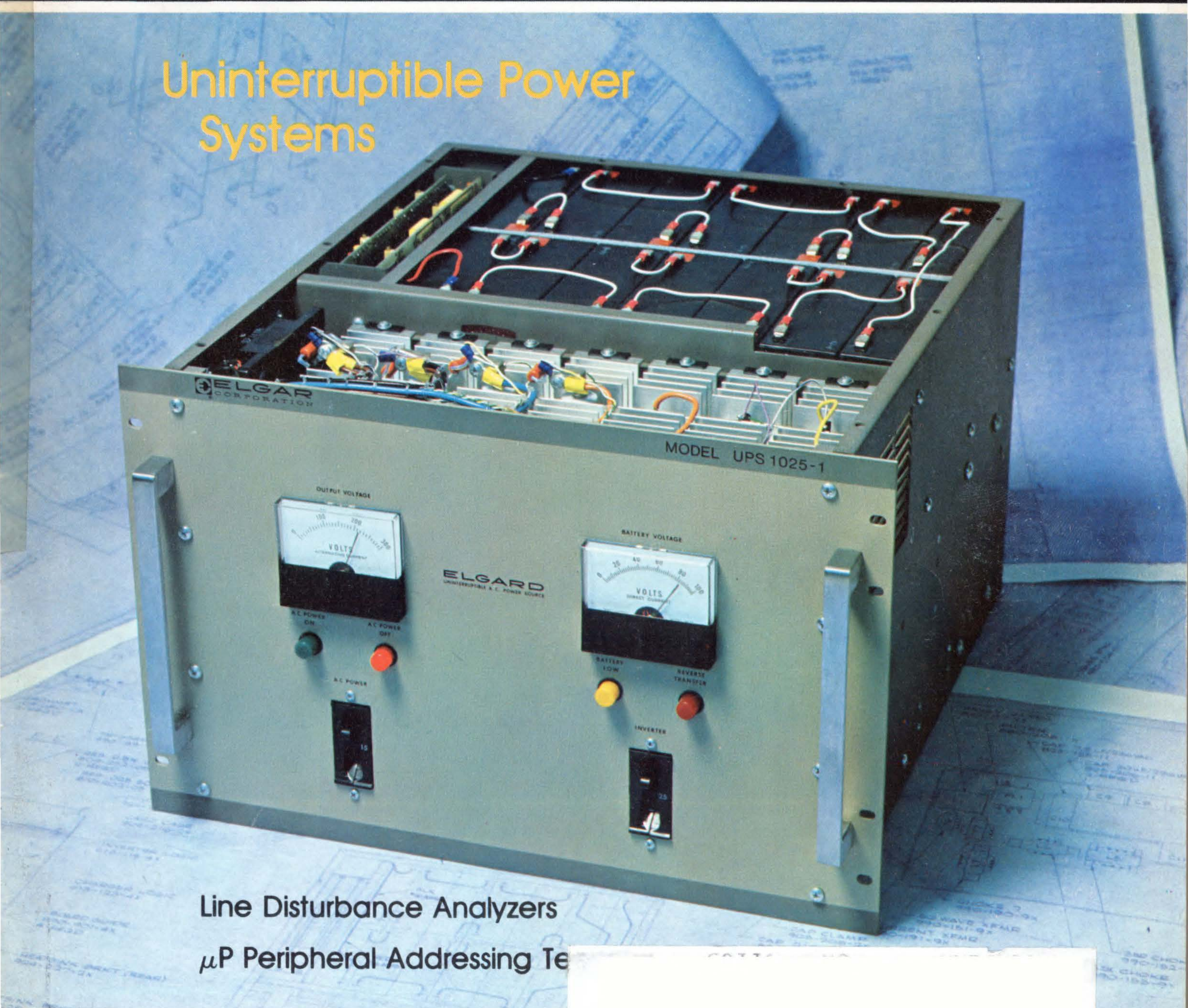
Special Report: Power Supplies

VOLUME 10, NO. 2 FEBRUARY 1980

Digital Design

The Magazine of Systems Electronics



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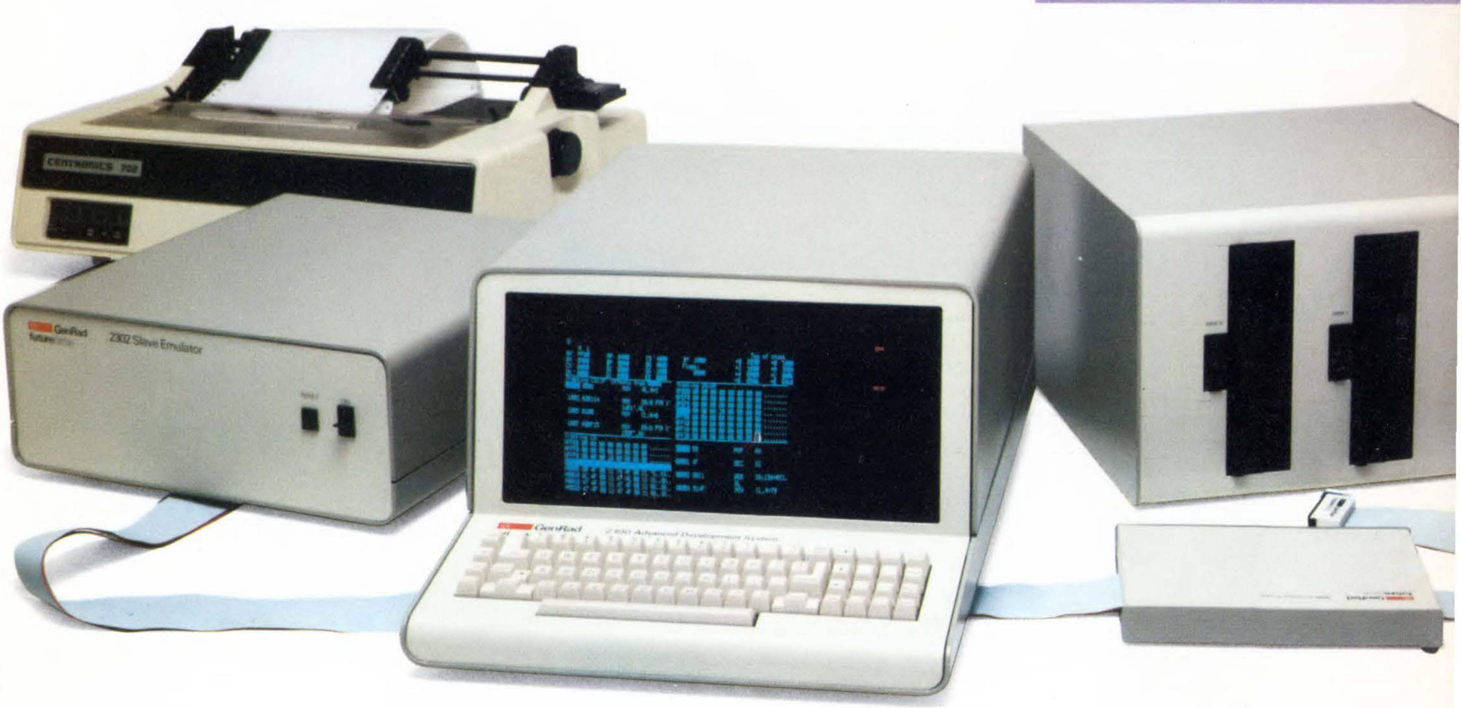
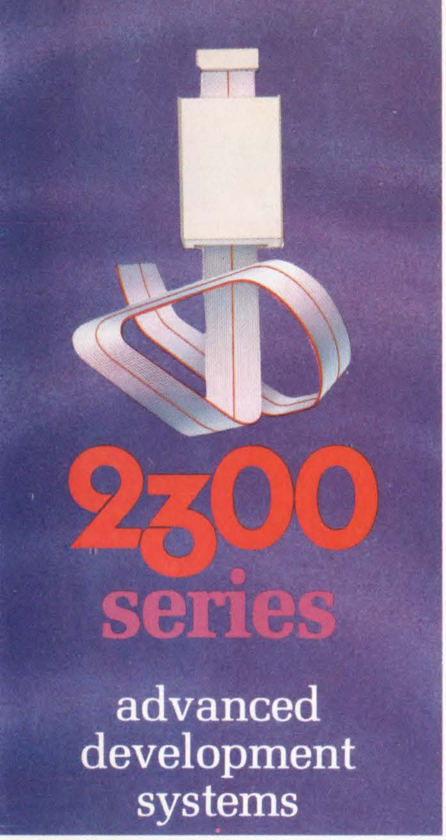
Ours is the only system capable of delivering transparent, non-stop, full-speed emulation





to 10 MHz. And it's the only system capable of emulating many different processors simultaneously.

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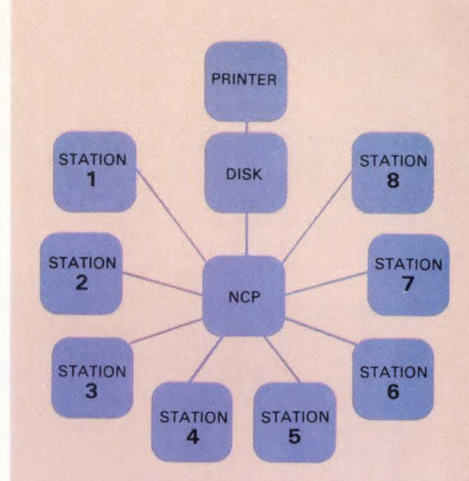

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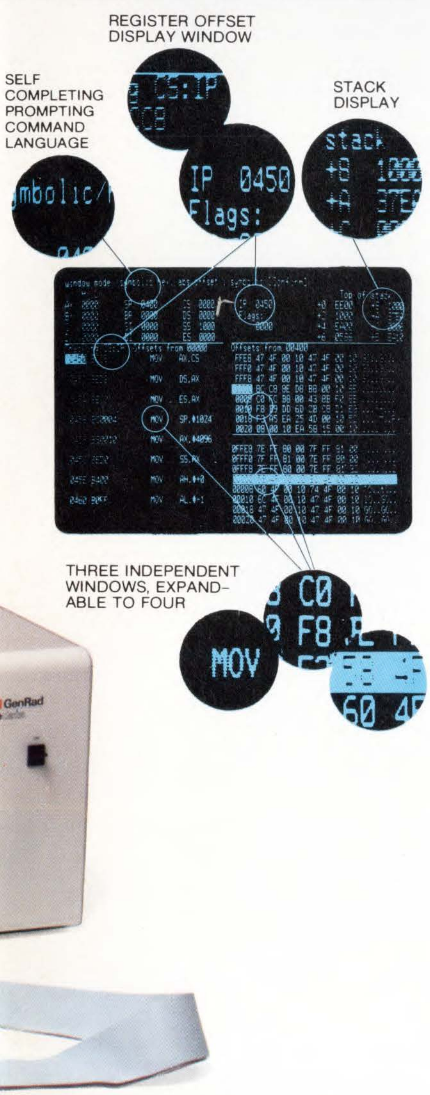

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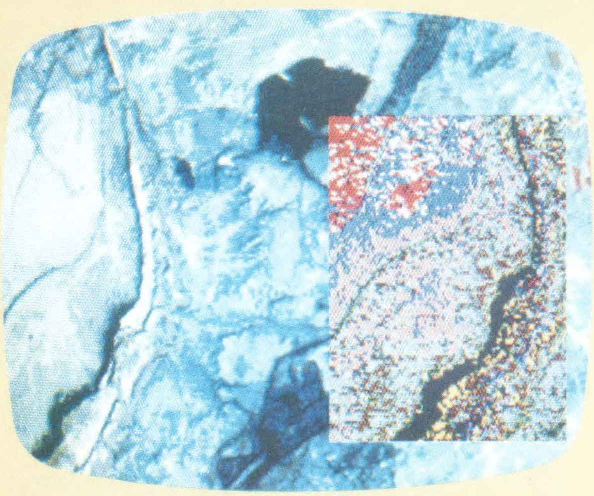

Now, with the Grinnell GMR-270 Image Processing System, you can have pipeline image processing tailored to fit your application.

The GMR-270 combines the best features of our proven GMR-27 line of high speed graphic display systems with a special package of sophisticated image processing features. The result is a modular image processing system that can be furnished with any or all of the following:

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In addition, the GMR-270 has a display resolution of 512 x 512 pixels and a video format that is RS-170 compatible. It is housed in a rack-mountable chassis and drives standard TV monitors.

Besides the GMR-270, Grinnell manufactures two complete lines of graphic television display systems: the GMR-27 Series and the GMR-37 Series. GMR-27 units are high speed, graphic and image display systems; GMR-37 units are low cost graphic display systems. Both are available with display resolutions from 256 x 512 to 1024 x 1024.

So, whether you want to analyze images from outer space or monitor a process in a plant, Grinnell has a system that can do it. For detailed specifications and/or a quotation, call or write today.

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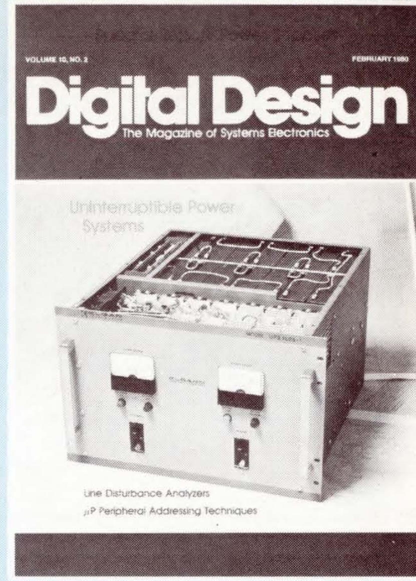

ON OUR COVER
Uninterruptible Power Systems are popular OEM products. This 1kVA UPS is packaged in a single rack-mountable enclosure. Cover courtesy of Elgar Corp., San Diego, CA.

p. 50

p. 51

p. 64

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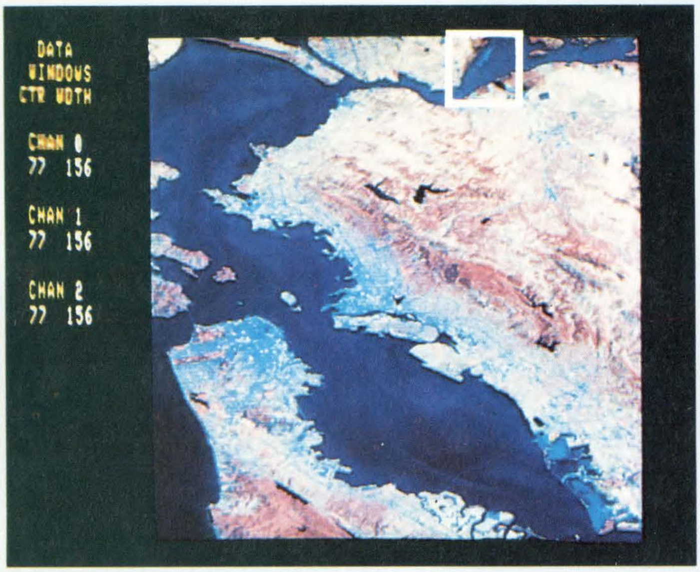
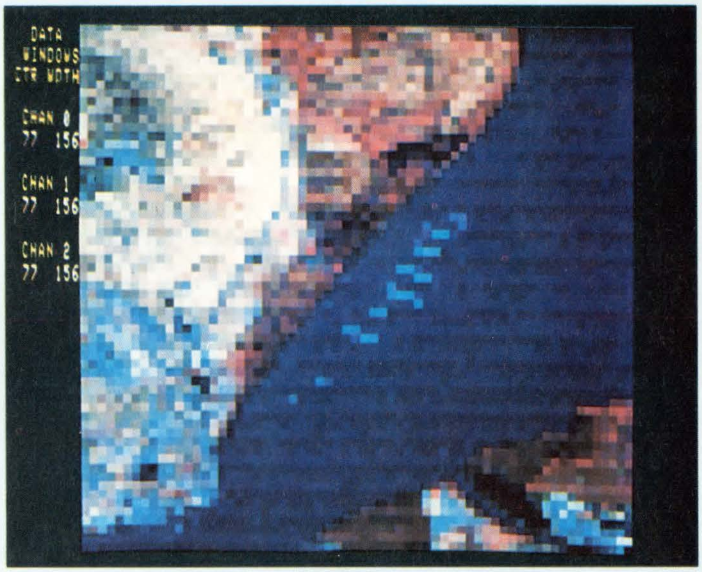


Three band LANDSAT image of San Francisco Bay



Eight-to-one zoom of Suisun Bay

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Letters

For A New Organization

Dear Editor:

Loved your Speakout, "The Winds of Change." I'm a company president and I agree 100%. Your editorial is posted on our bulletin board. The more experienced engineers are underpaid, especially in the Phoenix area, where salaries are often indirectly set by one major employer. I'm for a new organization that will work for the engineer, and not the present establishment.

Lorne S. Garrett, P.E.
Ecotronics, Inc.
Scottsdale, AZ

Likes December Issue

Dear Editor:

I wish to commend your staff on your excellent December issue. In my article, "Digitizers", I should have mentioned that different manufacturers employ variations in the use of the principles that I described. My explanation of "linearity" could also be: "The relationship between data points obtained by moving the cursor on a straight line and a straight line drawn through the plotted data points."

Warren J. Ridge
Talos Systems Inc.
Scottsdale, AZ

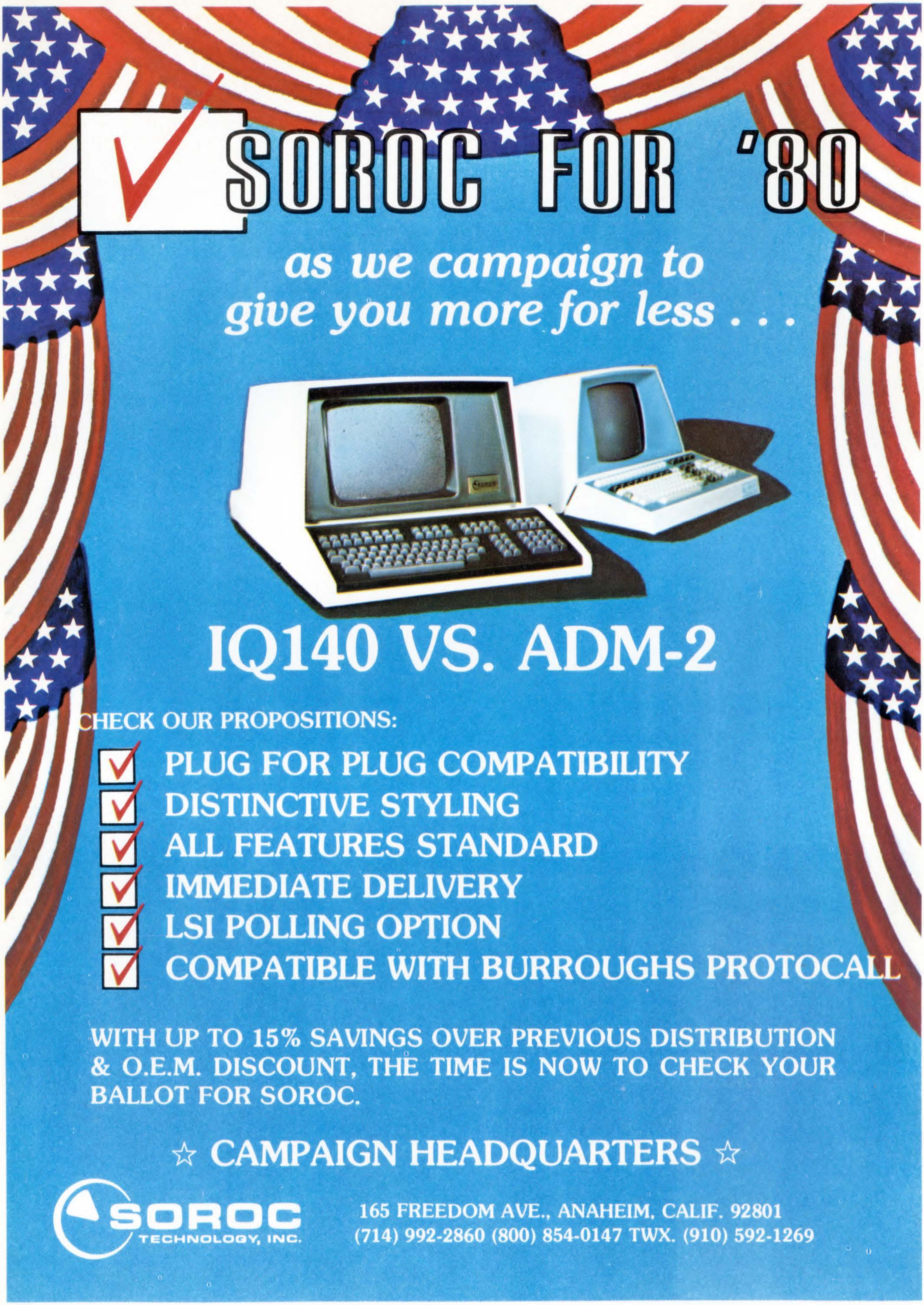
Will IEEE Respond?

Dear Editor:

Nowhere has the IEEE's bankruptcy been made more apparent than in the results of your recent survey. I sent copies to each member of IEEE's Board of Directors and encouraged them to reply. The silence is eloquent testimony to their ostrich mentality. Yet, with typical deviousness, IEEE decided to fund a public relations effort; it is budgeted for $216,000 in 1980 – to brainwash us into loving them. By stonewalling the genuine dissidents, IEEE's Board has assumed the appearance of an embattled enclave trying to stave off a catastrophic defeat.

However, there is one point in your September *Speakout* that cannot pass without comment. If IEEE were to advocate *direct* action to limit entry into our profession, it would run the risk of a lawsuit by the U.S. Department of Justice. So, we must be shrewd: there are several programs that we should push. They are: (1) We must insist that the National Science Foundation's funding be cut. After all, what is so terrible about reducing this funding to keep pace with the reduction in the number of college students? Moreover, NSF funds should be made available to private R&D organizations. At present, NSF funds support many – too many – faculty members. (2) We must insist that no foreign engineers be imported to work in the U.S. There is, at present, a concerted effort by American aerospace companies to import *thousands* of British engineers to work in the U.S. All that is needed is for us to insist on strict adherence to the present immigration laws. (3) We must insist that foreign students (and the bulk of them study engineering) return to their native country after graduation. (4) We must tighten the accreditation process; it is too loose and this results in little or no selectivity. (5) We must insist that engineering societies cease their counter-productive recruiting efforts. Frequently, this is done under the guise of "informing" the gullible high school student what a career in engineering is all about. Related to this is the necessary effort to have the U.S. Department of Labor present an honest description of the engineering profession in their *Occupational Outlook Handbook*. This is the principal source of career guidance and is used by almost every high school guidance counselor in the country. Engineering is presented as a wonderful, growing, and fulfilling career. By contrast, the description of the teaching profession is very pessimistic. But, after all, professional teachers have unions and political clout. (6) The engineering societies should not admit charlatans with a degree in something called Engineering Technology. This will help drive home to employers the differences between an engineer, who is a professional, and a technician, who is a sub-professional. After all, the "E" in IEEE does not mean "Technician".

Irwin Feerst
Committee of Concerned EEs
Box 19
Massapequa Park, NY



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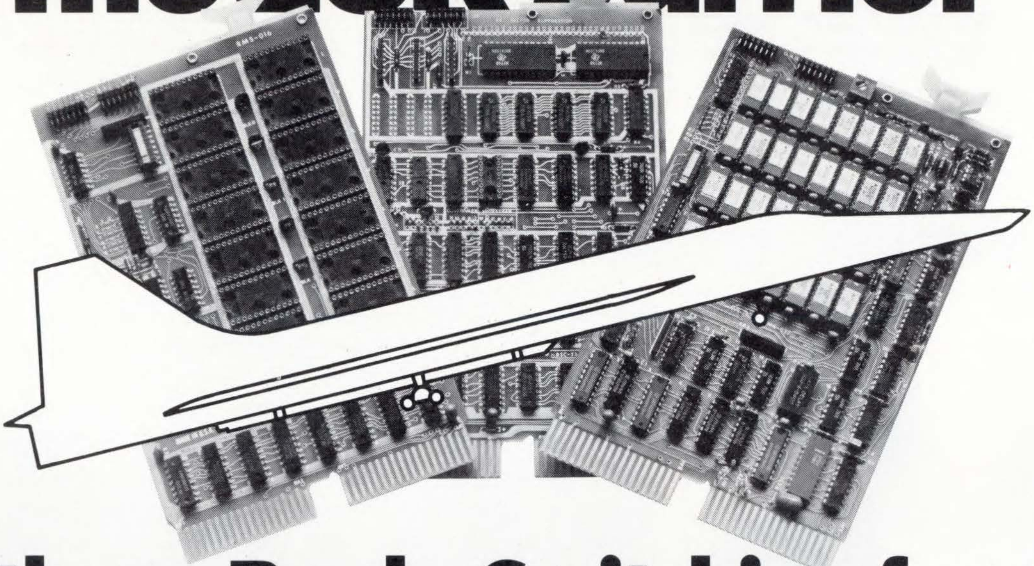

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DIGITAL PATHWAYS

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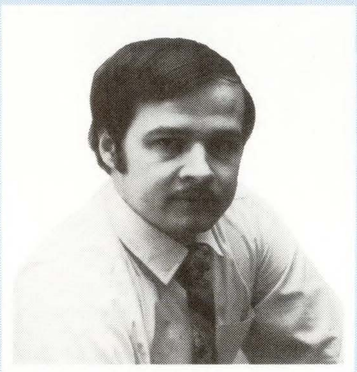
Speakout

Paul Snigier, *Editor*

Getting Things Done



Timewasting activities are like cancer. They're next to useless, sap your energy and keep growing. They can kill your career.

The solution? Radical surgery. Do the important; cut out (or put off) the irrelevant. First, begin by identifying your project's (and your) main objectives. Any activity that does not contribute that much to main objectives is a time waster. Now, you cannot avoid timewasters, so minimize those you can. In practice, however, refusing to do the irrelevant is not so easy. Since every task is on someone's must list, they try to coax you into assuming some responsiblity for it; and because you don't want to say "No" (as you should), you shoehorn it into your overcrowded itinerary. Then, when you come under deadline pressures, you put their tasks off until they return to bug you, until you give in and do it to get them off your back.

The solution? *Learn* to say "No" to the irrelevant; don't let anyone transfer their "monkey" to your back; send it back to its proper owner for care and feeding. Tactfully point out several urgent and important tasks already confronting you and suggest some alternatives for him. Your objective is not to get out of work, but to protect your time to do really important jobs.

This brings to mind the subject of planning. No engineer should operate without a long range (and daily) game plan; if not, he will wind up fire fighting – letting others' priorities dictate his own priorities, to his and his project's detriment. Spend time planning and list project tasks (and yours) in order of importance. Do this daily before leaving your desk or lab bench. The more time you spend in this planning, the less total time it will take to do these tasks. List the important (not necessarily urgent) tasks first. If the task's benefits are great, but little time is needed, then do it first. For example, delegate tasks before starting the top priority tasks for that day.

Engineers all too often resent their skills being wasted on lesser tasks that technicians do. Remember, if you are too busy doing tasks that you should delegate, then you have less time for the main design objectives for which you were hired.

Don't tie Pegasus to a plow.

Paul Snigier

Technology Trends

Will CRT Terminal Shipments Rise?

After several years of growth rates hovering above 30%, unit shipments of alphanumeric CRT terminals fell to a 22% growth rate during 1979. Although the industry continues to grow rapidly, the rate is not that much below manufacturer's projections.

According to a recent study, "Alphanumeric CRT Terminal Industry: A Strategic Analysis," by Venture Development Corp. (Wellesley, MA) projections made by terminal manufacturers during the first quarter of 1979 signaled a yearly growth rate "as good as or better than 1978." This growth rate did not materialize; second half shipments slowed when the heavy backlogs from 1978 were met.

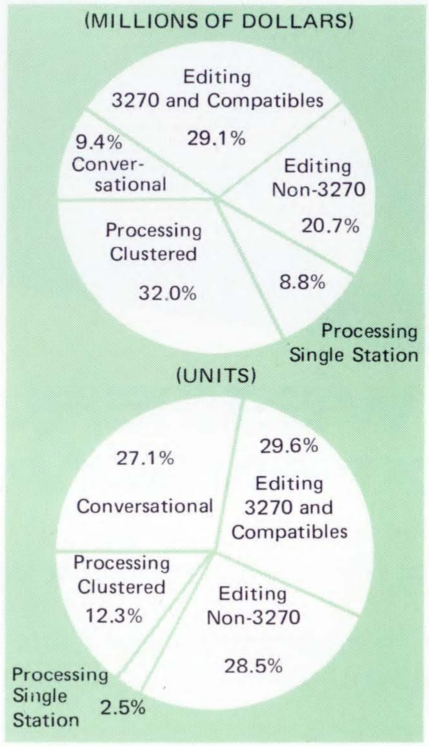
Significant gains made

Combined shipment volumes of conversational, editing, and processing CRT terminals reached 473,000 units in 1979. These units were valued at $1.6 billion – up 13% over 1978.

Sales of low-end conversational CRT terminals were up 28% over 1978. Shipments of these "glass-teletype" or "dumb" terminals, long thought to be declining, *made significant gains*, primarily due to price reductions. Product enhancement and added features, such as cursor controls and a page or two of buffered memory, also spurred the shipment growth of these low-end terminals.

Shipments of editing terminals composed of the IBM 3270 and terminals offered by 3270-compatible manufacturers increased only 13% in 1979. Demand for 3270-type terminals is high, but delivery times have been stretched out as production rates have reached their current limits. IBM's delivery problems have given 3270-compatible manufacturers a second wind following the 3270 price reductions and product enhancements announced in 1977.

The non-3270 editing CRT terminals led all categories in shipment growth during 1979. Shipments of this class of CRT terminal increased 31% over 1978 levels. Non-3270 terminals have at last caught up with the 3270-type terminal. By 1981 non-3270 editing terminals will surpass the 3270-type in annual shipments and continue to widen the gap through 1984.



Alphanumeric CRT terminal shipments shown by category indicate the share of total sales and units sold last year.

Thanks to distributed processing concepts and advances in communications, the processing CRT terminal category is beginning to expand. These "intelligent" terminals composed of single station and "clustered" units are expected to be the fastest growing sector of alphanumeric CRT terminals. 1979 shipments of "keystations" on clustered units were up 16% over 1978. VDC expects this growth rate to increase to 28% during the next five years, 1979-1984.

In analyzing the competition, the VDC study places IBM as the dominant manufacturer with a 23% market share of the installed base of all alphnumeric CRT terminals. This percentage is considerably below IBM's share of other computer equipment markets, but is nearly four times greater than any other CRT terminal manufacturer. IBM's strength is in the 3270 market, but 3270-compatible manufacturers are continuing to chip away at IBM's share. During 1979, IBM's share of the 3270 market eroded to 65% as the 3270-compatible manufacturers increased their share by 3% to 35%.

In the long term, total installed base of alphanumeric CRT terminals should grow at a compound rate of 21.6% for the five-year period (1979-1984). This growth rate will yield over 4,500,000 units installed at year end 1984, up from 1,700,000 at year end 1979.

Intelligent Copier/Printer Market Emerging At Dramatic Rate

The U.S. intelligent copier/printer (IC/P) industry, now on the verge of commercialization, will show a 107% compound annual growth in revenues through 1984. During the same time period, unit shipments will increase by a dramatic 160%, compounded annually, according to a market analysis by Creative Strategies International of San Jose, CA.

Fundamentally, IC/Ps are printers; and it is as printers that they will enter the market. However, IC/Ps will undergo a series of evolutionary changes and eventually become a significant link in corporate information systems. Toward the end of 1984, IC/P will be a multifunctional unit that will accept both hard copy and electronic signal input, have resident fonts and formats, incorporate input/output devices to allow communications within a network, have a high-speed laser or fiber optic/CRT electrophotographic imaging system, and possess a significant amount of temporary buffer memory.

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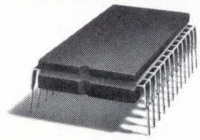

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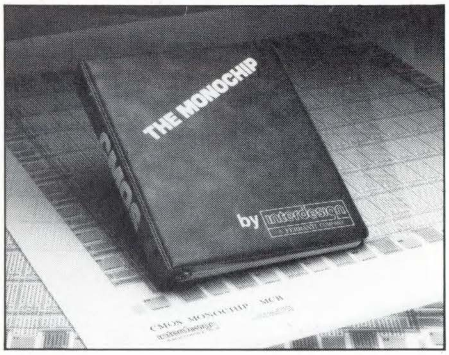

Our $59 Monochip Design Kit has everything you need to develop your own CMOS IC. You choose the size—from 100 to 400 gates.

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No first-generation products currently available meet all of these requirements. The IBM 6670 Information Distributor bears the closest resemblance, lacking only in the area of original document input.

The need for a fully evolved IC/P has resulted in part from the geographic dispersion of corporations. Managers feel an increasing need to control information and to be able to access it quickly. Therefore, the ability to communicate will be an essential capability of IC/Ps. The development of an easily accessible Advanced Communication Network Service (ACNS) is the single most important factor powering the growth of the market for IC/Ps. Users must be given flexibility in selecting from a variety of available network services in order to meet their company-specific communications needs. ACNS service will be available in late 1982 or early 1983. Currently, the common carrier system is the most frequently utilized method of transmission.

Entrants in the IC/P market will consist of those companies with expertise in relevant technologies and those whose markets will be affected by the introduction of IC/Ps. These will include vendors and manufacturers of copiers, facsimile, mainframes, SBCs, printers, word processors and photocomposition. In the industry's early states, entrants' marketing strategies will be determined by their previous experiences: companies from DP will sell IC/Ps for DP applications; those with experience in word processing will sell in WP environments. With the convergence of WP and DP and IC/P versatility, this distinction will eventually disappear.

Over a period of time, fully evolved IC/Ps will realize sales volume through use as a communication network link. Initially, however, sales will be primarily due to the cannibalization of market share from current printers: daisy wheel, impact line printers and large page printing systems.

Don't Ignore 14" Winchesters

Will OEM system designers who plan high-capacity products around 8″ Winchester disk drives lose a strong competitive edge? "Yes," said W. Ferrel Sanders, marketing VP of Shugart, in a recent interview.

"Designers shouldn't close their minds to 14″ Winchester disk drive benefits, although much attention is given to 8″ fixed disk drives," said Sanders. "Announcements in the trade press such as *Digital Design* indicate that no less than eight companies have introduced these 8″ drives, and many more announcements will come in the future. As a result of this publicity, some system designers may overlook the advantages of the 14″ Winchester fixed disk drives."

Sanders then went on to point out that Winchester disk drives, in general, are the most cost-effective and reliable rotating memory peripherals available today. "Three of the technology's major attributes are largely responsible for this reputation," he indicated. "First, the drives employ low-mass heads which start and stop in contact with the media. These head assemblies – which are relatively simpler and contain fewer parts than those found in

prior technologies – significantly contribute to the low-cost factor.

"Second, performance is enhanced because the heads operate at a reduced flying height relative to other rigid disk technologies. This allows reading of more densely packed data than has been possible with previous products. Finally," he explained, "the media and read/write head are enclosed in a sealed environment. Thus, Winchester disk drives provide inherent protection from various kinds of contamination that may occur with removable or other types of fixed media.

"Winchester drives complement the widely used floppy disk product," he went on. "Many small business, personal computing and word processing system designers have, up until now, used multiple floppy disk drives for system residence memory, operating system storage and mass storage memory, as well as for input/output and program load. OEMs designing higher-performance systems, however, may now prefer to use Winchester technology in lieu of floppy products for the first three applications.

"If, indeed, the designer does choose to upgrade to Winchester technology, the 8″ fixed disk drives have introduced a new dimension into that selection process: size versus capacity and performance. And even then, there are no cut-and-dry guidelines because 8″ and 14″ Winchester products overlap extensively in both cost and performance," Sanders cautioned readers.

"This is largely due to the fact that the various manufacturers of the new 8″ drives had two opposing objectives in product design. For Shugart and apparently one other company, low-cost was the most important goal. At Shugart, we were willing to make minor trade-offs in performance to achieve the lowest cost. Other companies, such as Pertec and IMI, appear to have targeted for somewhat higher performance and capacity.

"One can't make a blanket statement that the smaller 8″ package automatically means lower cost per box," Sanders stated. "On a cost-per-megabyte basis, the 14″ drives are usually the most cost-effective solution when the requirement is for more than 10 megabytes."

Sanders viewed the floppy-size package as being the key advantage of the newer 8″ products. "These disk drives can be easily exchanged for floppies because some of them fit right into the same slot that a floppy does. Similarity of electronics enables users to build a common interface to handle both the fixed and floppy disk drives.

"But, as the total computer system requirements for capacity and performance increase, many OEM system manufacturers should place less importance on package size and more emphasis on price per megabyte of storage. Furthermore, the 14″ drives are available in quantity from manufacturers today. The 8″ drive is not.

"Along those same lines, the user must also consider the difficulty of new product start-up when projecting new system designs around the eight-inch drives. The 14″ drives, in contrast, have been in production for over a year and present less risk."

So, as a rule-of-thumb, if capacity is more important to a designer than size, a 14″ drive will usually be the most cost-effective solution; if physical size is the key factor, it may be worthwhile to wait for the new 8″ drives."

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Peripheral Addressing in μP Systems

Mitchell Gooze and **Henry Davis**
AMI, Santa Clara, CA

As the state-of-the-art in LSI and VLSI leads to increased chip complexity, peripheral circuits in microcomputer (μC) systems are becoming more "intelligent." Along with this, peripherals are doing more of the overall system job as designers attempt to off-load dedicated tasks from the μP to peripheral circuits.

This design technique implies greater dependence on processor/peripheral intercommunication. There are several techniques available to optimize this communication. Three of the most widely used are: serial I/O, isolated I/O, and memory-mapped I/O (with the last two being bit parallel techniques). We will examine the three techniques, their implementation and trade-offs.

Parallel I/O techniques

Addressing peripherals as memory locations, now commonly referred to as memory-mapped I/O, is a relatively new I/O handling architecture, first made popular by the PDP-11 line. The enhanced flexibility, power, and popularity of this I/O architecture has since been adapted to μP systems. The architecture was first popularly employed in the 6800 family of processors.

Isolated I/O technique

Until the advent of memory-mapped I/O, the common technique in use was **isolated I/O**. This technique **(Fig 1)** is still used in many computer systems including μC's since it is a simple technique. Utilizing this approach, I/O devices communicate directly and only with the CPU's accumulator. In general, the total I/O instruction set consists of an IN instruction and an OUT instruction. In isolated I/O systems the number of addressable I/O locations is usually significantly less than the total memory address space. As an example, the 8080 has 65K bytes of memory address space, but only 256 I/O addresses. If additional I/O locations are required, external hardware would have to be added to the system to accommodate this.

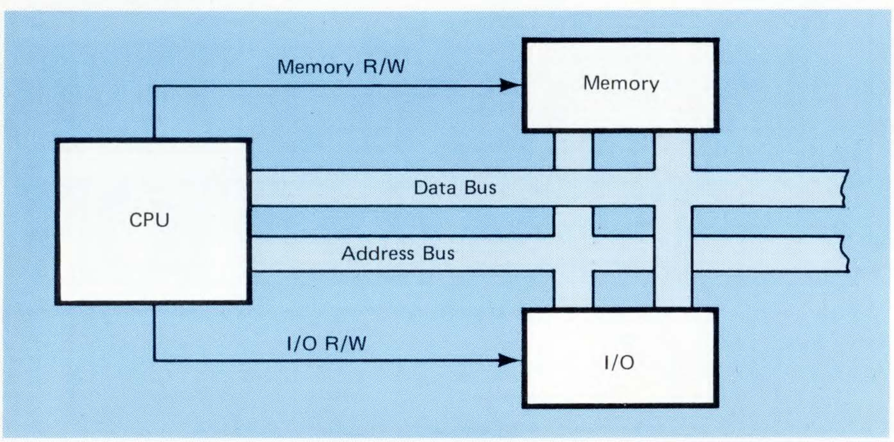


Fig 1 Isolated I/O enables I/O devices to communicate directly with the accumulator.

In exchange for the inherent simplicity of the isolated I/O technique comes an attendant lack of flexibility. This technique utilizes a communication structure which is constrained by the simple IN and OUT format. This I/O instruction set limitation requires that all I/O devices communicate through the accumulator (or some other special purpose I/O register) which can severely restrict design efficiency.

Memory-mapped approach

By assigning an area of memory address space as I/O, a powerful architecture can be developed that can manipulate I/O using the same instructions that are used to manipulate memory locations. This **memory-mapped approach** is an I/O handling technique whereby peripheral I/O devices are treated as memory locations. All peripheral devices "hang" on the same address and data bus as do memory devices **(Fig 2)**.

Each device is given a unique address in the memory field (map). Access to a particular device is then obtained by addressing the exact location (address) in the address field which has been assigned to that device.

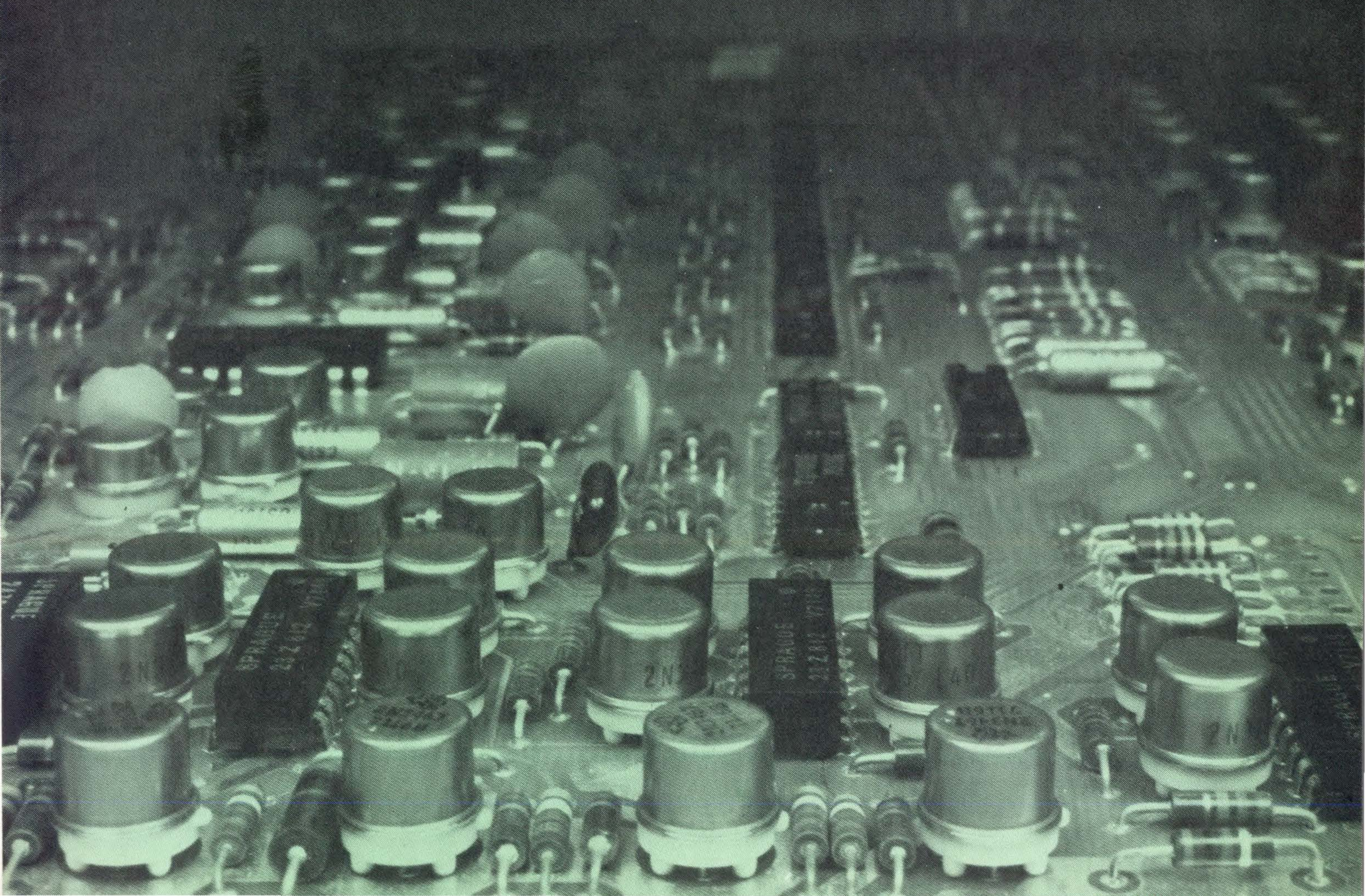
By treating I/O devices as memory, optimum flexibility is obtained. This technique allows all memory oriented instructions to be utilized for peripheral handling. It becomes obvious that the full power of the processor instruction set is thus available for use with peripherals, as well as memory. This improved peripheral handling technique provides enhanced system throughput.

Comparisons

While it can be said that isolated I/O techniques typically require only IN and OUT instructions, these are additional instructions which are not required in memory-mapped architectures. Since peripherals are handled identically as is memory, software is simplified. This simplication, along with the additional flexibility of memory-mapped I/O, improves system software. These improvements can be manifest in both reduced program development costs and reduced program memory. **(Fig 3)**.

Along with the advantages of memory-mapped I/O previously indicated, certain hardware advantages are also evident. The isolated I/O approach requires at least two additional bus lines for I/O devices; I/O read and I/O write. Since the memory-mapped approach treats peripherals as memory, I/O and R/W lines are identical to the memory R/W lines and are, therefore,

Continued on page 27



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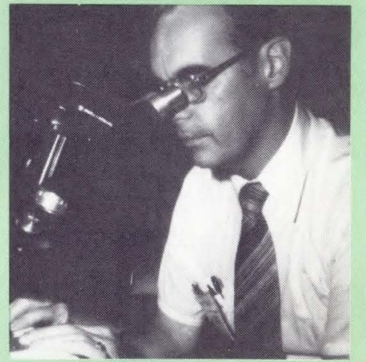

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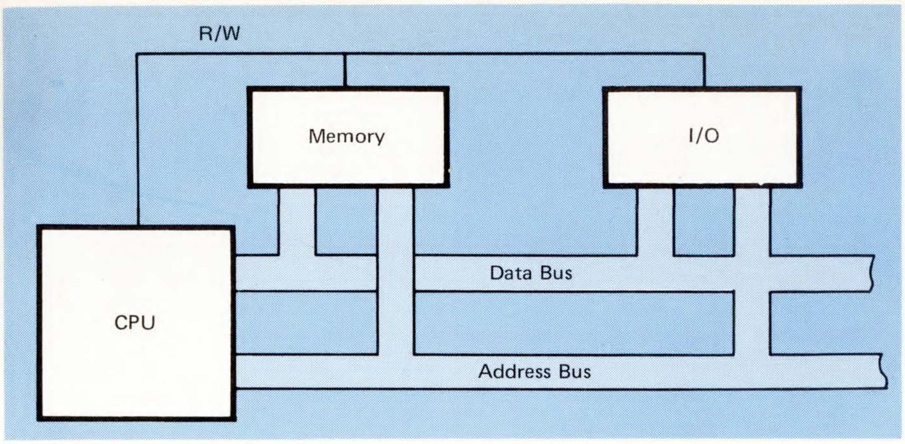

Fig 2 Memory-wrapped approach treats peripheral I/O devices as memory locations; both memory and I/O are on the same data and address bus.

Continued from page 22
not separately required (**Figs 1** and **2**).

In many cases, system de-bugging is made easier with memory-mapped I/O due to the ease and flexibility with which peripheral devices can be directly accessed. Peripheral devices can also be 'smarter' by taking advantage of the "memory" oriented instructions available for use with peripherals. Instructions such as read-modify-write can be handled as easily with a peripheral device as with a memory location.

Processors designed to perform isolated I/O (such as the 8080) can also be adapted to memory-mapped I/O. This can be accomplished by a variety of address decoding techniques to indicate I/O or memory devices. This technique has a significant drawback in that a processor designed to implement an isolated I/O structure will not usually contain the addressing flexibility or other architectural features which are useful in memory-mapped I/O structures. This being the case, an isolated I/O processor "rigged" to simulate memory-mapped I/O cannot perform this function as well as a processor designed for memory-mapped I/O. In fact, the processor will usually not perform as well as it would have performed utilizing its own isolated I/O. Exceptions to this statement include the new 16 bit processors like the S9900 – processors that offer a complete set of addressing mode and easily support memory-mapped I/O.

Isolated or programmed I/O have traditionally been limited by the addressing modes allowed, as well as the instructions for performing I/O. One departure from this type of programmed I/O technique is the S9900's Communications Register Unit (CRU). The significant difference is the increased addressing modes and instructions available with the S9900 CRU.

Command-driven programmed I/O (serial I/O)

The S9900 provides a unique and powerful I/O interface through the (CRU). Data is transmitted and received by the CRU in serial form. The CRU I/O utilizes three dedicated processor lines in a serial manner. CRU *input is externally asynchronous* but clocked on board the processor. CRU *output is clocked* and uses two of the three lines. The CRU instructions (LDCR, STCR, SBZ, SBO) permit transfer of one to sixteen bits. Standard CRU I/O devices (74LS251, 74LS259) are 16-pin packages and are, therefore, less expensive than memory-mapped I/O chips used on other systems (**Fig 3**). The use of smaller packages is made possible as result of the serial CRU, but the serial bus eliminates the need for several pins dedicated to a parallel-data bus with multiple control lines. Because variable length I/O fields are easily manipulated, optimal I/O interfaces are easily designed with a resulting system cost which is lower than many competing systems. This is achieved through simplified circuit layouts, increased density and lower cost components.

Addresses A3-A14 contain the address of the selected bit for data transfers. Suitable decoding of these lines allows separate I/O chips to be selected; yielding a possible maximum of 4,096 bits of input and output. CRU operations and memory-data transfers both use the address bus; however, these operations are performed independently, thus, no conflict occurs. Transfers are slightly less than 1 bit/μs.

Benefits of CRU type I/O include: lower system cost, easy hardware and software interfacing, increased system throughput, simplified circuit layouts, increased PCB density, lower component costs and fewer different parts in inventory.

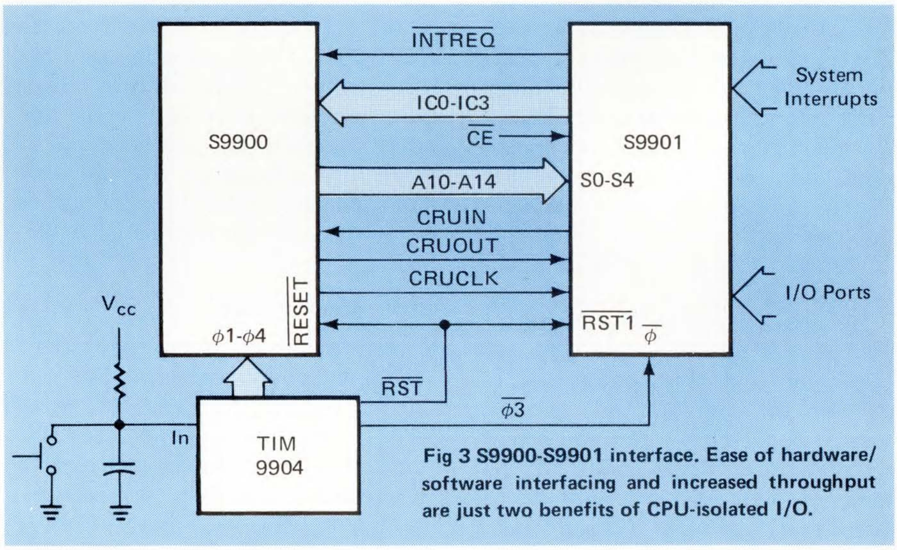

Fig 3 S9900-S9901 interface. Ease of hardware/software interfacing and increased throughput are just two benefits of CPU-isolated I/O.

Summary

In conclusion, the **CRU-isolated I/O architecture** offers simple, straight-forward peripheral handling structures. This technique offers advantages in limited I/O requirement systems or when the entire memory address space of the processor is already required for other uses in the system. The **memory-mapped architecture** offers enhanced flexibility and processing power with attendant savings in software and hardware. The **command-driven I/O approach** utilizing the CRU technique (as in the 9900) offers a very efficient, low-cost, serial I/O handling which can accommodate data transfer rates up to 1 bit/μs.

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Evaluating Power Line and Power Supply Performance In Computer Systems

Stephen J. Tharp
Dranetz Engineering Labs, Inc.
South Plainfield, NJ

Don't let line transients and power supply glitches ruin your computer

Are you contemplating tearing down your EDP installation in a last ditch effort to locate the cause of a perpetual series of random operational anomalies? If you are, you would do well to first consider these grim facts of industrial life: (1) most power lines are intolerably low in quality for computer-based high-reliability equipment, (2) very few power supplies concurrently used with peripherals, minis or μPs can withstand the normal range of line disturbances, and (3) many so-called "uninterruptible" power supplies are interruptible, and many more require special adjustment of thresholds and timing to work properly at a particular installation.

These facts could absolve your EDP equipment of all blame. Instead, your power line and local power supply could be the culprits. And most important, conventional test equipment and procedures might never fix the blame properly. It is a mistake to assume that "synthetic" (lab or bench) testing of computer performance is conclusive. Long-term, real-time oscilloscope observation of the power-line voltage is not practical for most applications. Even an exhaustive tabulation of miles of strip-chart recordings does not provide the complete, worst-case, cycle-by-cycle sag, surge and impulse data that fully define line performance. Instead, you must detect, record and analyze all significant deviations from ideal behavior.

Of course, the problem of correlating these line disturbances and deviations with their effects on the system power supplies, and ultimately on the EDP system itself, still remains. We will describe the means for solving these problems later, but let us first briefly examine the various types of power line aberrations that are commonly encountered and their influence on power supplies within EDP equipment.

Line Aberrations

Commercial power companies make a valiant and continuous effort to maintain the voltage, frequency and waveform on their lines within acceptable standards, but many factors beyond their control still exist. For example, customers who use power from a particular branch line connect and disconnect large loads at random, and create sudden sags and surges in the local line voltage, as well as random spikes and waveform notches. A power company cannot compensate for these local aberrations, any more than it can eliminate the transients caused by lightning hits or fault switching. The effects of these and other influences appear as line disturbances of a number of distinct types.

Surges and Sags. Rapid changes – surges and sags – in the amplitude of the AC line voltage sine wave persist for an appreciable fraction of one cycle (usually for a number of cycles) of the line frequency, with or without significant alteration of the waveform **(Fig 1a)**. The typical range is ±10%, but deviations of as much as 30% are occasionally encountered. Common causes of surges and sags include large, sudden and sustained load changes, interruption of current through inductive loads and lampload or capacitive-load inrush current.

Slow-Average Fluctuations. Slow variations in the RMS value of the sine wave are measured over an appreciable time interval – usually, 10 or more **(Fig 1b)**. The typical range is ±5%, but occasional fluctuations can be considerably greater. Overstressed wiring and brownouts commonly cause slow-average fluctuations.

Transient Impulses. Deviations from the ideal AC sine wave generate transient impluses. They are compared with one line-frequency cycle – typically from a fraction of a microsecond to several milliseconds. Their forms range from single pulses with extremely short rise and exponential decay times to oscillatory disturbances persisting for five to ten oscillations within an exponentially decaying envelope. The initial impulse which may increase or decrease the instantaneous amplitude of the sine waveform is described as a spike or notch, respectively **(Fig 1c)**. Typical deviations of ±100V are

Stephen J. Tharp is Product Marketing Specialist for Dranetz Engineering Labs, South Plainfield, NJ. He holds a BSEE degree from MIT.

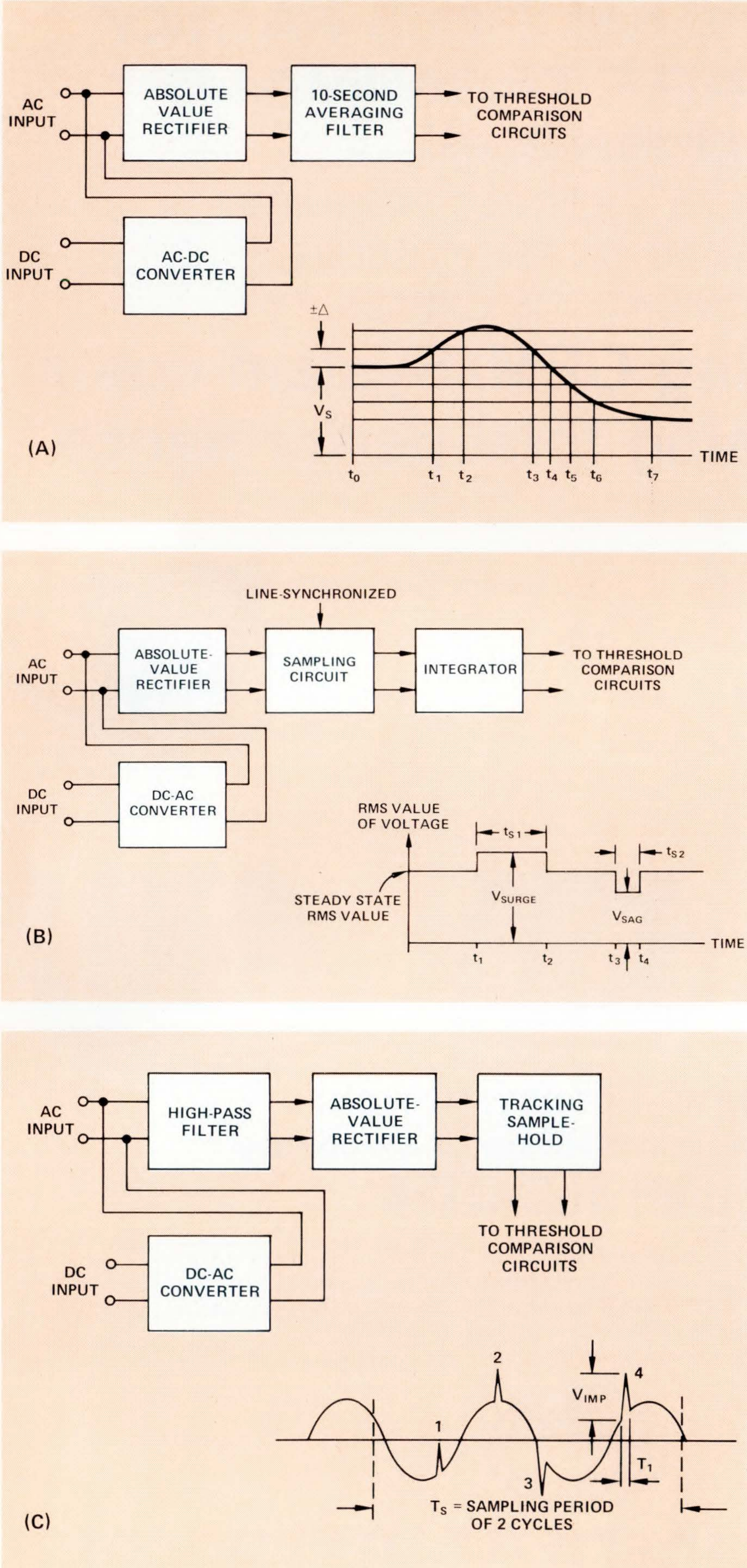


Fig 1 Of the three major types of power line disturbances, (A) represents surges and sags; (B), slow-average fluctuations; and (C), transient impulses.

common, and occasional impulses of ±1500V or even more occur on some 115V lines. Common causes include switching transients, lightning hits and protective-breaker operation.

By the way, transient impulses are frequently present on one line of a 2-wire service and not on the other. We must distinguish this differential mode of propagation from common-mode propagation, in which both lines experience the transient more or less simultaneously with respect to some common point (usually, ground or neutral).

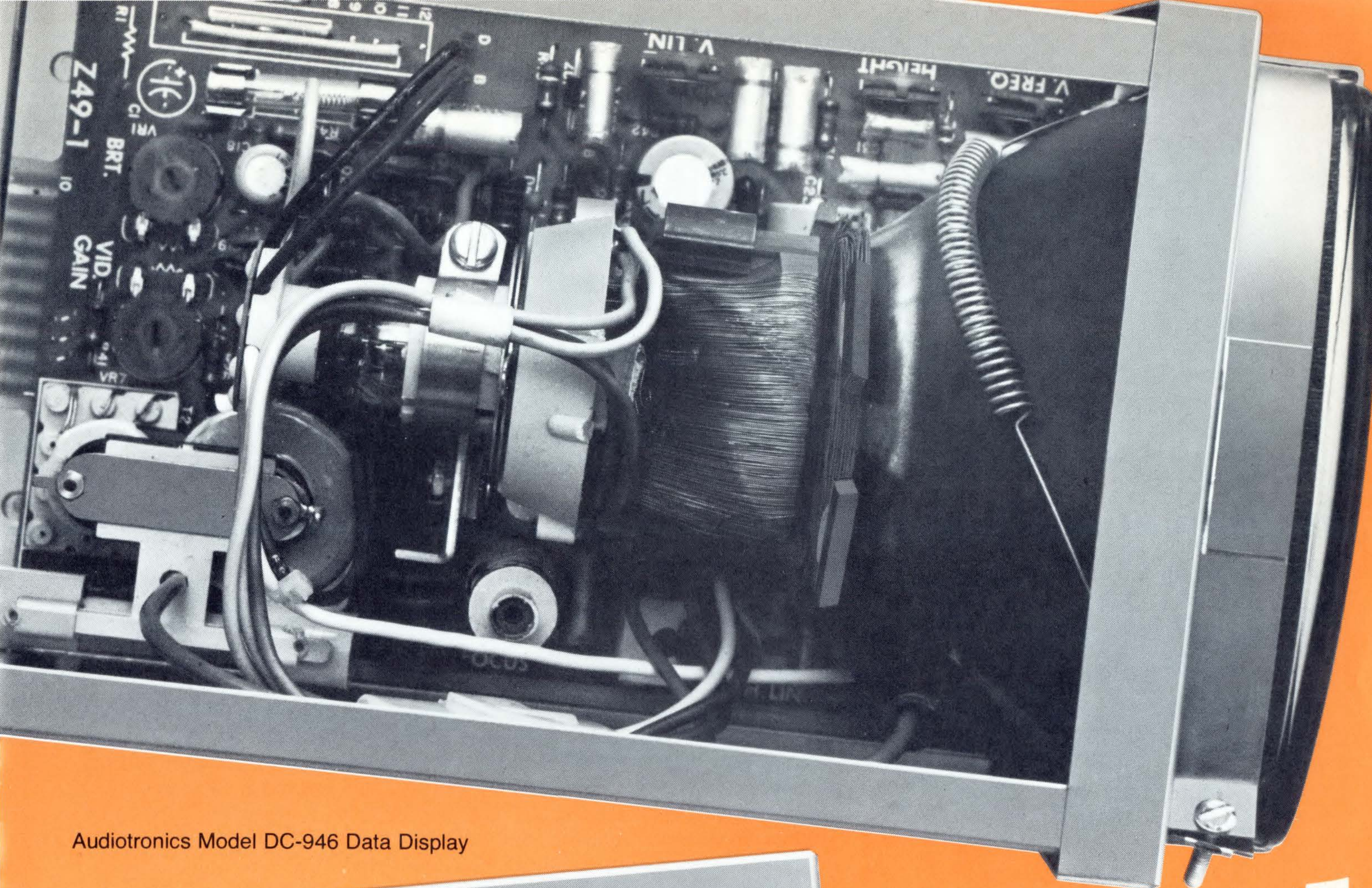
Line Interruptions. Instances occur when the line voltage sags to zero. We conventionally consider these line interruptions to be an absence of line voltage for an interval ranging from several cycles to hours or even days. Dropouts as short as one cycle are quite common on even the most reliable power lines. Line changeover switching is one common cause, as is breaker interruption.

Frequency Variation. Normally considered as changes in the average period of the power line sine wave, frequency variations are averaged over thousands of cycles. However, sudden shifts are also possible. In large commercial power systems, line-frequency changes are averaged to zero during each day, to maintain the overall accuracy of electric clocks and other devices that depend on this frequency. The largest short-term average variation seldom exceeds ±0.5 Hz, but the instantaneous changes can be as much as ±3 Hz in some small systems, especially standby units powered by diesel-driven generators.

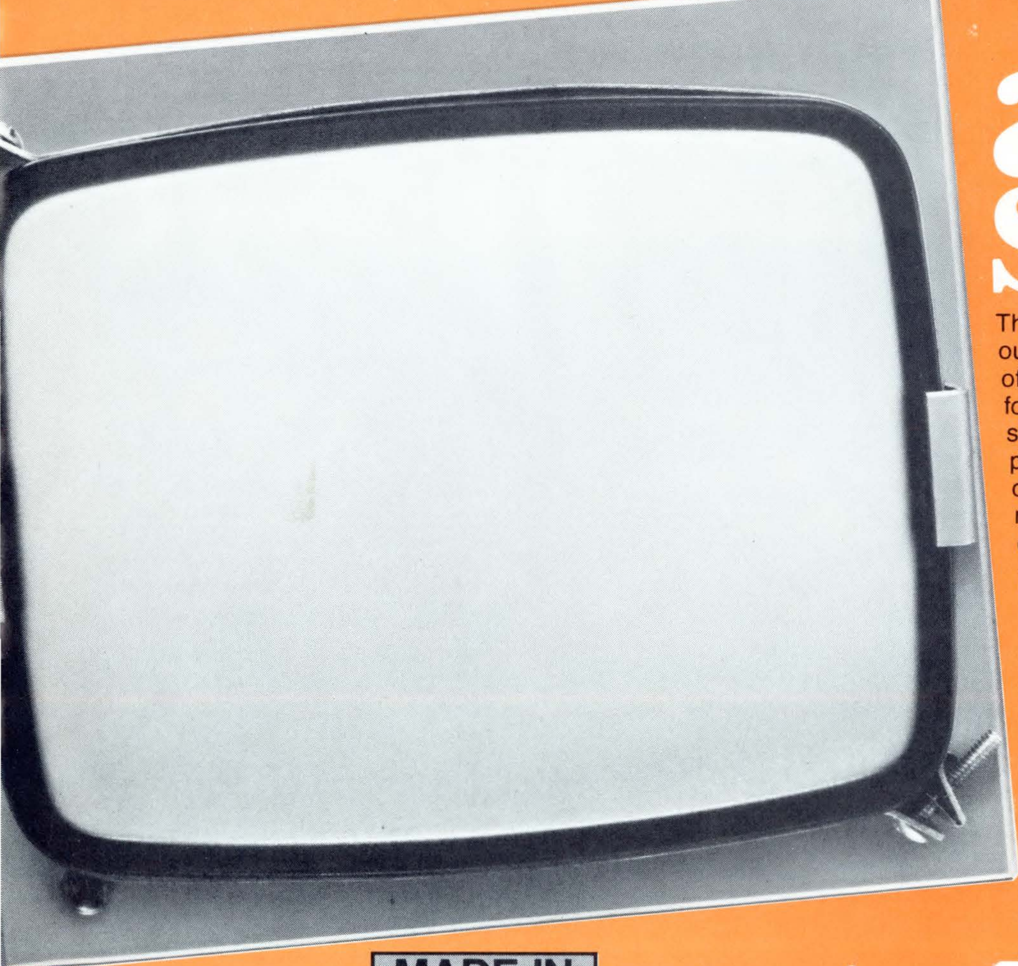
Regulation

Obviously, if the power line voltage excursion is large enough, or if the design of the equipment's DC power supplies is marginal, every one of the previously listed aberrations can cause trouble in any EDP application. Since the DC power supplies sit between the EDP equipment and the line, they help keep these line disturbances from reaching the equipment – within their design limitations.

An unregulated ("brute-force") supply passes a percentage of every line disturbance, just how much depends upon the amplitude of the excursion, its rate of rise and fall, and its duration, as well as on the output filtering of the supply – particularly the capacitance of the output filter capacitor. The load demand on the supply at the time of the disturbance is also signi-



Audiotronics Model DC-946 Data Display



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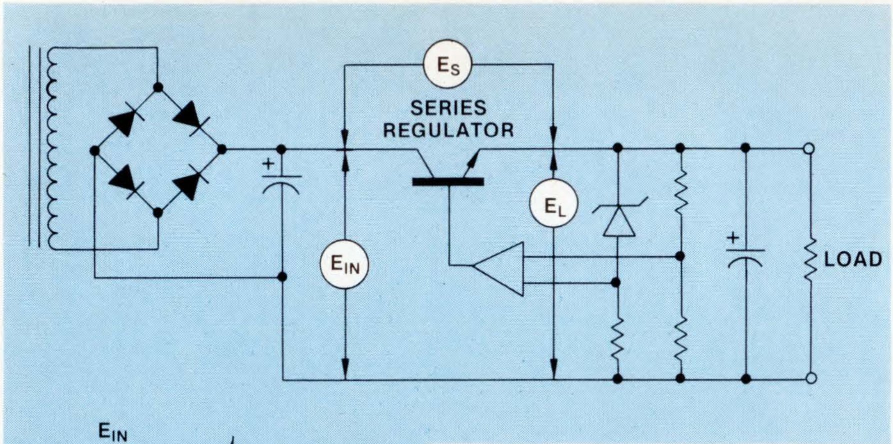

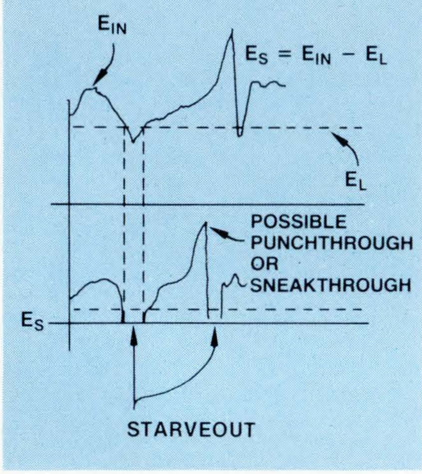

Fig 2 Input variations cause series regulator stresses.

ficant. For example, the load current determines the rate at which the output capacitor is discharged during intervals of low input voltage.

Most EDP power supplies use electronic regulation to help eliminate some of the line disturbances before they reach the system, particularly slow-average voltage fluctuations and line-frequency variations. Regulation can also reduce other types of disturbances to tolerable levels – within limits.

A series regulator is designed to maintain a specific voltage drop across its terminals **(Fig 2)** when the input line voltage to the supply is at its nominal value. When the line voltage drops, the regulator can reduce its own voltage to keep the DC output voltage steady, but it cannot reduce it below zero. (In fact, it cannot reduce it below $V_{cs\ (sat)}$.) The series regulator can absorb line voltage increases only to a limited extent, by excessive dissipation or by secondary breakdown in the regulator transistors. As this circuit approaches the upper or lower extremes of its range, its regulating ability deteriorates; since its speed of response at all levels is finite, high-speed line variations can often momentarily sneak through to the load. A large storage capacitance across the output of the supply can smooth out some of these transitions, but the same limitations apply here as for an unregulated supply. Although placing a ferroresonant regulator in front of the power supply can add a measure of stability in the face of a heavily disturbed line, such devices are frequency-sensitive. For example, a 1% frequency change commonly produces up to a 1.7% voltage change – a result that must be anticipated.

Switching regulators (like the popular off-line, pulse width-modulated type shown in **Fig 3**) suffer from the same kinds of range limitations as series regulators:

- Starvation occurs at the low end of the nominal input range, when the input voltage has dropped so far that the supply can no longer produce the required output voltage, even with the switching transistor turned ON all the time. Under these conditions, the output voltage drops rapidly below the regulation limits.
- Punchthrough can occur when the input voltage rises far enough (momentarily or for a prolonged period) so that, with the switching transistor cut off, the voltage drop across it exceeds $V_{ceo\ (max)}$, and the transistor goes into the secondary breakdown condition, and looks like a short circuit. Under these conditions, the output voltage rises rapidly above the regulation limits.
- Overheating can occur at sustained high input voltages, because the duty cycle (ON time/OFF time) becomes so short (to maintain the regulated output) that the ON time is comparable to the rise and fall times of the switch. This condition greatly increases the dissipation loss per ampere of load current.
- Sneakthrough of fast-rising, large-impulse-area transients can occur at any input level and duty cycle, due to the delay between error detection and switch-mode correction. These transients sneak through the parasitic capacitance of the smoothing inductor, and are not completely absorbed by the output capacitor, because of its ESR and ESX

UPS Systems

Uninterruptible power supplies are a mixed breed. Standby or switchover

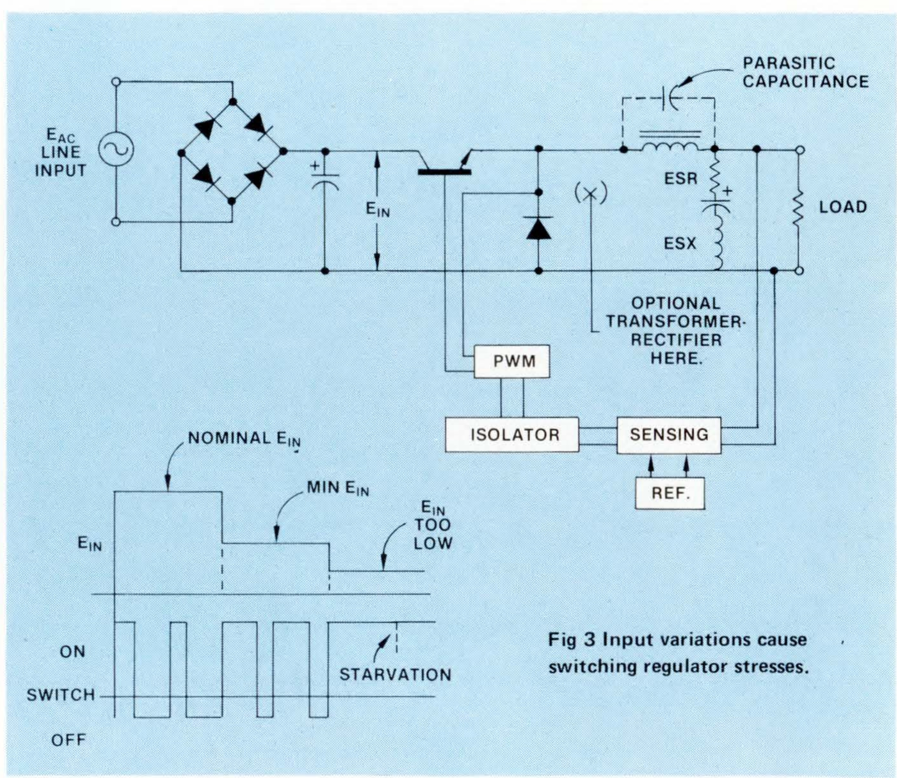

Fig 3 Input variations cause switching regulator stresses.

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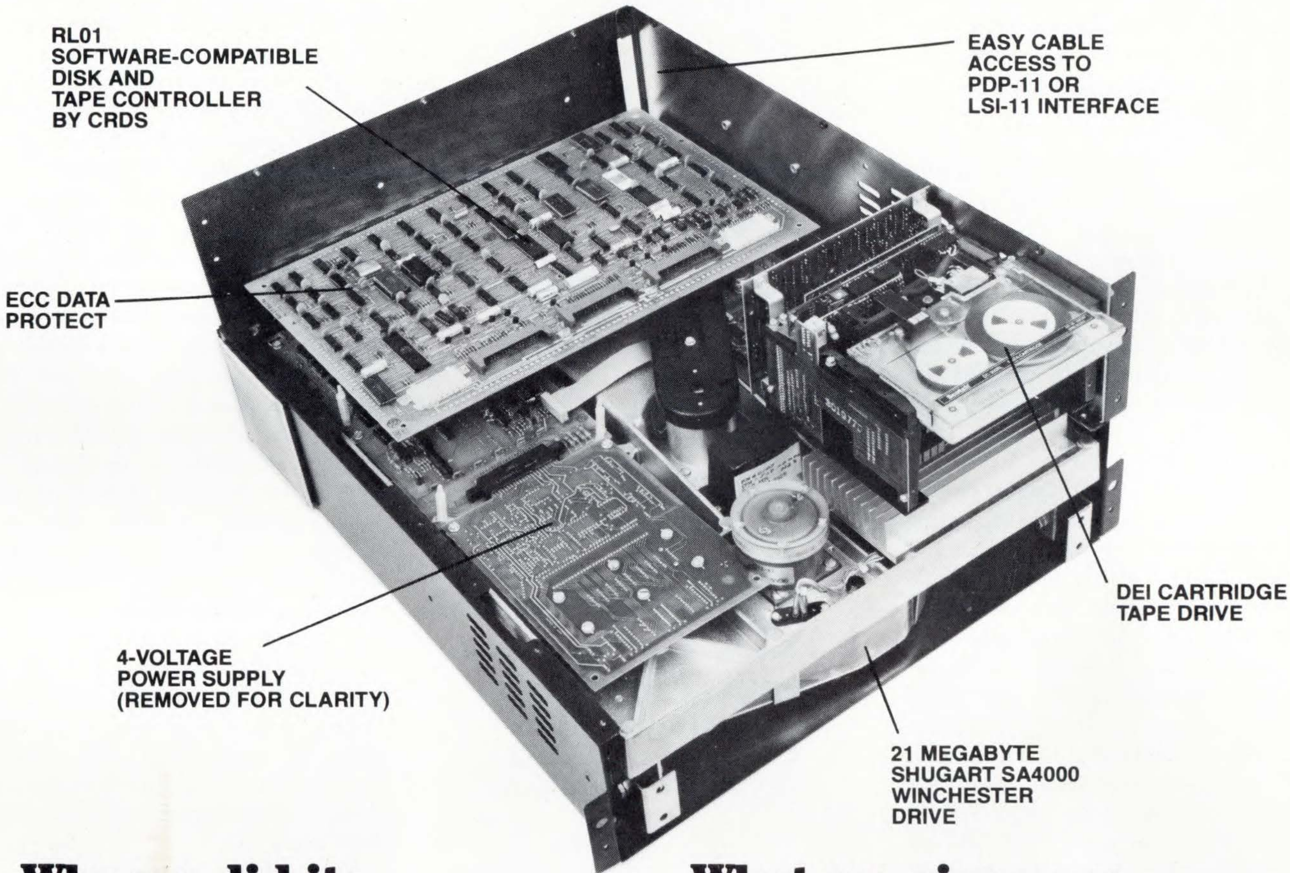

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types do not go into operation until the line-operated supply crosses a specific threshold. What happens to the DC input voltage to the computer or EDP equipment prior to that instant and during the transition is often unknown. Momentary and drastic interruptions can occur with consequent loss of data or erroneous data generation.

In the more expensive on-line UPS systems, the power storage facilities – battery or capacitance, or both – are designed to maintain certain practical limits and corresponding thresholds of safety (uninterruptibility). For a given system, operation in or near these threshold regions may be precarious. Just how precarious depends upon the type, magnitude and frequency of occurence of line disturbances and upon the power-demand schedule of the EDP system. In other words, if the system is still recovering from earlier "hits" or dropouts, its margins are much smaller than they would be following a long period of normal line voltage operation.

Unfortunately, performance predictions for a given system, operating with a given set of power supplies and a given power line, are not as reliable as they ought to be. No amount of bench testing – no matter how well synthesized, how carfully conducted, and how well monitored – can determine the actual, on-line performance. The only dependable and meaningful tests of power supply and power line integrity involve those performed in situ, on the very power line used by the system, with the system operating over a long enough period of time to ensure the presence of every type of disturbance, under every type of computing and data acquisitions program. The load must also truly represent actual field conditions. That set of conditions usually only occurs during true field trials (particularly in UPS installations fed by marginal power lines). And we must include some means of correlating precisely the disturbances with their effects on the DC supply outputs and on EDP system accuracy. We must correlate the following chain of events: AC input disturbance that causes DC output disturbance that causes EDP malfunction.

Testing

Until lately, definitive testing was simply not practical. However, a recently introduced class of microcomputer-based disturbance analyzers provides in a compact, convenient instrument the following capabilities:

- Round-the-clock unattended monitoring of AC line input and DC power supply outputs simultaneously
- External event entry for permitting correlations between the time and rate of system-generated errors with power supply input and output disturbances
- Uninterruptible analyzer behavior despite line dropouts or failures.

These analyzers (designated Series 616, manufactured by Dranetz Engineering Laboratories of South Plainfield, NJ,) make it possible to do the following: determine the effect of every type of AC line disturbance on the outputs of the system power supplies, determine the effects of power supply output disturbances from any source of the system's accuracy in various program modes, adjust transfer thresholds and fallback timing in UPS installations so as to optimize safety margins, and differentiate between computer-generated errors and data-acquisition errors, especially under marginal power supply conditions. The analyzer measures only 11″ high by 7″ wide by 11-1/2″ deep, weighs 20 lbs. and costs under $5,000.

0 0 0 4 CYCLES
C 20.6V SURGE
13:24:15

0 0 0 3 CYCLES
B 12.3V SURGE
13:24:15

0 0 13 CYCLES
A 121V SURGE
13:24:15

C 03.6V IMPULSE
B 08.4V IMPULSE
A 0176V IMPULSE
16:23:07

POWER ON 08:33:38
POWER OFF 08:33:10

C 000V AV 14:03:24
IMP 09.7V 0001 HTS
SURGE 12.6V 0014 HTS
LO AVERAGE 11.8V
HI AVERAGE 12.1V
B 12.0V AV 14:03:18
IMP 0178V 0001 HTS
SURGE 126V 0014 HTS
LO AVERAGE 117V
HI AVERAGE 123V
A 120V AV 14:03:12
TEST DAY 04 ACCUM

Fig 4 Series 616 DC/AC voltage disturbance analyzer prints out these typical messages.

To acquire the necessary data for a definitive analysis, in concrete, simplified, uncluttered form, the instrument detects sags and surges when they exceed predetermined standard levels established by the sensitivity setting of the equipment under test. It identifies each as a sag or surge, and records the time of occurrence, the magnitude and the duration at threshold levels selectable by the operator. It detects slow-average fluctuations when the change exceeds a predetermined (operator selectable) threshold, which it may compare to a fixed value of RMS voltage or the previous recorded RMS value. The record shows the time of occurrence, the actual RMS voltage and indicates whether the change is an increase or decrease. The instrument detects transient impulses when they exceed a predetermined (operator selectable) threshold. It identifies these aberrations as impulses and records the time of occurrence, the number of impulses and the peak value. It treats line interruptions as a special case of sag. Although significant frequency variations are uncommon, the analyzer records them when their deviation exceeds predetermined (operator selectable) limits.

The analyzer accumulates its record of disturbances by monitoring three input channels, one AC and two DC. The AC channel (A) is transformer isolated and monitors a 50- or 60-Hz line ranging from 40 to 250V RMS, 45 to 65 Hz, nominal. The two electrically independent DC channels (B and C) monitor voltages ranging from ±4 to ±25 V DC. Individual detectors monitor each channel for deviations that represent sags or surges, slow-average fluctuations or impulses. (Monitoring of frequency deviations is available as an option.) The detector outputs are scanned, digitized and presented to an internal μP. This processor also has access to preset threshold values for sag/surge, slow-average and impulse threshold values determined by the setting of selector switches on the front of the instrument. If the μP decides that a beyond-threshold disturbance has occurred, it analyzes the important parameters and directs a printout of the

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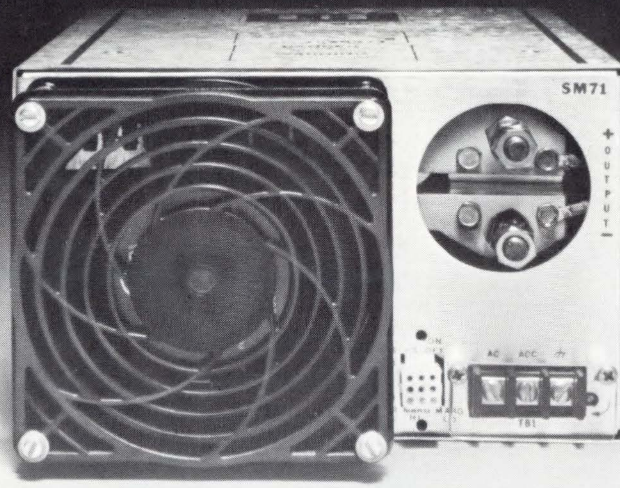

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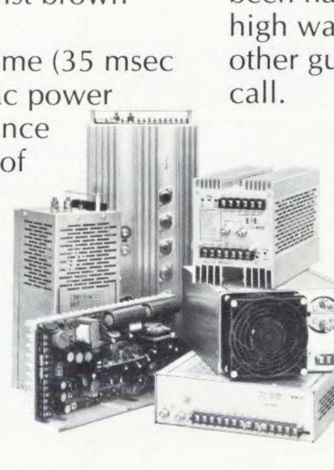

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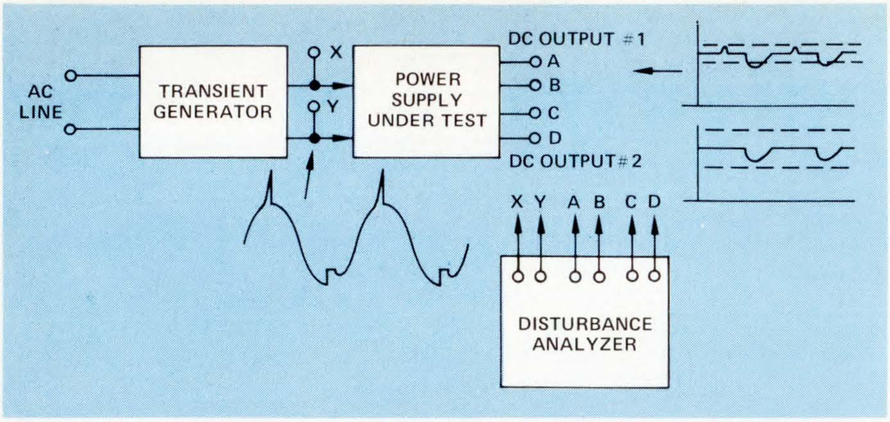

Fig 5 Setup evaluates transient throughput behavior of a dual-output power supply.

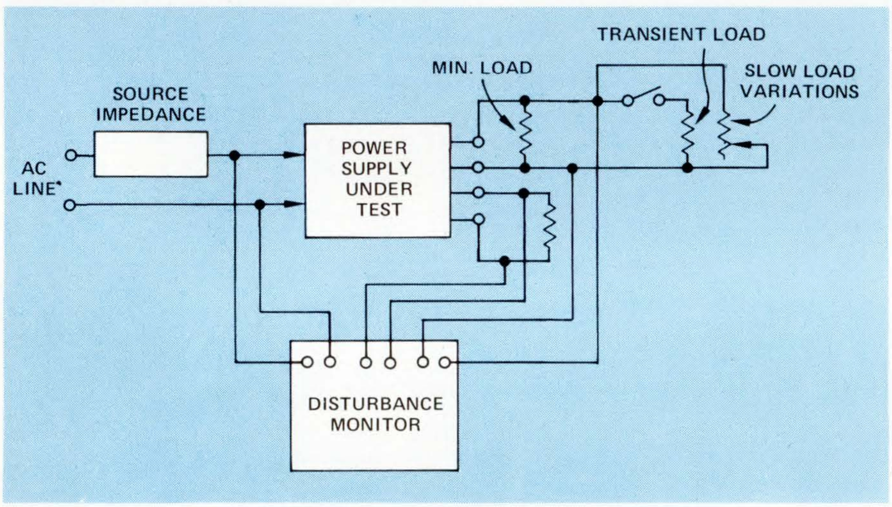

Fig 6 Setup analyzes the affect of variations in one DC output on input AC line and second DC output.

time of day, channel designation, type and magnitude of the disturbance, and the duration in cases of sag/surge and slow-average. **Fig 4** contains examples of printed-out data.

If you use an AC-DC line-disturbance analyzer to evaluate the transient throughput behavior of a dual-output power supply **(Fig 5)**, it measures disturbances on the line and simultaneously observes whether they feed through the supply and affect either or both of the DC outputs. You may perform the test by generating line disturbances, as shown in **Fig 5**, or by simply allowing a low-quality line to generate them randomly. Either way, the analyzer provides correlation by applying a time signature onto all observations. Therefore, you may assume that an output deviation beyond the selected threshold is due to an input disturbance that occurred at the same time. (There is the possiblity of a one-second time-code difference, but it is highly unlikely that this difference will occur, and if it does, the correlation is still evident.) This same setup also can implement conventional static line-regulation testing.

The instrument avoids loss of data on disturbances that occur during printout by storing all information on up to 15 disturbances that may occur while printing is in process. After 15 disturbances, the instrument continues to accumulate data, but in summarized form. As soon as the printer element is free, the stored information is recalled from the accumulator memory, the 15 disturbances are printed in sequence, followed by the summarized information.

Another typical test **(Fig 6)** applies large load variations to one DC and the effect on the input AC line and the other DC output is observed. Note that the setup should provide the same AC source impedance that the supply would see looking back into its on-site power line. In this way, the effects on AC line voltage of static and dynamic load changes are demonstrated. This source-impedance requirement is equally necessary for correct evaluation of output-to-output interactions, since the common line input is one of the major sources of such interaction (particularly if the AC line fed to the supply comes through a mag-amp or ferroresonant regulator). You can also use this setup to perform conventional static load-regulation testing.

Fig 7 illustrates how to test a UPS for output variations during fault-transfer switching. When the primary AC line power is removed, the disturbance analyzer records that fact, time-codes it, and then monitors the DC output or outputs to watch for and measure load disturbances that may occur as the UPS switches to battery operation. The same method is used to analyze the behavior of a reverse-transfer UPS if the inverter fails.

Such a complete and articulate tabulation in the examination and analysis of power line, power supply and EDP system analyses presents an obvious advantage. You can accumulate and study daily and weekly records at small cost. The automatic and arbitrary interim summaries make it unnecessary to search tediously for worst-case conditions, yet the detailed recordings are available for moment-by-moment inspection and analyses of intermediate cycles and specific incidents, and matching of disturbances with equipment malfunctions.

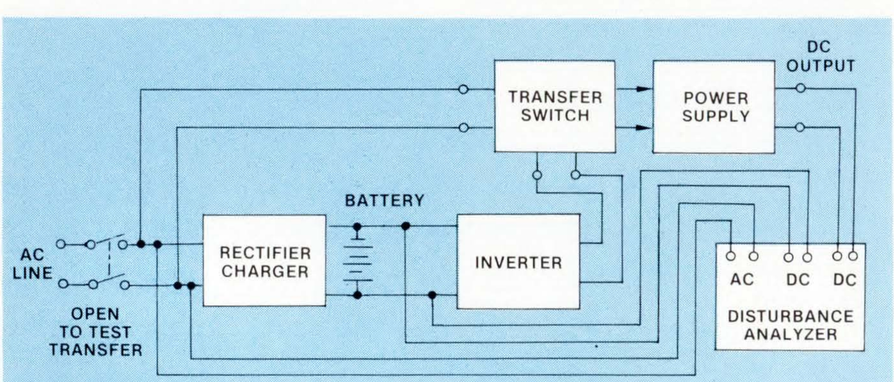

Fig 7 Setup tests a UPS for output variations during fault-transfer switching.

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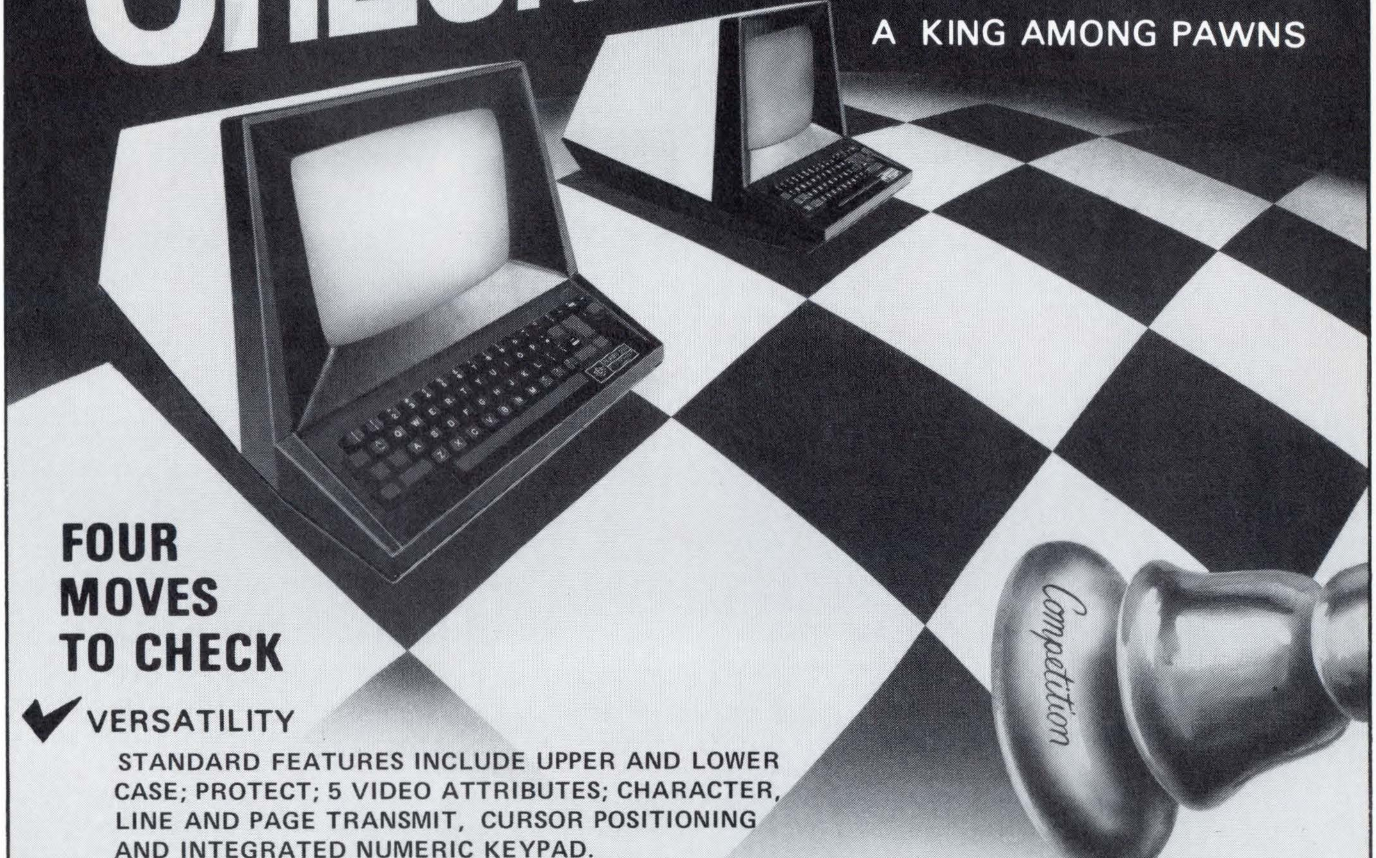

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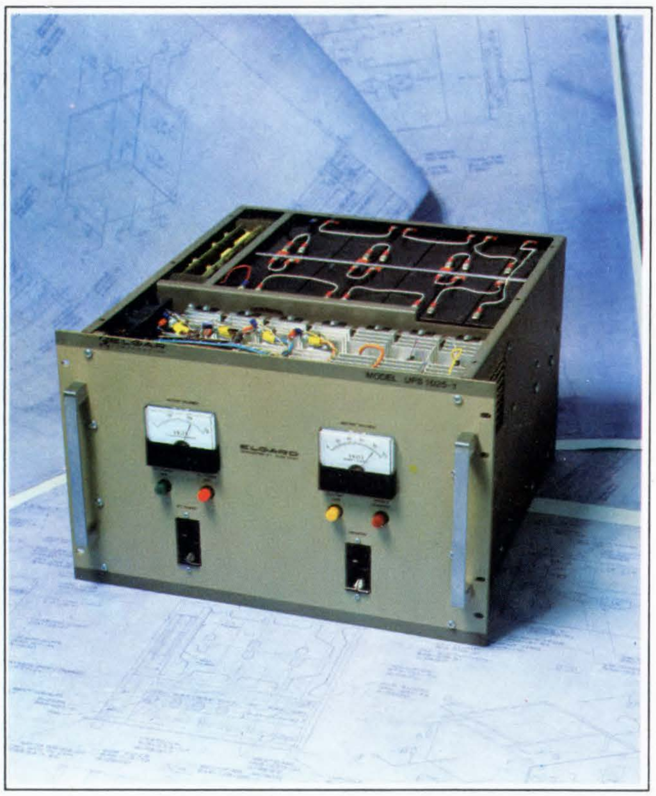
Uninterruptible Power Systems

Provide Computer System "Insurance"



John J. Waterman, Jr.
Elgar Corp, San Diego, CA

The burgeoning OEM market for Uninterruptable Power Systems (UPS) of every rating include system manufacturers in process control, security, data logging and telecommunications with products including an UPS as standard or optional.

A UPS (**Fig 1**) is a continuously on-line solid state device accepting utility grade AC input and providing precise, "computer grade" AC output. It has three basic elements: (1) Rectifier-Charger which converts the normal utility power to DC, (2) DC to AC Inverter to reconvert the DC power supplied either by the Rectifier-Charger or a storage battery to precise AC power for input to critical (load) equipment, and (3) Storage Battery, connected between the Rectifier-Charger and Inverter to sustain the AC power output from the UPS whenever utility power is out of tolerance or unavailable. Additionally, many UPS include a Static Bypass Switch (SBS) to automatically transfer (bypass) the critical load equipment from the inverter output back to the utility in the event of internal UPS malfunction.

Recently, several DC Power Supply manufacturers have offered some battery or Uninterruptible capability as an option with some of their products. While effective for saving small memories from wipeout or keeping limited amounts of logic running, these "DC UPS" don't address those system level problems which an AC Uninterruptible Power System must solve. A properly rated UPS, of the type discussed here, can provide power to an entire data processing facility, including logic, memory, disk and tape drives, output devices, terminals and system cooling equipment.

The growth of the markets for UPS and other power-conditioning equipment is being spurred by increased dependence of commerce and industry on electronic equipment coupled with a decline in the quality and availability of utility-provided power. Of all the problems which effect data processing, telecommunications on other sophisticated electronic devices, the most unpredictable and most frequently encountered are related to input power.

Unfortunately, modern high-speed digital equipment is sensitive to a wide variety of perturbations on the power line, not just the blackouts (interruptions) or brownouts (scheduled voltage reductions). Noise riding on the power line, momentary high or low voltage transients, dips and surges can all cause errors, shutdowns or even equipment damage, depending on their magnitude and duration. Quite often, the origin of power disturbances affecting proper operation of electronic equipment is not from the utility company. More frequently the problem arises from electronic noise generated by other equipment located in the vicinity of the critical load. But the utility can't provide transient-free power. Switching loads in and out of the utility power system results in voltage dips and surges at moments of switching. Switching of capacitor banks by the utility for power factor improvement may also cause distorted waveshapes and voltage surges. Lightning strikes, equipment and feeder faults, and clearing of short circuits within the power distribution system, all produce transients. With generating capacity declining compared with load requirements, the entire utility bus becomes more transient-prone; that is, an occurrence which would have created only a minor perturbation in previous years, now affects user equipment.

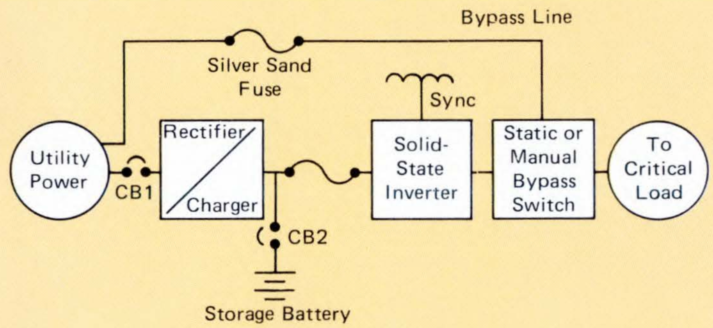


Fig 1 Typical UPS including common protective devices.

There are a variety of devices available, each designed to solve some of these power problems. Voltage regulation devices, for example, while too slow to prevent step changes from causing errors in digital gear, help by raising the threshold of sensitivity. This is accomplished by providing a constant, rather than varying, nominal from which transients depart. **Fig 2** lists principal devices available and the problems they solve. Unfortunately, all of the problems exist at least some of the time in most applications, leaving a UPS as the only dependable solution to power-related problems. The principal advantage of a UPS is its stored energy and consequent ability to regulate output voltage and frequency regardless of utility conditions.

The quality of power delivered to critical loads by a UPS is determined by an inverter. This device actually "generates" the AC output power, and it is in inverter design that key differences exist between manufacturers of UPS units. Inverter design is the principal determinate not only of output performance but also of overall UPS efficiency and cost. While a potential UPS user (even a major OEM) should not dictate design technique to UPS manufacturers, a basic knowledge of inverters and familiarity with their characteristics are essential to insuring proper compatibility of a UPS to equipment requiring protected power.

The inverters of most UPS meet the following basic requirements:

Voltage Regulation: ±2% for all combinations of line (down to battery end voltage) load (within rating) and temperature. This is a "steady state" specification.

Frequency: Normally synchronized or preferably digitally phase-locked to the utility (bypass) line. This will assure smooth switching when required as well as insuring internal clock compatibility of UPS load equipment with non-protected gear running directly from the utility. When the utility has failed, or when its frequency is out of tolerance, the inverter should have internal frequency stability of at least 0.5% with temperature being the only condition that might affect it.

Output Waveform: Sinusoidal with less than 5% Total Har-

Device	Remove Common Mode Noise (1)	Remove Normal (Transverse) Mode Noise (2)	Regulate Voltage (3)	Regulate Frequency	Remove Distortion	High Voltage Protection	Protect from Blackouts	Nominal Efficiency
High Isolation Transformer	Yes	Some	No	No	No	No	No	98%
Constant Voltage Transformer	Some	Some	Yes	No	Some	No	No	80%
Static Voltage Regulator	No	No	Yes	No	No	No	No	96%
AC Line Conditioner (4)	Yes	Some	Yes	No	Some (4)	No	No	94%
Motor-Generator	Yes	Yes	Yes	No (5)	Yes	Yes	No (5)	80%
UPS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	85%

Notes: (1) Noise from the power line to ground. This is the most common type of noise and cause of problem.
(2) Line-to-Line noise.
(3) With the exception of a UPS, this category applies to steady state, or relatively long term regulation. Most of these devices do not respond fast enough to prevent a transient from getting through before correction. By keeping the voltage at the right level, however, they do prevent all but larger transients from affecting affecting equipment.
(4) Generally a combination High Isolation Transformer and Static Voltage Regulator. Some superior devices will eliminate distortion but these are less efficient.
(5) Some Motor-Generators are designed to hold frequency but let voltage decay. These parameters can vary greatly with these devices. Also, some M-G's have flywheels to provide up to several seconds of "ride through" for momentary outages.

Fig 2 Relative protection capability of power conditioning devices.

Winchester users we did it!

monic Distortion (THD – the RMS sum of all harmonics) when operating a linear load.

Three widely-varying key parameters that must be considered, include:

Efficiency: This is obviously important to the user, as it is a principal determinate of operating costs. It is the percentage of real input power (in watts as opposed to volt-amps) that is available as output power at full load. If a 1000W output rated UPS required 1250W of input power, it is 80% efficient (250W represent losses in the form of heat). Sophisticated UPS customers assign a penalty to variations in efficiency, generally calculating the difference in losses at 5 to 10 ¢/KW hour over the expected life of the system, and with seven to ten years being most common. If the UPS

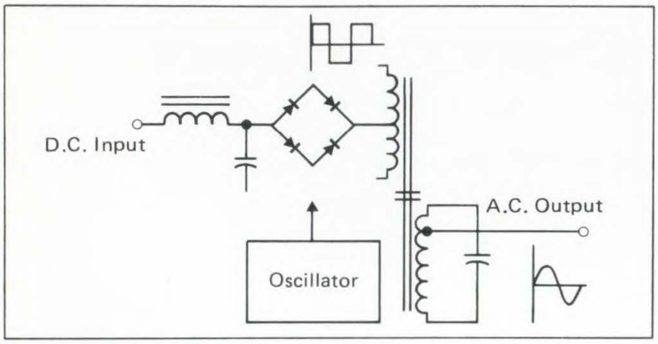


Fig 3 Ferroresonant (CVT) inverter.

is being installed in an air conditioned facility, this figure is doubled due to the added heat removal burden on the cooling system. If the UPS is powering a dynamic load – one where some of the equipment is cycled on and off such as with disk or tape drives – then efficiency at other load levels (75% or 50%) should also be considered apart from its cost importance. Efficiency can be a measure of the relative newness of the inverter design. The more modern pulse-width-modulated higher frequency inverters are generally more efficient than older approaches.

Transient response: This is the instantaneous reaction of the inverter output voltage to a step load change. It includes both the peak amplitude variation and the time required to drop to steady state voltage regulation limits. A typical specification would be ±10% p-p max. for a 50% (of rating) step load change recovering to within ±2% in 50ms. From a user standpoint, this parameter is important if a dynamic load is involved. An example of this is a sensitive piece of equipment, such as a CPU, that remains on while other devices are cycled on and off. The key is to make sure that the sensitive gear will be unaffected by the transient induced by the cycling (load change). With a fixed load, this parameter is important only when transferring the load from utility (bypass) power to the inverter. Even more than efficiency, transient response is a measure of the relative state-of-the-art in inverter design.

Overload capability: Unlike efficiency and transient response, overload rating is not related to inverter design techniques but to design derating practices. The magnitude and duration of overload that an inverter is capable of handling provides one indication of the conservatism of its manufacturer and possibly the reliability of the UPS. Typical specs are: for small, compact UPS up to 2.5KVA: 110% for 10 min and 150% for 10 s; and for larger UPS: 125% for 15 min, and 150% for 10 s. Overload is critically important to the user because many electronic devices require inrush current on startup. This current demand can

greatly exceed the steady state load and it is hardly cost effective to procure a UPS with a continuous rating adequate to handle momentary startup surges. If practical, this short-term inverter overload rating (e.g. 150%) should be adequate to handle the starting surge of the worst case device it has to power, when the balance of the load is already on. Some loads (certain disk drives, for example) have such large starting requirements (ten times running current) that they would seem to indicate a need for a steady-state rated UPS far larger than required. Such a load, when added to that of equipment already running, would cause the inverter to current limit to protect itself, dropping its voltage and shutting down the on-line loads. To handle such anomalies, many UPS manufacturers offer a feature which senses the overload and transfers to utility via the high-speed static switch. Retransfer is made when load current falls to within normal limits. With such a system, high inrush loads exceeding inverter overload rating could not be started in blackout situation (UPS on batteries) without adversely affecting other equipment.

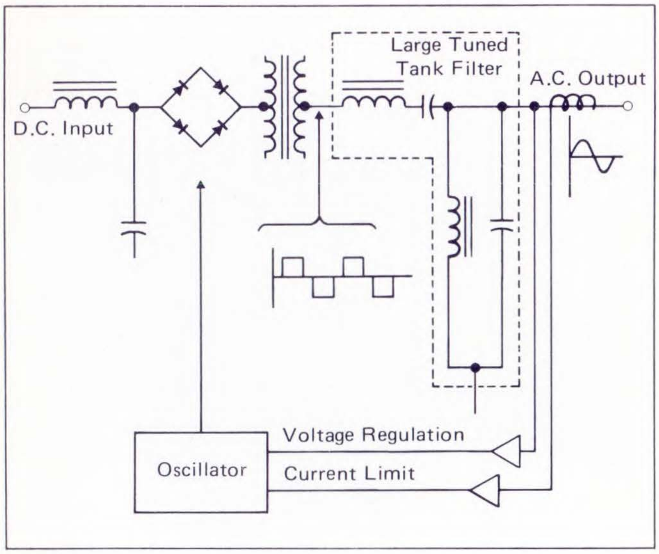


Fig 4 Quasi-square wave inverter.

Almost all inverters used in commercially-available UPS use switching techniques, although some linears still exist for very low-powered extremely precise requirements. Four approaches are the most common:

Ferroresonant (Fig 3): This approach uses a simple unregulated inverter switch to generate either a square wave or two square waves, offset 30° and summed, to eliminate the third harmonic. This square wave or zero-third harmonic waveform goes into a ferroresonant, constant voltage transformer, actually a resonant transformer/capacitor tuned for 60Hz operation. The transformer regulates the output voltage, smooths the waveform and provides inherent current limiting. Ferroresonant inverters have been in use for many years, are simple and, if well-designed, quite reliable. They are less efficient than other approaches because of the energy dissipated in the resonant output section and have comparatively poor transient response due to its high impedance. Ferroresonant UPS also tend to be bigger and heavier than those using other techniques.

Quasi-square wave (Fig 4): This approach is the simplest as it uses true electronic (rather than magnetic regulation). It has two square waves offset to produce a zero-third harmonic waveform. Regulation is achieved by changing the relation of the second square wave with respect to the first,

thus varying the pulse width and amplitude of the overlap and the RMS value of the ultimate output sine wave. A series/parallel LC filter is employed to filter harmonics from the 5th up. The performance characteristics of this approach are also limited by filter design and impedance, although both parameters are superior to those of a ferroresonant unit.

Pulse-width modulation (Fig 5): The commercial availability of ever more complex integrated circuits has eliminated early PWM user concerns, complexity, thus reliability. With PWM, a square wave is generated at a comparatively high frequency, 1.2 to 2.4KHz in SCR inverters, up to 40KHz in transistor inverters. The sine wave is synthesized by varying the duty cycle so that off-time is long compared to on-time near the zero crossing of the desired 60-Hz waveform, with a very long on-time, compared with off-time, at the crest. Output filtering, thus impedance, is greatly reduced with this technique, yielding excellent efficiency and transient response.

Synthesized or Stepped Waveform (Fig 6): Employed primarily in very large three-phase inverters (over 100KVA), this approach employs multiple inverter switches, divided into two sets. Each set produces a 3-phase waveform with 12 or more steps achieved by summing square waves. The two sets are then phase-shifted in respect to one another to regulate the ultimate output voltage. If they are 180° out of phase, the output is zero as they cancel out. When they are exactly in place, the output is at maximum. Because the multiple step waveform inherently eliminates most low frequency harmonics, this approach needs only a simple low pass output filter to achieve a very low distortion output sine wave. Again, transient response and efficiency are excellent. These systems, however, are very complex in the power section.

Most rectifier-chargers are highly efficient with only two techniques being widely employed. Most common is the phase-controlled SCR bridge, simply using controlled rectifiers which phase back at high line voltage and/or light loads or turn full-on at low line voltage with full load. The input power factor of these rectifiers varies inversely with utility line voltage, and should be specified to determine UPS input current requirements under all conditions. The other approach uses a simple unregulated diode bridge which feeds a DC-to-DC converter or chopper. This approach can result in size and weight savings, while keeping UPS input power factor relatively constant.

The most important rectifier/charger parameter is its rating. It should be sufficient to supply full inverter load requirements while recharging a fully discharged battery in a reasonable period. Most major UPS manufacturers size their rectifier/chargers at 125% of inverter input requirements at full load.

The question most frequently asked by potential UPS buyers is, "How much battery reserve time should I buy?" UPS are installed with batteries which provide as little as 30 s to 24 hrs. or greater backup time. Many customers purchase a UPS primarily to prevent costly errors that line transients can cause. There customers want only a reserve adequate to effect an orderly shutdown of the operation when a total blackout occurs. Others will install a standby engine-generator to provide long-term blackout support, supplying power to the UPS input when the utility has failed. In either of these cases a five to fifteen minute battery reserve is adequate. Other UPS users require continuous

operation regardless of utility conditions and don't want to bother installing a generator. For such installations, batteries capable of 12 to 24 hrs., or even longer, service are selected. Other customers may be concerned only with operation during peak business hours and will select 2-to-4-hr. battery support. The time range you select is thus dependent upon the objectives you have set for your UPS, and the available space – and the budget.

Assuming appropriate UPS design, the principal task facing a potential user is assessing his requirements. This includes load power requirements, space and facilities constraints, utility power definition and, again, budgeting. In defining load requirements, it's impossible to give too much information. Load voltage requirements (e.g., 120V, single phase, 120/208V, 3 phase, 4 wire, etc.) are primary. Specify only your load needs. Single phase UPS are much simpler and less costly than three phase devices and if you

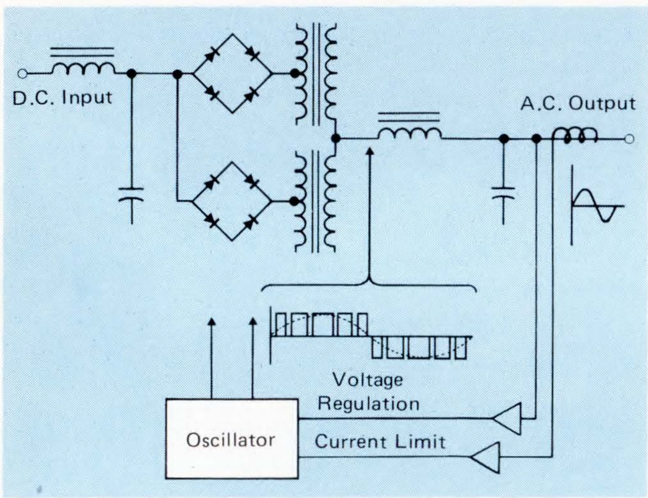


Fig 5 Pulse width modulated inverter.

only have single phase loads, buy only a single phase UPS – up to a total requirement of 20KVA. Above this level, single phase systems become unwieldy. After voltage, steady state load magnitude in amperes or VA is most important as it will determine required UPS rating. Load power factor and/or actual voltage requirements is also useful.

A word of caution on UPS rating: some UPS manufacturers still employ a rating system handed down from other generator manufacturers, where products are rated at 0.8 lagging power factor. A 10-KVA UPS so rated is designed to provide only 8KW of continuous power. This is reasonable for a mix of lighting and motor loads. Modem digital electronic equipment, however, usually has average power factors of 0.88 to 0.9. Thus, if the total load planned for a UPS were 10KVA, it would draw 8800 to 9000 W of real power – more than the 0.8 rated UPS could provide. Some manufacturers now rate their equipment to 1.0 or unity, solving the problem. But users should make certain they're getting the watts they need as well as volt amperes their loads require.

After steady state load, specify the inrush or starting current requirements discussed earlier. If you're a system OEM using several manufacturers' hardware you may find it difficult to get complete and accurate data on this parameter. Many UPS manufacturers equip their service personnel with devices required to measure inrush, and will be glad to do some testing for you.

In specifying facilities interface, consider first the input voltage or utility service to be supplied to the rectifier-charger. In most cases UPS input and output voltage should be the same. If the values are not equal, a transformer is then required in parallel with the UPS to supply the necessary power for bypassing the system in the case of a fault or for maintenance. Some cases demand different UPS input and output voltage configurations, however. In 15KVA or larger single phase output UPS, a three phase service is generally mandatory to the rectifier charger, due to the amount of power needed. In such cases, the user must provide a single phase input to the bypass switch. Remember, at least 60% additional service capability is needed at the UPS input to allow for efficiency losses, recharging batteries and UPS input power factor variations.

UPS are power supplies, and while they're available in ratings down to 100VA, they are often big and always heavy when compared to the equipment they're running. An OEM planning to provide UPS with his systems should count on obtaining ratings no higher than 2500VA which are packaged in rack-mountable configurations with internal or similarly-packaged batteries. Larger UPS come in big, free-standing cabinets. In units of 25KVA and up, several thousand pounds of electronics and batteries are required.

The key to UPS selection is not much different from other sophisticated electronic equipment: careful choice of a supplier. Make certain that you can verify claimed field experience. Warranty provisions and service capabilities including response time should also be reviewed. En-

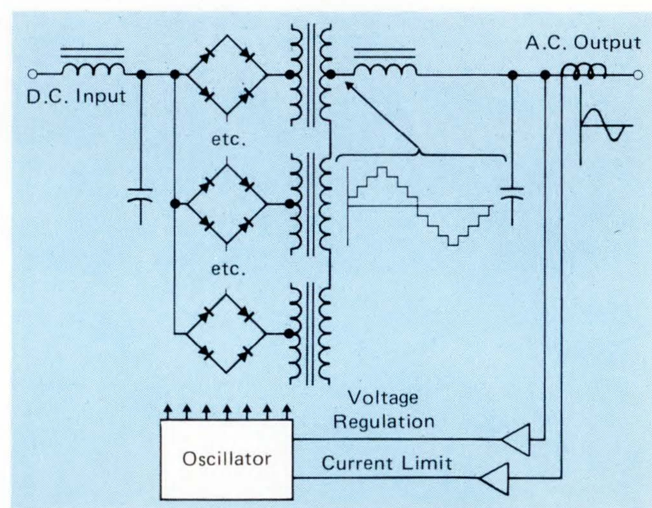


Fig 6 Step or synthesized waveform inverter.

vironmental constraints must also be detailed, remembering that a UPS must function when the power and air conditioners are off.

The principal purpose of a UPS is to improve reliability of power supplied to critical load equipment; thus, ultimately reliability must be the overriding concern. Unfortunately, it is probably the most difficult parameter to verify. A prospective buyer should request both predicted (calculated) and actual operating reliability figures. He should also request a quotation on a long term extended warranty or after-warranty service contract. A comparison of these figures could be far more meaningful than comparing MTBF's.

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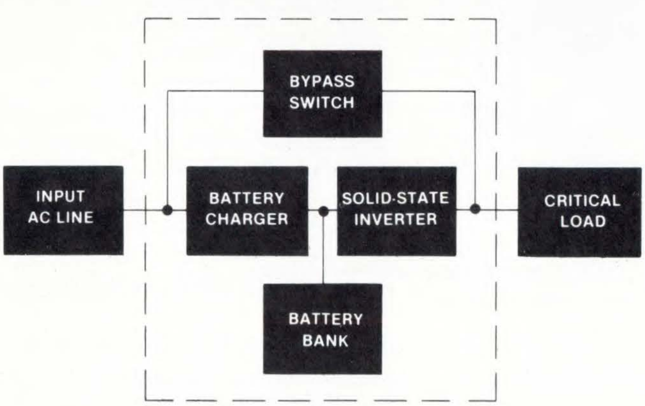

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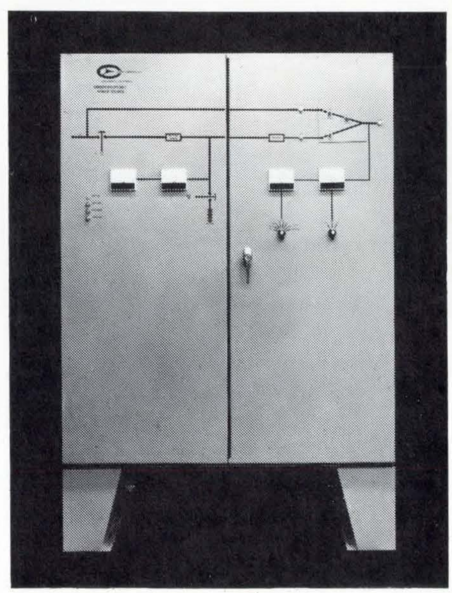

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Special Report:

Power supplies exhibit greater flexibility and higher efficiency.

When a power supply dies, the electronic life blood stops flowing, and the computer dies with it – sometimes gracefully, sometimes not. Perhaps you don't recognize the power supply as the heart of every digital system. Dull, boring and the least important item best left for last minute consideration – is that your attitude to selecting power supplies? If so, you're risking the destruction of your system, costly field service bills and your job.

Gone are the days when a system designer could make a few preliminary system power estimates, allocate some space and later overspecify to be safe. The power supply is taking more of the overall system cost for OEMs. Power supply technology is suddenly going through rapid change. There is less room for error today. Today's system designer must understand power supplies; if not well enough to design them (particularly switchers), then at least well enough to evaluate them. To this end, we will review the categories, special aspects and pitfalls to avoid when designing your own or ordering.

Let's look at what's available in various categories of regulated power supplies – ferroresonant, SCR, switching and hybrids – and examine their (dis)advantages.

Linear supplies – traditional

The series regulator takes an input through a transformer and one, two or four rectifiers and large filter capacitor(s) that smooth the rectified waveform. A series-pass power transistor in series with the load varies current flow to control the output voltage. A feedback network senses voltage on a divider across the output, comparing it with a reference. The network detects output changes and applies a control signal to the base of the series-pass transistor.

There are several types of linears. In a **shunt-regulator**, a zener across the load provides fairly-constant output voltage. A transformer supplies a half- or full-wave (or full-wave bridge or multiplier rectifiers), which is then shunted by a capacitor, a series resistor and then the zener and load in parallel. Although the shunt regulator provides better regulation than an unregulated supply, the zener carries heavy current at no-load, and such circuits are used for low-current (200 mA) applications when the input is fairly constant. Series-pass regulators are far more common.

Series-pass regulators using a zener reference, are more efficient, provide much more load current and better regulation (still poor) than a shunt-regulator. In such a supply, a common-base power transistor absorbs the difference between input and output voltages. In its simplest form, a zener absorbs base current, which is much less than load current.

Zeners and NPN transistors, for use in controlling series-pass base drive, are combined to cancel temperature differences between the two, resulting in a low net temperature coefficient. A filter may be added to the series-pass base.

In a **series-regulator with feedback**, a pot divider inserted across the output drives a feedback transistor or amplifier, which compares this feedback voltage with a reference and adjusts the output (to make them equal) by varying the base current of the series-pass transistor. This high-gain feedback loop improves regulation. In its simplest form, it is no more than a feedback transistor between the series-pass base and zener cathode, which has its base wired to a pot in a divider (across the output). In other versions, a Darlington series-pass handles higher current and improves regulation.

Fan-cooled switchers such as this 375W, two-output, 5V, 75A unit – offer densities up to 2.7 W/in^3 and 70% efficiency.

Many cookbook linear regulator circuits exist to improve current-limit operation and transient response, stabilize reference voltage and improve stability. Once made of discretes a decade ago, these linear circuits are now available in three-terminal IC form and regulate output within 5 mV.

Linears have advantages

Series regulators remain the most popular supply due to their superior reliability, regulation, ripple, transient response specs and lower cost (for lower-power units). On the other side, disadvantages include low efficiency (40-50%), larger cooling needs, larger size and greater weight. As input voltage rises, so does input power, and since output power is constant, the linear dissipates more power at higher inputs. Due to linears being a mature technology, due to rising energy costs (hitherto of minimal impact on supply selection), and due to rapid strides made by switchers, linears will be regulated to a smaller portion of the market. Unlike switchers, linear prices are driven more by the cost of iron, copper and steel – basic raw materials that will rise with inflation – unlike switchers, which are driven by technology (such as PWM control IC improvements).

Linear power supply makers are not giving up to switchers without a fight. By using higher-grade steel and square copper magnet wire, some manufacturers have reduced transformer losses over 12% and cut size and weight. By using higher-power and lower-saturation series transistors, they've reduced saturation and voltage drop dissipation by 40% or so. And, by incorporating higher-power Shottky rectifiers, derated 50% in current and voltage,

POWER SUPPLIES

Paul Snigier, *Editor*

rectifier losses (typically 20-30%) have been halved. Efficiencies are in the 50-60% range.

Ferroresonants – simplest (and reliable)

Want high efficiency, circuit simplicity, reliability, low cost and low component count? Try the ferroresonant regulator. It consists of a saturated (constant voltage) transformer, AC tuning capacitor on one secondary, and rectifiers and DC filter capacitor on the other (split) secondary. The saturating transformer converts the sinusoidal input, and via in its saturating action, creates a calmed sinusoid resembling a square wave that is then rectified and smoothed by an output filter capacitor.

Further advantages include very good immunity to line transients. They are well-suited for multiple series (or parallel) banking to meet higher-output voltage (or current) bulk power demands. Efficiency is high (70-90%) because regulation is by nondissipative means and virtually eliminates communation losses. It eliminates most EMI woes because the waveform is not steep and rich with harmonics. Then there's inherent overvoltage and short-circuit (by leakage reactance) protection. Control winding voltage can be selected for best components without regard to input and output voltages. Large temperature changes have little effect upon ouput voltages, changing 1%/40°C. Output voltage can stay under ±1% for static or dynamic line voltage changes up to ±15%. Other advantages exist. For a dead short, if load current reaches 250% of rated full-load current, output voltage drops in 1ms to zero and remains there until the overload or short is corrected. The ferroresonant is undamaged by dead shorts. Ferroresonants are very reliable: they have 1.5 times the MTBF of linears and 4.5 times the MTBFs of switchers.

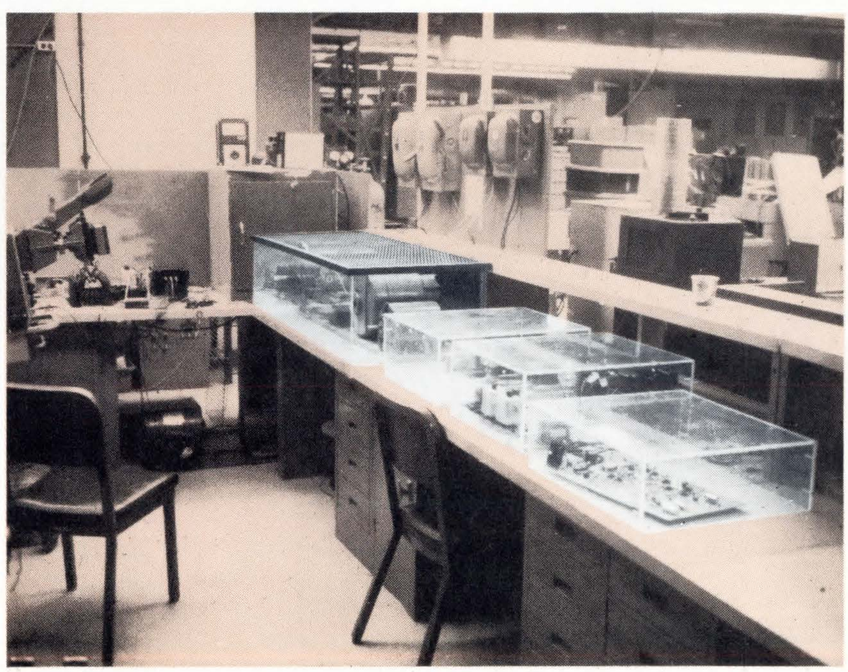
What about recovery time for line changes? If line change is under ±5%, no excursion outside the regulation envelop occurs; if over this and up to ±15%, it can return to its ±1% regulation envelope in milliseconds. Most utilities keep frequency variations under ±0.5 Hz; some go as high as ±3Hz. As for load changes, a sudden (step) change from full to half load takes a 60-80 ms recovery time to return to a ±2% regulation envelope.

Serious disadvantages exist: large size, sensitivity to line frequency changes, and higher transformer losses during saturation (increased hysteresis loss).

When line frequency changes, ferromagnetic output voltage drops drastically. Frequency variations of ±1Hz will produce a ±1.3% rise (drop) in output voltage. This is a linear relationship between 55-65Hz. Since mechanical generators at power plants suffer from short-term frequency changes, to ensure a precise number of cycles/day (5,184,000), utilities make late-night frequency corrections. The changes correct other problems, but could harm sensitive digital systems with ferromagnetic supplies.

SCR regulators – simple, but. . .

The SCR regulator has been used for systems and environments that tolerate greater ripple and noise. It has a transformer, two SCRs, low-pass LC filter and control circuit. The SCRs typically operate as two legs of a bridge rectifier, with each anode connected to the secondary; cathodes tied in common are fed through the filter to the positive



Power Supplies in noisy environments require special care. Our power supply tests found that abrupt power-line impedance-changes cause reflections and created transient voltage spikes exceeding 3kV. A short across a 240Vac line (at peak) exceeded a 1kA momentary surge. To clamp such voltage transients, use solid state suppressors (zeners, if dc) across supply inputs. Since our supplies were connected to the same bus as heavily-inductive devices (solenoids and motors), sudden current changes and kickbacks created voltage spikes. Adding a voltage snubber and catch diode across inductive loads (such as motor controllers) minimized this. To detect noise-susceptibility quicker, use transient- and noise-generating tests (zap gun, chattering relays, etc). Test circuit (lower right) was designed by author to detect source of transients.

output terminal. The low-pass filter passes only the average or DC component to the output. Regulation is performed by a comparator control circuit (with output wired to the two gates) which senses the AC input (through a center tap -V and -S through a resistor) and DC output, which is compared to a reference.

With dropping voltage, the control-circuit firing-pulse fires the SCRs earlier, passing more charge to the output filter. Since SCR regulators directly rectify line input, they avoid bulky 60-Hz components. Other advantages include small size, low cost and high efficiency. Disadvantages are high ripple and noise (up to 500 mV pp), poor regulation (0.05-1%) and slow transient (50-200 ms). They cannot be used in most applications.

What about switchers?

A switcher or switched-mode power supply (SMPS) may contain a bridge rectifier, switching transistors, pulse-width modulation (PWM) control circuitry, feedback network, high-frequency transformer, output rectifiers and filtering network.

Like linear supplies, all switchers compare output voltage to a reference; and a control circuit adjusts the on/off-time ratio of the series switching transistor(s), whose frequency is usually about 20KHz-40KHz. The chopped current passes to an output filter.

Since transistors saturated full on or off are not lossy, efficiency typically can be in the 60-90% range, resulting in higher power density, smaller size and lower heat dissipation and less need for forced air or fan cooling. With fast pulse-repetition rate, inductors, filter capacitors and transformers can all be smaller and lighter, consuming less raw materials like iron and copper. Switchers can operate through temporary line-voltage drops (brownouts), sustain output levels for 20-40 ms.

Switching supply specs, when compared to linear specs, do differ as follows . . .

	Linears	Switches
Size (W/In^3)	0.5	2
Efficiency (%)	40-55	60-85
Power Density (W/lb)	10	50
Ripple Noise (mV-pk-to-pk)	30	50
Line Cycle Carryover (ms)	2	25-50
Transient Recovery Time (μs)	25	500
Input Voltage Tolerance (%)	±10	>±20
Regulation (%)	0.1	0.1

Switchers have been criticized for a lower degree of stabilization, inrush current woes, higher noise, switching spikes and higher prices for low-power applications. Transformer imbalance in high-power push-pull switchers have caused failures (although twin-pulse PWM circuits are said to have alleviated this). In multiple output switchers, getting desired outputs simultaneously isn't always easy. But better designs and new generation components have lowered cost, reduced noise and spikes, increased efficiency, and raised reliabilities.

Switcher categories

Switchers are forward, flyback, half- and full-bridge push-pull converters, or combinations of these. Since it is the simplest and uses the least parts, the one-transistor **flyback converter** (blocking oscillator) is lowest in cost and has been used for switchers up to a few 100W. Not only does it offer simplicity, but the flyback regulator's "clean" waveform in terms of the transformer field or line currents over time provides superior RF suppression, with few current spikes and thus less high-frequency harmonic energy. Flybacks are used in multiple-output switchers, since each output only requires one capacitor and one diode. But smoothing can be a problem where ripple is severe.

Like all low-cost circuits, there's a tradeoff: high ripple and poor regulation. Flybacks behave like current sources and supply a wide high-voltage, low-power output range.

Flyback transformers provide a large inductive kick that almost doubles primary voltage, even if the switching transistor is only partially turned off. This means that it must withstand peak current, four times greater than average at double the voltage (if 115-VAC on the primary, this is 350V) for several tenths of a μs or so. Flyback converters all too often destroy bipolars, and overspecing is needed. VMOS FETs can handle it, and turn off in tens of nsec, but have disadvantages.

The flyback transformer primarily possesses tens of μH, and the core's B-field is not that intense, so there must be more core volume to store the energy (which is retained during half cycles and not passed from primary to secondary). Some flyback switchers get around this by using higher frequencies and lower ferrite permiability or use a medium-permeability core with an air gap for storing magnetic energy.

Notwithstanding these difficulties, the flyback regulator may have advantages. The continuous series impedance of the transistor means that the collector-current rise-time is well-controlled and relatively slow. What this means is that it is possible to turn off the transistor before the core saturates. Also, during the charge cycle, the secondary or load completely disconnects from the primary; if a secondary fault occurs, it's not directly reflected back to the primary.

Other advantages exist. The flyback regulator can operate at duty cycles less than the clock period, thus giving this regulator a very large dynamic range. Multiple regulated outputs are possible using a flyback regulator, with regulation obtained on two of these secondaries by regulation of the third. On the other hand, regulation of such a transformer is not as good as a conventional DC-to-DC converter. This is so because the core material provides poorer coupling, although some manufacturers have tightened regulation by using multifolar and parallel-windings.

Do you want greater power? Easily done. The output is increased by paralleling the number of stages. Since the stages are unlimited, output power is unlimited. This is inherent because the transformers are current (not voltage) sources. By timing the parallel stages so their transformers dump stored energy into the load on a staggered basis, ripple is decreased. Although the reliability is high, as already mentioned, it can be increased if there are enough stages so that one failure won't affect the load. Simply fuse the secondary diodes and primary transformers; when one fails, that stage is removed from the primary and load.

Forward converters use only one switching transistor and offer low output ripple. They are used more in lower-voltage, higher-power applications than flybacks, although most outputs are not above several 100W. Since inductor cores are driven in only one direction, power flywheel diode and series inductor with the load ensure a steady current despite the switching transistor's state.

Duty cycle limits of many forward converters at time saturate the main power transformer, resulting in switcher failure. Circuits have been developed to prevent this.

Push-pull converters, though they may use two or more power transistors and two flywheel diodes (and cost more), provide higher power output, lower ripple (frequency doubles, making filtering easier) and more efficient (bidirectional) use of transformer cores. Consequently, push-pull switchers are popular.

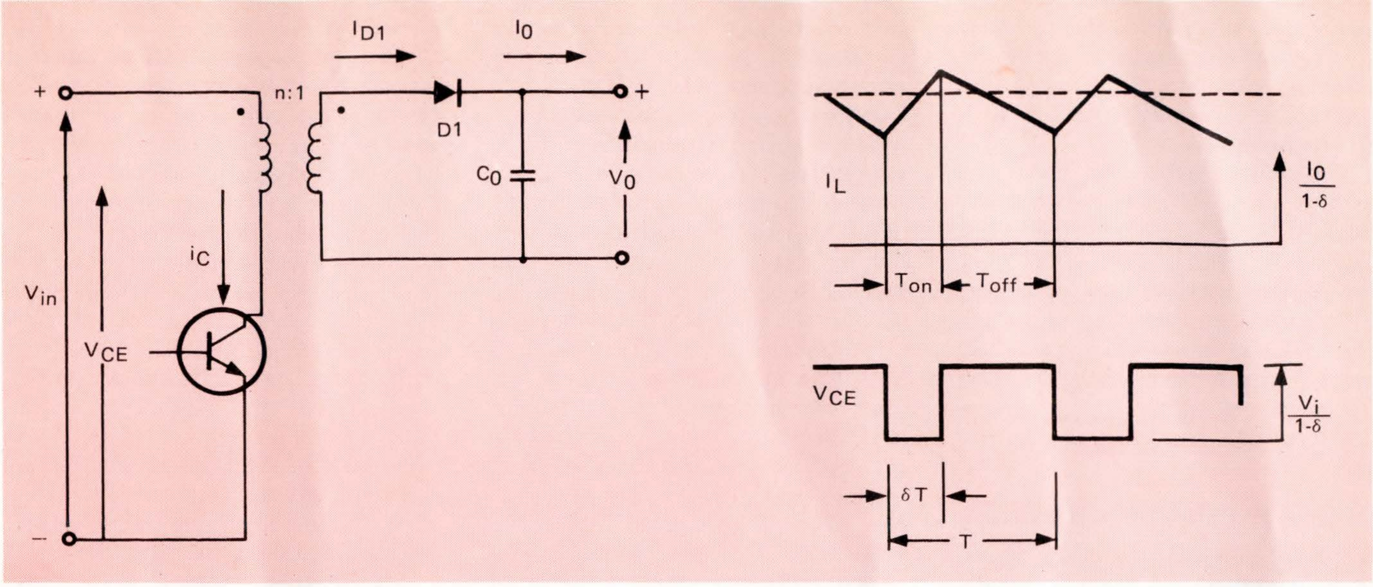


Fig A The flyback converter, uses only one inductive element. During the transistors on-time (forward) period, energy is stored in the choke's magnetic field. During flyback, the transistor is off, inductance current falls, and the diode becomes forward-biased. The magnetic field collapses, transfering its energy to the capacitor. With proper values, the on-off action provides a smoothing action. $V_{CE}=V_{in}/(1-\sigma)=V_{in}/(1-0.5)=2V_{in}$ where σ is the transistor's duty cycle and T is its cycle time. $V_{in}=V_{CE}(1-\sigma)$.

If using single-ended or half-bridge circuits (the latter withstand twice line voltage and are suitable for low- to medium-power switchers), then push-pull regulators must use two (or more) switching transistors; if using a full-bridge for more power, then four – although paralleling power transistors up to eight or so has been used to boost overall current capacity.

Push-pull disadvantages exist. Although they create the lowest output ripple, they have the most complex base drive. The converter, if excessive positive feedback saturates the transformer core, may hang up in one state (latching) irrespective of what the driving circuit does. Core saturation, caused by cross-current saturation, takes place when all switching transistors simultaneously conduct. Core saturation can occur from DC imbalance. Push-pull converters are limited in input range, a problem solved by a switching regulator before the push-pull. The tradeoff is a noisy switcher-push-pull combination that's not only inefficient and degrades isolation, but recovers slowly from load transients.

Control ICs are solving many push-pull problems, particularly for high-power units. Pulse-width and pulse-amplitude imbalance have long been the killer of push-pull switchers (transistors and diodes), although push-pull makers claim that transformer imbalance has been beaten by the twin-pulse circuit without overspecifying transistors. Since one pulse is wider than the other due to load variations, one push-pull transistor is driven harder, and its transformer flux density is greater, leading to lower diode PIVs. Conventional push-pulls drive the switching transistors directly with a narrower pulse (for a rising output) to shorten on-time, thus providing negative feedback and lowering output.

But the twin-pulse PWM control IC applies one output to one transistor. A flip-flop, set by the PWM's other pulse, provides an identical pulse (delayed by T/2) on the second transistor.

Switcher reliability

Pareto's Law applied to switchers says that three-quarters of all switcher failures are due to failure in one-tenth of the parts (electrolytic capacitors, pots, power diodes and transistors). Putting more housekeeping functions on-chip will significantly increase reliability – but only if the correct functions. Those control ICs that lower capacitance, inductance and transformer needs will lower stress factors and increase MTBFs. Also, the fewer high-current active devices used, the less that can overheat and go wrong.

Reliability is improved and cross-talk variations (dependent on assembly) are reduced by PC board links and greater care in partitioning functional sections, thus minimizing interconnections and wires.

Military-grade parts offer a 3.5-fold improvement in MTBFs. To improve reliability, the switcher vendor may prefer not to use better parts and manipulate statistics to create better MTBFs on paper, knowing that some OEMs (who are usually aware of this specsmanship game) will prefer this initial lower cost, despite lower, long-term overall cost of the initial more-costly unit. Then again, some OEM cottage shops selling systems, incorporate the cheapest switchers they can can get, and don't care.

Misleading MTBFs have soured users. Traditional MTBF calculations are more meaningless for switchers than linears, and all too often don't account for real-life situations. Switcher makers can validly juggle the data to provide any MTBF they want, and it's not as if they aren't aware of the different ways to determine MTBF.

The principles needed to improve reliability are well known. It's known that a MTBF improvement of eight-fold is possible with only a 50% increase in cost of critical components. With increased costs for better screening, system burn-ins, etc., a \$500 switcher (unit qty.) would sell for \$750. Does this raise OEM system costs? Does it save on overall cost (over, say, five years)? Definitely. Let's see why you, the OEM, will save in the long run. The N-year cost includes initial supply cost plus a factor: (repair cost/ failure plus spares allowance, perhaps 10% of initial cost) times the ratio of switcher life to MTBF. In reality, the cost of a failure also includes something more than the cost of repair – the cost of outage or revenue for your customer. If MTTR is low, say half an hour, repair expenses involve field service visits, travel time and expenses (with energy-related travel costs expected to skyrocket), shipping costs, etc. So, a repair cost per failure can easily exceed \$140 – and far more later.

Reliability studies show that a two- or three-year MTBF switcher costs less than a 10-year MTBF unit for the first four to five years. After seven years, the initially-cheaper unit costs twice as much; and in ten years, 2.5 times more. With replacement costs and field service costs outpacing inflation, these figures are optimistic; the breakeven point may be more like four to five years.

Control ICs alter switcher design

Precision references, ramp oscillators, error amplifiers and differential voltage comparators are the four control elements of a PWM circuit, and were around in separate IC form for years. But when a single monolithic IC was first offered, switcher design changed. These monolithic and power hybrid control ICs have reduced components count and increased reliability by providing compactness, reproducibility, reduction of parastics, accuracy and more control functions at lower cost. The rapid proliferation of control circuits, with over a dozen circuits or more now available, has created confusion even among power supply designers. The difference between these control chips, even though they do provide similar functions, are sufficient enough that it requires considerable time to compare them. The ICs, in turn, are growing more sophisticated, with more control and protective housekeeping functions on-chip. This makes switchers a technology that is silicon-dependent, and one that has far to go before maturing. This means that instead of designing a cage-full of PC cards, today's SMPS designer uses a handful of ICs and modules to handle conditioning, control and drive functions. This leads to not only smaller size and increased reliability, but substantial savings in assembly time, testing and inventory control.

Traditional switcher ICs (SG1524, MC3420, TI TL497, Ferranti ZN1066), first offered in 1976, have given way to superior chips. These include PWM SG1525, TL497A, MC3421 and many other improved versions or new families. New firms entering this growing (25% per year) market for IC controllers include AMD and other semi makers. These newer, souped-up ICs offer more functions, such as more accurate references, dual output drives that source/sink more, oscillator synchronization, on-chip power driving, error amplifier, adjustable current-limit amplifier, spare output transistors, wider frequency ranges (several Hz to several 100Hz), independent sensing/control of output voltage and current, overvoltage and multiple-level current-limiting, stop-start latch (for fast switch-off or slow starts, remote on/off controls, adjustable dead time, etc.)

Inrush current protection, usually a thermistor on the input rectifiers, prevents inrush currents when charging large capacitors. But inrush-limiting circuits that perform under all input voltages and temperatures are complex. The problem is to decide if a momentary AC line dropout necessitates a soft restart or reapplication of AC (hard restart). Inrush limiter circuitry in a closed loop can detect the inrush and then reapply AC. Softstart IC circuits are of varying sophistication.

How can switchers lower EMI?

Although confusing, laws regulating switching supply emissions exist in every country. If you expect to sell your computer systems in these nations, be sure to specify a switcher that meets their standards.

Until recently, most switchers met CISPR requirements, which were the easiest to pass. Today, more supplies are able to meet the West German VDE standards, the toughest in the world. As a result, some supply makers offer different versions of a given supply, differing only in the shielding and EMI suppression. Why install a VDE supply on a system selling in quantity in a country that mandates a more lenient standard?

The West German agency, Verband Deutcher Electrotecniker, created VDE-0871 specs to govern units operating above 10KHz to 30MHz. VDE-0875 omits the 10-150KHz portion of this band, the low frequency area in which most switcher's fundamental and low-order harmonics occur. The 0875 spec is easier to meet because filter components can be smaller to filter only the higher frequencies. More switchers now can pass VDE-0875, and only recently did the first switcher meet 0871 requirements.

FCC Rules and Regulations (Part 15) require limits that are 20 dB more stringent than CISPR limits, and at points, exceed VDE limits. Aside from CISPR limits, USSR limits are the most lax for radiated emission (0.1 MHz-1 GHz) and for conducted emission (0.1MHz-1.3MHz).

Switchers generate EMI by switching and line transients. Since periodic functions are composed of an essentially infinite series of sinusoids of harmonically-related frequencies, a PWM square wave is rich in harmonics that extend into the MHz region.

Peak current surges on start-up or fault recovery cause low-frequency conducted emissions. Soft-start circuitry is needed. With control ICs incorporating more functions, more sophisticated decision-making (hard vs. soft start) is minimizing current inrush. Switchers (unlike linears) reject line transients and conducted interference, isolating input and output when the switching transistor turns off.

EMI can be reduced by several means. These include filtering, shielding and pulse-rounding. The 60-dB/decade roll-off can be reduced to 60-80 dB with pulse rounding (eliminating higher spectrum components). If not included in the supply, an RC network installed across the switching transistor (E-C) will round off pulses.

Innumerable filtering schemes for input and output can be used to minimize input line spikes or load transient effects. In one scheme, following the rectifier, a series inductor(s) is followed by a shunt capacitor on the regulator input to attenuate ripple. In another, center-tapped-to-ground (series) capacitors shunt the rectifier output, followed by two series inductors (on each line) and a shunt capacitor before the regulator input. Filter problems exist. If highly-inductive, filters ring (resonate) from a pulse train; if capacitive, leakage to ground (1-2 mA) may violate standards in many countries. Capacitors are space-consumptive. Low-cost RC networks are used to supplement voltage limiters, MOVs, varistors and breakover diodes.

Input transients are usually generated by interrupted inductive elements (relay coils, motors, compressors, fans) and sudden impedance changes that cause reflections on the AC power line. Back EMFs (kickback) from even small, 24-V relays can generate 100s of volts (and 1000s of volts on 115VAC lines) if interrupted near the sinusoid's peak. Although engineers are careful to use snubbers, MOVs and suppression networks to protect active elements in their circuits, the worst "power line polluters" – the motor, compressor and heavy equipment manufacturers – somehow avoid using transient suppression.

Lightning, a summer phenomenon occuring more in certain locations, is a source of line spikes and can induce 20V per foot of line even if the strike (up to 100MV) is a mile distant, thus building up 30KV pulses. Transients of 2KV-3KV are common; if from lightning, they may reach 6KV at the input to your supply.

In selecting a supply, be aware that straight current- and foldback current-limiting overload protectors don't always work. In a straight current-limiter, output current is held to 130%-150% of nominal output current, and power dissipation shoots up. Foldback limiters consume less power at overloads and limit at 50% of maximum output current. They can latch-up if the supply load is a high-resistance, constant-current-source. Under power-up under full load or overload, the supply could become bistable and latch in either of two states – a situation inherently impossible in straight current-limiters.

MOVs limit or clamp (not crowbar) at 5V to several 100s of volts. They are superfast, transient-energy absorbers. Silicon avalanche suppressors ("TranZorbs") are very large-junction zeners that handle several volts to 200V or more at 1.5-KW peak power at a l-ps response time. But beware: don't use ordinary, high-wattage zeners for this; they can't dissipate the high-power spikes fast enough. The chip, not sink, must dissipate this sudden heat.

In most supply applications, the transient suppressor parallels the load or protected components. In this shunt configuration, suppressor and lead inductance produce an overshoot. So, when using such transient protectors, keep device leads short and place them as close to the protected load or component as possible to minimize overshoot. And, even though transient suppressors are designed especially to dissipate the energy from transients, overstressing is possible. Provide some (as much as possible) impedance between it and the transient source.

In case long transients are expected, varistors (shorter knee) can handle more than zeners. In high-power applications, hybrid protectors combine a (1) gas tube that crowbars the main power (110V to several KV at up to 20KA) with a (2) faster, lower-voltage clamping device.

Shielding switchers

Without shielding, even the best switcher may fail EMI testing. Proper shielding techniques vary with the switcher, depending upon individual electrical and mechanical details, and require careful placement of line filters, transformer shields and heat sinks.

Ironically, the main source of conducted EMI – the switching transistors, rectifiers and transformers – are the very ones that need a heat sink on the chassis, thus allowing RF ground currents to flow in the chassis and into the inputs and outputs. Capacitance (100 pF) between a switching transistor and mica-insulated heat sink can induce a 1 mA, 1MHz ground-loop current in the chassis.

To solve this, some supply makers connect the heat sink to the emitter, that is, sandwich a small screen between the heat sink and transistor. Beryllium oxide insulators, being thicker, also provide less capacitive coupling. Good supply designers keep high-current di/dt and dv/dt lines short and input and output lines far from EM and ES sources, or use shields. When examining a supply, beware of slots (joints, etc.) perpendicular to induced shield current; an EM field will appear across the gap and radiate.

What's coming for switchers?

What does the future hold for switchers? They are the future. Present boinkles will be ironed out as switchers reach higher and lower output power levels. Switcher frequency is in the 20-KHz to 40-KHz region, although with autoregulated driver circuits and improved electronics, they should reach up to 200KHz. But magnetic components are the big fly-in-th-ointment. As switcher frequency increases, cores become smaller and winding turns decrease; and since core power-loss and temperature both rise, cores using high flux densities prove less practical at higher frequencies. Expect to see the debut of new magnetic materials with very low power losses at 100KHz, 2 Kgauss and at 60-100°C that are under 200 mW/cm^3. Since transformer loss has a core and copper (50%) component, reducing windings reduces copper loss, but unfortunately increases operating flux density. To provide proper inductance and avoid saturation problems, these new ferrite materials will provide higher amplitude permeability and saturation flux density. Cores will provide low permeability (μ_R under 70), resist flux saturation and offer lower hysteresis loss.

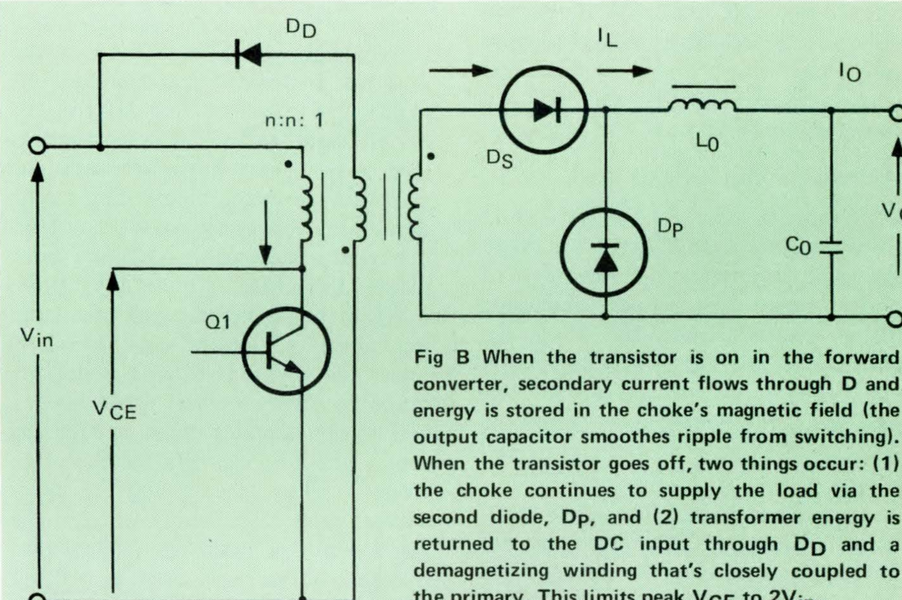


Fig B When the transistor is on in the forward converter, secondary current flows through D and energy is stored in the choke's magnetic field (the output capacitor smoothes ripple from switching). When the transistor goes off, two things occur: (1) the choke continues to supply the load via the second diode, D_P, and (2) transformer energy is returned to the DC input through D_D and a demagnetizing winding that's closely coupled to the primary. This limits peak V_{CE} to $2V_{in}$.

Other obstacles to higher-frequency regulators will be overcome. Even though these higher frequencies will make it easier to filter the rectified output and prevent switcher noise getting back into the line, a drop in filtering efficiency occurs at 100KHz due to parasitic resistance and inductance of secondary filter capacitors. Although experts consider the capacitor a mature component which will be subject only to evolutionary improvements, recent developments include significantly-improved ESRs and ESLs or "inverter-rated" electrolytic filter capacitors.

Will the government mandate or provide tax incentives for use of switchers? It's possible. If switchers replaced other supplies (40% of the total), calculations show this could save 68 million barrels of oil/year five years from now (based on a 40% linear and 75% SMPS efficiencies, and including cooling costs).

Until now, energy savings of switchers wasn't much of a sales point. No one cared. Why buy a more expensive supply if your overall system will lose out to your competitors' on initial cost? So, an 82% efficient, 250-W switcher – even though it could save $160/year (vs. a 30% efficient linear) – just didn't sell to end users. But now, with oil costs skyrocketing, with nuclear plant construction hampered by student protesters, and with brownouts and blackouts coming, suddenly end users are becoming worried and taking overall operating and field service costs into account.

Hybrids – the best of both

Combining switchers and linears (usually lower-current auxiliary outputs) in the same supply can offer the best of both, with the switcher handling higher power output. By letting the switcher handle most of the regulation and following it with series-type post-regulators, the voltage drop across the series regulators is smaller and overall supply efficiency can reach 60-75%.

If using a 60-Hz, step-down transformer, then: (1) switching noise will not conduct back to the line, (2) this low-voltage switching will cost much less, and (3) will provide input/output isolation advantages. Other hybrids employ off-line high-frequency switching at the input (providing greater efficiency and smaller size) and then feed this into a dual series regulator.

Multiple-output supplies may use two different regulators and converter types, and may even combine a switcher with linears. Flybacks and forward converters are available in a single, low-cost supply. In such a hybrid supply, the flyback provides a rock-bottom price for output (assuming low current load, high ripple and less-than-optimum regulation are tolerable) and provides a forward converter for the outputs that require better regulation and lower ripple. If more performance is desirable, a hybrid push-pull/forward converter multiple-outputter provides the main output from its push-pull converter. Phasing each forward converter differently reduces ripple. Other hybrids follow the push-pull regulator with a linear regualtor for each output; and though efficiency drops, it's often no concern, since these are lower-power outputs. Flyback converters can supply internal, secondary switchers.

The hybrid supply has boinkles (noise spikes, for example); and if extra care isn't taken by the supply designer, it will plague the hybrid supply. It's essential to control normal and common mode paths before connecting the linears. Most switcher output noise is common-mode in origin, becoming normal-mode when it reaches unbalanced loads.

"Dirty power" kills

In the years ahead, most computer systems will be confronted with power outages and lower line quality (fluctuations, brownouts, transient spiles) that will increase downtimes for real systems and increase output glitches, late nights and missed schedules for end users. Disturbances of a few nsec duration may affect both software and hardware, reversing binary data at random. This can create strange systems behaviour: reduced throughput, unexplained branching or jumps, mysterious program halts, inability to break out of a loop and loss of data stored on tapes and disks. Hardware is not immune to "dirty power" disturbances; and power supplies, mass storage and semiconductors can be affected or destroyed. Some effects may be more subtle; long term undervoltages (far more common than overvoltages) can overheat devices and shorten MTBFs. Although orderly shutdown protects files and instructs remote terminals to stop sending data, restart time (after a crash) needed to return a computer to where it was when processing was interrupted can be devastating.

Although power utilities consider an outage a "power failure" if it's over five minutes, a 2 ms interruption is enough to lose computer data and damage equipment. Over 50% of all outages last under 6 sec. IBM found the average computer in the U.S. can expect 25 to several hundred yearly processing errors due to power line troubles, depending upon location. Power factor correction and capacitor switching (and network or load switching) causes 62.6 oscillatory, decaying disturbances per month and 14.4 under/overvoltages exceeding 8.3 ms per month. Customer-induced sources (noisy environment) combined with power network switching and lightning-induced voltage spikes generated 50.7 disturbances per month. Total incidents per month was 127.7. With computers moving more into the harsh environments of manufacturing plants, these problems are worsening. Before specifying power protection, measure the end users' environments.

Measurements and fault detection

Bench testing with chattering relay, zap gun and other testing techniques cannot simulate on-site conditions. And, unlike blackouts, on-site power disturbance are not easy to measure without sophisticated equipment. Many system designers simply are unaware of the frequent and dramatic line fluctuations that occur so often. Traditional test procedure – lab simulation or on-site monitoring with scope or strip-chart recorder – is not sufficient to detect and record all worst-case disturbances.

Several new μC-based instruments are now available to monitor on-site power lines, detect and record system errors, power line disturbances and power supply changes, and provide correlations. These intelligent "line disturbance analyzers" record the magnitude, duration and occurence of both sags and surges and slow voltage fluctuations, transients, frequency variations and other variables. Future line measurement instruments will be more intelligent and provide greater computational capability for isolating faults and disturbances.

In multi-supply or multi-voltage systems, fault detectors convert supply voltages to digital data, monitor the levels, record the nature of a fault, the supply causing it and initiate a power-down sequence signal to the system controller for a orderly shut-down. Under/overvoltage detectors detect excursions by comparing the line level with a reference. A sequential arming circuit inhibits fault indicators during normal power-up/down. In a first-fault detector, a fault is recorded, a lockout command is generated and prevents additional faults from being recorded.

The future will see far more intelligent and lower-cost fault detectors than this. They will: (1) monitor supply and line voltages, EMI, temperatures at various locations and computer performance, (2) detect faults and disturbances, (3) store the data, and (4) even analyze and correlate the data with sophisticated algorithms, giving immediate analysis of the data.

Who needs system insurance?

With these alarming statistics in mind, should you rush to specify a costly, multiple-output Uninterruptible Power Supply (UPS) that provides backup power for memory, for alarms and for orderly system shutdown? Perhaps not. As we said, 50% of all outages are under 6 sec. Only 15% last over 11 minutes. Batteries may not be feasible to provide power protection for much beyond this, and a battery-generator combination is probably less costly.

Like insurance, OEMs cannot afford to offer end users power protection against every conceivable risk – just the most common risks – and in fact, cannot afford to go without some basic power protection. But is a costly UPS necessary? Although UPS does provide full protection from blackouts and transients, other power protection devices (line conditioners, voltage regulators, ultra-isolation transformers, dedicated lines, CMOS instead of MOS, batteries, etc.) may suffice for many applications.

To determine what your system may require, begin by defining your end users' worst-case environments, probability of trouble, its nature and the risks involved (inconvenience or critical). If it is a professional desktop (personal) computer, why bother? But the following conditions mandate a high degree of protection: (1) the sytem controls costly chemical processes, industrial furnaces, semiconductor fabrication facilities or where material losses could occur, (2) equipment damage or personal injury, (3) costly data is involved, and (4) critical services (medical, banking, alarms) that cannot afford downtime. Consider an UPS for: (1) bridging the transistion (5-10 min) between line failure and engine-generator startup, (2) buying time for orderly shutdown (15-30 min) of the computer to secure data and avoid hardware and software damage or (3) for short-term (to 90 min) power for evacuation lighting per OSHA guidelines until line power is restored. High-pressure sodium lamps cannot tolerate interruptions.

UPS beat blackouts

Solid state UPS systems use batteries to buffer the computer from power line disturbances, and during a blackout, an engine-generator provides power. In a typical on-line, automatic reverse-transfer UPS, an inverter shapes and filters the battery DC to produce AC; in a standby UPS, it operates only during blackouts or during line glitches. Standby UPS, though considered less costly, won't offer much protection from "dirty power" such as current surges and line drops. During its cut-in transition, momentary interruptions can occur.

A typical reverse-transfer UPS protects the computer when AC power is on from surges and sags, transients, faults and brownouts; when down, it switches in a battery bank and continues with previous protection. Line power is converted to DC by a rectifier/charger, which charges a battery bank and powers the inverter. The inverter converts DC to an AC sinusoid, shapes and regulates it and cleans up any spikes and noise. This AC is then sent through a transfer switch to the computer system.

Now, if line level drops too far, perhaps 20%, the battery bank takes over from the AC-to-DC rectifier/charger and supplies DC to the inverter. With this on-line UPS, DC is always inputted to the inverter, and transition interruptions of off-line UPS don't occur.

Be sure the rectifer stage has an "AC walk-in" feature; otherwise the load suddenly will be applied to the AC line on startup, with a fuse-blowing inrush current. The AC bypass transfers the load to raw line power to meet high-inrush demands (eg., motor startup). Most UPS offer this AC walk-in feature. Harmonic feedback into the primary interferes with other sensitive equipment or the AC line. To minimize this, some UPS use high pulse-number rectifier or tuned LC-tank circuits.

Battery banks must be serviced; some rectifier outputs are so well-filtered that the banks can be disconnected and the rectifiers directly fed to the inverter. Examine recovery or

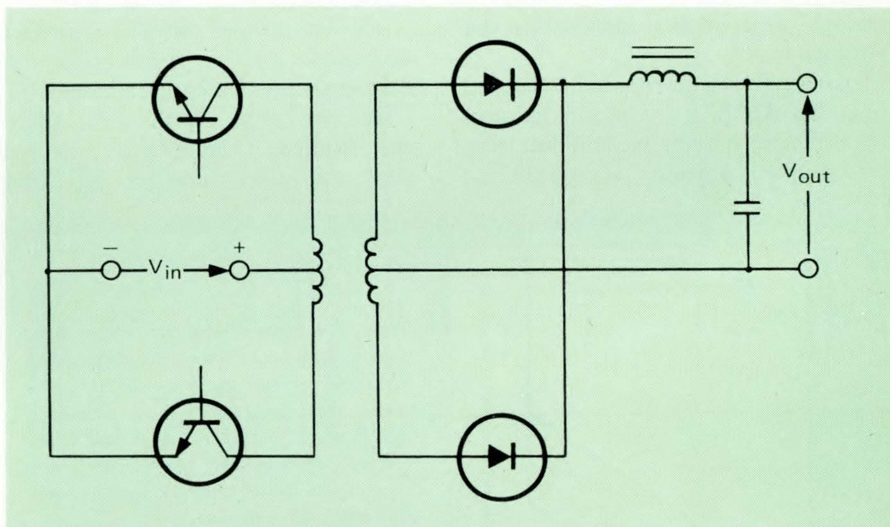


Fig C The push-pull converter transistors are turned on during alternate half cycles, with the push-pull action doubling the ripple current frequency in the output. The diodes rectify the secondary rectangular waveform. Peak V_{CE} is $2V_{in}$.

What happens if the inverter fails or if a sudden load demand occurs? The automatic transfer switch bypasses the UPS to the power line (unless line conditions are unacceptable). When the inverter output is suitable once again, the transfer switch cuts out the bypass and returns the computer load to the UPS.

Things to look for in UPS

Rectifier/charger. When comparing on-line UPS, examine input voltage tolerance: the lower the line drop with battery charging, the better it is. A system that still charges its battery back at a 20% line voltage drop or lower is better than one at 15% (typical on larger, over-15KVA systems). Why is superior brownout-proofing important for your system? Because prolonged brownouts all too often end in a blackout. The superior input-voltage tolerance UPS will go into the blackout with charged batteries.

recharge rates; they are longer than discharge times, since the rectifier must simultaneously supply the load and recharge the bank. Recovery rates are defined on spec sheets as charge (or recovery)/discharge time ratio or minimum recharge time. A recharge ratio of 8-15 is considered fast and acceptable.

The trend for utilities to demand higher rates for peak power usage is an ill wind for many UPS, since some have a habit of voraciously consuming large and sudden amounts of power at the wrong time (during peak demand periods). Your customers may be shocked to find that your systems increase their utility bills without any increase in power consumption. If the UPS you're evaluating is for a large system, it may pay to select one with a battery recharge-limit to limit charging during costly peak power periods.

Wet or dry-cell battery bank. The traditional wet-cells are nickel cadmium (too costly for UPS) or lead-acid batteries, which are lead-antimony in older UPS and lead-calcium in newer ones (due to less water, less maintenance and a lower floating current requirement). Maintenance-free dry-cells use a gelled electrolyte and are used where battery maintenance is difficult or dangerous.

For smaller UPS, battery storage is no problem; with larger units, it becomes a serious consideration. A poor design choice could be costly and dangerous. Two- or three-tier battery racks are common. First, determine the floor plan layout; then, with this information, select the best rack size. Despite the greater weight/ft^2 of the bank, keep the UPS and bank close; and if not in the same room, then close enough to minimize installation and wiring costs.

Battery room air should be changed once per day or so to prevent noxious or explosive battery gas buildup. Battery suppliers provide exact ventillation directions. Be sure that bold warning notices are sprinkled liberally throughout maintenance booklets and posted on walls, and that readily-visible fire extinguishers, a well posted and enforced smoking ban, gloves, goggles and shower or eye wash are available.

How much reserve time will your system require? If a motor-generator is coming on-line, then 5-10 minutes is enough; for an orderly shutdown, 10-30 minutes. In each case, battery size, weight, type and cost will differ. Consider worst-case ambients. High temperatures shorten battery life. But charge loss occurs at normal ambients. At 20°C, sealed lead-acid batteries lose half their charge in one year; rechargeable nickel-cadmiums, in 55 days. Derate battery, amp-hour output for colder temperatures. At −30°C, sealed lead-acids and nickel-cadmiums deliver half their normal output.

In some smaller, μP-based systems, memory boards have on-board batteries, but may lack a practical state-of-charge indicator, since voltage measurements alone aren't all that meaningful for lead-acids (and less so for nickel-cadmiums).

Inverter. This is the heart of any UPS and is the most complex stage. Transforming the rectifier's (or bank's) DC into regulated AC, the inverter controls output magnitude via any of several control methods (PWM and ferroresonant transformers). If PWM-controlled, the nonsinusoidal output must be filtered to reduce harmonics (to under 5% or so). PWM may be true harmonic-reduction, multiple-, single- or sinusoidal-pulse modulation.

PWM-controlled inverter operation boils down to this: firing SCRs, then forcing them off, creating an oscillatory waveform which is then modulated and filtered. Commutating methods vary and affect inverter efficiency.

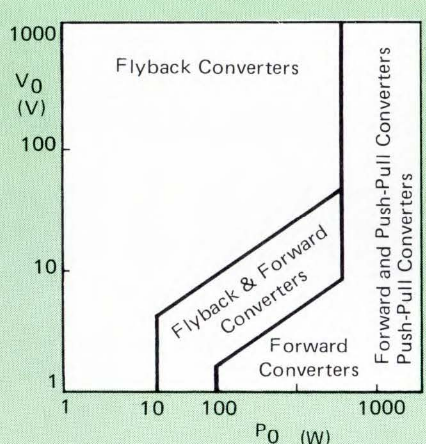


Fig D To choose a suitable converter type, simply plot the coordinate point(s) of output voltage and power. For a flyback, percentage ripple rises to unacceptable levels with greater power and lower voltages. Above 1kW, the flyback's simplicity is no longer a factor, and the push-pull is directly superior.

Ferroresonant constant-voltage transformers are simple and reliable, but are for low (under 30KVA) outputs. Very good voltage regulation, no feedback circuits or need for extra filters, and outputting sinusoidal waveforms with 5% or less worst-case harmonic distortion – for these and other reasons that we discuss elsewhere, forroresonants are well-suited for inverters that supply sensitive computer systems.

Inverter specs and advantages may include: ±1% voltage regulation, +10% to −8% dynamic regulation, adjustable AC output, precise frequency-tracking of the bypass line, automatic line-drop compensation and high efficiencies (to 90% for 150KVA units).

Automatic transfer switch. Whether the load is drawn from the AC bypass line or inverter is decided by a solid-state transfer switch, which makes a fast, no-break transition (mechanical switches take a 50-100 ms break – and may lose data). To ensure a perfect transition from inverter to bypass line, the transfer switch's synchronous circuit synchronizes the two AC sinusoidal waves.

What about modular supplies?

Known as "power modules," "modular supplies" and "encapsulated supplies," these small and low-power supplies first burst on the design scene over a decade ago – and just as quickly earned a "bad guy" reputation among designers. With strong kamikaze tendencies, these vintage modulars all too often did one of three things: operated in an overheated mode, spectacularly caught fire or peacefully slipped into an overvoltage mode, blowing every IC on the board, much to the consternation of its designers, the OEMs and end users. Times have changed and today's modulars are quite reliable.

Modulars mounted on a board are near the load, suffer less from long-run line-drop problems and are well-suited to future add-on power needs. Advantages are many and include: off-the-shelf availability, good efficiencies, easy handling for production, resistance to chemical baths (such as solvents used to remove flux), good vibration and shock resistance, imperviousness to humidity and most particulate atmospheres, up to quad-outputs, and flexibility for design and production. With a need for an outboard supply, associated wiring, connectors and hardware, the layout and construction are easier, with systems being smaller and providing longer MTBFs.

Modulars range in size. Some are a mere 1.2″ x 0.5″ x 0.4″ linear units ($6.70) outputting 12V at 25mA at 60% efficiency from a 3V to 7V input; others are 4.5″ x 6.5″ x 3.9″ modular switchers that supply up to 20A at 5V DC. But most modulars come in 2.5″ x 3.5″ black plastic (sometimes metal) cases with a 1″ or 2″ height, occupying 8.75 in^2 of PC board (PCB) real estate. Components are mounted on a small PCB, then encapsulated with hard epoxy, or sometimes a softer, spongier encapsulent surrounded by hard epoxy to absorb stresses from temperature variations, vibration and shock.

Boxlike modulars have their pins on the bottom (board-mountable) or with a terminal barrier strip (chassis-mountable). Most look alike. Internal differences are great, and differences such as plastic-foam thermal insulator barriers between the output capacitor and pass transistor and transformer can permit full-output at 70°C. Switchers, linears and DC/DC converters – all available as modulars – come in 1-W to 50-W power levels with single-, double-, triple- and quad-outputs. If you want to look inside an encapsulated modular, don't expect all modular makers to provide too much detailed information. In such cases, dissolve the encapsulant in a solvent (kits are available if you've never done this before). It's a slow process, and though the components left resemble burnt toast, they're still identifiable. The author has used this to determine component and internal heat sink size and locations of competitor's products. It can also provide facts necessary for proper orientation of a modular on a board for maximum cooling.

Or, better yet, to get heat measurements, make up several thermocouples by twisting thermocouple wires at the ends, weld them and then epoxy the small, bead-like tips onto the modular locations to be measured. (Use heat resistant epoxy). Take measurements at various locations in different orientations under different conditions. To make temperature measurements within larger units, drill holes at locations, insert tip and fix in place.

The debate of DC/DC versus AC/DC shows advantages for both. DC/DC onboard converters keep AC line voltage off PCBs, leading to safety, less hum pickup and small PCB real estate usage. (AC/DC modules must meet CSA, UL and VDE spacing requirements.) On the other hand, board-mounted DC/DC modules inject spikes back on the power bus, causing glitches in memory and logic, despite decoupling.

Do "μP supplies" really exist?

Cynics claim that μP power supplies were invented by slick public relations and glib marketing personnel to sell unsophisticated software-turned-hardware designers, and that other non-μP supplies can do the job just as well or better (true) and that so-called μP power supplies can be used for non-μP power applications (true). Although they aren't a separate family, μP power supplies play an important role.

What traits do μP supplies have? They offer: multiple outputs, smooth and well-damped power-on/off responses, low output noise, no output spikes, overvoltage protection, constant voltage outputs under digital logic's fast switching, and low impedance to the load. Pitfalls exist. Don't overspecify. Keep in mind that today's logic can withstand more output noise and wide switching margins.

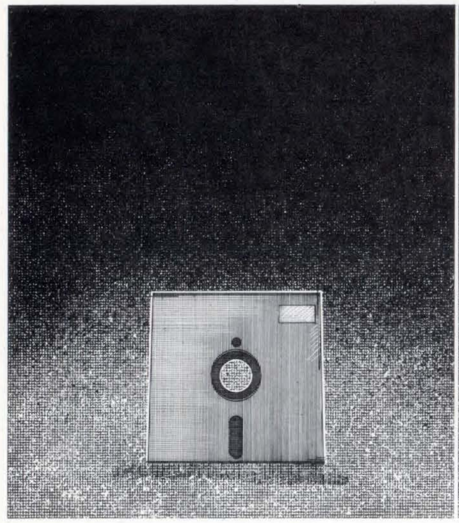
Should you select a supply designed for an 8080, 6800, Z80 or a universal μP supply? As a general rule (in anything), if the product literature claims that the product does everything ("one size fits all"), you better believe it probably does – but not well, or if it does it well, the supply is going to cost extra for such flexibility that you probably don't need. In the past, overspecifying a supply was not serious; the added cost (a form of insurance) was absorbed by total system cost. Not so today. With semiconductor costs falling, power supplies take a greater percentage of system size, weight and costs. If operating at lower output levels, efficiency (particularly for switchers) drops.

Product liability

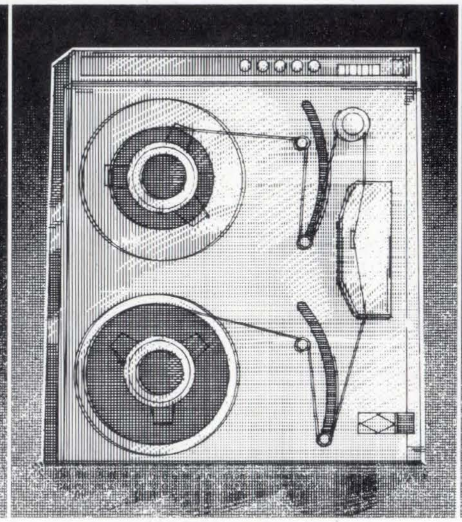
The need for greater product safety has created new and confusing legal pressures on power supply and OEM system designers. Product liability trends are affecting the decision to buy or make supplies. Engineering and management are liable in four areas: (1) design, (2) manufacturing and materials, (3) packaging, installation and application, and (4) warnings and labels. Be aware, that as a system designer, liabilities stemming from your designs will arise from a concealed danger, from safety devices you omitted, from inadequate material or hardware (that didn't comply with accepted standards) or from a potentially hazardous or dangerous condition that may occur due to *a customer abuse of your system or supply that you did not take reasonable measures to prevent or warn against.*

Suppose you see such a possible dangerous misuse and there is no realistic design safeguard. Cover yourself by informing other department heads – manufacturing, marketing, etc. – and document this with memos. Or, get someone else to take the credit. Suitable warnings and labels must vividly make this potentially dangerous situation known. On the other hand, the legal test arising in litigation will involve what a *knowledgeable, reasonable designer* would have done; the system and/or power supply need not be encumbered with excessive safety features that make it noncompetitive. Reasonableness will come down to benefit-cost ratios and risk-utility. The court will determine whether you considered availability of safer replace-

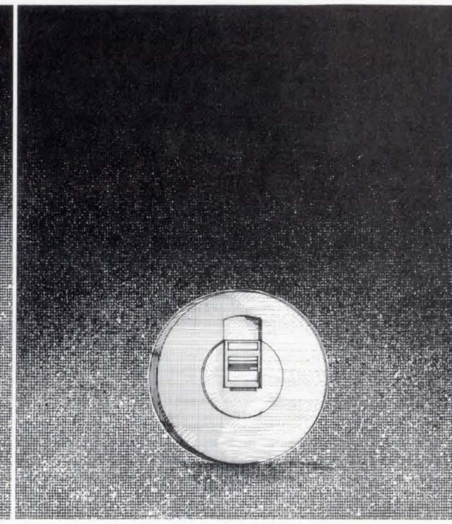
THERE ARE A LOT OF ALTERNATIVES TO THE DISK BACK-UP PROBLEM.



FLOPPY DISKS
Storage capacity: limited.
Handling problems.
Low cost.



REEL-TO-REEL TAPE DRIVES
Low performance: 36 megabyte capacity.
High performance: 90-100 megabyte capacity.
Large, bulky, high cost drives.
Cost: very expensive, up to 20 times that of floppy disks.



DISK CARTRIDGES
Storage capacity: 5-10 megabytes.
Back-up data remains on a disk.
Large drive mechanisms.
Cost: up to $5000.00.

HERE'S THE SOLUTION.

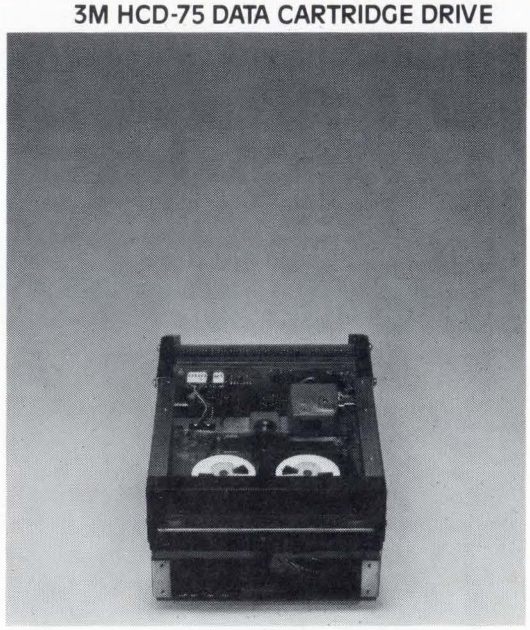
3M HCD-75 DATA CARTRIDGE DRIVE

Storage capacity: 75 megabytes formatted (144 Mbytes unformatted).

Drive dimensions: 4.62" x 7" x 8.625".

Preformatted tape, allows unlimited record replacement.

Built-in error detection/ correction capabilities.



Fully-buffered I/O channel, permits asynchronous data transfers.

Serpentine recording, eliminates wasted rewind times.

List price, including Controller, $2,150.00.

To learn more, check the listing at the right and contact the Data Products Representative nearest you. Or write: Data Products/ 3M, Building 223-5E/3M Center, Dept. 125, St. Paul, MN 55101.

THE DISK BACK-UP SYSTEM THAT'S SUDDENLY WAY OUT FRONT.

3M

ments, probability and seriousness of injuries, obviousness of danger, customer expectations, ease of risk minimization without impairing the product, state-of-the-art, ease of retrofits or redesigns, and did your firm use its leverage ("sellers' market") to scrimp on precautions. Finally, as we said above, did your firm provide obvious warnings of latent design defects? If the warning must be sharply-worded, and you failed to do so, this will constitute, ipso facto, an obvious sign that you should have redesigned your system or supply – or switched vendors. Your firm is liable and you're in trouble.

It's likely that the courts will soon look at the instruction and operating manuals. If they were poorly written in too-technical jargon or so bad that users could not readily understand them, and serious injury or damage resulted, is it your fault? The U.S. Navy, for example, recently had a bad and costly experience due to poorly-written manuals.

There is quite a bit more to product liability, and engineers who fail to gain a good grasp of the subject may rudely awaken to find themselves scapegoats on the wrong end of a round of finger-pointing. If you feel quantitized criteria to evaluate what constitutes an "unreasonably dangerous" power supply or system doesn't exist, you're right. It is this vagueness that is so frustrating to engineers (and difficult for courts).

There is a trend afoot to force engineers into taking some credit when their firm is sued. As software- and hardware-based products rapidly penetrate new and lucrative markets (with users growing increasingly unsophisticated), expect to see a flurry of product liability lawsuits coming your way at an ever-accelerating rate. This will still occur if you purchase a power supply. If you make your own, however, product liability is just one of several dangers.

Why not make a switcher?

Is it better to buy or make a switcher? No matter how great a designer you are, think twice first. Unless you work for an OEM giant (where power supplies make up a substantial amount of the hardware in your peripherals, terminals and computers), then it may cost more in time and aggravation than you anticipate. Small-to-medium OEMs all too often underestimate the magnitude of the problem, and to make matters worse, too often assign the task of designing a switcher to less-experienced designers and production engineers. The switcher is not a simple black box, unlike linears, and the design alone may take five to 20 times longer than designing a linear supply.

As for experienced SMPS designers, they're scarce; and if you're not experienced, then you must not only learn to cope with designs for protective circuits, reliability, logic and control sequencing, dynamic switching ranges, system integration, component derating, RFI shielding, meeting regulatory (UL, VDE, FCC) approvals, product liability, mechanical package and interconnection design, etc., but you must also gain hands-on experience in high-voltage switching transistors, Schottky diodes and control ICs.

Control ICs have gone through several generations in four years, and a glance at several spec sheets won't be enough. Don't expect too much help from the semi makers that make them; they're just learning. Those small OEMers that went the "roll your own" route have criticized the IC makers for not providing enough applications assistance. Some experienced switching supply designers claim that the applications data isn't the best and that the semi makers were learning from them how to use it. Semi makers, on the other hand, admit this was once true but that things are now improved. But if you decide to buy a switcher, the road also is strewn with potholes.

Buying a switcher? Beware.

Are you confused by claims made by power supply makers? Are you confused by the sometimes downright suspiciously-high values (particularly MTBFs)? Do all warranties look alike? And, if you decide an off-the-shelf supply doesn't fit your applications, and if you decide to go outside for a custom supply, and you overspecify, will the vendor take advantage?

There's no way to avoid all risks, but keeping the following points in mind will avoid many pitfalls. First, don't pick a supply from data sheets, even if you are an expert. Worse, if you're a μC software designer, or otherwise unqualified to compare power supplies (particularly switchers), then delegate the task to someone who is more knowledgeable. Always visually evaluate a supply. Remove the cover plates and inspect it for inspection ink dots, soldering and wiring quality, types of connectors, PC board quality, etc.

Calculated MTBFs, as everyone

knows by now, are useless; and calculations based on a manufacturer's own derating standards may be inadequate. Ask about them. However, it's better if calculated against a recognized standard. You will want to determine the maker's QC procedures, visual inspection of screw connections, solder joints, etc., full power burn-in and warrenty limitations. Check the vendor's reputation and get a list of (un) satisfied customers.

Some supply makers provide off-the-shelf one- to three-day delivery ARO. There is no practical way to stock the thousands of models that some offer; if not in stock, they build on a per-order basis. If so, don't expect credit for returns, cancellations or for units ordered in error. In the case of off-the-shelf suppliers, a 10% restocking fee may be charged prior to return for credit.

When ordering, compare terms. Here are some things to consider. After prices and quantity discounts are compared, consider export handling charges and financing. How much do they charge for in-plant (source) inspection? What is the charge for anti-moisture, fungus-resistant varnish coating? How serviceable is the supply? What about replacement parts? Are they mostly standard? Are parts shipped within 24 hours ARO?

Warranty times terms vary. Those supplies with bargain basement prices raise questions of reliability; those from big-name makers provide warranties that require scrutiny. Warranty periods extend from one to five years, although encapsulated supplies (non serviceable) are for less (usually one year). Some manufacturers include a retest and inspection charge.

What about reps in the area? Can you reproduce information from their technical data sheets in your manuals and literature? What about the quality of applications assistance? And on what level?

Beware of specmanship. We discussed this earlier. Qualifiers like "up to" or "greater than" are more likely the case than better values or indicate the values vary or are difficult to measure.

If you decide to have a custom switcher made, don't specify more than what you need. Never call out a range too broad. For example, why meet transient response under all input conditions when your application doesn't need it? It only increases cost and lowers reliability. In your comparisons, don't place price so far ahead of overall cost that you force vendors to cut corners.

In considering supplies, and if you're not sure of your supply savvy, it's all the more important to consider company reputation. But, remember, there's more than reputation; many first-rate firms specialize on certain supply categories (modules, for example) or tailor their supplies to certain users (military, aerospace, mainframe, medical), while others offer certain categories only as a convenience to their customers. With larger firms, you pay extra for reputation; smaller firms, if you shop carefully, offer many excellent bargains in terms of lower cost and high quality.

Remote sensing, ground loops and . . .

Suppose you've selected and specified a supply that's suitable for your application. You're not home yet. Ignore interconnections and you will undo all your work. The following safeguards will help avoid hard-to-trace ground loops, improper DC distribution, incorrect remote-sensing, and improper loading of multiple loads.

Unequal load voltages and load interraction create cross talk, noise, interload oscillation and pulse coupling, since many load currents are time-varying. Because of line drops, loads further down in a parallel-loading scheme see a varying voltage in spite of decoupling measures taken. Connect each load separately to the DC distribution point.

No two ground points in a computer system have exactly the same potential; these small differences degrade system performance by causing ground loop problems, voltage spikes, unequal voltages at different loads and noise. Be sure there is only one ground return point in your system. With a rack-mounted system with separate supplies and loads, multiple ground connections are sometimes used. Although each supply chassis is tied to the AC line power cord safety ground, the supply rack is earth ground, creating circulating ground currents that may be insignificant only if confined to the ground system and not into the DC power output. Because there is only one DC common point, connect it to ground by only one wire. With remote sensing, separately wire the supply sensing terminals (+S and –S) to the heaviest load. Remote sensing maintains precise voltage despite varying heavy-current loads, and improves remote terminal output impedance and transient response.

Sensing lines pick up noise. Shield them. But avoid using the sensing-lead shield as one lead; connect it to DC power common (–V). To avoid the danger of a sense line accidentally opening (with the supply output shooting up to its maximum), a supply should include internal resistors (or diodes) between the outputs and sense lines. Ask the vendor for this sensing-line open-circuit protection; if unavailable, install it externally.

If a remote sensing supply oscillates, it's serious: contact the maker. He will remove the time delay by readjusting the internal loop stability control – or redesign the supply.

Check line continuity. Reversing the AC hot, neutral and safety ground still does happen. Three accidents can occur. (1) By reversing the AC hot line and safety ground, the supply chassis becomes hot; if floating, fuses blow the instant a tech grounds the chassis or connects a scope. (2) On the other hand, reversing the AC neutral (cold side) and hot line removes the fuses' role; if they blow due to overload, the supply chassis is still hot. (3) Reversing the safety ground and neutral lines makes the chassis neutral (not ground), generating circulating ground currents that worsen ripple.

Where do power supplies go now?

Rapid change will alter power supplies, particularly switchers. The trend to SMPS will increase, accelerated by energy costs that will create a growing awareness among OEM customers (typically end users) for energy-efficient systems. End users now will look at total field service and energy cost over the useful life of a system more than in the past. Furthermore, with Russian and Cuban troops invading the Middle East and Africa, certain strategic materials will rise in cost, none of which will help linears.

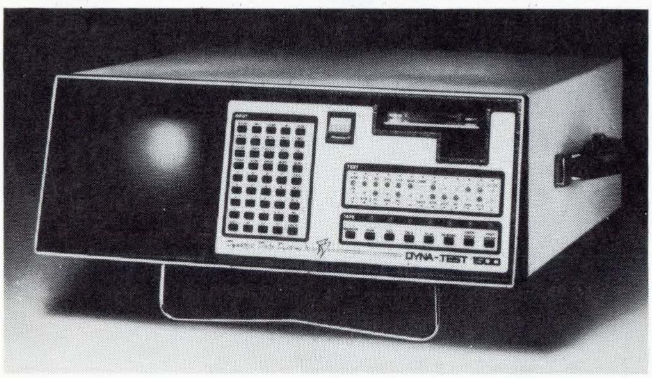
But, perhaps the greatest change will be brought about by new regulator control and support ICs with new functions. With ever-growing sophistication, the SMPS of the future may be available in dumb, smart and intelligent versions. In any case, one thing is certain: New developments in power supplies will offer system designers more options than ever imagined before.

Rate this article: circle 3L, 3M or 3H on Reader Inquiry Card.

New Products

THREE OPEN-FRAME 75W SWITCHING POWER SUPPLIES come in single ($152), triple ($184) or quad ($198) output versions and free users of computer peripherals, business machines and industrial control systems who have been limited to linear power supplies. All have outputs regulated to 0.1% for 92-138V, 47-440Hz AC line input, and 0.5% for 0 to 100% load changes. Efficiencies exceed 70% of full load. Ripple and noise are less than 50mV peak-to-peak from 50 to 10Hz. **Gould/Electronic Power Supply Div.**, P. O. Box 6050, El Monte, CA 91731. **Circle 247**

BIT-ORIENTED DATA LINE MONITOR performs all levels of data communications monitoring diagnostics. By replying to multiple choice questions on the CRT, users can define network protocol and perform data line monitoring functions. The Dyna-Test 1500 operates with async, sync, BLDC, HDLC, SDLC (NRZI), DDCMP, X.25 and IPARS



data formats with up to 5 languages, ASCII and EBCDIC standard; and V.35, Bell 303, IBM 3600 and RS449 optional. The unit operates at up to 100 Kbps. Prices: $4700 without tape; $7000 with tape. **Dynatech Data Systems,** 7644 Dynatech Ct., Springfield, VA 22153. **Circle 254**

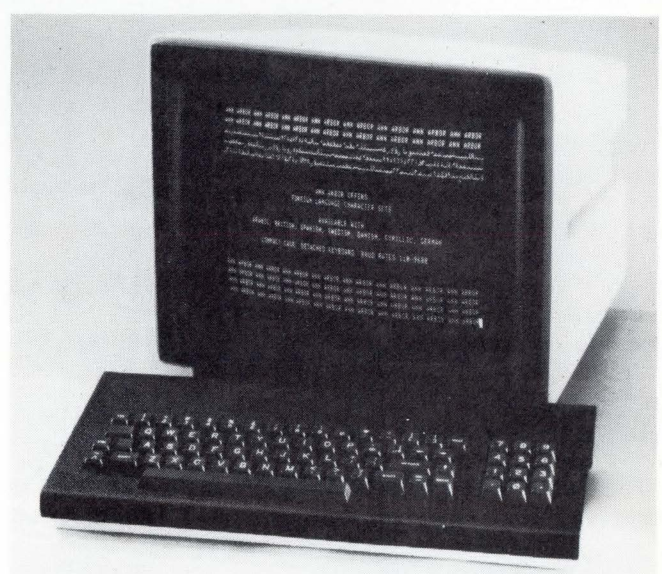
MICROPROCESSOR EMULATOR TERMINAL lets a host computer serve as an MDS to solve hardware and software needs with the 6800, 6802, 8048, 8080, 8085A and Z80A (Other microprocessors and microcomputers to be supported in the future. 8049, 8041, 8035, 8039, 8748 and 8021). The Emulator also serves as a terminal with dedicated MDS from Intel, Motorola and Zilog. Designers need not be "locked in" to a single MPU; even with a dedicated system, they can support six different MPUs. The unit operates at up to 6MHz. Price: $4500. Emulator cards: $1000 to $1500. **Millennium Systems Inc.,** 19020 Pruneridge Ave., Cupertino, CA 95014. **Circle 256**

LOGIC ANALYZER, the LA5000, is a cost-effective alternative to Biomation's 100-MHz, 16-channel K-100D. An MPU-based instrument with keyboard control, self-test, CRT display, active probes, recording capabilities and data analysis modes, the LA5000 costs $6700, 30 percent less than the K-100D. Operating at a maximum data rate of 50 MHz, the analyzer uses four channels of input and storage capability of 1024 words of memory, and can be expanded to eight channels at 25 MHz and 512 words of memory, or to 16 channels at 12.5 MHz and 256 words of memory. **Gould, Inc., Biomation Div.,** 4600 Old Ironsides Dr., Santa Clara, CA 95050. **Circle 239**

SYSTEM DEVELOPMENT PRODUCTS from Motorola include versions of the MC6809 EXORciser II and EXORterm 220 and six update packages to adapt EXORciser I, IA or II systems to MC6809 system design. New EXORciser II and EXORterm 220 systems contain an MPU module with an M6809 component complement.

Present EXORciser/term owners can upgrade their systems to permit M6809 design with an update package consisting of an MPU module; DEbug module; floppy disk controller PROM firmware; and MDOS diskette containing Macro Assembler and CRT editor. Price $3200, qty. 1-5. Complete MC6809-based EXORciser/term development 115V systems with 32K memory and Macro Assembler and CRT editor on MDOS diskette, in quantity 1 to 5, costs $7900 with 32K dynamic memory; $8500 for static memory. EXORterm 220 development systems with 32K dynamic memory cost $8765 in quantity 1 to 5; $9365 with static memory. Complete MC6809 development systems and various updates are also available with the user system evaluation (USE) module along with the standard MPU module. These permit development systems to be interconnected with a user's external prototype, providing a more flexible development system. Adding a USE system to any of the systems priced above increases its price $400. **Motorola Microsystems,** P.O. Box 20912, Phoenix, AZ 85036. **Circle 243**

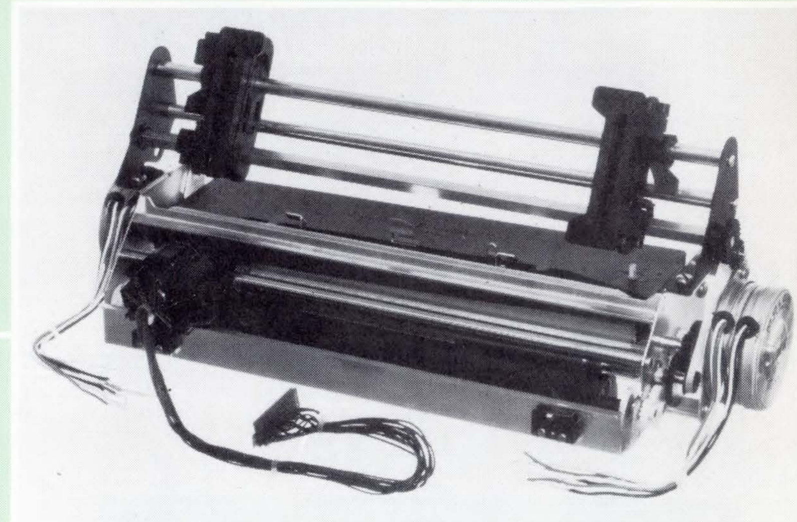
FOREIGN LANGUAGE CRT display terminals and controllers display Arabic (Farsi), Swedish, Danish, Cyrillic, British, German and Spanish in a 24-line by 80-character display format. Characters are formed in a 7x7 dot matrix in a 10x10 dot field. Character accents include blink, dim and reverse-video. The desktop terminals include a 15" non-glare screen and 72-key detachable keyboard. Baud



rates from 110 to 9600 are keyboard selectable, as are I/O, keyboard and display modes. Options include uc/lc, carriage return/linefeed options, export power, 20MA current loop interface, read cursor, double-wide and double-size characters. Prices start at $1270 for the complete terminal and $865 for the controller only. **Ann Arbor Terminals, Inc.,** 6175 Jackson Rd., Ann Arbor, MI 48103. **Circle 250**

Product Highlight

Variable-Speed Printer Mechanism



Two-Day Corporation, of Glendale, CA, is marketing its new 80-column "B" Model 100600 matrix impact printer mechanism. This uses two 12-V DC stepper motors; one to drive the print head across the print line, the other to advance paper. The two motors, running independently, can produce unusual graphics.

Listed Specifications of Series 100600 "Printers"

Printing Method:	Impact 7 Wire Dot Matrix
Throughput Speed:	60 Lines per Minute
Printable Width:	8.0 Inches (203 mm)
Character Size:	0.104 Inch (2.6 mm) High X 0.08 Inch (2.0 mm) Wide Nominal (Width is variable software controlled).
Number of Columns:	80 (at 10 characters per inch)
Print Position:	Subminiature Microswitch – One Each End
Line Spacing:	Model 100600 – A: 1/6 Inch (4.2 mm) Model 100600 – B: Variable – 0.0070 Inch (0.18 mm) Minimum
Paper:	9.5 Inches (241 mm) Maximum Width 0.0013 Inch (0.33 mm) Maximum Thickness
Paper Feed Speed:	Model 100600 – A: One 1/6 Inch Line per Second Model 100600 – B: Variable – Nine 1/6 Inch Lines per Second Maximum
Paper Loading:	Bottom or Rear
Ribbon:	Single Color, 1/2 Inch (13 mm) Wide, Cartridge
Motor(s):	Model 100600 – A: One Synchronous Motor, 105 to 125 VAC, 60 Hz, 8 Watts Model 100600 – B: Two Stepper Motors, 12 VDC, 20 Watts
Print Solenoids:	40 VDC ±10%
Data Entry:	Synchronous
Life Expectancy.	Print Head 100×10^6 Characters Drive Mechanism. 10×10^6 Lines Ribbon: 5×10^6 Characters
Operating Conditions.	40° to 120° F (4° to 49° C) 10% to 90% Relative Humidity Non-Condensing
Size:	Model 100600 – A: 147 Cubic Inches Total Volume Model 100600 – B: 163 Cubic Inches Total Volume
Weight:	Model 100600 – A: 3.5 Pounds (1.6 kg) Model 100600 – B: 4.5 Pounds (2.0 kg)

Paper on the "B" model may be fed vertically in increments of one-half dot, or it may be rolled at the rate of 10 lps. When the unit is equipped with an optional tractor feed, (Model 100900) it is still capable of friction-feeding roll paper by simply flicking a lever.

Varying the linear speed of the printhead produces print-outs at corresponding variable densities. Throughput speed is 80 cps, with bidirectional printing. The 7-wire print head is claimed by Two-Day to have a minimum life of 100 million characters.

Flexibility of design in the "B" mechanism provides the user with a choice of options. He may print at densities of 10 cpi, or 12 or 16.5 to provide 80, 96 or 132 cpl (or almost any other density desired). The paper advances vertically, because of the separate motors, independent of printhead motion. It can move forward as little as desired by the operator or can slew at the indicated maximum rate of 10 lps. The combination of these two features (linear-speed adjustment and independent paper advance) can provide interesting graphics capabilities, says the company. Furthermore, because there is no need for AC power, the printer-mechanism is suitable for installation in delivery trucks and other mobile applications.

The company describes its printer mechanisms as follows:

"The 100600 Series Impact Dot Matrix Printers are of low cost, small size, and of advanced design. The printing elements are clapper type heads of unique concept. The printers utilize a multiple turn cylindrical cam driven by a synchronous motor to move the printing element across the print media at a constant velocity. The design incorporates a cartridge with an extremely long life ribbon which moves continuously while the print head is in motion to assure uniform print density with continuous bi-directional printing. Cartridge replacement is simple and fast with no need for the fingers to touch the ribbon. The Model 100600-A is a synchronous paper feed printer. One synchronous motor drives both the print head and the paper feed mechanism. Paper advance is accomplished automatically at the end of each line by a spring driven paper feed pawl which follows a cam for smooth operation. The Model 100600-B is an independent paper feed printer. Two stepper motors are employed, one to drive the print head, and another to advance the paper. In addition, the Model 100600-B printer is specially built to receive the Model 100900 Tractor Feed Option."

Bob Erickson, VP of Two-Day says: "Due to the rapid expansion of low-cost small business systems and personal compuers, the need for and interest in low-cost printers has skyrocketed. We started production in October, 1979 and two months later had an order backlog in excess of 60,000 units! Our printer mechanisms are manufactured entirely in the USA using only domestic parts and components all of which add to the very high reliability of the units. This newest version of our matrix impact printer-mechanism is already stirring up a lot of interest because of its flexibility, small size and low price."

Price for a single Model B printer mechanism (which requires external electronics) is $235. The Model A mechanism, without the variable features, is $35 less. Two-Day offers generous OEM discounts, delivery on evaluation samples in 10 days and production quantities in 90 days. For further information contact Bob Erickson, **Two-Day Corp.**, 1915 W. Glenoaks, Glendale, CA 91201.

New Products

COMPUTERS. Covering all aspects of hardware, software and printware, this 6 wk. highly-intensive course by Russ Walters begins in July and gives unlimited use of mainframe, mini, micros and many peripherals all hours of day and night, including weekends. Master's degree credit. Tutoring extends day and night, plus weekends. Special text prepared for the Wesleyan program. Post-course follow-up consultation by phone. James Steffenson, Wesleyan Univ,. Middleton, CT 06457. (203) 347-9411. **Circle 154**

COMPUTER GUIDE. In an updated and expanded edition, "The Secret Guide to Computers" by Russ Walters (a lucid and entertaining 6-vol. series) covers Basic (through very advanced), kinds of languages, manipulating lists/data, functions, strings, files, tough algorithms, hardware, assembly languages, Pascal, PL/I, Algol, Cobol, advanced Fortran, APL, STATPACK, SPSS, etc. Russ Walter, **Computer Guide**, 92 St. Botolph St, Boston, MA 02116. **Circle 176**

MAP ARRAY PROCESSOR MEMORY. HMOS memories in 300 ns and 170 ns cycle times ranging from 16KB to 64KB are packaged on std. MAP multiwire boards (15″ x 18″). The 170-ns version uses 2147-3 chips. NMOS memories with 500 ns cycle time from 64KB to 256KB maintain minimal board count. From $4000 for 16KB (300 ns HMOS); $7500 for 16KB (170 ns HMOS), $7500 for 64KB of 500 ns NMOS. **CSB Inc**, 40 Linnell Circle, Billerica, MA 08121. **Circle 152**

COLOR DISPLAY AND PRINTER. The IBM 3279 color display station transforms data from existing applications to 4C alphanumerics. Up to 7 colors as well as graphics can be displayed on the 14″ screen. It uses color for accent. The IBM 3287 color printer uses a 4C cartridge ribbon and provides printed copy of the alphanumeric or the optional graphic data that appear on the color display. 4-color printed material can include reports, charts, graphs. The IBM 3101 is a light-weight, low-cost display terminal, designed for businesses and schools where many locations need displays; the IBM 3102 printer produces copies of data shown on the 3101. The compact, TTY-compatible 3101 offers more relaxed viewing by displaying easily read characters on a screen which can be tilted or swiveled as needed. IBM 3287, $6,125-$6,500. **IBM**, 1133 Westchester Ave., White Plains, NY 10604. **Circle 222**

PLMX AN 8-/16-BIT μC UNIVERSAL LANGUAGE PLMX is for use in μC product development systems and real-time process control. PLMX incorporates all beneficial PL/M features and can be used with any 8- and 16-bit μP now or to come. PLMX syntax is identical to PL/M's and existing PL/M programs can be compiled under PLMX. PLMX can be adaped to interface with practically any operating system. The PLMX compiler can run under TEKDOS and CP/M operating systems. TEKDOS is the operating system for Tektronix' 8002A Universal Microprocessor Development System, and CP/M is an operating system that can support just about any 8080-based system in use today, including many hobbyist and small industrial systems. Interfaces to other operating systems will be available later this year. Is PLMX user-oriented? Yes, PLMX source statements resemble simple English declarations in a well-defined logic structure, making programming rules easy to learn. It's claimed that programmers familiar with PL/M learn the language in a few hours. There are no arbitrary formatting rules or line numbers. PLMX is free format and comments may occur anywhere in the source text, except within reserved words, identifier names and numbers. Key to PLMX is its modular structure, allowing it to be both μP- and OS-independent. The language is also excellent for modular programming by facilitating the division of large programming projects into modules so that several programmers can compile, test and debug independently, then link the modules together later. $1000. **Systems Consultants, Inc**, Product Development Group, 4015 Hancock St, San Diego, CA 92110. **Circle 186**

MICROSYSTEM ANALYZERS. New μPs supported by the universal Micro-System Analyzer Series 4000 now include the 8021, 8035, 8039, 8041A, 8048, 8049 and 8748. Three different pods are adaptable to support the μPs. The 8021 and 8041A each have individual modules; another is adaptable to the 8035, 8048, 8748, 8039 and 8049. Modules that support more than one μP are switch-selectable within the pod. $2K ea. Delivery: 60 days ARO. **Millennium Systems, Inc.**, 19020 Pruneridge Ave., Cupertino, CA 95014. **Circle 173**

750W/1KW SWITCHERS. Meeting UDE8071 and with internal filter, these "brownout proof" Super-MITE additions accept 85-130 VAC/166-260 VAC at 47-63 Hz and provide a 35 ms holdup time. 2ms before DC power loss, a power-fail signal triggers. **LH Research**, 1821 Langley Ave, Irvine, CA 92714. **Circle 163**

New Products

DOUBLE-TRACK MINI DISK. FD-50C uses FM/mFM/m^2FM recording formats and a track density of 100 tpi to provide a capacity 2x in FM and 4x in mFM/m^2FM recording formats as large as a conventional FM 48 tpi mini disk. Convert existing single-density 48 tpi mini-disk software to take advantage of the FD-50C's increased capacity; upgrade to 315.4KB (formatted). Track-to-track access time is 25 ms; settling time, 10ms. **Teac Corp**, 3-7-3, Maka-cho, Musashino, Tokyo, Japan. **Circle 133**

VIDEO DISPLAY TERMINALS and the 300 Series Ballistic printer are described in a 6-pg. brochure, as are the ADM-3A Dumb Terminal console, ADM-31 smart editing terminal and ADM-42 semi-intelligent terminal. **Lear Siegler**, 714 N. Brookhurst St, Anaheim, CA 920803. **Circle 135**

PDP-11 ADD-IN/ON MEMORY. This free instructional booklet provides practical/"how-to" advice on PDP-11 memory expansion and electronic/hardware interfacing, as well as a Unibus/Mudbus tutorial and charts on compatible boards/boxes and their functions. **Dataram Corp.**, Princeton Hightstown Rd., Cranbury, NJ 08512. **Circle 128**

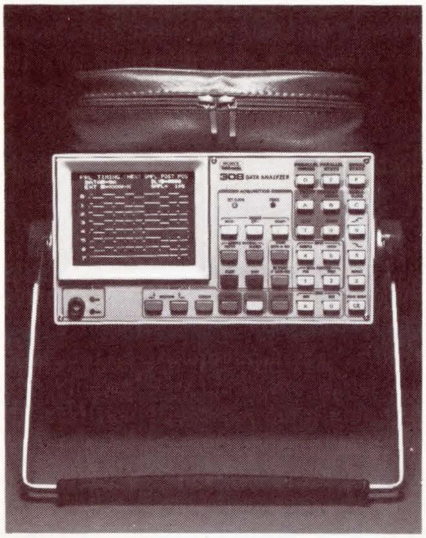
Z-80 SYSTEM. The Primarius IVS (Interactive Video System) weds sophisticated color computer graphics with a Z-80 to present multi-sensory interactive lessons stored on single cassette tapes. Each tape contains a recorded soundtrack as well as an entire digitally recorded program that allows the IVS to operate remote from its PDP-11/45 w/o giving up on-line capabilities. It has 256 x 192 pixels (2 color), 128 x 192 pixels (4 color) and full ASCII. Memory capability is 8K ROM, 16K user RAM, and 6K video RAM, with 300KB bulk storage. Input is via a 12-key KB and 8.5" x 11" sensor panel for high-resolution photographic overlays. $1200. **Primarius, Inc.**, 4186-J Sorrento Valley Blvd., San Diego, CA 92121. **Circle 129**

RX02-COMPATIBLE double density floppy. MF-211 dual floppy/LSI-11/2 does all the 11 V03-L does. It's functionally identical to the DEC 11V03-L, but uses 10.5" rack space. Features include: double and single density operation, over 1 Mbyte storage system, comes with 4-quad slot or 8-quad slot backplane, DEC software and interface cards optional and 30K addressable memory. **Charles River Data Systems, Inc.**, 4 Tech Circle, Natick, MA 01760. **Circle 130**

8-BIT µP CASSETTE SYSTEM. The ADPI storage system has a Phi-Deck Master and 1 to 3 slave drives. The Master contains the 8035 and interfaces to the external environment via 8-bit parallel (RS232 or current loop interface available). Each drive contains the transport mechanism and a printed circuit card to control the drive activity. 4 MB/system, 256 B RAM buffer storage, direct access at 100 ips. **Analog & Digital Peripherals, Inc.**,815 Diana Dr., Troy, OH 45373. **Circle 131**

"ALL-IN-ONE-COMPUTER" includes two Z80s, floppy disk storage, smart video terminal, heavy-duty KB, numerical pad and 16K RAM expandable to 48K. It runs programs written in Benton Harbor BASIC, Microsoft BASIC and assembler languages. WP and business accounting software packages available soon. All terminal functions are controlled by KB or software. 8 user-function keys give an extra measure of flexibility. Baud rates of up to 9,600 are KB selectable. Kit, $1,595; assembled, $2,295. **Heath Co**, Dept, 350-920, Benton Harbor, MI 49022. **Circle 132**

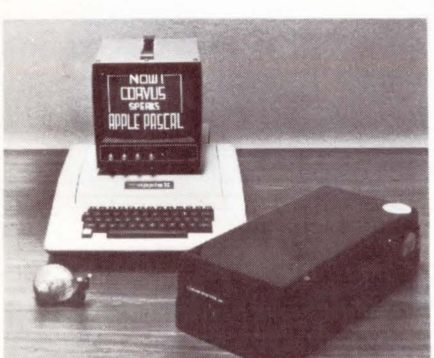
LOGIC ANALYZER. The 308 Data Analyzer, said to be the first logic analyzer to combine parallel state and timing, serial and signature analysis. Because of the color-coded keyboard and menu concept, it's particularly suited as a "satellite" design tool or



for the service and manufacturing environment which will be experiencing a 35+% growth rate (per year) in the use of logic analysis over the next 5 yrs. 8 lbs. $3K. **Tektronix, Inc**, Box 500, Beaverton, OR 97077.
Circle 167

COLOR MONITOR. The base Monitor has been designed as a 19" color display module suitable for OEM packaging. In addition, a 19" rack mount package and a separate enclosed cabinet for desk or table top locations are available. These Monitors optimize digital data and graphic displays with a RS170-compatible input. Typ. resolutions of up to 650 dots on a nominal 250 video lines at a 60 Hz refresh rate. Customers will benefit by having the brightest, best appearing and most cost effective color pictures in the industry. **Industrial Data Terminals Corp**, 1550 West Henderson Rd, Columbus, OH 43220. **Circle 146**

APPLE PASCAL FROM MICRO TO MINI. This 10-MB disk system (8" Winchester disks) makes Apple Pascal



perform like a mini. (Apple Pascal has a large data base and highly sophisticated processing capability.) Model 11AP is 100% compatible with Apple Pascal. All these run w/o modification: Apple Pascal disk and earlier Apple 3.2 disk OS, any applications running on the 280-block Apple FDs, new applications too large for Apple floppies. Dynamic volume management allows the 10-MB data base to be used as a single large block or to be broken into any number of smaller blocks with the same management flexibility. $5350. **Corvus Systems**, 900 S. Winchester Blvd, San Jose, CA 95128. **Circle 180**

SYNCH TAPE TRANSPORT. This dual-format synchronous tape transport utilizes 10½-in. reels. With the TDF 4050 Formatter, users easily can daisy-chain up to 4 TDI 1050 transports simultaneously (saving rack space and freeing slots formerly occupied by an external formatter). **Tandberg Data Inc.**, 4060 Morena Blvd., San Diego, CA 92117. **Circle 240**

New Products

FLAT CABLE CONNECTORS. The FCN-710 series connect flat cables to PC boards permanently by dip soldering; no wire stripping is required. The IDC mass-terminating system terminates 1.27 mm (0.05″) center-spaced flat cables of 10-60 conductors. Includes: dual in line terminals, low profile 5.3 mm (0.209″) above PCB, mate with std. IC sockets, and manufactured with solvent-resistant resin. **Fujitsu America, Inc**, 910 Sherwood Dr, Lake Bluff, IL 60044. **Circle 174**

IMAGE PROCESSOR. Offering advanced image analysis with high speed arithmetical and computational power, 12S Model 70, performs, in real-time, arithmetic and computations at 10 million arithmetic operations/sec and processes images at 100 ns/pixel. Features include: intensity manipulation, SCROLL ZOOM and ROAM. **Stanford Technology Corp.**, 650 N. Mary Ave., Sunnyvale, CA 94086. **Circle 134**

CONDUCTIVE MODIFIERS are aluminum alloy flakes or fibers that are added to polyesters, polycarbonates or nylon to yield high electrical and thermal conductivity. Transmet flake and fiber products are based on melt extraction and melt drag. The Transmet K-102 flake and B-103 thru B-106 fibers have a wide range of shapes and lengths (3 mm to 18 mm). $0.75/ft^2. **Transmet Corp**, 1375 Perry St., Columbus, OH 43201. **Circle 158**

256-BIT ECL RAM. The 256 x 1-bit DM10414 accesses data in 12 ns (max) and 7 ns (typ). Typ. chip select access time is 3ns. Contained in a 16-pin Cerdip, it's compatible with Fairchild's 10414 and Motorola's 10142 ECL RAMs. It has an unterminated EF output; allows wired-OR interconnects for multiple-RAM arrays. This output uses 50Ω to a 2V supply to provide a low output when the 10414 is off. $10.65 (100). **National Semiconductor**, 2900 Semiconductor Dr, Santa Clara, CA 95051. **Circle 151**

EXERCISERS for testing disk drives, floppy disk drives, tape drives and related equipment (such as communications and storage modules) locate problems before they go into a system – or even after they've occured. These universal QA/Service testers can check out every operating function continuously to locate intermittent errors. **Wilson Laboratories, Inc**, 2237 N. Batavia St, Orange, CA 92665. **Circle 159**

GRAPHIC DISPLAY SYSTEM FAMILY. Looking for a complete OS? The GMR-37s have: display generator, MOS refresh memory, vector and rectilinear graphics, alphanumerics in 4 sizes, bi-directional RS-232 computer interface and RS-170 video interface. Systems, including supplies, are in a 7″, rack-mountable chassis and drive std. closed circuit monitors. GMR 37-10 ($3300) has 256 x 256 resolution, on-ch RGB color plus blink. (2 ch.: $3700); GMR 37-20 ($3700) has 256 x 512 res, one-ch. RGB color and blink. (2 ch.: $4500); GMR 37-30 ($4500) has 512 x 512 res, one-ch. RGB color and blink; GMR 37-60 ($4700) has 1024 x 1024 res, one-ch. B/W. **Grinnel Systems**, 2159 Bering Dr., San Jose, CA 95131. **Circle 210**

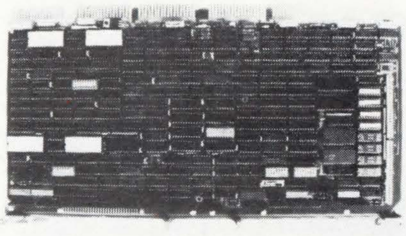
New Products

FLOPPY DISKS. These 96 tpi drives, offering 70 tracks/side (vs. 77 on the original MegaFloppy) uses the same mechanical device features. The new series recovers data from a std. single-track-density 48 tpi diskette. Drive head reads equivalent of every other track when 35 track (48 tpi) diskettes are inserted – or all 70 tracks on a 96 tpi diskette. The 1015-V ($450) has 436 KB of unformatted storage and FM/MFM recording; 1016-V ($490), 532 KB of unformatted storage using GCR; 1015-VI ($530), a 2-head version of MFM drive, has 872 KB; and 1016-VI ($570), a 2-head drive, has 1.064 MB and GCR encoding. **Micropolis Corp**, 7959 Deering Ave, Canoga Park, CA 91034. **Circle 185**

GRAPHICS COLOR VIDEO display controller, the FS 2500 Color, has a rack-mountable display generator unit plus optional free-standing desktop KB with full U&L case tri-mode and numeric/control pad, and optional 13" or 19" color monitors. Char. include 64 ASCII UC and 31 LC char. in an effective 10 x 8 matrix and effective 12

x 9 field. "Semi-graphics" char. sets include 2 x 3 element symbols, 64 in an effective 12 x 9 matrix, plus 31 which replace the LC char. set. $4275. **Ramtek Corp**, 2211 Lawson Lane, Santa Clara, CA 95050. **Circle 160**

UNIBUS/DISK DRIVE INTERFACE. This intelligent, single-board controller interfaces Unibus with Winchester and other std. SMD interface high-capacity disk drives, and is aimed at OEMs using PDP-11 and VAX series. The MSC-1101 controller includes command chaining, automatic error correction and retry recovery, implied overlapped seek, automatic head and cylinder switching, DMA load regulation, and 2-drive, dual-port control. Has software integration packages for RT-11, RSX, IAS, RSTS/E and VAC/VMS OSs. It plugs directly into a hex-high SPC slot in PDP-11/04 through 11/70 and VAX-11/780 systems. Communication with the controller is accomplished via control blocks assembled in main storage and Unibus registers as-

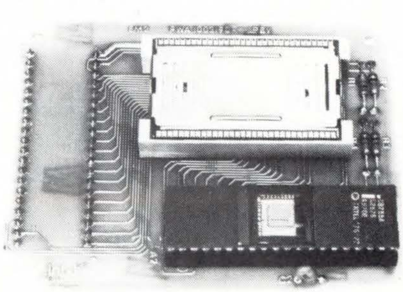


signed to the controller. $4850. **Microcomputer Systems Corp**, 432 Lakeside Dr, Sunnyvale, CA 94086. **Circle 184**

LINEAR MOTION problems facing digital system designers are met by these single- and twin-open/closed pillow blocks, precision linear 2 D-motion building block components, and shaft support rails. **Thomson Industries, Inc**, Manhasset, NY 11030. **Circle 149**

COLOR PRINTER/PLOTTERS. The T-100, a plain paper printer/plotter using impact raster matrix technology, provides 100 x 100 dots/in. plotting which is available with a 2-speed option switch that offers letter-quality printing at 150 lpm or std. printer quality at 250 lpm. It's plug-to-plug compatible with Printronix, Centronics and Data Products equipment. The same features and capabilities come in a special model of the T-100 to Versatec users with software and plug compatibility. Colorplot 100 is based on the T-100 technology. **Trilog, Inc**, 17391 Murphy Ave, Irvine, CA 92714. **Circle 157**

EM2 EMULATES 8022. The EM2 Emulator Board converts the ROM-based 8022 into an EPROM-based version that has readily accessible internal functions and is functionally and electrically equivalent. You can



correct program errors by checking internal operations and then by reprogramming the EPROM. The board measures 2.75" by 4.25" and plugs into a std. 40-pin μC socket and requires no interfacing, cabling or special supply. $500. **Intel Corp**, 3065 Bowers Ave, Santa Clara, CA 95051. **Circle 177**

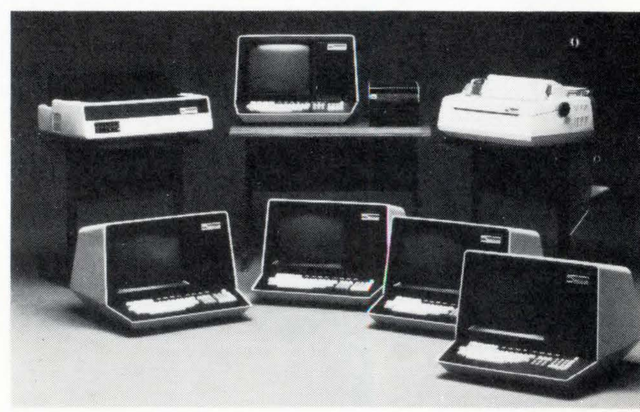
New Products

PORTABLE VIDEO MONITOR R-1018A has been designed for field servicing video and information display systems. The monitor will locate system malfunctions and allow system adjustments in field of view and scene focus and will determine performance in monitors, cameras and data transmission equipment. **Motorola Inc.**, 1301 East Algonquin Rd., Schaumburg, IL 60196. **Circle 249**

DEVELOPMENT SYSTEM DCS/80, an industrial-quality Multibus Development/Control System, includes dual 8″ floppy disks, 5-slot Multibus backplane and power supply. It fits a std. 10.5″ rack space. The DCS/80 Floppy Disk Controller is an intelligent Multibus-compatible system containing its own 8080, permitting concurrent operation with the main CPU as well as extensive system error reporting. CP/M supports high-level languages (such as Fortran, Cobol, Basic). CP/PLUS DOS has batch processing, logical-to-physical device mapping, supports up to 933 files/diskettes, etc. 16k unit, $3595 (unit qty). Delivery: 45 days ARO. **Distributed Computer Systems**, 223 Crescent St., Waltham, MA 02154. **Circle 137**

DATA DISPLAY. The DC-946 features: modular construction, 5″ cathode ray tube, solid state, 12 V dc inputs, choice of signal inputs, TTL (standard) and composite video (plug-in module), standard 15,750 KHz horiz. scan freq. and 650 lines resolution. **Audiotronics Video Display Div**, 530 Fifth Ave, N.W., NewBrighton, MN 55112. **Circle 143**

PROCESSING SYSTEMS. The Office Mate standalone system, ($9500 to $14500) features an intelligent input terminal, 48K RAM, two built-in 5-1/4″ double sided, double density floppy disk drives (600K capacity), the high speed



NEC "Spinwriter" printer, and field-proven XMARK Software. The DIABLO Line Printer and CENTRONICS High Density Dot Matrix Printers are available options. **XMARK Corp.**, 3176 Pullman St., Suite 119, Costa Mesa, CA 92626. **Circle 144**

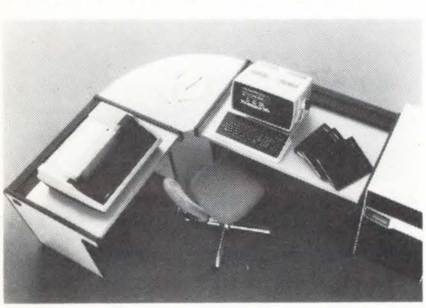
RC-11/RF-11 FHD MEMORY. The BC-201 Bulk Core system emulates the RC-11/RS-64 Disk System, and BC-202 emulates the RF-11/RS-11. It's completely hardware/software transparent to the host PDP-11 and uses up to 128K x 18 DR-128 module. Both are provided with necessary cable assemblies for Unibus interfacing. Features include: 1000x faster access time, high throughput, zero error rate, built-in "off-line" tester, hardware and software transparency, LED-indicated fault isolation, 128K modularity, non-volatility, and 1 M word capacity in 15.75″ chassis. **Dataram, Corp**, Princeton-Hightstown Rd, Cranbury, NJ 08512. **Circle 145**

μP POWER SUPPLIES. Providing a 30 to 40% efficiency improvement over series regulators, yet 30 to 45% smaller and costing half that of comparable switchers, this family of linear dc supplies boasts a 60-khr to 80-khr MTBFs. Single-output units include 5V (9,12, 18, 25, 40A), 12V (12,18A), 15V (11, 16A). 24V (8,12A); dual-outputs include ±15V (5.5A); triple-output μP units include 5V (12A), ±12V (2A), 5V(18A), ±12V (3A). $85.80 – $199.40 (100). **Adtech Power, Inc,** 1621 Sinclair St, Anaheim, CA 92806. **Circle 150**

NOVA 1200 option board converts NOVA 1200 to execute Nova 4 instructions. Model 2010 CPU Option Board updates Data General NOVA 1200 Series and D-116 computers to accept the complete instruction set for Data General's new NOVA 4 Series computers. The option board used with existing Nova 1200 memories also increases Nova 1200 speed by about 25%. If existing memories are replaced by a 32KW Memory Board, Nova 1200 system speed can be increased even further, to 800 ns (about 40%). $1800. **Quentin Research, Inc.,** 610 Hawaii St., El Segundo, CA 90245. **Circle 191**

LOW-PROFILE PRINTERS. The IMP Series of low cost, ultra-low profile 7 x 7 dot-matrix, 96 ASCII char. set, impact printers, styled for office or home , stand only 3-1/2", print 80, 96 or 132 col. of hardcopy with a throughput of 1 lps. IMP-1, which has friction feed, can make 3 copies on plain 8.5" wide paper for WP, and handles TTY rolls as well. IMP-2 also provides tracter feed, with tracters adjustable from 2.5" - 9.5". IMP-2 handles graphics under software control. $695. **Axiom Corp,** 5932 San Fernando Rd, Glendale, CA 91202. **Circle 169**

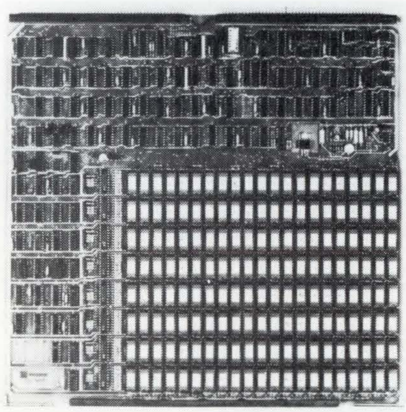
9000 COMPUTER SYSTEM. System hardware includes a 16-bit microNova 602 processor, 64K RAM memory, swivel and tilt display terminal with



matching detached keyboard (up to three additional terminals may be comfortably added), 10-Mbyte hard disk with a 5-Mbyte removable cartridge (an additional 12.5-Mbytes may be added), and high-speed matrix printer. Included are BASIC: and ASSEMBLY languages, reference manuals, training, starter and delivery. $19,995. **Compal, Inc.,** 6300 Variel Ave, Woodland Hills, CA 91604. **Circle 170**

VDT. Featuring U & L case, protect, char., line and page xmit, cursor positioning and numeric keypad, the 510 utilizes one PCB and contains 18 ICs. $660 (OEM qty). **TEC, Inc,** 2727 N. Fairview Ave, Tucson, AZ 85705. **Circle 155**

NOVA 3/ECLIPSE 256KB ADD-IN. The 256KB DR-123S for the Nova 3 and 256KB DR-125S for the Eclipse line both are packaged on 15" x 15" PCBs for simple insertion into the host mini. Configurations include: 32KB, 64KB, 128KB and 256KB for DR-123S. Parity is std. Cycle and access times are 500 and 325ns, respectively. An 8-position DIP-switch selects desired starting address, in 8-KB



increments, from 0 to 256KB. 128KB (64K x 17) DR-123S, $3000; 256KB (128K x 17), $5.090. **Dataram Corp,** Princeton-Hightstown Rd, Cranbury, NJ 08512. **Circle 182**

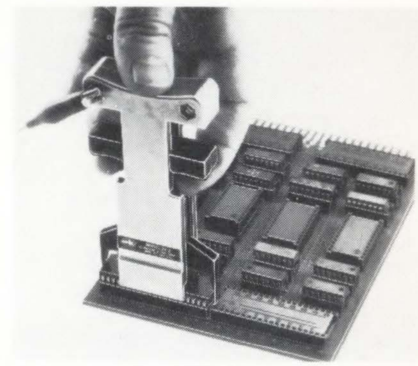
SYSTEM/38 ALTERNATIVE. The VS virtual storage computer accepts present RPG programs (like a System/3), Cobol and Basic – with increased interactivity and programmer productivity. VS grows incrementally, w/o swapping-out peripherals or re-writing programs, up to a VS 100 (which supports 128 users), 2 MB main memory, 4.6 BB storage and full complement of communications, peripherals, data base management software and WP. **Wang Laboratories, Inc,** One Industrial Ave, Lowell, MA 01851. **Circle 168**

VAX-11/780 ADD-IN MEMORY, MK8016 uses 4116s, and is a direct replacement for DEC's M8210. Capacity is 32K words x 72 bits (64-bit data, 8-bit ECC) or 256KB on a single card (15.64" x 11.93" x 0.4"). It's got a 1-yr. warranty. $4500. **Mostek Corp,** 1215 W. Crosby Rd, Carrollton, TX 75006 **Circle 179**

New Products

DEC/DG DISK CONTROLLERS. Single-board disk controller (DEC or Data General) provides multi-drive capability, multiple-sector transfer and hardware error correction. $3500 (unit qty). **MiniComputer Technology**, 2470 Embarcadero Way, Palo Alto, CA 94303. **Circle 211**

28-40 PIN IC EXTRACTOR is CMOS safe. Model EX-2 extracts all 28-40 pin DIP IC's having 0.600″ body widths. It's self-adjusting and gently lifts IC from socket or board using uniform pressure applied simultaneously at both ends of the IC. Designed for one-hand operation. It has heavy chrome plating for reliable static dissipation, as well as a terminal lug for attaching a ground

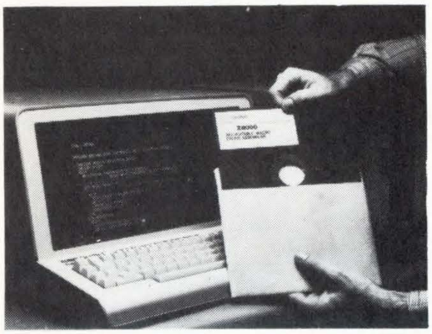


strip (strap not included). **O.K. Machine And Tool Corp**, 3455 Conner St, Bronx, NY 10475. **Circle 181**

45 CPS CHARACTER PRINTER. Model 9601/9602 features letter-quality print, μP-controlled print configurations, platen drive, an interchangeable print wheel and a choice of serial or parallel interface. The Model 9601/9602 Character Printer is 9″ high, 31.1″ wide, 22.2″ deep, and weighs approx. 70 lbs. With the optional stand, the printer is 32.5″ high, 31.1″ wide, 22.2″ deep, and weighs approx. 100 lbs. Model 9601 (serial printer), $4,950 (leased, $145/mo. for 3 yrs.); 9602 (parallel printer), $5,500 (or $160/mo for 3 yrs. leased). **Datapoint Corp**, 9725 Datapoint Dr, San Antonio, TX, 78284. **Circle 175**

LOW-COST SMART TERMINALS. Both the TVI-912 and -920 include U&L case, 14-key numeric pad, underlining, tabbing, editing, cursor addressing, reduced intensity, reverse video and other features, such as self-test mode, protected fields, blinking and/or blanking capability. Options include serial-buffered printer port and second-page display memory. **TeleVideo, Inc**, 3190 Coronado Dr, Santa Clara, CA 95051. **Circle 162**

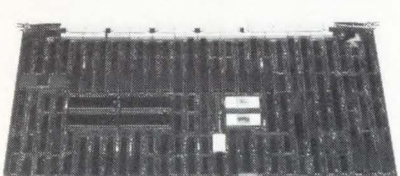
Z-8000 RELOCATABLE CROSS ASSEMBLER. Up to 10 times faster than competitive assemblers, and designed for use with GenRad/Futuredata 2300 Series Universal Advanced Development Systems, the cross assembler lets users create programs and



reproduce them in PROM for execution on the target μP. All important parts of the programs are written in assembly language to optimize execution speed and memory usage; the assembler program overlaps I/O operations so that as source lines are being processed, the next lines of source are being read simultaneously (i.e. multiprocessing); all disk operations are handled by an intelligent μP-based disk controller. Macro facility, conditional assembly and psuedo op are compatible with all 2300 Series assemblers. $750. **GenRad/Futuredata**, 6151 W. Century Blvd, Suite 1124, Los Angeles, CA 90045. **Circle 165**

VT-52 EMULATION TERMINAL. Model 11 features include: protected fields, graphic symbol set, blinking, reverse and half-intensity video. Format: 24L by 80 char; char. at a time, line at a time, or partial or full screen transmission. Terminal status display at bottom line of screen. All functions KB selectable. **I T L Data Sciences Inc**, Box 5050, Saskatoon, Saskatchewan, Canada, S7K 4E3. **Circle 183**

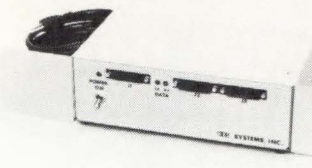
PDP-11 SMD CONTROLLER. S33/A, is a single-board, software compatible, SMD controller, packaged on a standard DEC hex board. It's software compatible with DEC's RM02 I/O driver, allowing the S33/A to operate wtih DEC'S RSTS/E and RSX11-M operating systems and RM02 diagnostics. S33/A operates with CDC's 9762 SMD drive and other equivalent SMD drives, including those from Ampex,



Ball and Century Data. S33/A offers media compatibility with the RM02 SMD drive supplied by DEC. The CDC 9762 SMD, or equivalent, drive which can be used with S33/A controller has an unformatted/formatted capacity of 80MB/67.4MB. The 9762 SMD uses a three platter pack, with 823 cylinders/pack and 32 sectors/track. Rotational speed of 3600 RPM results in a data rate of 1209KB, 50% faster than the data rate of the RM02 system supplied by DEC. $4900. **Dataram Corp**, Princeton-Hightstown Rd, Cranbury, NJ 08512. **Circle 171**

6502. "Programming The 6502," by Rodnay Zaks, updates the first edition of this book with a revised text and 100 extra pages (388 pgs). This well-structured paperback goes from the basics to I/O, addressing, data structures and applications. Lucid explanation of the 6502 instruction set. **Sybex, Inc**, 2020 Milvia St, Berkeley, CA 94704. **Circle 153**

LINE ADAPTER FOR LINE PRINTERS. This Parallel Long-Line Option Adapter Box allows all MDB line printer controllers to operate almost any printer for full-speed, parallel-data transmission up to 3,000′. Long-line capability is available with MDB PDP-11, Perkin-Elmer, Data



General and H-P line printer controllers. Long-line capability has been extended to MDB controllers for PDP-8 and LSI-11 and Series/1 to operate Centronics, Dataproducts, Data Printer, GE Terminet, Printronix and others. $525. **MDB Systems, Inc**, 1995 N. Batavia St, Orange, CA 92665. **Circle 178**

PDP-11/LSI-11 WIREWRAP BOARDS. The MDB-W9501 ($175) Universal Wire Wrap Module (for the LSI-11/PDP-11) handles 90 14 to 40-pin low-profile sockets or ICs. The MDB-M91WW ($75) Dual I/O Wire Wrap Module handles custom interface applications between std. modules or peripheral interfaces and provides 28 sockets or ICs. Other wire wrap modules for use in DEC computers include hex, quad and dual in several versions. Also for Data General, Perkin-Elmer, IBM Series/1 and Intel Multibus SBC. **MDB Systems, Inc.**, 1995 N. Batavia St., Orange, CA 92665. **Circle 138**

New Products

WIRE-WRAP TOOL. With human-engineered enclosure for optimized hand-held operation, the battery-operated (2 "C" NiCads), the BW928 is well-suited for extensive wire-wrap applications where reversible rotation, interchangeable bits/sleeves and lightweight, cordless operation are needed. $49.95. **OK Machine & Tool Corp,** 3455 Conner St, Bronx, NY 10475. **Circle 147**

PDP-11/44 has "large-system" features including a 1 MB max. memory, integral 8 Kbyte cache memory, a μP-controlled programmer's console, and provisions for optional floating-point and commercial instruction set processors. The CPU includes a min. 256 KB of ECC MOS memory, 2 serial line units, μP-controlled ASCII interface, 8 KB of cache memory and supply. Central processor, $23,900. **Digital Equipment Corp,** Maynard MA 01754. **Circle 140**

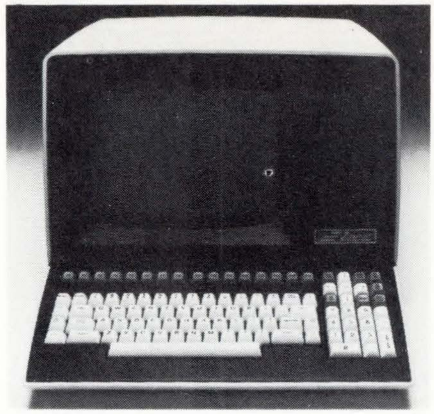
LSI-11/2 FLOPPY. The MF-211 Dual Floppy/LSI-11/2 System, uses the CRDS Double Density Controller and is functionally equivalent to the DEC 11V03-L. It uses 10.5" rack space. Features include: double and single density operation, complete software/media compatibility with LSI-11/2, over 1MB storage system, with 4-quad slot or 8-quad slot backplane, optional DEC software and interface cards, and 30K addressable memory. **Charles River Data Systems, Inc,** 4 Tech Circle, Natick, MA 01760. **Circle 148**

PASCAL GRAPHICS. A graphics software package written in the licensed version of UCSD PASCAL. PASCAL Graphic Procedures (GRAPHPRO) has a set of routines and procedures for programming of business, scientific and educational applications on Ramtek's RM-6114 (color) and RM-6113 (B&W) graphics computer systems. Programmers no longer need go to the pixel level for constructions. Using procedural calls, they can summon graphics routines for faster, easier data presentation on the video screen. The software is consistent with the SIGGRAPH Core Standards of August 1979. One-time license fee, $1,750. **Ramtek Corp,** 2211 Lawson Lane, Santa Clara, CA 95050. **Circle 136**

FOUR-COLOR GRAPHIC DISPLAY. Developed for applications in CAD, simulation and training, mapping, command and control and air traffic control, this Desktop Color Indicator employs a layered phosphor, beam penetration technique that enables simultaneous display of 4 colors. The full deflection rates of a high speed display system can be utilized for all 4 colors. A typ. character can be traced in

2.1μs in any color, including red. The Color Indicators include a built-in test feature which, at the touch of a button, displays a test pattern that will visually indicate if any modules have failed. The displays feature a ruggedized structural foam construction technique that enables them to be shipped intact, ready for use. The indicators are available in the Model 740 Series 21" rectangular face, and the Model 760 Series 23" round configuration. Each is available in either desktop or rack mounted version. 740, $17.5k; 760, $20k. **Sanders Associates, Inc.,** Daniel Webster Hwy. South, Nashua, NH 03061. **Circle 139**

SMART TERMINAL. Compatible with such alphanumeric terminals presently being offered by Lear Siegler, including the ADM-31, the Zephyr is a μP-based video display terminal that offers a wide range of intelligent features including full cursor addressability, full editing and protected forms mode. It has a large 12" non-glare CRT that provides 24 lines of 80 char. each, plus a 25th line, designed to display operator error messages and terminal status information. It stores 2 pages of 1920 char. each and a blinking underline cursor may be positioned anywhere within either page display. The displayable 128 character ASCII set is enhanced by a variety of video attributes which may be utilized under program



control including dim, reverse background, blinking and underlining. $976 (100). **Zentec Corp,** 2400 Walsh Ave, Santa Clara, CA 95050. **Circle 166**

RL02 DISK DRIVE. This 10.4 MB cartridge disk drive is a rack-mountable, top-loading unit employing the dual-density 5440-type disk cartridge as its storage medium. It is designed for use with all PDP-11-based systems, PDP-11/03L and PDP-11/23-based microcomputer systems, and PDP-8/A systems. The RL02 is available in a subsystem configuration – a disk drive and controller. $6,900. **Digital Equipment Corp,** Maynard, MA 01754. **Circle 156**

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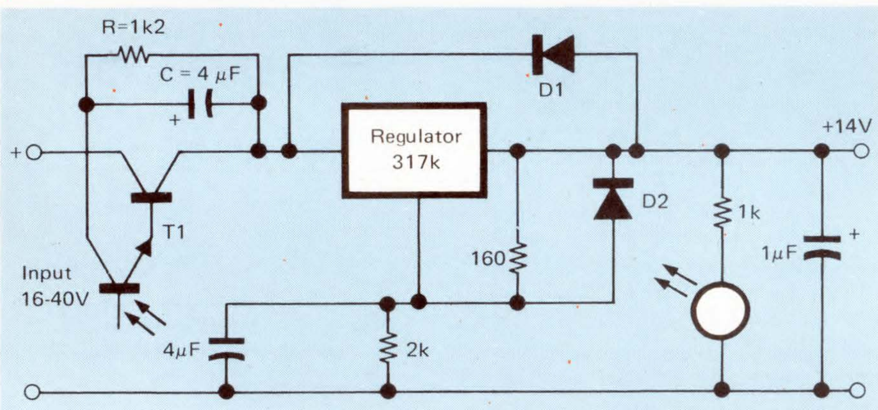
Designers' Notebook

μP System Regulator Minimizes Short Circuit Shutdown-Time

In many applications, it is necessary to have an instantaneous shut down regulator in case of short circuit at input or output terminals. Most power supplies use thermal shut down or a short-circuit, current-limiting resistor, which means either a time lag between short circuit and shut down or an unnecessary voltage drop across the resistor – particularly if the load current is high. In some cases, the system can be protected by a fuse, but this is inconvenient as it is not known when the short circuit condition will be removed, particularly if the supply is remotely controlled.

The circuit shown avoids time lag and an unnecessary voltage drop and will resume operation by itself as soon as the short circuit condition is removed. The extra current requirement is about 8 to 10 mA, to drive a LED; the same LED can be used also to indicate output voltage 'on' if the light sources can be brought out from the opto coupler through a fibre optic link.



The three-line regulator, a 317k, receives its input from the series-pass Darlington (T1) and provides a feedback path from the regulator output to the base of T1.

Circuit operation is straightforward. When the supply is on, the surge current across C will switch on the Darlington pair T1. Therefore, the LED current will keep T1 conducting and output voltage will be maintained. In the event of a short, the Darlington pair will be cut off and the supply will be folded back. As the short circuit is removed, the emitter of T1 will try to reach the collector potential, so the capacitor C will start to discharge through the resistor R and bring the Darlington pair "on" again. The supply will then recover its output voltage.

The short circuit current can be limited to about 10mA and depends on the value of R and input voltage. The regulator itself is protected from momentary short circuit by diodes D1 and D2.

L. N. Ser, 25 Warrender Way, Ruislip, Middx. HA4 8EB, England.

Rate this design: circle 8L, 8M or 8H on Reader Inquiry Card.

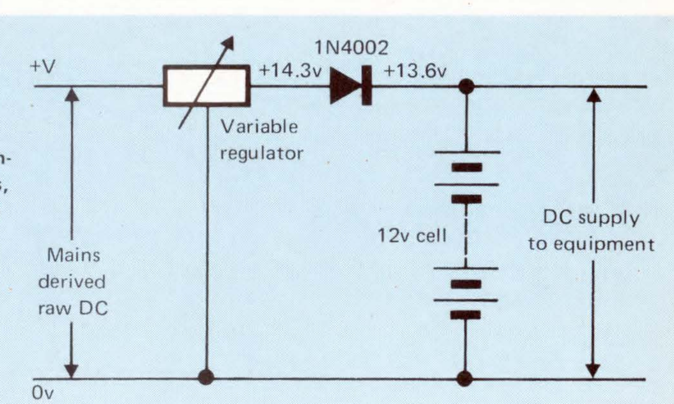
Battery Backup Provides No-Break/Automatic Shutoff Operation

The circuit described here supplies 10 V to 15 V to a load, even in the event of a power failure. The main criteria was that the load should run on battery power for as long as possible with no discontinuity of supply during the change over from mains derived to battery supply.

Frequently, in applications where battery back-up keeps equipment functioning during main power failure, interaction is often encountered between the main derived supply and charging system, and the battery itself – especially when using a single regulator configuration. The usual way to overcome this interaction is to use a blocking diode (**Fig. 1**). However, this does not overcome the problem when the battery is fully discharged, since it appears as a short-circuit to the regulator and thus pulls the supply rail to the rest of the equipment down.

This problem can be partially overcome by employing two regulators and a diode "OR" gate configuration as shown in **Fig. 2**. In the particular application that was being investigated, it was required to supply a circuit with 15 V DC under main supply conditions, hence for battery operation a 12-V battery would have to be selected. The circuit ceased to function at 10 V. The disadvantage of the circuit in **Fig 2** is that under battery supply conditions, with the battery at full charge, because of the blocking diode the supply rail starts at 12.9 V and not 13.6 V which would be desirable. Con-

Fig 1 To prevent interaction problems, a blocking diode is used.



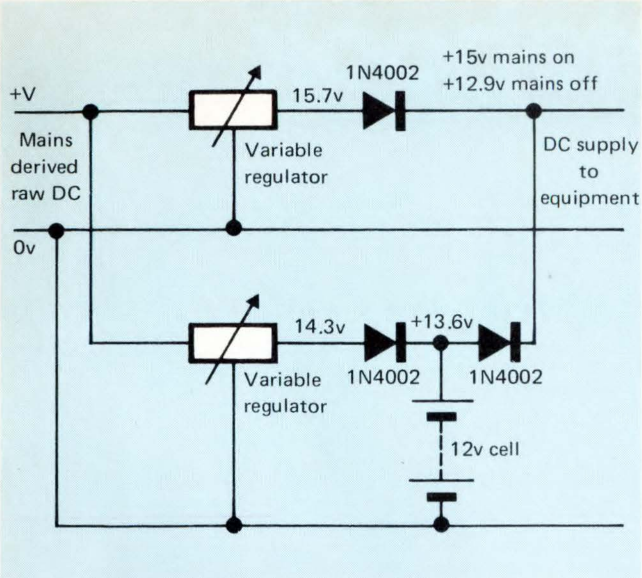


Fig 2 This 2-regulator diode-OR circuit partially solves the full-discharged-battery problem.

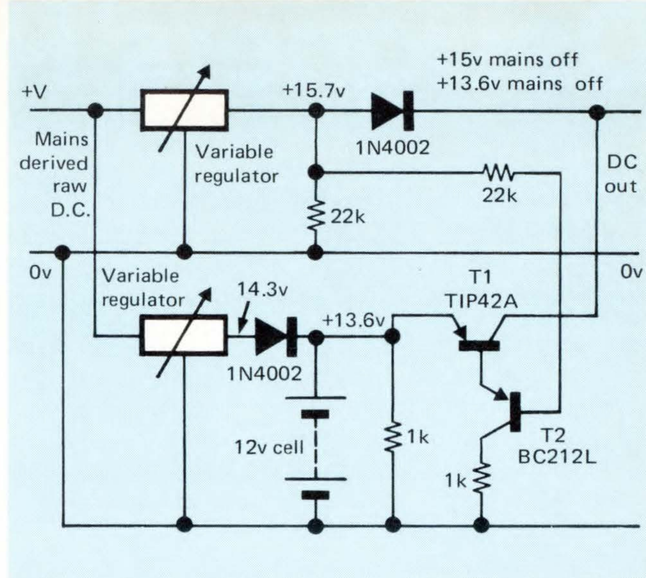


Fig 3 To provide maximum battery-driving time, replace the diode by a transistor switch, T1.

sequently this means that the maximum battery-driving time is not obtained, the 0.7-V drop of the blocking diode effectively reducing this time by a factor of 20%. This problem can be overcome by using the circuit of **Fig 3**, where the diode is replaced by a transistor acting as a switch. Using the device specified, a voltage drop of 50 mV-only is encountered under battery operating conditions. The transistor switch, T1, is driven by transistor, T2, which monitors the main-derived supply rail. When the main supply fails, the 15 V rail goes low which causes T2, and in turn T_1, to turn on, thus energizing the circuit from the battery. When the main-derived supply is at 15 V, T2 and T_1 are both turned off, hence the battery is fully isolated.

In order to prevent the battery from being deep-discharged, I added an automatic disconnect circuit (**Fig 4**). IC1 form a level detector whose switching threshold may be varied from 5 V to 10 V by RV1. When, under battery operating conditions, IC1 monitors the battery voltage and when it falls below the threshold voltage set, output of IC1 goes high; and thus, by T4, T3 and T2, it turns T1 off. The purpose of T3 and T4 is to buffer IC1 output and ensure that when battery voltage is above threshold set, both T2 and hence T1 are fully turned on as the low-output voltage of IC1 is about 1.5 V, which is greater than a $V_{be\ on}$ which is about 0.6 V, and would thus tend to turn T2 and T1 off. The circuit (**Fig. 4**) has run for six months.

T. Austin, 180 Brook Lane, Sarisbury Green, Southampton, Hants. SO3 6EA, England.

Rate this design: circle 9L, 9M or 9H on Reader Inquiry Card.

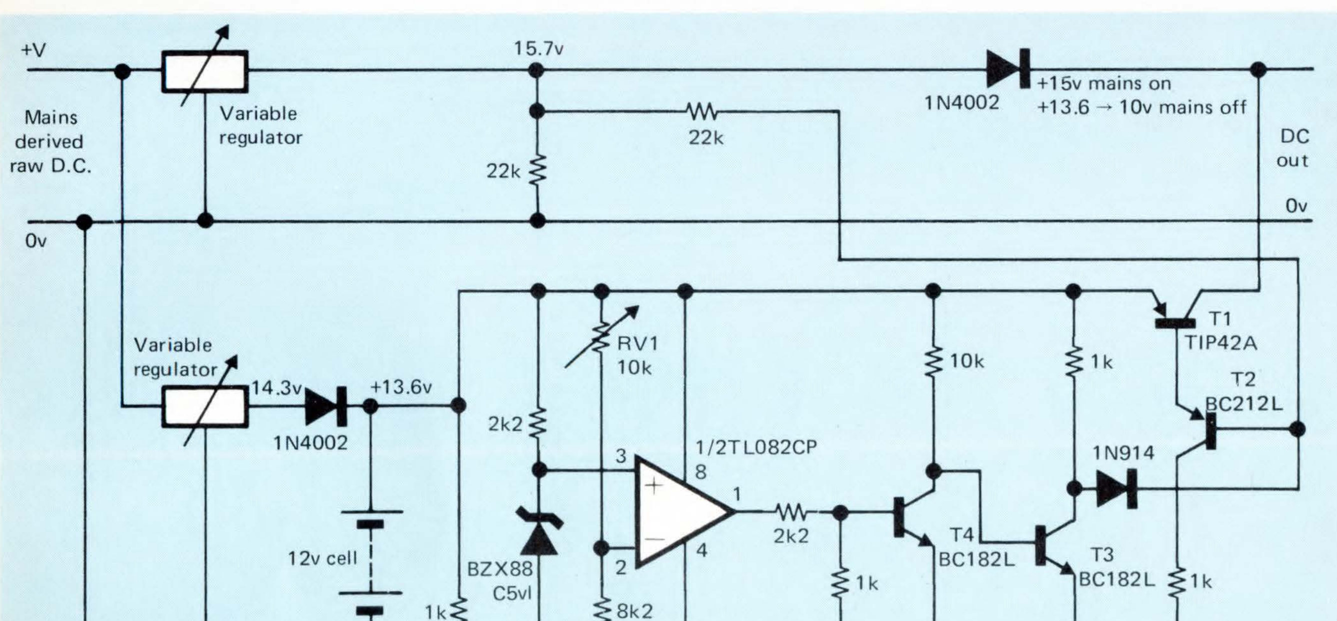


Fig 4 Automatic disconnector prevents deep-discharging batteries. IC1 level-detecting threshold is varied by RV1.

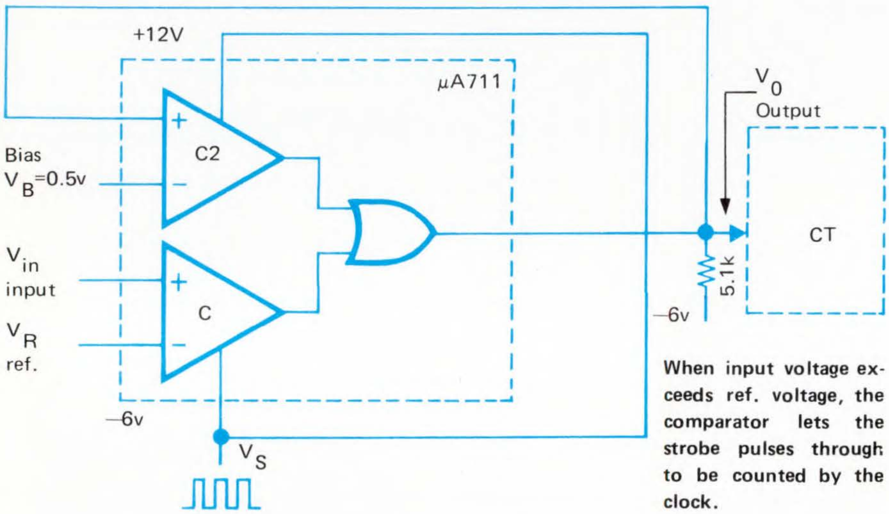
High-Resolution Comparator Provides High Speeds

In many types of digital voltmeters like voltmeters with V/T or V/F converters, and a lot of other applications, try this circuit. V_{in} (+) and V_R (−) are inputted into a comparator, whose output is NANDed with the strobe voltage to provide an output to a clock.

For an input signal $V_{in} \geqslant V_R$ (V_R is a ref. voltage), the comparator C opens the gate and pulses are counted by CT counter. When $V_{in} < V_R$, no pulses are counted. The accuracy is strongly influenced by the comparator's resolution and propagation time.

For a high resolution and good propagation time, use a dual voltage comparator – such as the μA711 in the circuit diagram. (C_1, C_2 and OR-gate represent the equivalent circuit for the dual comparator.) If the strobe voltage V_s is LOW ("0" logic), then output voltage V_0 is LOW disregarding the value of the input V_{in}. If V_s is HIGH ("1" logic), there are two cases: when $V_{in} < V_R$, V_0 is LOW and when $V_{in} \geqslant V_R$, V_0 is HIGH.

However, if strobe voltage consists of "0-1" pulses, these pulses are transmitted to the counter input only when $V_{in} \geqslant V_R$. For $V_{in} < V_R$ the pulses are not transmitted. The positive feed-back of the comparator for C_2 ensures a high voltage resolution, better than 0.1 mV. The circuit needs no gate. If the pulses have a low duty cycle, the device provides a good noise insensitivity, since the comparators are activated only when the pulses are HIGH.



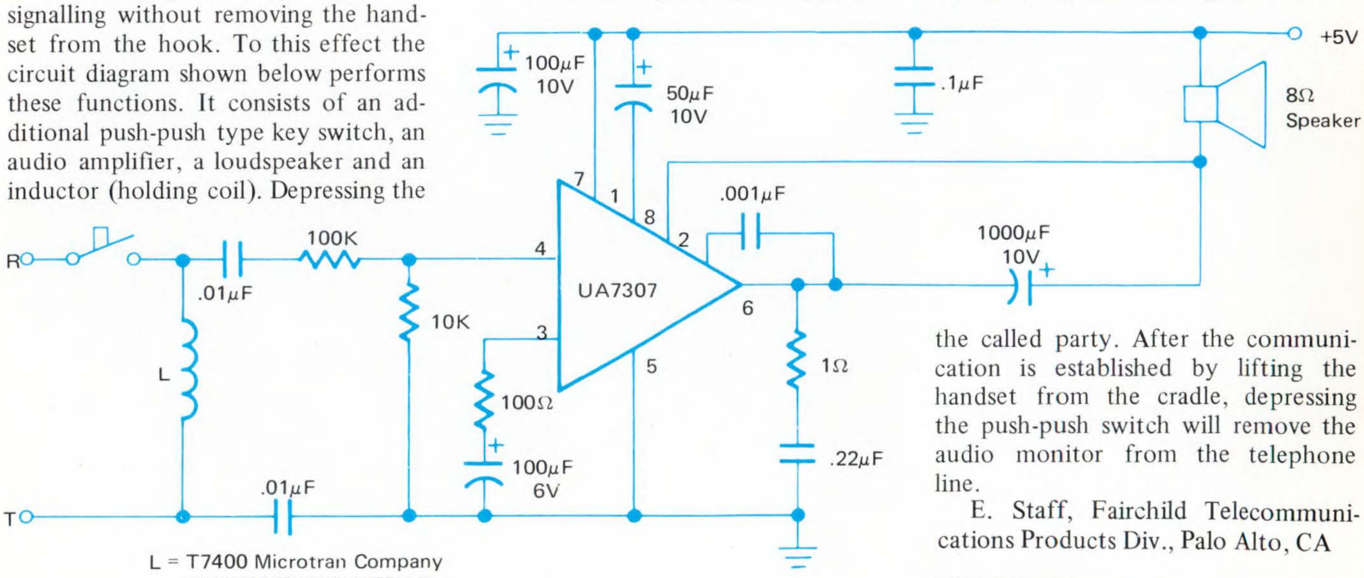
When input voltage exceeds ref. voltage, the comparator lets the strobe pulses through to be counted by the clock.

V. Tiponut, Facultatea de electrotehnica, B-dul V. Parvan nr. 2, Timisoara 1900, Romania.

Rate this design: circle 10L, 10M or 10H on Reader Inquiry Card.

Telephone Line Audio Monitor

In an application of the Fairdial Set CES200 or CES201 as an adjunct dialer to a telephone instrument, it is often desirable to monitor the progress of a telephone call during the phase of signalling without removing the handset from the hook. To this effect the circuit diagram shown below performs these functions. It consists of an additional push-push type key switch, an audio amplifier, a loudspeaker and an inductor (holding coil). Depressing the switch will place the holding coil and the audio amplifier across the line initiating a connection. The central office responds with the dial tone. Dialing can therefore begin using the appropriate key from the Fairdial (dial, LND, or any of the memory or scratch pad keys). At the end of dialing, the central office responds with a ring signal or a busy signal indicating the status of the called party. After the communication is established by lifting the handset from the cradle, depressing the push-push switch will remove the audio monitor from the telephone line.

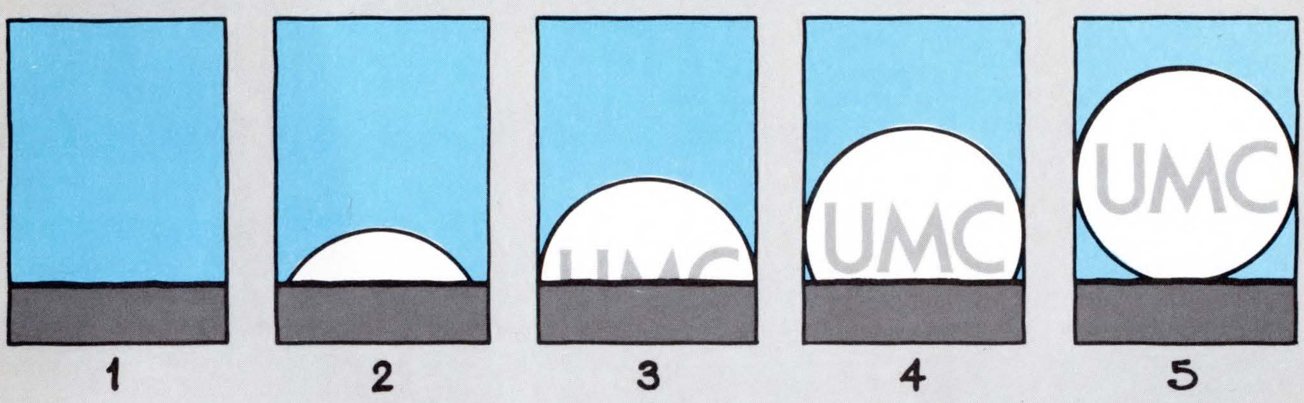


In this telephone line audio monitor, the phone call status is monitored *without* removing the handset off the hook.

E. Staff, Fairchild Telecommunications Products Div., Palo Alto, CA

Rate this design: circle 11L, 11M or 11H on Reader Inquiry Card.

PDP-11 ready for the 80s ?



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