA-ZG, AA-ZH, AA-ZI, AA-ZJ, AA-ZK, AA-ZL, AA-ZM, AA-ZN, AA-ZO, AA-ZP, AA-ZQ, AA-ZR, AA-ZS, AA-ZT, AA-ZU, AA-ZV, AA-ZW, AA-ZX, AA-ZY, AA-ZZ	42	Sanyo, Matsushita	
Aluminum-iron disulfide (Al/FeS₂)	1.5	10 mA	AA, AAA, AA-A, AA-B, AA-C, AA-D, AA-E, AA-F, AA-G, AA-H, AA-I, AA-J, AA-K, AA-L, AA-M, AA-N, AA-O, AA-P, AA-Q, AA-R, AA-S, AA-T, AA-U, AA-V, AA-W, AA-X, AA-Y, AA-Z, AA-AA, AA-AB, AA-AC, AA-AD, AA-AE, AA-AF, AA-AG, AA-AH, AA-AI, AA-AJ, AA-AK, AA-AL, AA-AM, AA-AN, AA-AO, AA-AP, AA-AQ, AA-AR, AA-AS, AA-AT, AA-AU, AA-AV, AA-AW, AA-AX, AA-AY, AA-AZ, AA-BA, AA-BB, AA-BC, AA-BD, AA-BE, AA-BF, AA-BG, AA-BH, AA-BI, AA-BJ, AA-BK, AA-BL, AA-BM, AA-BN, AA-BO, AA-BP, AA-BQ, AA-BR, AA-BS, AA-BT, AA-BU, AA-BV, AA-BW, AA-BX, AA-BY, AA-BZ, AA-CA, AA-CB, AA-CC, AA-CD, AA-CE, AA-CF, AA-CG, AA-CH, AA-CI, AA-CJ, AA-CK, AA-CL, AA-CM, AA-CN, AA-CP, AA-CQ, AA-CR, AA-CS, AA-CT, AA-CU, AA-CV, AA-CW, AA-CX, AA-CY, AA-CZ, AA-DA, AA-DB, AA-DC, AA-DD, AA-DE, AA-DF, AA-DG, AA-DH, AA-DI, AA-DJ, AA-DK, AA-DL, AA-DM, AA-DN, AA-DO, AA-DP, AA-DQ, AA-DR, AA-DS, AA-DT, AA-DU, AA-DV, AA-DW, AA-DX, AA-DY, AA-DZ, AA-EA, AA-EB, AA-EC, AA-ED, AA-EE, AA-EF, AA-EG, AA-EH, AA-EI, AA-EJ, AA-EK, AA-EL, AA-EM, AA-EN, AA-EO, AA-EP, AA-EQ, AA-ER, AA-ES, AA-ET, AA-EU, AA-EV, AA-EW, AA-EX, AA-EY, AA-EZ, AA-FA, AA-FB, AA-FC, AA-FD, AA-FE, AA-FF, AA-FG, AA-FH, AA-FI, AA-FJ, AA-FK, AA-FL, AA-FM, AA-FN, AA-FO, AA-FP, AA-FQ, AA-FR, AA-FS, AA-FT, AA-FU, AA-FV, AA-FW, AA-FX, AA-FY, AA-FZ, AA-GA, AA-GB, AA-GC, AA-GD, AA-GE, AA-GF, AA-GG, AA-GH, AA-GI, AA-GJ, AA-GK, AA-GL, AA-GM, AA-GN, AA-GO, AA-GP, AA-GQ, AA-GR, AA-GS, AA-GT, AA-GU, AA-GV, AA-GW, AA-GX, AA-GY, AA-GZ, AA-HA, AA-HB, AA-HC, AA-HD, AA-HE, AA-HF, AA-HG, AA-HH, AA-HI, AA-HJ, AA-HK, AA-HL, AA-HM, AA-HN, AA-HO, AA-HP, AA-HQ, AA-HR, AA-HS, AA-HT, AA-HU, AA-HV, AA-HW, AA-HX, AA-HY, AA-HZ, AA-IA, AA-IB, AA-IC, AA-ID, AA-IE, AA-IF, AA-IG, AA-IH, AA-II, AA-IJ, AA-IK, AA-IL, AA-IM, AA-IN, AA-IO, AA-IP, AA-IQ, AA-IR, AA-IS, AA-IT, AA-IU, AA-IV, AA-IW, AA-IX, AA-IY, AA-IZ, AA-JA, AA-JB, AA-JC, AA-JD, AA-JE, AA-JF, AA-JG, AA-JH, AA-JI, AA-JJ, AA-JK, AA-JL, AA-JM, AA-JN, AA-JO, AA-JP, AA-JQ, AA-JR, AA-JS, AA-JT, AA-JU, AA-JV, AA-JW, AA-JX, AA-JY, AA-JZ, AA-KA, AA-KB, AA-KC, AA-KD, AA-KE, AA-KF, AA-KG, AA-KH, AA-KI, AA-KJ, AA-KK, AA-KL, AA-KM, AA-KN, AA-KO, AA-KP, AA-KQ, AA-KR, AA-KS, AA-KT, AA-KU, AA-KV, AA-KW, AA-KX, AA-KY, AA-KZ, AA-LA, AA-LB, AA-LC, AA-LD, AA-LE, AA-LF, AA-LG, AA-LH, AA-LI, AA-LJ, AA-LK, AA-LM, AA-LN, AA-LO, AA-LP, AA-LQ, AA-LR, AA-LS, AA-LT, AA-LU, AA-LV, AA-LW, AA-LX, AA-LY, AA-LZ, AA-MA, AA-MB, AA-MC, AA-MD, AA-ME, AA-MF, AA-MG, AA-MH, AA-MI, AA-MJ, AA-MK, AA-ML, AA-MM, AA-MN, AA-MO, AA-MP, AA-MQ, AA-MR, AA-MS, AA-MT, AA-MU, AA-MV, AA-MW, AA-MX, AA-MY, AA-MZ, AA-NA, AA-NB, AA-NC, AA-ND, AA-NE, AA-NF, AA-NG, AA-NH, AA-NI, AA-NJ, AA-NK, AA-NL, AA-NM, AA-NO, AA-NP, AA-NQ, AA-NR, AA-NS, AA-NT, AA-NU, AA-NV, AA-NW, AA-NX, AA-NY, AA-NZ, AA-OA, AA-OB, AA-OC, AA-OD, AA-OE, AA-OF, AA-OG, AA-OH, AA-OI, AA-OJ, AA-OK, AA-OL, AA-OM, AA-ON, AA-OO, AA-OP, AA-OQ, AA-OR, AA-OS, AA-OT, AA-OU, AA-OV, AA-OW, AA-OX, AA-OY, AA-OZ, AA-PA, AA-PB, AA-PC, AA-PD, AA-PE, AA-PF, AA-PG, AA-PH, AA-PI, AA-PJ, AA-PK, AA-PL, AA-PM, AA-PN, AA-PO, AA-PP, AA-PQ, AA-PR, AA-PS, AA-PT, AA-PU, AA-PV, AA-PW, AA-PX, AA-PY, AA-PZ, AA-QA, AA-QB, AA-QC, AA-QD, AA-QE, AA-QF, AA-QG, AA-QH, AA-QI, AA-QJ, AA-QK, AA-QL, AA-QM, AA-QN, AA-QO, AA-QP, AA-QQ, AA-QR, AA-QS, AA-QT, AA-QU, AA-QV, AA-QW, AA-QX, AA-QY, AA-QZ, AA-RA, AA-RB, AA-RC, AA-RD, AA-RE, AA-RF, AA-RG, AA-RH, AA-RI, AA-RJ, AA-RK, AA-RL, AA-RM, AA-RN, AA-RO, AA-RP, AA-RQ, AA-RR, AA-RS, AA-RT, AA-RU, AA-RV, AA-RW, AA-RX, AA-RY, AA-RZ, AA-SA, AA-SB, AA-SC, AA-SD, AA-SE, AA-SF, AA-SG, AA-SH, AA-SI, AA-SJ, AA-SK, AA-SL, AA-SM, AA-SN, AA-SO, AA-SP, AA-SQ, AA-SR, AA-SS, AA-ST, AA-SU, AA-SV, AA-SW, AA-SX, AA-SY, AA-SZ, AA-TA, AA-TB, AA-TC, AA-TD, AA-TE, AA-TF, AA-TG, AA-TH, AA-TI, AA-TJ, AA-TK, AA-TL, AA-TM, AA-TN, AA-TO, AA-TP, AA-TQ, AA-TR, AA-TS, AA-TT, AA-TU, AA-TV, AA-TW, AA-TX, AA-TY, AA-TZ, AA-UA, AA-UB, AA-UC, AA-UD, AA-UE, AA-UF, AA-UG, AA-UH, AA-UI, AA-UJ, AA-UK, AA-UL, AA-UM, AA-UN, AA-UO, AA-UP, AA-UQ, AA-UR, AA-US, AA-UT, AA-UY, AA-UZ, AA-VA, AA-VB, AA-VC, AA-VD, AA-VE, AA-VF, AA-VG, AA-VH, AA-VI, AA-VJ, AA-VK, AA-VL, AA-VM, AA-VN, AA-VO, AA-VP, AA-VQ, AA-VR, AA-VS, AA-VT, AA-VU, AA-VV, AA-VW, AA-VX, AA-VY, AA-VZ, AA-WA, AA-WB, AA-WC, AA-WD, AA-WE, AA-WF, AA-WG, AA-WH, AA-WI, AA-WJ, AA-WK, AA-WL, AA-WM, AA-WN, AA-WO, AA-WP, AA-WQ, AA-WR, AA-WS, AA-WT, AA-WU, AA-WV, AA-WX, AA-WY, AA-WZ, AA-XA, AA-XB, AA-XC, AA-XD, AA-XE, AA-XF, AA-XG, AA-XH, AA-XI, AA-XJ, AA-XK, AA-XL, AA-XM, AA-XN, AA-XO, AA-XP, AA-XQ, AA-XR, AA-XS, AA-XT, AA-XU, AA-XV, AA-XW, AA-XX, AA-XY, AA-XZ, AA-YA, AA-YB, AA-YC, AA-YD, AA-YE, AA-YF, AA-YG, AA-YH, AA-YI, AA-YJ, AA-YK, AA-YL, AA-YM, AA-YN, AA-YO, AA-YP, AA-YQ, AA-YR, AA-YS, AA-YT, AA-YU, AA-YV, AA-YW, AA-YX, AA-YY, AA-YZ, AA-ZA, AA-ZB, AA-ZC, AA-ZD, AA-ZE, AA-ZF, AA-ZG, AA-ZH, AA-ZI, AA-ZJ, AA-ZK, AA-ZL, AA-ZM, AA-ZN, AA-ZO, AA-ZP, AA-ZQ, AA-ZR, AA-ZS, AA-ZT, AA-ZU, AA-ZV, AA-ZW, AA-ZX, AA-ZY, AA-ZZ	42	Sanyo, Matsushita			
Aluminum-iron disulfide (Al/FeS₂)	1.5	10 mA	AA, AAA, AA-A, AA-B, AA-C, AA-D, AA-E, AA-F, AA-G, AA-H, AA-I, AA-J, AA-K, AA-L, AA-M, AA-N, AA-O, AA-P, AA-Q, AA-R, AA-S, AA-T, AA-U, AA-V, AA-W, AA-X, AA-Y, AA-Z, AA-AA, AA-AB, AA-AC, AA-AD, AA-AE, AA-AF, AA-AG, AA-AH, AA-AI, AA-AJ, AA-AK, AA-AL, AA-AM, AA-AN, AA-AO, AA-AP, AA-AQ, AA-AR, AA-AS, AA-AT, AA-AU, AA-AV, AA-AW, AA-AX, AA-AY, AA-AZ, AA-BA, AA-BB, AA-BC, AA-BD, AA-BE, AA-BF, AA-BG, AA-BH, AA-BI, AA-BJ, AA-BK, AA-BL, AA-BM, AA-BN, AA-BO, AA-BP, AA-BQ, AA-BR, AA-BS, AA-BT, AA-BU, AA-BV, AA-BW, AA-BX, AA-BY, AA-BZ, AA-CA, AA-CB, AA-CC, AA-CD, AA-CE, AA-CF, AA-CG, AA-CH, AA-CI, AA-CJ, AA-CK, AA-CL, AA-CM, AA-CN, AA-CP, AA-CQ, AA-CR, AA-CS, AA-CT, AA-CU, AA-CV, AA-CW, AA-CX, AA-CY, AA-CZ, AA-DA, AA-DB, AA-DC, AA-DD, AA-DE, AA-DF, AA-DG, AA-DH, AA-DI, AA-DJ, AA-DK, AA-DL, AA-DM, AA-DN, AA-DO, AA-DP, AA-DQ, AA-DR, AA-DS, AA-DT, AA-DU, AA-DV, AA-DW, AA-DX, AA-DY, AA-DZ, AA-EA, AA-EB, AA-EC, AA-ED, AA-EE, AA-EF, AA-EG, AA-EH, AA-EI, AA-EJ, AA-EK, AA-EL, AA-EM, AA-EN, AA-EO, AA-EP, AA-EQ, AA-ER, AA-ES, AA-ET, AA-EU, AA-EV, AA-EW, AA-EX, AA-EY, AA-EZ, AA-FA, AA-FB, AA-FC, AA-FD, AA-FE, AA-FF, AA-FG, AA-FH, AA-FI, AA-FJ, AA-FK, AA-FL, AA-FM, AA-FN, AA-FO, AA-FP, AA-FQ, AA-FR, AA-FS, AA-FT, AA-FU, AA-FV, AA-FW, AA-FX, AA-FY, AA-FZ, AA-GA, AA-GB, AA-GC, AA-GD, AA-GE, AA-GF, AA-GG, AA-GH, AA-GI, AA-GJ, AA-GK, AA-GL, AA-GM, AA-GN, AA-GO, AA-GP, AA-GQ, AA-GR, AA-GS, AA-GT, AA-GU, AA-GV, AA-GW, AA-GX, AA-GY, AA-GZ, AA-HA, AA-HB, AA-HC, AA-HD, AA-HE, AA-HF, AA-HG, AA-HH, AA-HI, AA-HJ, AA-HK, AA-HL, AA-HM, AA-HN, AA-HO, AA-HP, AA-HQ, AA-HR, AA-HS, AA-HT, AA-HU, AA-HV, AA-HW, AA-HX, AA-HY, AA-HZ, AA-IA, AA-IB, AA-IC, AA-ID, AA-IE, AA-IF, AA-IG, AA-IH, AA-II, AA-IJ, AA-IK, AA-IL, AA-IM, AA-IN, AA-IO, AA-IP, AA-IQ, AA-IR, AA-IS, AA-IT, AA-IU, AA-IV, AA-IW, AA-IX, AA-IY, AA-IZ, AA-JA, AA-JB, AA-JC, AA-JD, AA-JE, AA-JF, AA-JG, AA-JH, AA-JI, AA-JJ, AA-JK, AA-JL, AA-JM, AA-JN, AA-JO, AA-JP, AA-JQ, AA-JR, AA-JS, AA-JT, AA-JU, AA-JV, AA-JW, AA-JX, AA-JY, AA-JZ, AA-KA, AA-KB, AA-KC, AA-KD, AA-KE, AA-KF, AA-KG, AA-KH, AA-KI, AA-KJ, AA-KK, AA-KL, AA-KM, AA-KN, AA-KO, AA-KP, AA-KQ, AA-KR, AA-KS, AA-KT, AA-KU, AA-KV, AA-KW, AA-KX, AA-KY, AA-KZ, AA-LA, AA-LB, AA-LC, AA-LD, AA-LE, AA-LF, AA-LG, AA-LH, AA-LI, AA-LJ, AA-LK, AA-LM, AA-LN, AA-LO, AA-LP, AA-LQ, AA-LR, AA-LS, AA-LT, AA-LU, AA-LV, AA-LW, AA-LX, AA-LY, AA-LZ, AA-MA, AA-MB, AA-MC, AA-MD, AA-ME, AA-MF, AA-MG, AA-MH, AA-MI, AA-MJ, AA-MK, AA-ML, AA-MM, AA-MN, AA-MO, AA-MP, AA-MQ, AA-MR, AA-MS, AA-MT, AA-MU, AA-MV, AA-MW, AA-MX, AA-MY, AA-MZ, AA-NA, AA-NB, AA-NC, AA-ND, AA-NE, AA-NF, AA-NG, AA-NH, AA-NI, AA-NJ, AA-NK, AA-NL, AA-NM, AA-NO, AA-NP, AA-NQ, AA-NR, AA-NS, AA-NT, AA-NU, AA-NV, AA-NW, AA-NX, AA-NY, AA-NZ, AA-OA, AA-OB, AA-OC, AA-OD, AA-OE, AA-OF, AA-OG, AA-OH, AA-OI, AA-OJ, AA-OK, AA-OL, AA-OM, AA-ON, AA-OO, AA-OP, AA-OQ, AA-OR, AA-OS, AA-OT, AA-OU, AA-OV, AA-OW, AA-OX, AA-OY, AA-OZ, AA-PA, AA-PB, AA-PC, AA-PD, AA-PE, AA-PF, AA-PG, AA-PH, AA-PI, AA-PJ, AA-PK, AA-PL, AA-PM, AA-PN, AA-PO, AA-PP, AA-PQ, AA-PR, AA-PS, AA-PT, AA-PU, AA-PV, AA-PW, AA-PX, AA-PY, AA-PZ, AA-QA, AA-QB, AA-QC, AA-QD, AA-QE, AA-QF, AA-QG, AA-QH, AA-QI, AA-QJ, AA-QK, AA-QL, AA-QM, AA-QN, AA-QO, AA-QP, AA-QQ, AA-QR, AA-QS, AA-QT, AA-QU, AA-QV, AA-QW, AA-QX, AA-QY, AA-QZ, AA-RA, AA-RB, AA-RC, AA-RD, AA-RE, AA-RF, AA-RG, AA-RH, AA-RI, AA-RJ, AA-RK, AA-RL, AA-RM, AA-RN, AA-RO, AA-RP, AA-RQ, AA-RR, AA-RS, AA-RT, AA-RU, AA-RV, AA-RW, AA-RX, AA-RY, AA-RZ, AA-SA, AA-SB, AA-SC, AA-SD, AA-SE, AA-SF, AA-SG, AA-SH, AA-SI, AA-SJ, AA-SK, AA-SL, AA-SM, AA-SN, AA-SO, AA-SP, AA-SQ, AA-SR, AA-SS, AA-ST, AA-SU, AA-SV, AA-SW, AA-SX, AA-SY, AA-SZ, AA-TA, AA-TB, AA-TC, AA-TD, AA-TE, AA-TF, AA-TG, AA-TH, AA-TI, AA-TJ, AA-TK, AA-TL, AA-TM, AA-TN, AA-TO, AA-TP, AA-TQ, AA-TR, AA-TS, AA-TT, AA-TU, AA-TV, AA-TW, AA-TX, AA-TY, AA-TZ, AA-UA, AA-UB, AA-UC, AA-UD, AA-UE, AA-UF, AA-UG, AA-UH, AA-UI, AA-UJ, AA-UK, AA-UL, AA-UM, AA-UN, AA-UO, AA-UP, AA-UQ, AA-UR, AA-US, AA-UT, AA-UY, AA-UZ, AA-VA, AA-VB, AA-VC, AA-VD, AA-VE, AA-VF, AA-VG, AA-VH, AA-VI, AA-VJ, AA-VK, AA-VL, AA-VM, AA-VN, AA-VO, AA-VP, AA-VQ, AA-VR, AA-VS, AA-VT, AA-VU, AA-VV, AA-VW, AA-VX, AA-VY, AA-VZ, AA-WA, AA-WB, AA-WC, AA-WD, AA-WE, AA-WF, AA-WG, AA-WH, AA-WI, AA-WJ, AA-WK, AA-WL, AA-WM, AA-WN, AA-WO, AA-WP, AA-WQ, AA-WR, AA-WS, AA-WT, AA-WU, AA-WV, AA-WX, AA-WY, AA-WZ, AA-XA, AA-XB, AA-XC, AA-XD, AA-XE, AA-XF, AA-XG, AA-XH, AA-XI, AA-XJ, AA-XK, AA-XL, AA-XM, AA-XN, AA-XO, AA-XP, AA-XQ, AA-XR, AA-XS, AA-XT, AA-XU, AA-XV, AA-XW, AA-XX, AA-XY, AA-XZ, AA-YA, AA-YB, AA-YC, AA-YD, AA-YE, AA-YF, AA-YG, AA-YH, AA-YI, AA-YJ, AA-YK, AA-YL, AA-YM, AA-YN, AA-YO, AA-YP, AA-YQ, AA-YR, AA-YS, AA-YT, AA-YU, AA-YV, AA-YW, AA-YX, AA-YY, AA-YZ, AA-ZA, AA-ZB, AA-ZC, AA-ZD, AA-ZE, AA-ZF, AA-ZG, AA-ZH, AA-ZI, AA-ZJ, AA-ZK, AA-ZL, AA-ZM, AA-ZN, AA-ZO, AA-ZP, AA-ZQ, AA-ZR, AA-ZS, AA-ZT, AA-ZU, AA-ZV, AA-ZW, AA-ZX, AA-ZY, AA-ZZ	42	Sanyo, Matsushita			
Aluminum-iron disulfide (Al/FeS₂)	1.5	10 mA	AA, AAA, AA-A, AA-B, AA-C, AA-D, AA-E, AA-F, AA-G, AA-H, AA-I, AA-J, AA-K, AA-L, AA-M, AA-N, AA-O, AA-P, AA-Q, AA-R, AA-S, AA-T, AA-U, AA-V, AA-W, AA-X, AA-Y, AA-Z, AA-AA, AA-AB, AA-AC, AA-AD, AA-AE, AA-AF, AA-AG, AA-AH, AA-AI, AA-AJ, AA-AK, AA-AL, AA-AM, AA-AN, AA-AO, AA-AP, AA-AQ, AA-AR, AA-AS, AA-AT, AA-AU, AA-AV, AA-AW, AA-AX, AA-AY, AA-AZ, AA-BA, AA-BB, AA-BC, AA-BD, AA-BE, AA-BF, AA-BG, AA-BH, AA-BI, AA-BJ, AA-BK, AA-BL, AA-BM, AA-BN, AA-BO, AA-BP, AA-BQ, AA-BR, AA-BS, AA-BT, AA-BU, AA-BV, AA-BW, AA-BX, AA-BY, AA-BZ, AA-CA, AA-CB, AA-CC, AA-CD, AA-CE, AA-CF, AA-CG, AA-CH, AA-CI, AA-CJ, AA-CK, AA-CL, AA-CM, AA-CN, AA-CP, AA-CQ, AA-CR, AA-CS, AA-CT, AA-CU, AA-CV, AA-CW, AA-CX, AA-CY, AA-CZ, AA-DA, AA-DB, AA-DC, AA-DD, AA-DE, AA-DF, AA-DG, AA-DH, AA-DI, AA-DJ, AA-DK, AA-DL, AA-DM, AA-DN, AA-DO, AA-DP, AA-DQ, AA-DR, AA-DS, AA-DT, AA-DU, AA-DV, AA-DW, AA-DX, AA-DY, AA-DZ, AA-EA, AA-EB, AA-EC, AA-ED, AA-EE, AA-EF, AA-EG, AA-EH, AA-EI, AA-EJ, AA-EK, AA-EL, AA-EM, AA-EN, AA-EO, AA-EP, AA-EQ, AA-ER, AA-ES, AA-ET, AA-EU, AA-EV, AA-EW, AA-EX, AA-EY, AA-EZ, AA-FA, AA-FB, AA-FC, AA-FD, AA-FE, AA-FF, AA-FG, AA-FH, AA-FI, AA-FJ, AA-FK, AA-FL, AA-FM, AA-FN, AA-FO, AA-FP, AA-FQ, AA-FR, AA-FS, AA-FT, AA-FU, AA-FV, AA-FW, AA-FX, AA-FY, AA-FZ, AA-GA, AA-GB, AA-GC, AA-GD, AA-GE, AA-GF, AA-GG, AA-GH, AA-GI, AA-GJ, AA-GK, AA-GL, AA-GM, AA-GN, AA-GO, AA-GP, AA-GQ, AA-GR, AA-GS, AA-GT, AA-GU, AA-GV, AA-GW, AA-GX, AA-GY, AA-GZ, AA-HA, AA-HB, AA-HC, AA-HD, AA-HE, AA-HF, AA-HG, AA-HH, AA-HI, AA-HJ, AA-HK, AA-HL, AA-HM, AA-HN, AA-HO, AA-HP, AA-HQ, AA-HR, AA-HS, AA-HT, AA-HU, AA-HV, AA-HW, AA-HX, AA-HY, AA-HZ, AA-IA, AA-IB, AA-IC, AA-ID, AA-IE, AA-IF, AA-IG, AA-IH, AA-II, AA-IJ, AA-IK, AA-IL, AA-IM, AA-IN, AA-IO, AA-IP, AA-IQ, AA-IR, AA-IS, AA-IT, AA-IU, AA-IV, AA-IW, AA-IX, AA-IY, AA-IZ, AA-JA, AA-J					

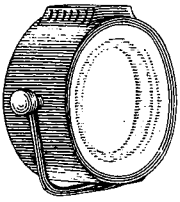
Also in All Batteries  
Also in The Squared Electronic

*Note: This is not an endorsement or indication of the relative merits of different types of cell. The data has been compiled from data sheets from a number of different manufacturers to give a current assessment of the normal spread in capability, price for each technology. Unusually large or small cells have not been included. The table does not claim to be comprehensive, and E.ON Energy Industry cannot accept responsibility for any errors or omissions.*

NOTES 14/50-see test

EMT4V – Most but not all cells exhibit a pronounced drop in their EMT to nominal operating voltage (V<sub>N</sub>) – typically within the first few milliseconds. Where deviations from figures are given above.

**Maximum Capacity:** This indicates the maximum continuous current and capacity available under typical environmental conditions. A range is shown where a cell type is available in a number of package sizes and this value is the smallest value.



## SPOTLIGHT 15

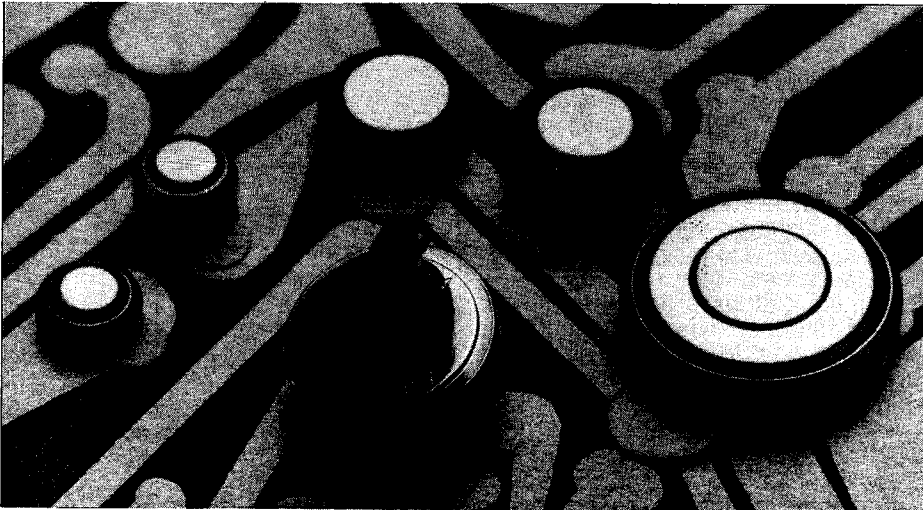


Fig. 8 Button cells have allowed products such as hearing aids to become more discrete. Shown here is a selection of Duracell products

+60°C, Zinc-air cells have begun to offer an attractive alternative to Lithium and Mercury button cells.

This type of battery, which is a spin-off from fuel-cell research, offers obvious attractions since the oxygen

required for the electro-chemical reaction is obtained from the air, via a semi-permeable membrane. The battery can then be fitted with twice as much zinc—thus doubling its power density. One disadvantage is that there seems to be a limited number of packages available at present—most manufacturers aiming to top the well defined hearing-aid battery market first.

### Secondary cells

Portable equipment which requires high levels of power will routinely use re-chargeable batteries. Secondary cells, however, do not offer anything like the power densities which are available from primary cells.

■ Silver-Zinc (rechargeable type): 0,16Wh/cm<sup>3</sup>; 0,038Wh/g

■ Nickel-Cadmium (NiCd): 0,06–0,1Wh/cm<sup>3</sup>; 0,02–0,03Wh/g

■ Lead Acid: 0,06Wh/cm<sup>3</sup>; 0,07Wh/g compared with (even) carbon-zinc primary cells at 0,15Wh/cm<sup>3</sup> and 0,Wh/g.

# Designer's ca thieves

The raid was foiled within seconds of the bank door bursting open. Before the masked men had a chance to make their demands, the manager's hand brushed against his coat pocket, activating the silent alarm at the local police station.

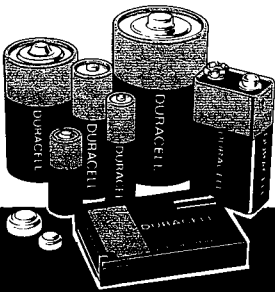
Secure in the knowledge that the alarm system had operated perfectly, the staff responded to the raiders' demands and the money was passed over the counter.

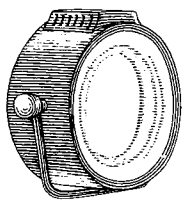
What the raiders didn't realise was that the tiny Duracell battery in the pocket warning device, had already done the job.

Just as the designer knew it would.

When he was faced with the difficulty of creating a compact, effective alarm system, he knew that he would require a primary power source which not only fitted such a discreet alarm, but would also generate power reliably whenever the need arose.

His first job had been to call Duracell. They were able to assist him with his project by designing in





## SPOTLIGHT 16

Discharge curves are fairly flat with all the secondary batteries though the self discharge characteristic varies from 30%/ann with silver to 55%-100% with NiCd and 100% with lead acid.

The relatively low cost/W and high power to weight ratio of lead acid lends itself to high current applications. Because of the large amount of material used it is not as efficient in smaller sizes and is therefore only usually offered as a 6V or 12V battery. Gates (via All Batteries), offer it in single cell (2V) sizes down to a 2Ah 'D' cell however. Most modern designs are maintenance free and sealed, allowing them to be operated in any orientation. Apart from the well-known automotive battery manufacturers, suppliers of sealed lead acid batteries for OEM use include Gates, Mafsa, Panasonic, Varta and Yuasa.

The rechargeable Lithium cell has at last become a reality: the CL2020 from Panasonic is a Carbon Lithium sec-

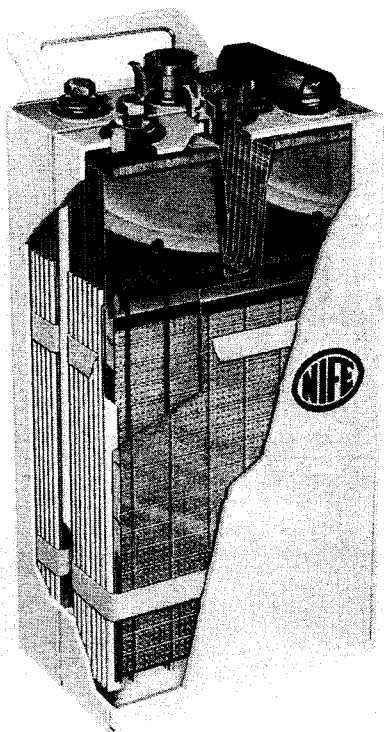


Fig. 9 Cutaway illustration of the SAB-NIFE lead acid battery

dary battery with a 3V nominal voltage and 1 $\mu$ A to 5mA average usable current. The cell measures only 2mm in diameter and is capable of withstanding more than 2000 charge/discharge cycles.

Another development from Panasonic is the CS1634 paper-thin Lithium battery. This cell features a discharge capacity of 20mAh with a 64k $\Omega$  load resistance. The utilisation of film layer technology has enabled Panasonic to keep the thickness of this battery to the minimum possible 0.5mm.

It is obvious that Panasonic presently lead the Lithium cell technology race, but it can be reliably assumed that other manufacturers will soon follow and develop this technology still further.

Chris Palmer

Acknowledgements  
Gresham Powerdyne

# It helps capture

CASHIER



exactly the right battery for the job. Naturally, because it was a Duracell battery, reliability was ensured. Duracell have

60 different types of cell which have been used to create more than 500

different designs of battery pack. Even if your specifications cannot be met by an existing Duracell battery, one can be custom built to your requirements.

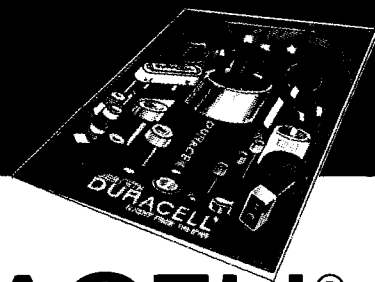
Both Duracell and the designer had done their job well.

By the time the raiders fled, the road blocks had already been in position for several minutes.

They would never know that a clever designer and help from Duracell had caused their downfall.

If your next design needs a primary power source, be like this designer - call Duracell first and get it right. Success may well depend on it.

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