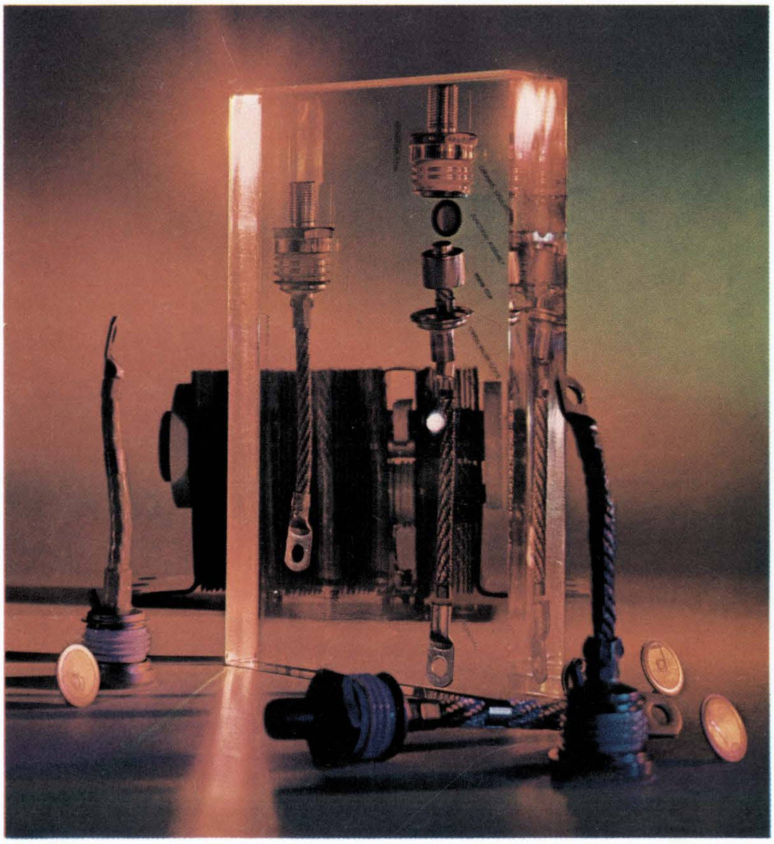
VOL. 28 NO. 1
JANUARY 1969

THE ELECTRONIC ENGINEER



The promise of ion implantation p. 68
Part 2 of telemetry course p. 81
What about high di/dt ratings? p. 89

NEW Calibrated TDR with 35 ps risetime and 12.4 GHz sampling in one easy-to-use plug-in

See More...Do More with the HP 180 Scope System! Now, in one measurement, you can find out what, where, and how much—when you design connectors, circuits, antennas, strip lines and similar components. No interpolation or extrapolation needed. Now HP has combined high resolution time domain reflectometry and 12.4 GHz sampling in the HP 1815A double-size plug-in that fits the standard 180A Oscilloscope mainframe or the 181A Variable Persistence and Storage mainframe.

The 1815A in conjunction with the 1817A remote feed-through sampler and the 1106A pulse generator provides calibrated 35 ps risetime TDR—with capability of resolving discontinuities down to *a quarter of an inch apart.* New signal averaging circuitry reduces noise and jitter at a ratio of 2 to 1 or more.

And the 1815A not only provides more accurate answers, it provides them faster and easier. Why waste your valuable time? Get direct readouts in reflection coefficient (rho) and feet (meters optional) for instant answers that previously required time-consuming calculations. Get direct, front panel calibration of dielectric constants for air and polyethylene, or use a variable control to set the dielectric constant between $\epsilon = 1$ to $\epsilon \cong 4$.

In addition, the 1815A/1817A combination can be externally triggered to provide 12.4 GHz (28 ps) sampling capability. The signal averaging technique allows you to use the entire bandwidth capabilities of the plug-in/sampler — undistorted by noise and jitter.

If you don't need the full capability of the 1815A, a lower cost and lower frequency sampling head (1816A) and tunnel diode pulse generator (1108A) are available for 4 GHz 90 ps risetime sampling and 110 ps TDR (60 ps pulses).

Prices: 1815A, $1100; 1817 Remote Sampler, $1500; 1106A Tunnel Diode Pulse Generator, $550; 1816A Remote Sampler, **$850;** 1108A Tunnel Diode Pulse Generator, $175.

Isn't it time you took a step forward in your oscilloscope measurements? Call your HP field engineer and he'll tell you about the all-solid-state, proven HP 180 scope system, which now includes TDR and sampling. Or, write for data sheet to Hewlett-Packard, Palo Alto, California 94304. Europe: 1217 Meyrin-Geneva, Switzerland.

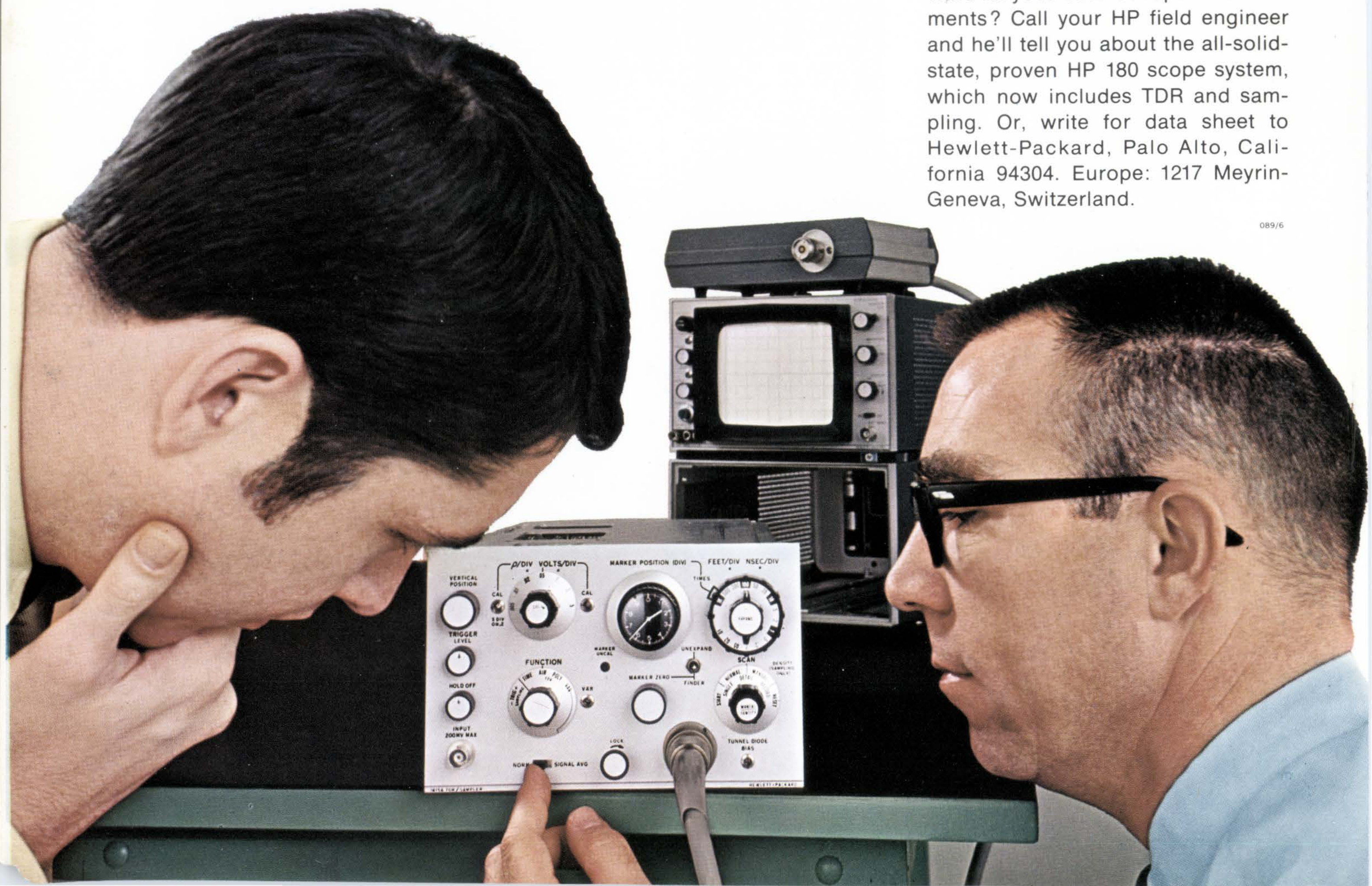
STEP FORWARD

HEWLETT hp PACKARD

OSCILLOSCOPE SYSTEMS

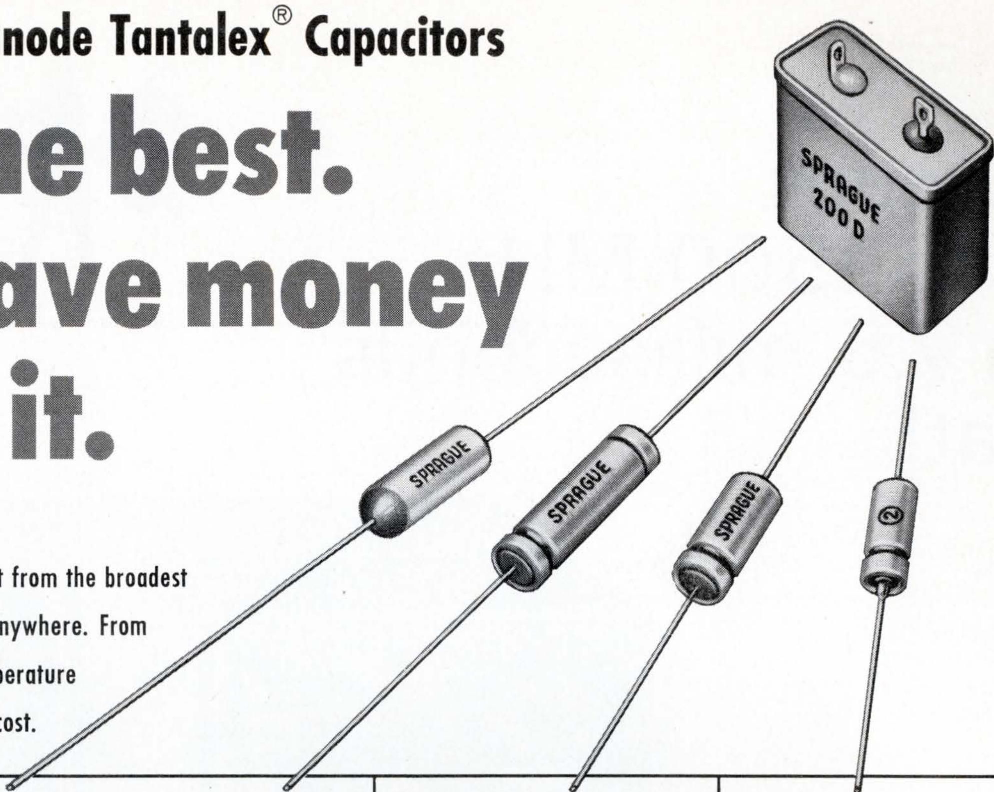
Circle 1 on Inquiry Card

089/6



Wet-sintered-anode Tantalex® Capacitors

Buy the best. And save money doing it.



Here's how: Select from the broadest line of tantalum capacitors anywhere. From Sprague. The lower your temperature requirement, the lower your cost.

For operation to + 85 C		For operation to + 125 C	For operation to + 175 C
Type 145D Volumetric efficiency up to 210,000 μF-volts per cubic inch. For use in miniature commercial/industrial printed wiring boards, packaged circuit modules, and wherever else cost and space are prime considerations. Elastomer end seal capped with plastic resin insures against electrolyte leakage and lead breakage. Available in voltage ratings from 6 to 75 VDC.	**Type 109D** A superior design that meets all the basic military requirements for capacitors within this temperature limit. There is no compromise in quality. Voltage ratings from 6 to 150 VDC. **For extra large values of capacitance, use Type 200D or 202D package assemblies, which consist of several 109D - type capacitor elements in a hermetically-sealed case.**	**Type 130D** Exceptional electrical stability due to chemical inertness of tantalum oxide film to specific electrolytes used, low diffusion of TFE-fluorocarbon elastomer seal, and special aging for 125C operation. Voltage ratings from 4 to 100 VDC. **Dual temperature ratings of Type 200D and 202D package assemblies give you extra high capacitance values for +125 C operation.**	**Type 137D** Proven glass-to-metal hermetic seal qualifies these outstanding capacitors for use in satellites, missiles, and other critical aerospace applications. They have greater volume efficiency than has been previously available for wet-sintered-anode capacitors in this temperature range. Type 137D capacitors exhibit extremely low leakage currents. Available in voltage ratings from 2 to 150 VDC.
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Select the capacitor type that meets your temperature requirements. That's how to save money. Specify Sprague Tantalex® Capacitors. That's how to get the best.

For complete information on Type 145D Capacitors, write for Engineering Bulletin 3750 (Type 109D, Bulletins 3700F and 3700.2; Type 130D, Bulletins 3701B and 3701.2; Type 137D, Bulletin 3703A; Type 200D and 202D, Bulletin 3705B) to the Technical Literature Service, Sprague Electric Company, 233 Marshall St., North Adams, Mass. 01247.

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sweeps 5 to 1500 MHz in 7.5 milliseconds flat!

We can supply a sweep generator with rally stripes on special order, but the frequency range and the sweep rate are standard.

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Frequency Range
(Seven different plug-in oscillators available) ...... .02 Hz-1500 MHz

Sweep Width
(F_1-F_2 or $F_c/\Delta F$) .... .02 Hz-1495 MHz

Frequency Marking
(Four different marker plug-ins available) ....Fixed or variable

Attenuation
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Sweep Rate
(Select from two rate plug-ins) ....0.001 to 60 sweep/sec.

Log Amplification
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Detection
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EE

The Electronic Engineer

January 1969 Vol. 28 No. 1

COVER

Dan Piccone and Steve Somos of G.E. have written the article, "Are you confused by high di/dt SCR ratings?" for this issue. In the article they make some interesting points that could be controversial, partly because they play down certain aspects. And this is interesting because Dan and Steve, along with Angelo DeCecco, hold a patent for such devices. Some G.E. devices using their discovery are shown on the cover.

Circle 5 on Inquiry Card

EE

The Electronic Engineer

Vol. 28 No. 1 January 1969

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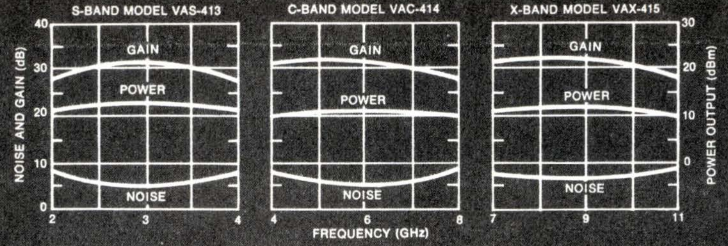
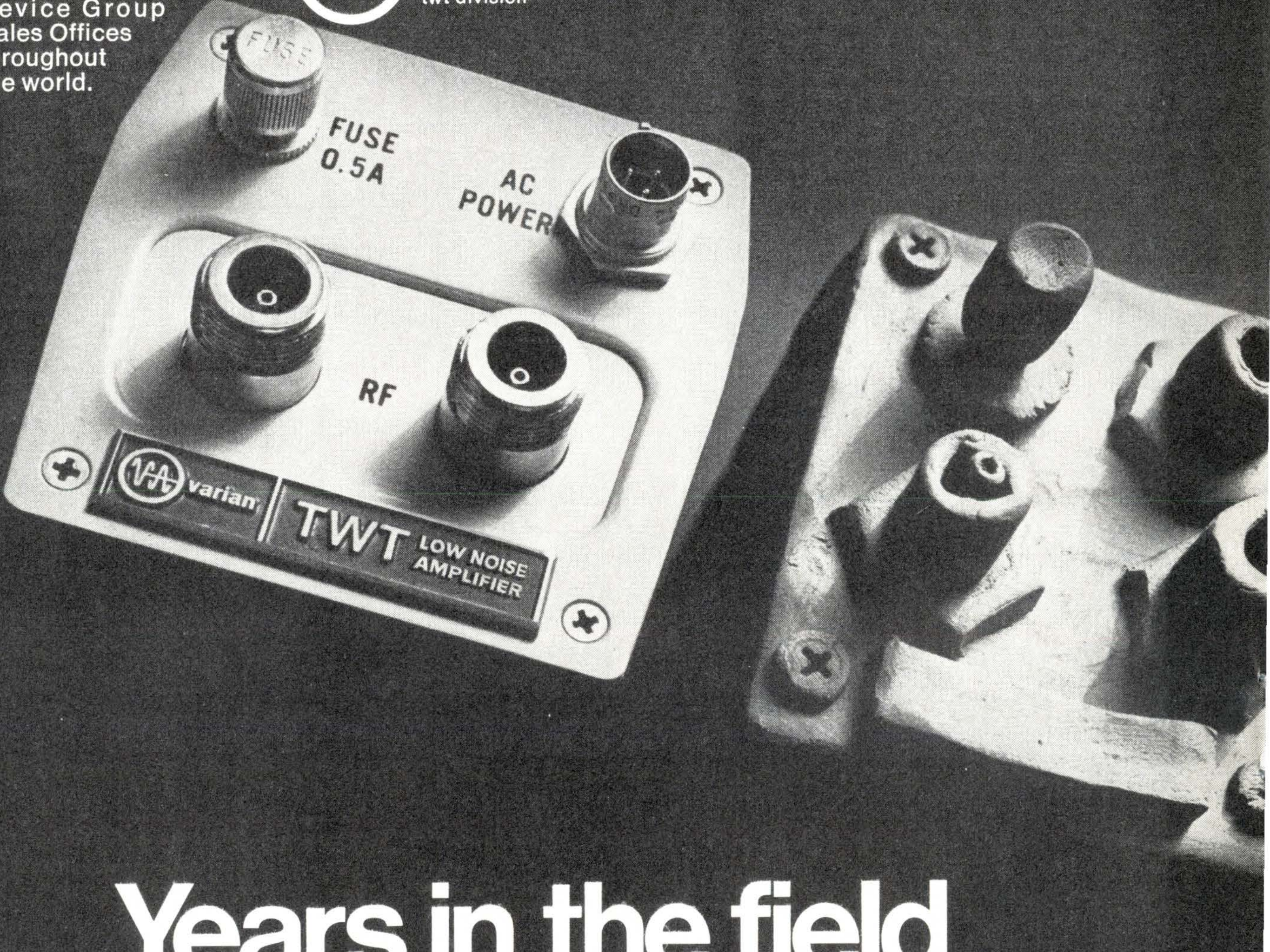


Our miniature SRPM low noise TWT amplifiers were the only ones of their kind when we introduced them over two years ago. This time in the field established their excellence. And now, the supreme endorsement. One of our competitors has copied them.

The noise, gain and power figures graphed here are obvious reasons for imitation. Some others: All three models weigh less than 7 pounds, are only about 3 by 3 by 11 inches long. All include built-in power supplies and withstand severe environments.

So compare versions. Then get your field-proven Varian original from our TWT Division, 611 Hansen Way, Palo Alto, California 94303, or any of the more than 30 Varian Electron Tube and Device Group Sales Offices throughout the world.

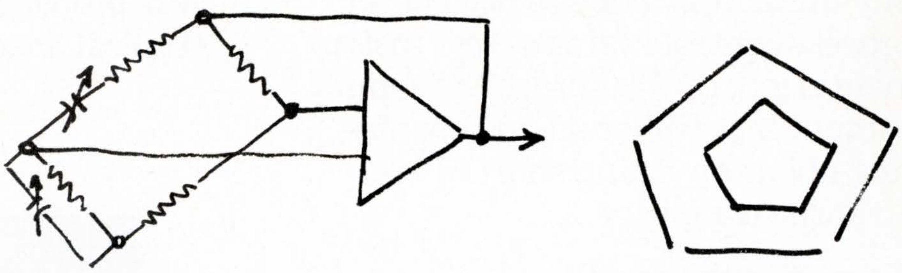
varian
twt division



Years in the field proved it's worth copying.

EE EDITORIAL

From Wien to Washington



This year has started with a bright note for electronic engineers who believe engineering common sense has a place in government. David Packard, who has his name inscribed on many an instrument in electronic labs, has been nominated Deputy Secretary of Defense for the incoming Administration.

Most of our readers have heard the story. William Hewlett and David Packard formed their now famous company in 1939, to develop equipment embodying a "contribution" or an "advancement in the state of the art." Their first commercial instrument was the still-around 200A audio oscillator, based on Hewlett's idea to use a Wien bridge to stabilize the oscillator's amplitude.

Much as his technical ability accounted for the reputation of H-P's products, it is David Packard's ability to motivate *people* that accounts for H-P becoming the largest electronic instrumentation company in the world; and it is for this ability that he has been drafted for such a responsible job in Washington.

To David Packard go, I am sure, the best wishes of all electronic engineers in this country, to which we add our own. May the judgment he has so wisely applied to both people and hardware at his company be with him when he manages the people and hardware that guard this Nation.

Ions do their thing . . . on semiconductors

In this issue, you will find a report on the newest darling in semiconductor processing —ion implantation. Ion implantation will not give us new devices, just better ones. It does not speed up the production process, but it can make it more reliable.

Better yet, what makes ion implantation attractive is that it is believable. In a field where breakthroughs are the order of the day, ion implantation is modestly billed as a method to complement—rather than replace—semiconductor diffusion.

The report on ion implantation is authored by our Western Editor, Steve Thompson, who until recently worked at the Semiconductor Division of Hughes Aircraft Corp., installing one of the most advanced ion implantation systems in the country. To write this report, Steve visited every semiconductor manufacturer and many big users of semiconductors. Some had never heard about ion implantation; some are investing heavily on it; some were most surprised that we knew they were working on it; one even invited Steve to visit its plant, then closed the door to him after realizing the competitive position it had thanks to ion implantation. You can read his interesting report starting on page 68, as well as future developments in future issues.

Mean-time-between-successes

As we close this issue, we are glued to transistor radios listening to the successful completion of the Apollo moon mission. Our heartfelt congratulations to astronauts Frank Borman, William Anders, and James Lovell, to NASA and, in particular, to all the electronic engineers who have directly or indirectly cooperated in the Apollo project. As our eyes rose to the sky following the trailblazing spacecraft, we prayed that the MTBF's would be accurate, that the redundancies would be enough, and that the designs would fly. They did.

Alberto Socolovsky
Editor

OUR NEW COVER . . .
. . . reflects the constant improvement we will be implementing in our magazine in 1969, to make it more helpful to you, the electronic engineer. Look for a more attractive cover on the outside, a more useful magazine in the inside.

←Circle 7 on Inquiry Card

If you're building any computer except a Computer, you need CTμL.

CTμL integrated circuits will give you more speed for less money than any other ICs. They're perfect for process control systems, test instrumentation, central processing units, computer peripheral equipment—just about anything short of an airborne computer.

Keep it in the family.

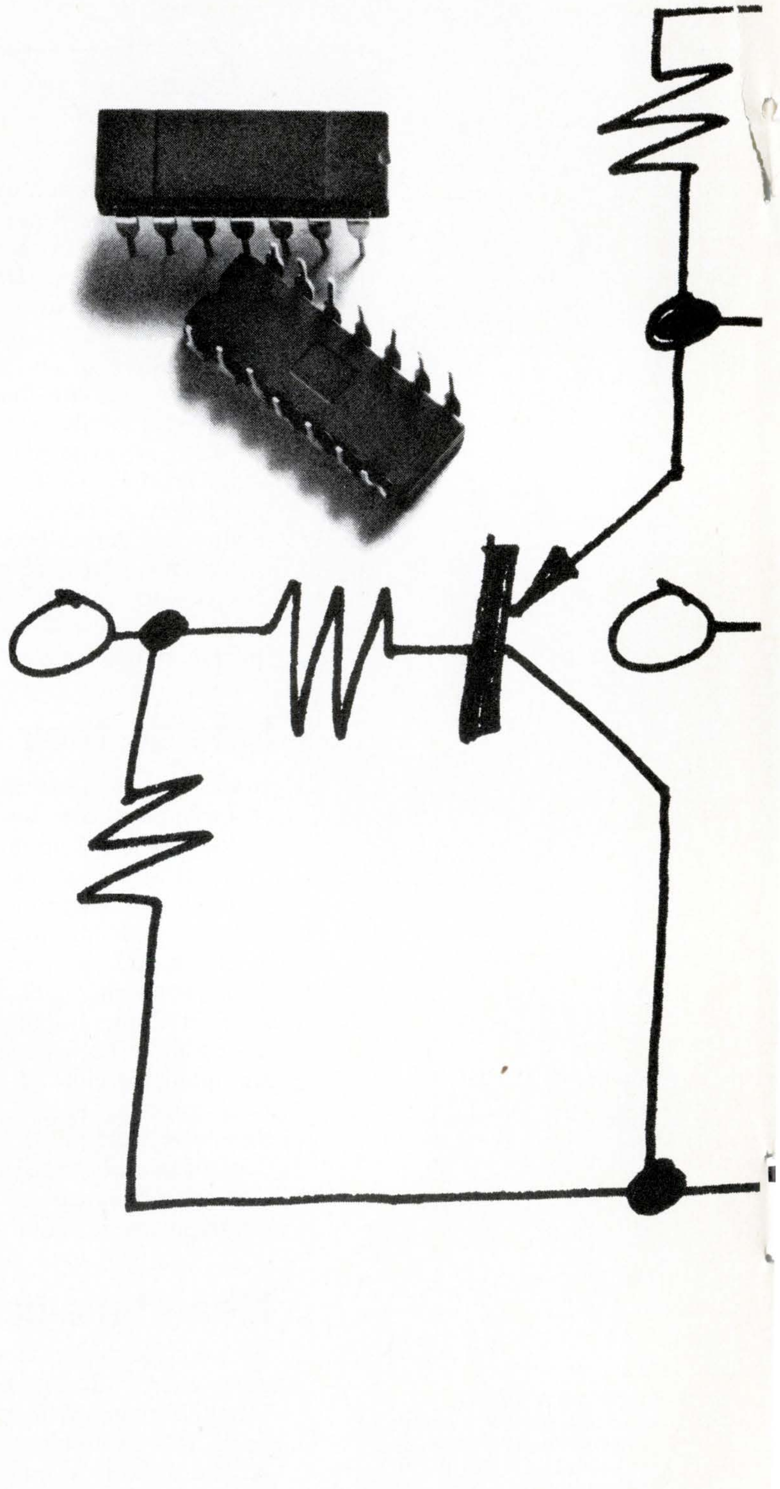
You can build a complete digital logic system with Fairchild's family of CTμL devices. We have gates, flip-flops, inverters and memory circuits. A dozen different devices that make a computer easy to package. And, you'll need only about 80 percent as many packages as required with TTL.

You get out of it what you put into it.

The key CTμL characteristic is non-saturating logic. That means you get fast gate propagation delay (typically 3nsec) with slow rise and fall times (typically 6nsec). So, there's no need for transmission lines or complex packaging. You can build an entire computer with normal two-sided circuit boards. Also, CTμL can handle signal swings as large as 3V. It also provides typical noise immunity of 500mV.

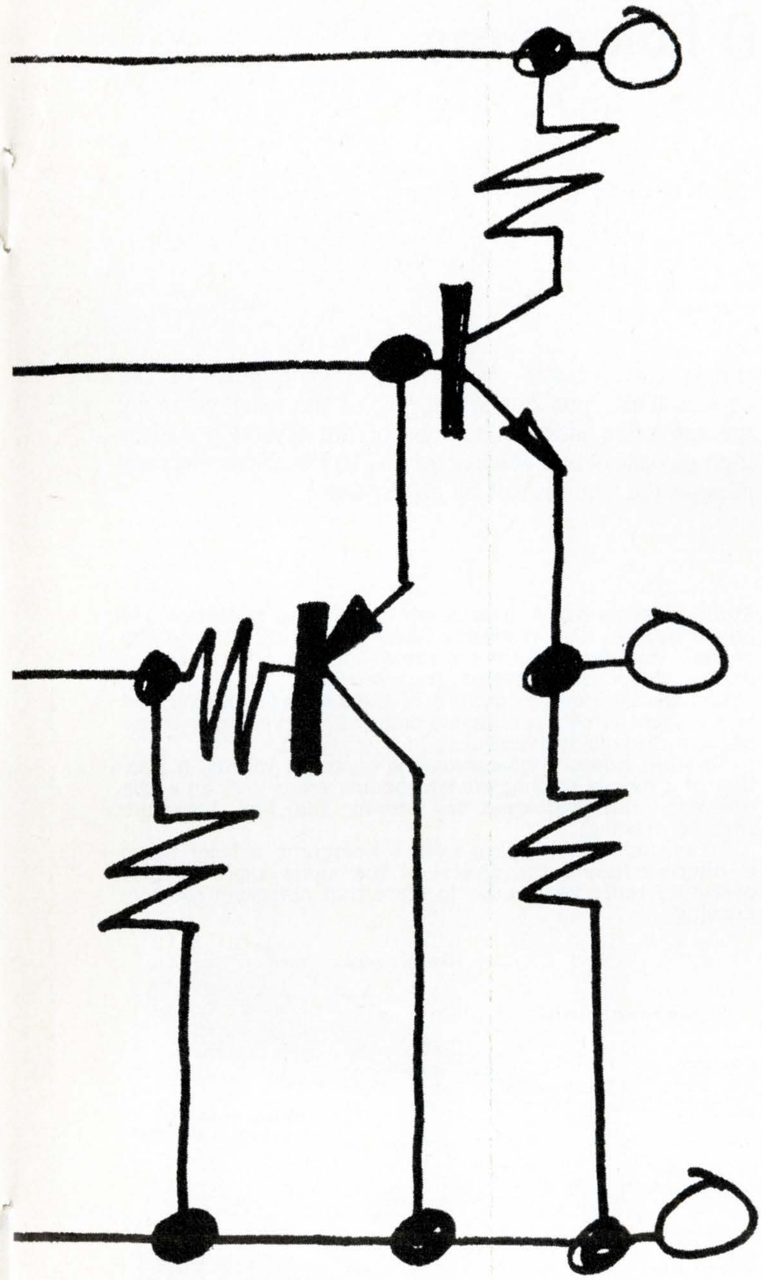
What we'll do for an encore:

MSI CTμL will be out before the year ends. CTμL-II will be out even sooner, offering improvements like gate propagation delay of 1.5nsec. (typical, loaded) and a buffer and



The world's largest manufacturer

inverter with propagation delays of 5nsec, compared with 12nsec in standard CTμL. And, the new MSI and CTμL-II circuitry will interface beautifully with all these standard CTμL devices:



Device	Price (100-999)
9952 Dual NOR Gate	$1.25
9953 Triple AND Gate	1.25
9954 Dual Four-input AND Gate	1.25
9955 Eight-input AND Gate	1.25
9956 Dual Buffer	1.25
9957 Dual-rank Flip-flop	2.00
9964 Dual Three-input and Single-input AND Gates	1.25
9965 Quad Single-input AND Gate	1.25
9966 Quad Two-input AND Gates, one pair with OR-tie	1.25
9967 JK Flip-flop	2.00
9968 Dual Latch	2.00
9971 Quad Two-input AND Gates with OR-tied pairs	1.25
9972 Quad Two-input AND Gates, one pair with OR-tie	1.25

If you want CTμL-II in sample quantities, call Fairchild. If you want standard CTμL in production quantities, call a Fairchild distributor. He has everything you need to build any computer. Even a Computer.

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# of LSI admits there's another way:

EE UP TO DATE

Single crystal stores 1,000 holograms

New lithium niobate crystal shows promise as an "optical memory".

Holograms—photographic records made through a form of lensless photography—are best known for their ability to reproduce 3 D images. But, equally important, is their potential to store an enormous amount of information.

Now scientists at Bell Telephone Laboratories have discovered a single crystal that they can use as a new holographic material. The lithium niobate crystal can temporarily store up to 1000 different holograms. Such an "optical memory" could store information that could easily be retrieved or erased.

In operation, a single, cubical crystal of lithium niobate is placed on a rotatable platform. Functioning as a holographic plate, the crystal records the interference patterns of light waves as one laser beam is split into two parts (reference and object beams). The reference beam shines directly on the crystal, while the object beam shines through a transparency of the object being stored and strikes the crystal. After a hologram is formed through the one-centimeter thickness of the crystal in one direction, the crystal is rotated a fraction of a degree for each new hologram to be stored.

A lithium niobate crystal can store holograms because the laser beam frees enough electrons in the crystal to set up an internal electric field. This field causes a change in the refractive index of the crystal.

Because this change varies with the intensity of the laser light hitting the crystal, the crystal can record intensity variations of a reference beam interfering with an object beam in much the way that an ordinary holographic plate does. However, a holographic plate records this interference pattern as *permanent* changes in its transmission properties.

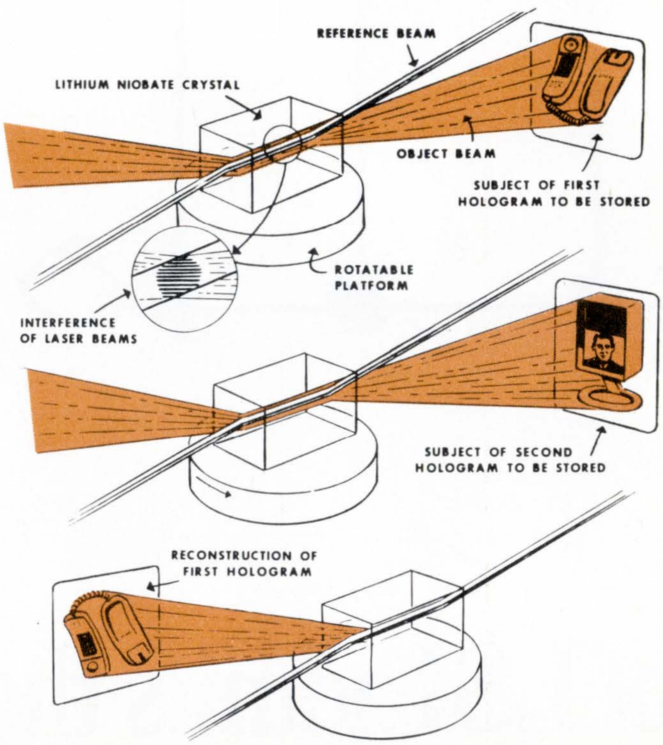
With lithium niobate, the interference pattern is recorded as *semipermanent* changes in the index of refraction through the thickness of the crystal. Holograms stored in a lithium niobate crystal can be erased by heating the crystal to 170°C. The crystal can then be used again and again.

When a laser beam reconstructs an image of an object stored in an ordinary holographic plate, part of the beam is absorbed by the transmittance variations of the plate. This absorption accounts for a low efficiency (6%) in ordinary holographic plates. With lithium niobate, however, some parts of the reconstructing beam simply travel faster through different regions of the crystal. This "phase modulation" of the laser beam by the refraction index variations of the crystal produces high reconstruction efficiencies (42%) because virtually none of the beam is lost by absorption.

Storing holograms. A laser beam is split into reference and object beams. The reference beam shines directly on the crystal, while the object beam shines through a transparency of the object being stored (top drawing). The cut-away shows the interference pattern of the two laser beams that is recorded as semipermanent changes in the index of refraction through the thickness of the crystal.

To store a second hologram, the crystal is rotated a fraction of a degree so that the two beams enter it at an angle different from that used for storing the first hologram (middle drawing).

To reconstruct an image from a hologram, a laser beam is directed toward the crystal at the same angle as that of the reference beam used to store that hologram (bottom drawing).



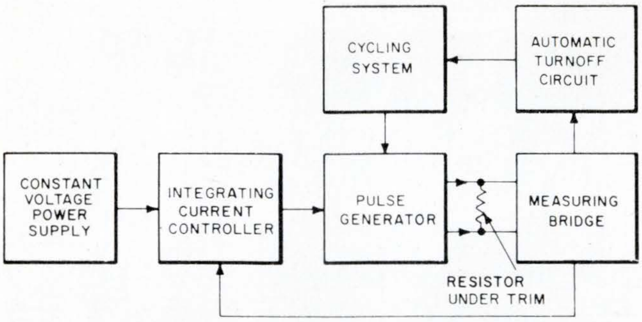

SEE US AT NEPCON BOOTHS 351-353
FEBRUARY 11-12-13
ELCO

Electric discharge trims glaze resistors

Non-destructive process decreases resistor value.

Palladium oxide glaze resistors give you the advantages of fast economic production with reliable results. However, in most cases the resistors must be given a final adjustment to achieve the proper value for the intended application. Normally these glaze resistors are trimmed by abrasive disks or wheels or even lasers.

Most widely used is the air abrasive method in which portions of the resistor are cut away until the desired value is reached. The methods mentioned all require accurate positioning and accessibility to the surface of the resistor for trimming; and, they are basically destructive in that portions of the resistor are removed and some fresh resistor surface is left exposed. Also, with these methods, trimming is normally done prior to the final encapsulation of the resistor.



With an electric discharge method developed at IBM's Components Division in Hopewell Junction, N.Y., you don't have to mechanically position the resistor and you need not have access to the resistor's surface. The method is non-destructive, and after trimming, the resistor is left intact as deposited.

Trimming is done by applying a series of high-voltage, short duration pulses directly to the resistor's terminals. The attendant high electric fields affect the resistor without destroying the resistor material, and result in a **decrease** in resistor value. By choosing the way the field is applied to the resistor you can control the amount and rate of **decrease.**

The resistor value may be **increased** if a large amount of energy is dissipated locally in the resistor material. The electric discharge destroys the material in this area, making it non-conductive and causes the overall resistance value to **increase.**

Some material characteristics, such as Temperature Coefficient of Resistance (TCR) and thermal sensitivity, react differently after trimming. The differences appear to be a function of the formulation used.

Non-destructive trimming of resistors is done by applying a series of high-voltage, short duration pulses to the resistor. Both the amplitude and cutoff are controlled automatically by circuitry which measures the resistor during trimming.

The dice are loaded—automatically

Semiconductor dice handling has been just about fully automated with a new system built by Transistor Automation, Woburn, Mass. According to the makers, their System 1000 virtually eliminates all manual handling of dice from probing through die attach.

The new system has three major parts. The first, a wafer prober, interfaces with the user's test equipment and data logging to classify all devices on the wafer. The wafer is then diced, and the dice placed, one by one, on a continuous strip of flexible "die tape." This tape can be rolled up for storage or for transportation to the third station. Here, the dice are unloaded fom the tape for die attach.

Besides the handling ease, other benefits are claimed. A permanent film record of device location on the wafer is provided at step one. This should help to pinpoint failure sources and boost yields. And, die losses should be cut down.

How much will this cost? About $55,000 says Transistor Automation Corp. Texas Instruments, Dallas, is the only taker thus far.

MOS IC takes video in, gives digital out

An unusual circuit developed by RCA accepts an analog video signal and has an ON output during sync and an OFF output at all other times.

This "sync separator" from RCA's Somerville, N.J. facility is a straight p-channel MOS device. According to an RCA source, the circuit was prototyped purely as an MOS feasibility model, and will not be sold as a catalog item or used in any RCA commercial products in the near future.

Why MOS? The spokesman would only say that he didn't know whether the device could be made in bipolar form and whether any firms were pursuing this. No further details are available at this time.

Hybrid LSI is repairable

Progress in digital system density depends just as much on packaging as it does on the chip itself.

With this in mind, the Research and Development Laboratories of Fairchild Semiconductor have developed a universal approach to hybrid design. Amenable to bipolar, MOS and other chip technologies, the technique uses a compatible multilayer metallization for both the chips and the substrates. Among the results: high-density packaging, minimal thermal interface problems, easy chip replacement, and relatively low cost.

To demonstrate this multilayer metal substrate, the firm constructed a dual 4-bit arithmetic unit containing 26 monolithic ICs and a 16 k-bit random access memory with 304 monolithics.

Dense duos

The base of the substrates are flat alumina cards; sizes range from 1 x 2 in. to 4 x 5 in. On the smaller unit, a density of up to 3 ICs per cm^2 is achievable. With the 4 x 5 card, density is 6 to 9 ICs per cm^2— where typical IC size is 90 x 100 mils^2. Maurice Dumesnil, member of the technical staff at Fairchild R&D and co-inventor of the technique, says previous state-of-art density in hybrids was about one IC per cm^2, on cards measuring 1 x 1 in.

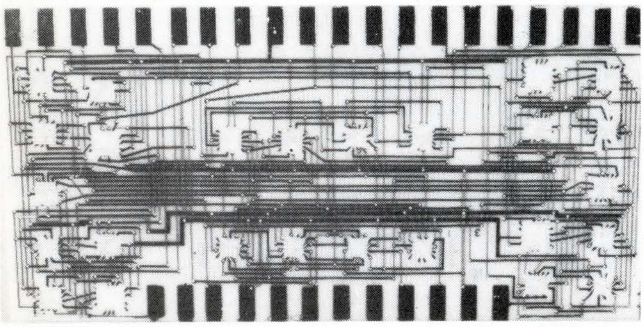
Only a single high-conductivity metal—aluminum—is used in the hybrids. This eliminates potential metal interface failures, such as those encountered when both aluminum and gold are used. It also removes the problem of different thermal coefficients of expansion. Moreover, when dissimilar materials are present, bonds are weakened by the interdiffusions that occur.

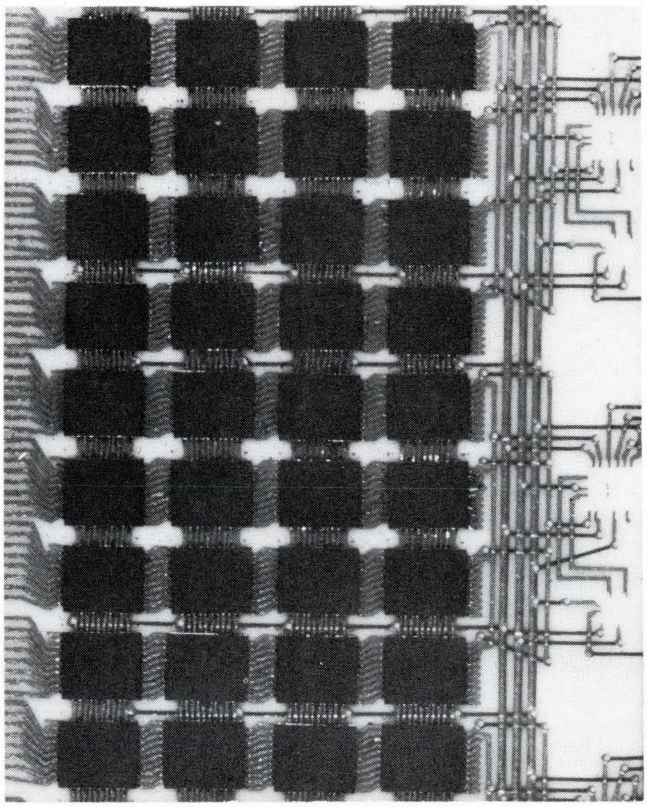
To cut costs, the substrate's two metal layers are formed on one side only; this obviates the need for drilling holes through the ceramic. The two metal layers are separated by a glass layer.

Aluminum beam lead devices on the monolithics ease alignment and permit nonthermal bonding. For repairs, simply snip the beams and replace faulty chips. Again, the use of aluminum here—instead of the gold beam lead system Fairchild experimented with earlier—is consistent with the one metal approach.

A company spokesman predicts the hybrid multilayer metallized substrate will be incorporated in catalog products later this year. He expects the first commercial entries will be in memory products, both bipolar and MOS. Dumesnil and associate John Schroeder will present a paper on the techniques at next month's ISSCC meeting in Philadelphia.

Dynamic duo. Hybrid LSI units from Fairchild use two-layer metallization on the substrate to achieve high packaging density. Below is dual, 4-bit arithmetic IC; it contains 26 monolithics on a 1 x 2 in. card. Subsystem at right is part of a 304-IC memory; shown are 36 beam-leaded storage chips (each is a 64-bit MOS memory) occupying an area of about 1100 x 600 mils^2.





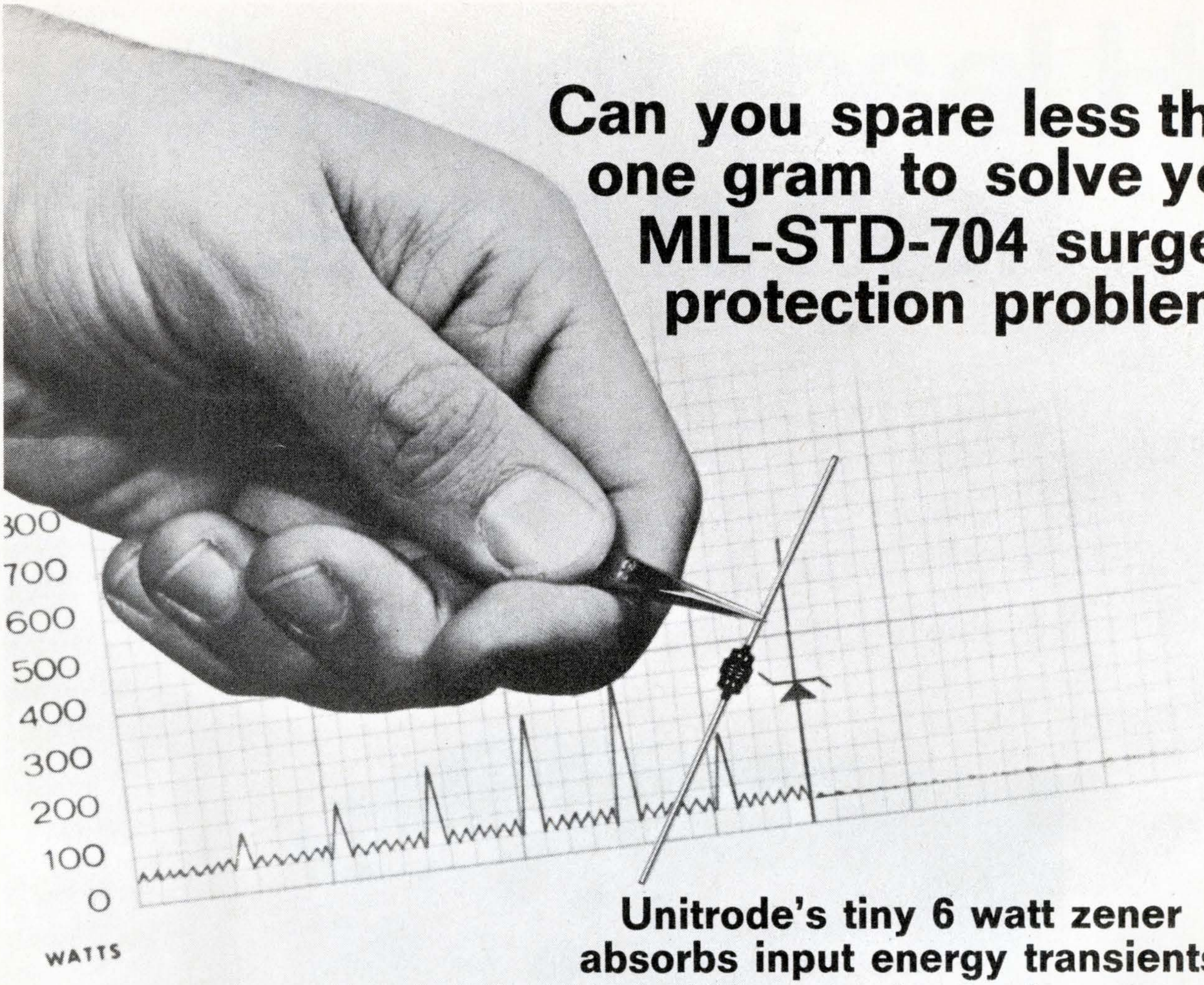
Metric committee formed

The USA Standards Institute has established a Metric Advisory Committee. The new committee is expected to lead whatever course of action this nation takes on the metric question.

It will discuss problems experienced by industry as a result of the metric conversion of other countries and will help to develop policies and programs that will aid in studies of metric conversion in the U.S. Specific as well as general problems involved in metric conversion will be explored and solutions developed.

Louis Polk, a director of the Institute, will chair the committee. Executives from some of the country's largest manufacturing concerns will serve on the Committee.

Can you spare less than one gram to solve your MIL-STD-704 surge protection problems?



Unitrode's tiny 6 watt zener absorbs input energy transients up to 1000 watts for 1 microsecond.

- **350 watt surge capacity is 600% more than conventional 10 watt . . . 35% more than a 50 watt.**
- **Weighs less than 1 gram . . . 1/10th of a conventional 10 watt . . . 1/20th of a conventional 50 watt.**
- **Available in 10 watt rating, stud mounted.**
- **6.8 to 100 volt range**
- **low leakage current.**
- **Electrical characteristics remain stable throughout life, exceeding the environmental requirements of MIL-S-19500.**

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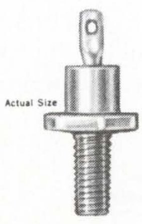
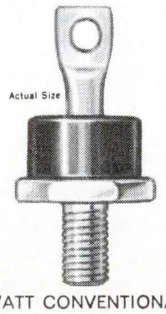
This one won't do it . . .



10 WATT CONVENTIONAL

This one won't do it, either . . .

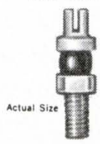


50 WATT CONVENTIONAL

But this one will,

6 WATT UNITRODE

And so will this one . . .



10 WATT UNITRODE

Because it is built like this on the inside.

Hard glass fused to silicon surface

Terminal pins metallurgically bonded directly to silicon

So . . . better get yourself a complete set of specs.

Check off the reply card number now or call Dave Green COLLECT at (617) 926-0404

Circle 11 on Inquiry Card

E-H leads the pulser field in price...

E-H MODEL 137

and performance.

If you decide to buy a pulser just because it costs less and it solves your immediate problems, your problems may have just begun. Before you know it, that pulser has become obsolete and you're out shopping for another one. Need a better solution? E-H offers it.

Every E-H instrument is designed to give you the most advanced solution to your problems today. And to take care of tomorow's problems, each instrument has a built-in margin of performance you never see in the written specs. That's the extra that makes an E-H pulser extra useful in years to come.

Here, for example, is one of our newest problem solvers — the **E-H Model 137.** This all solid-state pulser has rep rates of 10 Hz to **100 MHz,** pulse amplitude of up to $\pm$**5V** into 50 ohms ($\pm$10V open circuit), DC offset of up to $\pm$**5V** into 50 ohms ($\pm$10V open circuit), transition times of $<$**2ns** to 200 μs, leading and trailing edges independently variable up to ratio of **10:1,** external drive requirements **1.2V pos or neg.** Price, **$1,950.** f.o.b. Oakland.

Call your E-H representative for a demonstration now. And if our new Model 137 doesn't quite fit your needs, ask about E-H's eighteen other advanced problem solvers.

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In Japan: Iwatsu Electric Co., Ltd., No. 710, 2-Chome Kugayama Suginami-Ku, Tokyo, Japan

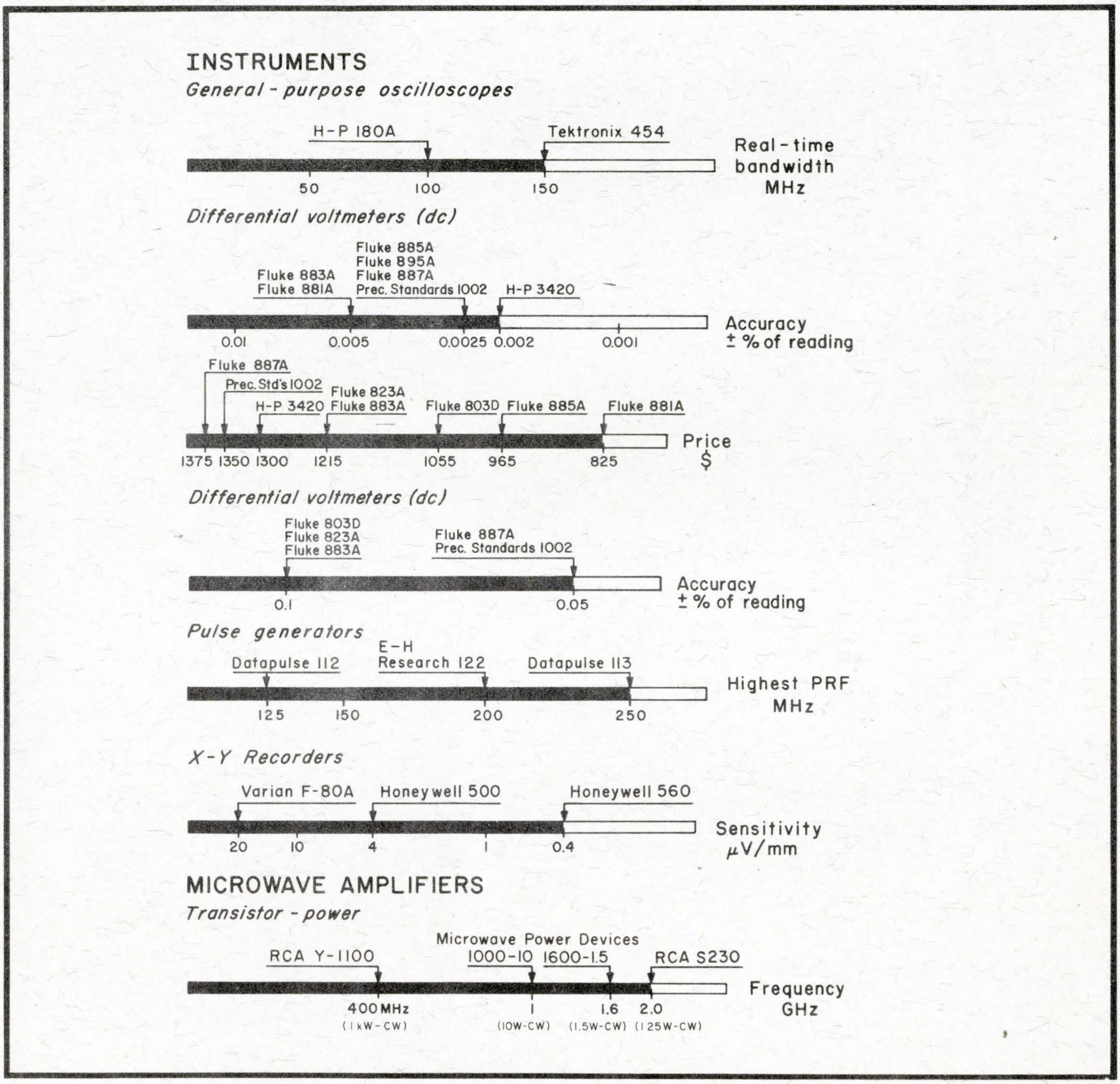
EE FOREFRONT

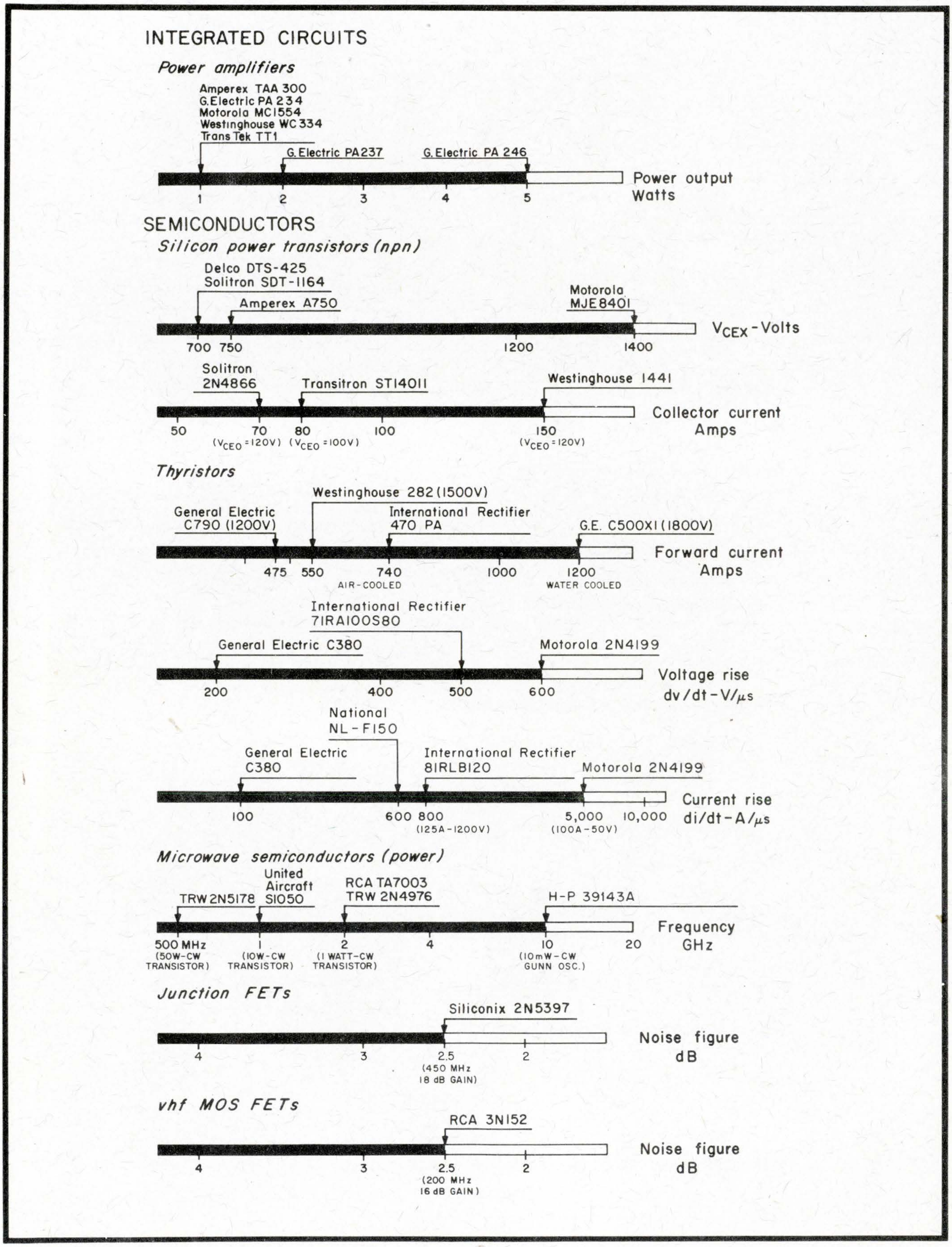
The EE Forefront is a graphical representation of the practical state of the art. You will find here the most advanced components and instruments in their class, classified by the parameter in which they excel.

A word of caution

Keep in mind the tradeoffs, since any parameter can be improved at the expense of others. If there is no figure-of-merit available, we either include other significant parameters of the same products, or we provide additional bar graphs for the same products.

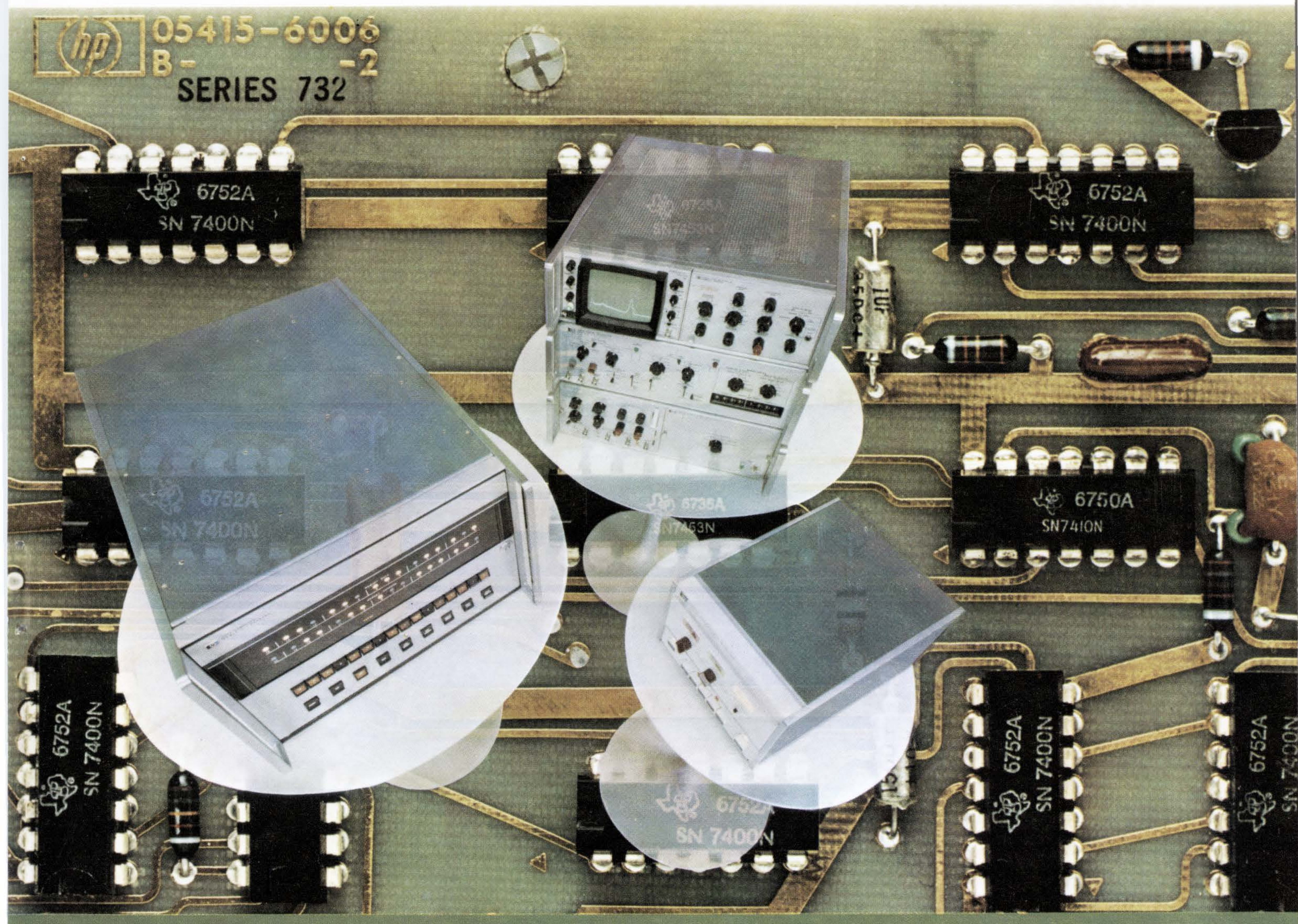
Do not use these charts to specify. Get complete specifications first, directly from the manufacturers.




INTEGRATED CIRCUITS
Power amplifiers
Amperex TAA 300
G.Electric PA 234
Motorola MC1554
Westinghouse WC 334
Trans Tek TT1
G. Electric PA237
G. Electric PA 246
1
2
3
4
5
Power output
Watts
SEMICONDUCTORS
Silicon power transistors (npn)
Delco DTS-425
Solitron SDT-1164
Amperex A750
Motorola
MJE8401
700 750
1200
1400
VCEX - Volts
Solitron
2N4866
Transitron ST14011
Westinghouse 1441
50
70
80
100
150
(VCEO = 120V)
(VCEO = 100V)
(VCEO = 120V)
Collector current
Amps
Thyristors
Westinghouse 282 (1500V)
General Electric
C790 (1200V)
International Rectifier
470 PA
G.E. C500X1 (1800V)
475
550
740
1000
1200
AIR-COOLED
WATER COOLED
Forward current
Amps
International Rectifier
71RA100S80
General Electric C380
Motorola 2N4199
200
400
500
600
Voltage rise
dv/dt - V/μs
National
NL-F150
General Electric
C380
International Rectifier
81RLB120
Motorola 2N4199
100
600 800
(125A-1200V)
5,000
(100A-50V)
10,000
Current rise
di/dt - A/μs
Microwave semiconductors (power)
United
Aircraft
TRW 2N5178
S1050
RCA TA7003
TRW 2N4976
H-P 39143A
500 MHz
(50W-CW
TRANSISTOR)
1
(10W-CW
TRANSISTOR)
2
(1 WATT-CW
TRANSISTOR)
4
10
(10mW-CW
GUNN OSC.)
20
Frequency
GHz
Junction FETs
Siliconix 2N5397
4
3
2.5
(450 MHz
18 dB GAIN)
2
Noise figure
dB
vhf MOS FETs
RCA 3N152
4
3
2.5
(200 MHz
16 dB GAIN)
2
Noise figure
dB

TTL Trends

from Texas Instruments



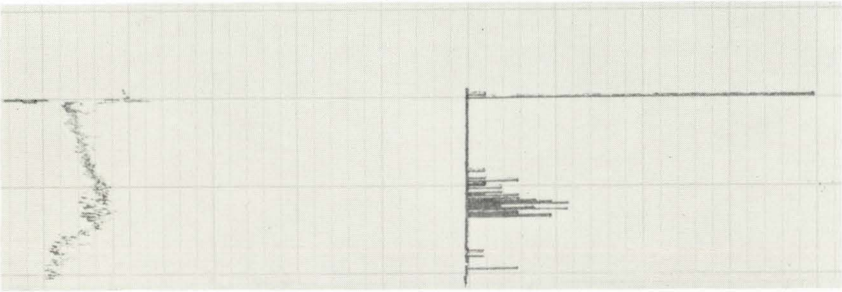
At Hewlett-Packard, TTL from TI is taking over the tough jobs... in measurement... in computation... in analysis. The following pages tell why, and show how TTL is helping HP better serve tomorrow's customer needs—today!

TI helps Hewlett-Packard...

head off heart attacks before they happen

Recent events have focused attention on the "Cardiac Intensive Care Unit"—one of modern medicine's newest weapons in the battle against heart disease. It is here that diagnosis and prompt treatment enables doctors to effectively head off fatal coronaries before they happen. To serve this need, Hewlett-Packard developed the Model 7822A Arrythmia Monitor—first of a new generation of ultra-high-reliability, compact and low-cost medical instruments made possible with Series 74N TTL integrated circuits from TI.

This instrument "remembers" the normal heartbeat characteristics of a coronary patient, then compares each succeeding beat against the stored norm. If disturbances occur, it provides an immediate warning, enabling hospital personnel to effectively head off catastrophic heart attacks before they happen.



Selling for under $2,000, the HP 7822A uses fewer than 75 TTL plastic plug-in packages, neatly arranged on just four PC boards.

This simplicity underlies the inherent reliability of the instrument. Circuits such as SN7473N and SN7474N multifunction flip-flops plus MSI Counters, Shift Registers and Quad Latches greatly reduce the probability of failure.

And the rugged plastic package was proven—by months of actual hospital field trials and lab tests—to have outstanding durability. For example, one HP engineering testing program subjected the 7822A to 6 months of continuous operation under the most severe hospital environment conceivable: 45°C temperatures and 95-98% relative humidity. *Not a single IC failed during the entire 6-month period!*

Typical use of HP 7822A is shown here. As a focal instrument in today's "Cardiac Intensive Care Unit," it is an important new aid in the prompt detection and treatment of potentially fatal coronaries.

at Hewlett-Packard

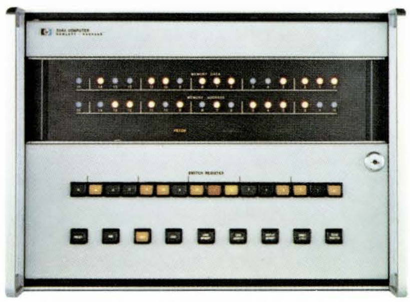
TTL takes over the tough jobs

Recently, three divisions of Hewlett-Packard faced three difficult – but totally different – design challenges. Independently, all three solved their problems with Series 74N TTL integrated circuits from Texas Instruments. Here's what happened:

In measurement – many exclusive MSI functions helped drastically reduce package count and interconnections, giving life-saving reliability to HP's new 7822A Arrythmia Monitor.

This instrument "remembers" the normal heartbeat characteristics of a coronary patient, then compares each succeeding beat against the stored norm. If disturbances occur, it provides an immediate warning, enabling hospital personnel to effectively head off castastrophic heart attacks before they happen.

In computation – Over 290 TTL circuits – including high speed Series 74H units – helped HP to halve the size and trim the cost of it's lowest-cost computer by another 31%. The Model 2114A accomplishes all this while retaining 2.0 μsec memory performance and a wide range of input/output options.



In analysis – HP cracked a two-year design deadlock when they zeroed-in on TTL. After two state-of-the-art logic approaches were explored without success, HP engineers tried TTL and that turned the trick. The Model 5400A Multi-Channel Analyzer features 100 MHz clock rate, 1024 channels, and a 2.2 μsec memory . . . all this for $9950. Nearly 400 Series 74N ICs make it possible.

In yet another instance, the same division significantly reduced development time on the Model 5480A Signal Averager by building on experience gained with the 5400A.

TTL added values

These successes brought bonus benefits. Other HP divisions are now designing new instruments around TTL and achieving lower development expense, better performance, reduced overall costs, and improved reliability.

This mushrooming usage of TTL also brings to HP the advantages of volume purchasing . . . quantity discounts and assured availability. Furthermore, inventory costs are held down because one family of ICs now takes the place of several.

What are your problems? Take a tip from Hewlett-Packard and design with TTL from TI. You'll likely end up with a better product at a more attractive price – and probably increase your profits to boot!

TEXAS INSTRUMENTS
INCORPORATED

crack a two-year design deadlock

HP 5480A Signal Averager helps researchers pull weak signals out of overwhelming noise.

HP 5400A Multi-Channel Analyzer typifies sophisticated new generation of analytical instruments — made possible by TTL integrated circuits.

HP engineers liked what they saw when they investigated Series 74N TTL. They had already spent two years trying to develop the 5400A Multi-Channel Analyzer... an advanced instrument which would feature the fastest known A/D converter (100 MHz clock rate), 1024 channels with 10^6 counts per channel, and a 2.2 μsec memory cycle. Two state-of-the-art custom logic approaches had been explored without success.

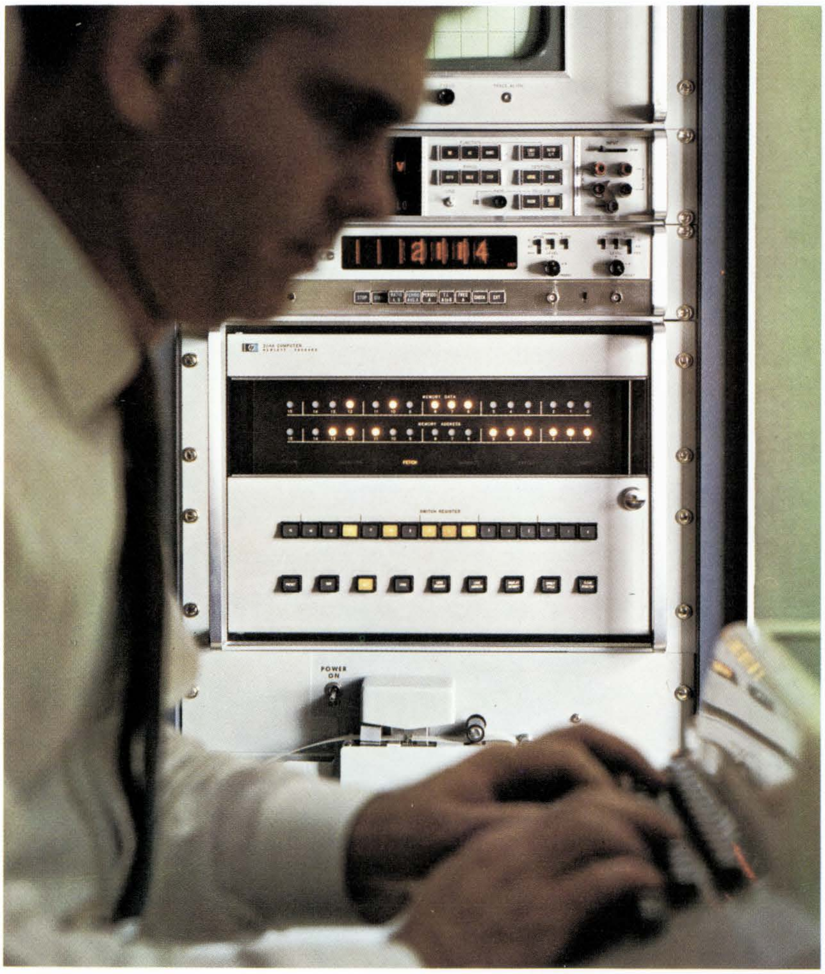
With Series 74N TTL, HP found a broad selection of standard multifunction circuits, a reliable plastic package, volume availability, and low cost per function – important considerations in a design using almost 400 IC packages and yet carrying a price tag of only $9950.

Performance-wise, the 74N TTL line proved to have almost ideal characteristics — speed, fan-out and noise immunity.

One success leads to another. Experience with TTL in the Model 5400A paved the way for its use in the Model 5480A Signal Averager. This new instrument enables scientists to see low-level repetitive signals literally buried in extraneous noise. It also features a 1000-word, 24 bit-per-word memory, and 100,000-sample-per-second sweep rate.

Again, use of Series 74N TTL logic substantially shortened the overall design cycle. Although development of the 5480A Signal Averager started two years later than the Model 5400A, both reached production at virtually the same time.

trim the cost of low-cost computers by another 31%



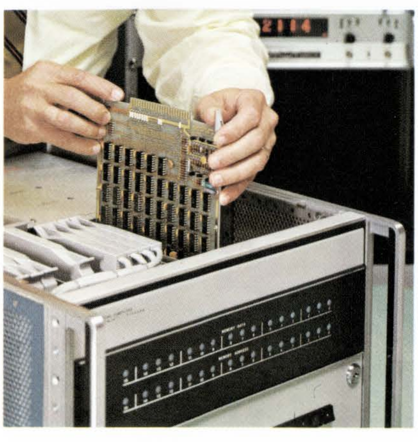
Cut cost by another 31 percent... reduce size by 50 percent...yet retain virtually all the speed and performance capabilities of the existing HP lowest-cost model. This tall order faced HP engineers when they set out to design a desk-top, third generation computer to serve scientific and industrial markets. Specifically, they wanted the new Model 2114A to sell for less than $10,000.

An analysis of various logic types soon cut the problem down to size. Comparison revealed that TI's Series 74N TTL cost less than half as much and consumed only one-third the power of the logic family then considered standard. Equally important, there were no serious interface problems between TTL and the earlier logic. This assured compatibility with a wide variety of existing HP input/output peripherals and companion accessory equipment.

In the area of performance, HP engineers were pleased to find that standard and high-speed TTL logic could more than fill the bill. And all circuits were available in the same plug-in plastic package.

Furthermore, the single voltage requirement of both standard and high-speed TTL further reduced power supply requirements. And noise margin and other characteristics were also compatible.

Finally, a large selection of MSI functions was readily available. Among more than 250 IC's in the Model 2114A are such key circuits as 7483N Four-bit Full Adders and 7475N Quad Latches. These paved the way to important package count reductions, resulting in lower cost, smaller size and improved reliability.



General lab use typifies new low-cost applications for HP 2114A Computer — made possible by TTL technology. Desk-top compactness and easy accessability are IC bonus features.

EE SHORTS

David and Goliath. Control Data Corp. has sued IBM for treble damages. Charges are that IBM violates antitrust laws and engages in monopolistic practices. IBM will "defend the suit vigorously".

Separate software. By July 1, IBM will restructure support prices. A possible result: such "free" services as maintenance, software, training, debugging, and updating will be priced separately. This will lower hardware costs.

Supercool. A Bell Labs aluminum-niobium-germanium material becomes superconductive when cooled with liquid hydrogen, at about 30°F warmer than with liquid helium, which is much more expensive.

Gigabits. An Ampex experimental random-access memory system stores 50 billion bits on a 10½-inch reel of tape. The system is based on videotape recording techniques.

Congressional fallout. Congress passes the Radiological Control Act. It directs the HEW Secretary to administer standards for all electronic products.

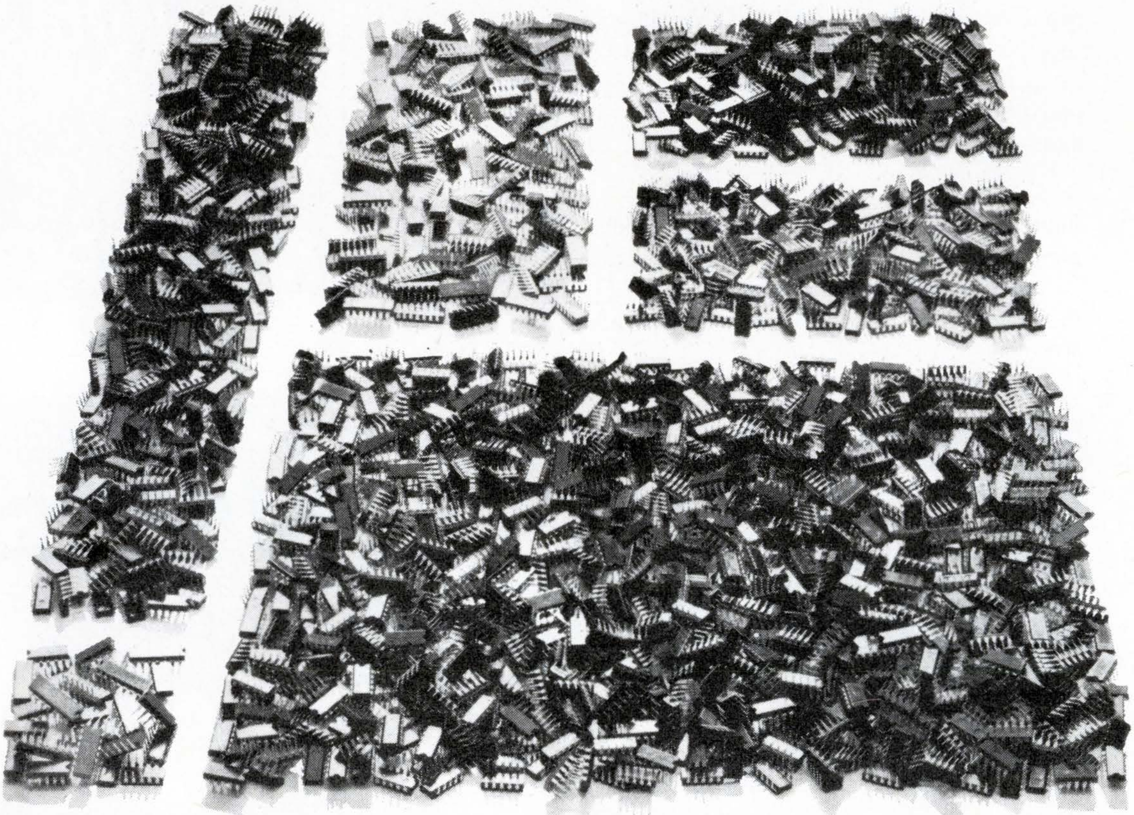
No compensation. Motorola will offer a low-input-current, high-slew-rate compensationless IC op-amp by July. Currently, only National Semi, Radiation, Inc., and Fairchild compete.

Tuned in. A new phase-locking technique, which permits user-tuning, will be incorporated in an upcoming Signetics linear IC.

Inductorless regulator. Vidar Corp. has taken the filter from in front of a regulator and put it directly off the power transformer secondary through rectifiers to switching transistors. Data acquisition products using this principle will be available shortly.

Microwave hothouse. Engineers at Raytheon Corp. looking for improved methods of cooling microwave tubes, have uncovered a potential bonanza. They have prototyped a device, no larger than a coffee can, which can reportedly heat an entire home economically.

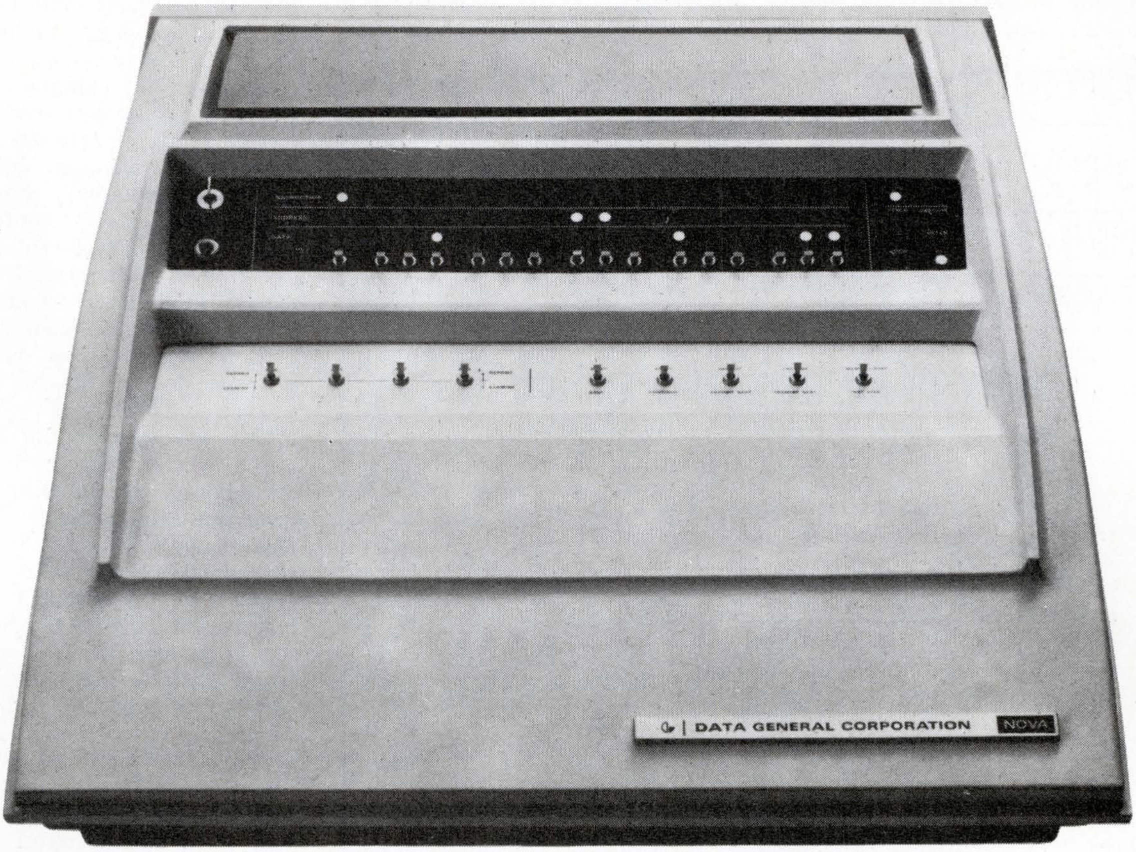
Fairchild told everyone what MSI could do.



Ever since we introduced medium scale integration in 1967, we've been talking about the systems approach to computer design. Basic, compatible fundamental building blocks that do more jobs than a hundred Integrated Circuits.

Versatile circuits that function like shift registers, counters, decoders, latching circuits, storage elements, comparators, function generators, etc. We said we had enough MSI device types to build more than half of any digital system you could design. An imaginative company in Boston took us up on it.

We're glad someone was listening.



Data General Corporation built a revolutionary computer with Fairchild MSI circuits. The building block approach allowed them to design and build the whole system in six months. And put it in either a desk top console (shown above) or a 5¼-inch high standard 19-inch rack mount package. The central processor fits on two 15-inch by 15-inch plug-in circuit boards.

Another board houses a 4,096-word core memory. A fourth board provides enough space for eight I/O devices. And there's still enough room left for boards that expand the memory capability up to 16K. Any circuit board can be changed in seconds, so the computer has zero down time. The NOVA is the world's first computer built around medium scale integration. The first general-purpose computer with multi-accumulator/index register organization. The first with a read-only memory you can program like core. The first low-cost computer that allows you to expand memory or build interfaces within the basic configuration. And the first to prove the price/performance economy of MSI circuitry: The NOVA 16-bit, 4K word memory computer with Teletype interface costs less than $8,000.

If you'd like more information on MSI, use the reader service number on the opposite page. For specs on the NOVA, use the reader service number below.

FAIRCHILD
SEMICONDUCTOR

FAIRCHILD SEMICONDUCTOR / A Division of Fairchild Camera and Instrument Corporation ■ 313 Fairchild Drive, Mountain View, California 94040, (415) 962-5011 ■ TWX: 910-379-6435

 Circle 15 on Inquiry Card

EE SPEAK UP

Yes, relays do fail

Sir:

"Why relays fail . . ." in your October 1968 issue (pp. 69-72) is a timely article covering common misconceptions regarding use of electromechanical relays by electronics engineers. Let us have more of the same on relays and their common abuses. We would like to supplement the article as it were by pointing out that the 100 mA failure area due to contact contamination is referred to by the military as "minimum current" and test requirements both above and below do not preclude contact failure in between as was explained in the article. Not all QPL crystal can relays require minimum current capability to be tested for, but can be had from QPL sources if proper part number is specified—e.g. M5757/10-017.

That contacts are not synchronized in action—especially for crystal can relays, where contact travel is minimal—is well taken. Bifurcated contacts that are available from some manufacturers would be better. Readers should be cautioned not to parallel contacts on the mistaken assumption that heavier currents can be switched. Also, screening relays to select those where contacts may appear to both "break-before-make" (form C) is dangerous. If the circuits are critical to "make-before-break" (form D), action screening will not uncover effects of wear, shock, vibration, drift with time and temperature. Bifurcated contacts where one side has a different resonant frequency than the other will result in less open contact time under contact bounce without the hazards mentioned.

Peter Amedeo
Reliability &
Maintainability Control
Grumman Aircraft
Engineering Corporation
Bethpage, L. I., New York

The mathematician and the transformer

Sir:

The article "The mathematician and the transformer" [**The Electronic Engineer,** Sept. 1968, p. 19], with output voltages in a series of powers of three recalls to me a design of mine made by PAECO Products of Palo Alto and sold to me at Hewlett-Packard in April 1961. PAECO's transformer #6-1592 has secondary voltages of 1/3, 1, 3, 9, and 27 V.

(Continued on page 30)

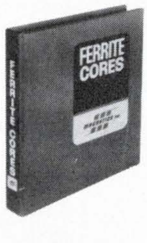
Let us throw you a curve

If you've problems with LC circuits, Magnetics' new Iso-Q contour curves speed ferrite pot core selection.

No more squinting at tangles of curves on log paper to find the ferrite pot core size you need. Magnetics' new Iso-Q contour curves let you zero in on your target size in seconds. We've plotted over 100 of these time-savers to handle more than 90% of normal design requirements. They're all contained in our new Ferrite Cores Catalog, first of its kind in the industry.

Magnetics' high purity ferrites cover frequencies up to 2 megahertz. Linear temperature coefficients on 750, 1400 and 2000 permeability materials are guaranteed from −30° to +70°C. Flat temperature coefficient on 2300 perm material is guaranteed from +20° to +70°C.

Magnetics' wide selection of ferrites comprises eight international standard sizes and five additional sizes—175 part numbers for design freedom. We can give you quick delivery from our large inventory that includes both gapped and ungapped cores in your most asked-for sizes. Of course, we provide one-piece clamping hardware for most sizes. Finally, we offer you a complete choice of tuning assemblies, bobbins and shapes—toroid, E, U and I.



Get your set of our new Iso-Q Curves. You'll like their curvilinearity.
Magnetics Inc.,
Butler, Pa. 16001

MAGNETICS inc. ®

Tape, Powder, Bobbin, Ferrite Cores • Laminations • Photo-etched Parts • Specialty Metals • Engineered Control Systems

Circle 17 on Inquiry Card

EE SPEAK UP

(*Continued from page* 28)

I was pleased to see your magazine publish the detailed mathematical explanation of the method of determining the proper connections for any desired voltage. So that your readers might not be left with the impression that there was no simple method of learning these connections, I have referred to my notes and offer the same example that was presented in the article. There is certainly an advantage in not having to refer to any tables.

Winding connections

The desired voltage can be expressed as the sum of terms which are powers of three with coefficients of +1, −1, or 0. These coefficients dictate whether the transformer windings are connected in phase, out of phase, or not at all.

The following algorith will quickly determine the sequence of the coefficients without reference to any tables. The desired number (voltage) is repeatedly divided by three, with the remainders saved. At any step where the remainder is 2, subtract 3 from the remainder and add 1 to the quotient at that step. The desired sequence of coefficients is given by reading the remainders in reverse order, from the last one to the first.

Example: Let the number (voltage) be 65.

Remainders

```
3 |65
   21  2 −3 = −1
   +1
3 |22
3 | 7          1
3 | 2          1
    0  2 −3 = −1
   +1
3 | 1
    0          1
```

The desired sequence is thus: 1, −1, 1, 1, −1

That is: 65 $=(3^4) - (3^3) + (3^2) + (3^1) - (3^0)$

or 65 = 81 − 27 + 9 + 3 − 1

and the windings are connected

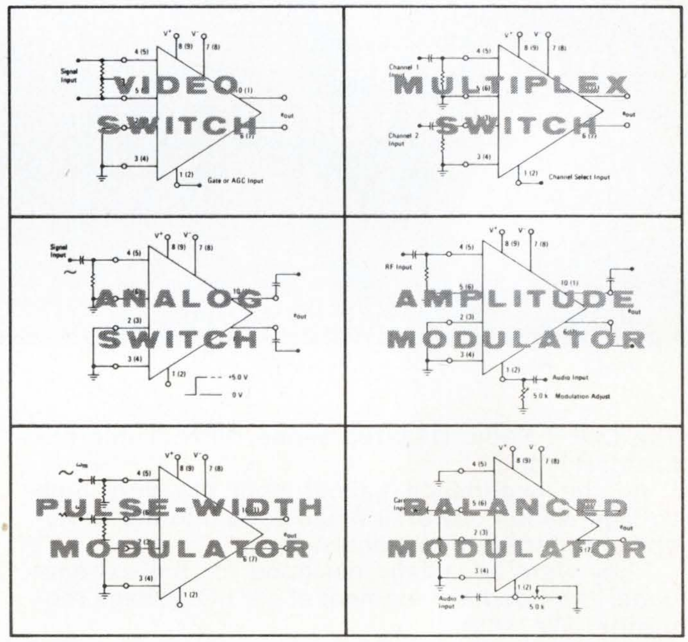
81v	27v	9v
in phase	out of phase	in phase

3v	1v
in phase	out of phase

Robert H. Youden
Director of Engineering
Miracle-Hill Electronics
Santa Clara, California

Letters to the editor are published at the discretion of the magazine. Please say so if you do not want to be quoted. Signed letters have preference over anonymous ones.

Our New MC1545 Is A Gated, Dual-Channel, Differential Inputs & Output DC Wideband Video Amplifier Integrated Circuit!



How versatile can one chip get?

So universally-usable is this new linear circuit, you can use it as a video switch, sense amplifier, multiplexer, modulator, FSK (frequency-shift-keying) circuit, limiter, AGC circuit, or pulse amplifier . . . to name just a few typical applications.

To make it even more universally usable, we've priced it at just $5.50 (100-up). And, that's for a full-temperature-range device – in the 10-pin TO-5. It's also available in the dual in-line ceramic package and ceramic flat pack.

You can use the new MC1545 in a wide variety of equipment, too; like C.A.T.V. and Closed-Circuit TV, because of its excellent wideband characteristics (75 MHz, typ) and its gate-controlled, two-channel amplifier. Other uses include computer memory systems, communications systems and instrumentation.

Here are some of the features that make it all possible:

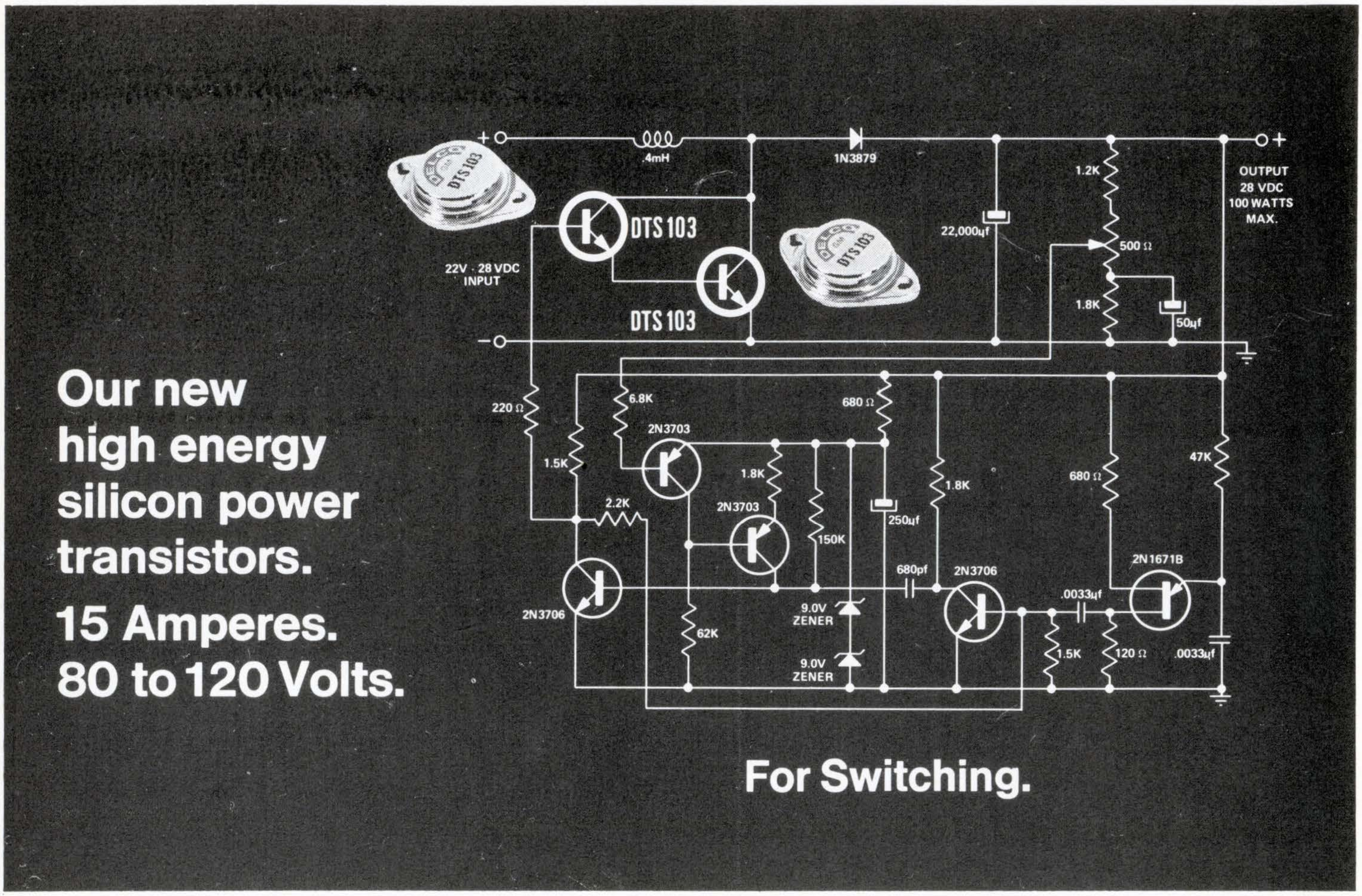
- 20 nSec (typ) channel-select time.
- Differential inputs and output.
- High Input Impedance – 10 K ohms (typ)
- Low output impedance – 25 ohms (typ)

To prove to yourself that MC1545 is the *Best Wide-band Amplifier Yet,* send for our data sheet.

–where the priceless ingredient is care! **MOTOROLA** *Integrated Circuits*

MOTOROLA SEMICONDUCTOR PRODUCTS INC./P.O. BOX 20912/PHOENIX, ARIZONA 85036

Circle 19 on Inquiry Card

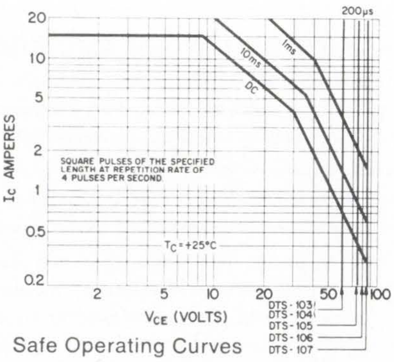


The Delco Radio DTS-100 series. NPN. Triple diffused. Rugged.

All the experience gained from our very high voltage silicon power line has gone into the development of these new transistors.

They were especially designed for the extreme under-the-hood environment of our I.C. voltage regulator. We found these devices ideal for applications requiring high efficiency switching or high power amplification.

The Delco triple sequential diffusion gives the DTS-100 series the high energy reliability that's needed for very tough switching jobs—resistive or inductive. The 28-volt shunt regulator above, for example, is amply handled by the DTS-103 (V_{CEX} of 80 volts). For complete data on this circuit, ask for our application note No. 42.



Safe Operating Curves

In the direct coupled audio amplifier above right, the DTS-107 displays the excellent frequency response, gain linearity and transconductance of this family. This circuit is covered in our application note No. 43.

Our solid copper TO-3 package provides maximum thermal capacitance to absorb peak power pulses. Its low thermal resistance (0.75°C/W Max.) assures the extra reliability you expect from Delco.

Like more information? Just call us or your nearest Delco Radio distributor. All our distributors are stocked to handle your sample orders.

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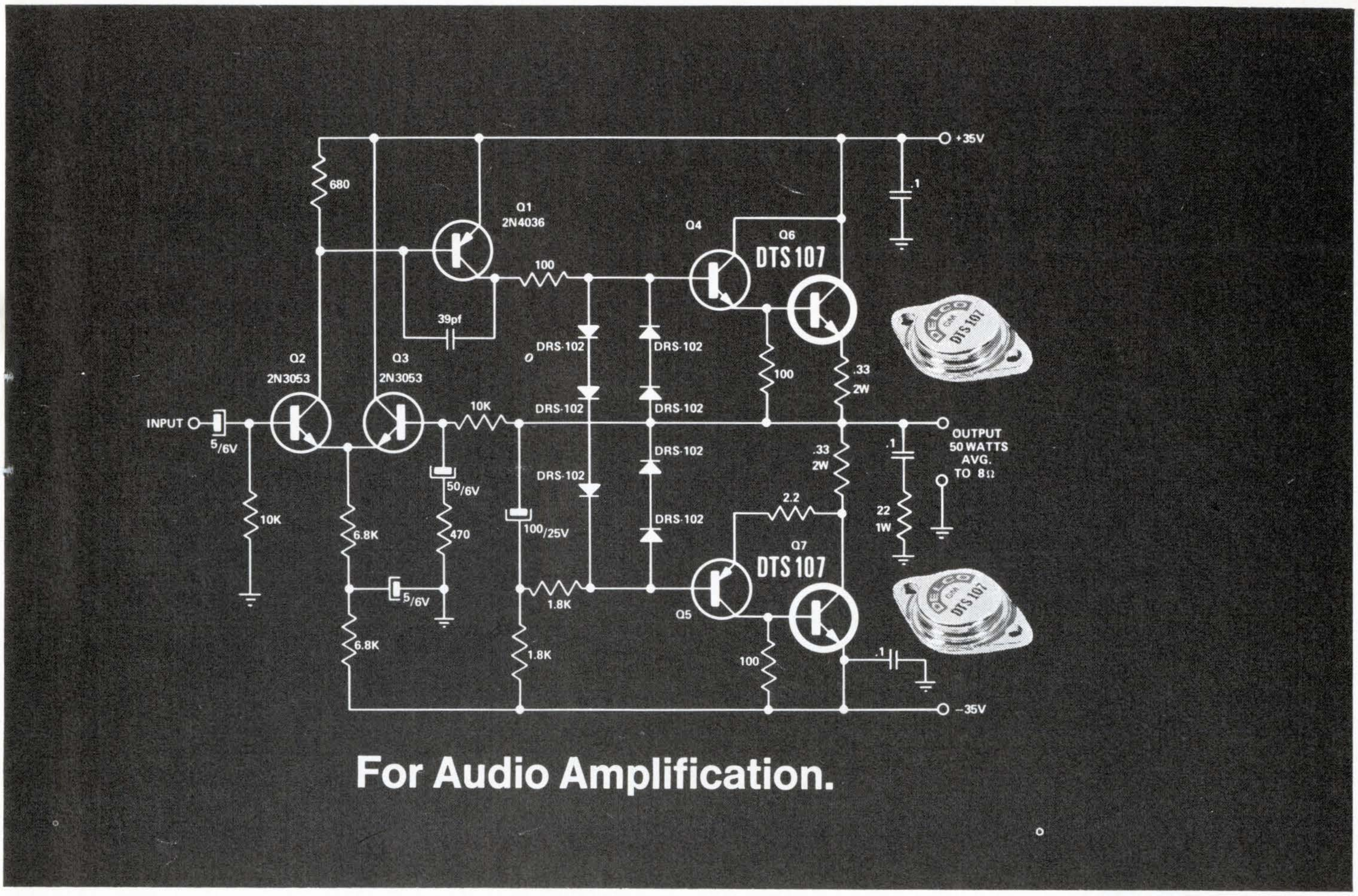

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EE CALENDAR

JANUARY

12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Jan. 21-23: Reliability Symp., Palmer House, Chicago, Ill. Addtl. Info.—J. E. Condon, Office of Reliability & Quality Assurance, NASA Hdqs., Washington, D. C.

Jan. 22-24: Hawaii Int'l Conf. on System Sciences, Univ. of Hawaii, Honolulu, Hawaii. Addtl. Info.—F. F. Kuo, Dept. of EE, 2565 The Mall, Univ. of Hawaii, Honolulu, Hawaii 96822.

Jan. 26-31: Winter Power Meeting, Statler Hilton Hotel, New York, N. Y. Addtl. Info.—J. W. Bean, Amer. Elec. Pwr. Svc. Corp., 2 Bdwy., New York, N. Y. 10004.

Jan. 28-31: Int'l Symp. on Information Theory, Nevele Country Club, Ellenville, New York. Addtl. Info.—David Slepian, Dept. of Transportation, Washington, D. C.

FEBRUARY

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Feb. 2-7: ASTM Winter Meeting, Denver Hilton Hotel, Denver, Colo. Addtl. Info.—American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

Feb. 10-11: Transducer Conference, Washingtonian Motel & Nat'l Bur. of Standards, Washington, D.C. Addtl. Info.—H. P. Kalmus, Harry Diamond Labs, Dept. of the Army, Washington, D.C. 20438.

Feb. 11-13: Aerospace and Electronic Systems Winter Conv. (WINCON), Biltmore Hotel, Los Angeles, Calif. Addtl. Info.—Roy Gregory, Northrop Nortronics, 1 Space Park, Palos Verdes Peninsula, Calif. 90274.

Feb. 12-14: Nat'l Meeting on Composite Materials: Testing and Design, Jung Hotel, New Orleans, La. Addtl. Info.—American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

Feb. 19-21: Int'l Solid State Circuits Conf., Univ. of Penna. & Sheraton Hotel, Philadelphia, Pa. Lewis Winner, 152 W. 42nd St., New York, N. Y. 10036.

Feb. 21: 10th Annual West Coast Reliability Symp., Century Plaza Hotel, Beverly Hills, Calif. Addtl. Info.—Robert H. Anderson, TRW Systems, Redondo Beach, Calif. 90278.

MARCH

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March 5-7: Particle Accelerator Conf., Shoreham Hotel, Washington, D. C. Addtl. Info.—E. H. Eisenhower, Ctr. for Radiation Res., NBS, Washington, D.C. 20234.

March 24-27: IEEE Int'l Conv. & Exhbt., Coliseum & N. Y. Hilton Hotel, New York, N. Y. Addtl. Info.—J. M. Kinn, IEEE, 345 E. 47th St., New York, N. Y. 10017.

'69 Conference Highlights

WESCON—Western Electric Show and Conv., August 19-21; San Francisco, Calif.

IEEE—Institute of Electrical and Electronics Engineers Int'l Convention & Exhibition, March 24-27; New York, New York.

Call For Papers

October 22-24, 1969: Systems Science and Cybernetics Conf. Submit abstracts of about 1000 words before **April 15, 1969** to Hugh A. Raymond, Valley Forge Space Technology Ctr., General Electric Co., Box 8555, Philadelphia, Pa. 19101.

October 26-29, 1969: Biennial Joint Materials Handling Conf. Submit 25-word abstract by **March 1, 1969** to Max Frey, Conference Program Chrmn., Project Engineer, Cascade Corp., Box 7587, Portland, Ore. 97220.

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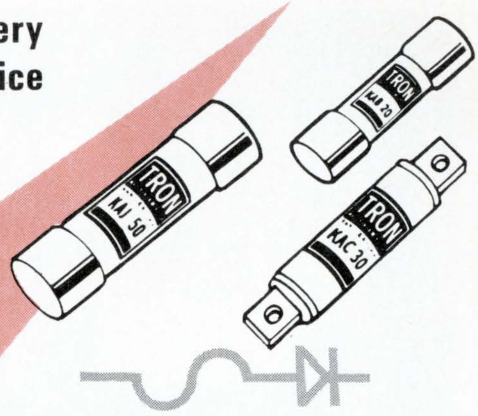

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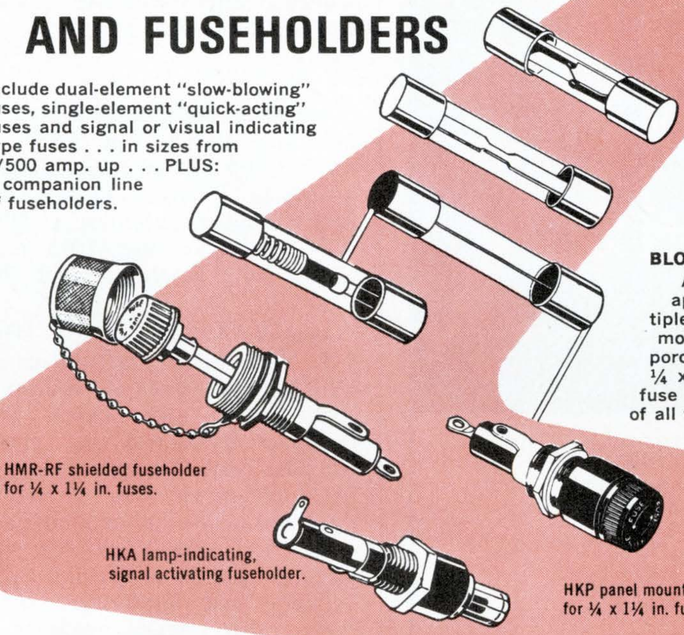

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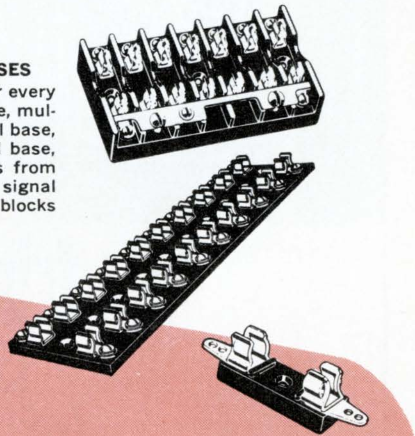

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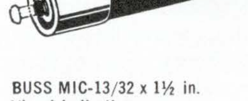

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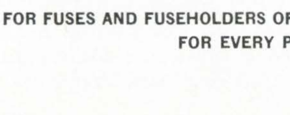

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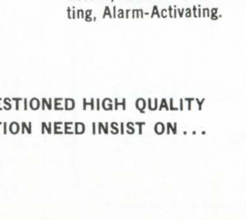

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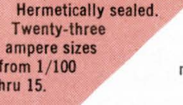

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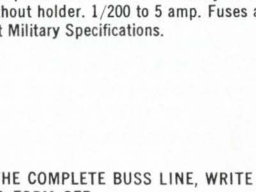

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"Operations and Maintenance," Feb. 3-7, May 19-23, Sept. 15-19. Sine and random fundamentals along with a study of circuits. $175. School Registrar, Ling Electronics, a Div. of LTV Ling Altec, Inc., 1515 S. Manchester Ave., Anaheim, Calif. 92803.

"Computer-Aided Circuit Design," Feb. 3-7, Boelter Hall, Rm. 5704, UCLA. Fundamental concepts of computer software, circuit theory, manufacture control and planning; compiler writing systems; languages for automatic test systems, circuit design, and process control; design automation language; graphic on-line language; partial differential equation language and interpreter; symbolic computation: ASAP, FORMAC; SIMSCRIPT; future language trends in circuit design, process control, and testing. $275. Box 24902, Engineering and Physical Sciences Extension, University Extension, UCLA, Los Angeles, Calif. 90024.

"IC Engineering Fabrication Laboratory Seminars," Feb. 10-14, Mar. 17-21, April 21-25, Phoenix. Impact of integrated circuits, basic materials and processes, photo mask-making, wafer processing, process control, thick and thin films, assembly techniques, basic design considerations, MOS processing, photo mask design and layout, digital ICs, digital systems, linear systems, equipment considerations, testing and specs, reliability, failure analysis, etc. $500. ICE Corp., 4900 E. Indian School Rd., Phoenix, Ariz. 85018.

"Computer Graphics I," Feb. 13 (Los Angeles), Feb. 14 (San Francisco). Graphic concepts and terminology, display hardware and software, data structures and applications. $40 for ACM members, $55 for non-member employees of ACM corporate members, and $70 for other non-members. Association for Computing Machinery, ACM Professional Development, 211 E. 43rd St., New York, N. Y. 10017.

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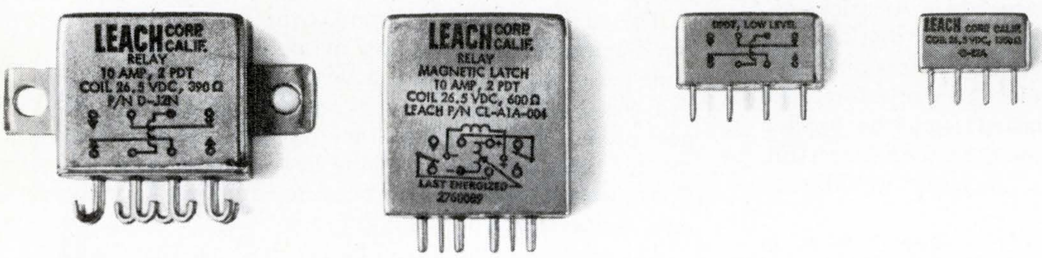

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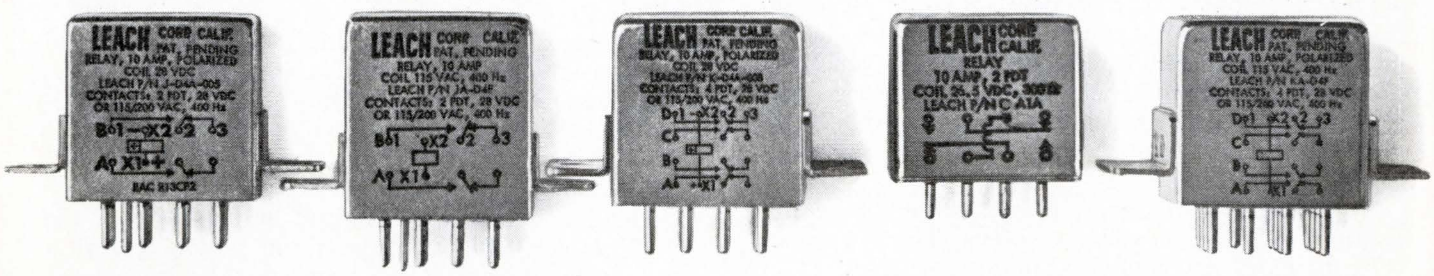

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New product management

Part I: How to get more products for your engineering dollars

Only 30% of new product expenditures will result in successful products. But with improved management techniques, you can weed out the failures early—and thus concentrate your resources on the probable successes.

By Eugene W. Parry, Microwave Calibration, Manager
Hewlett-Packard, Palo Alto, Calif.

Each year industry spends several billion dollars on research and development.* This money is spent in the quest for new products needed for further growth and increased profits. Current sales of major corporations are commonly made up of products introduced less than 10 years ago.

Seventy percent of the money spent for new products will not result in successful products for American industry.[1] In terms of efficiency, this means that the new product effort is only 30% effective. The loss of money is not as important as the misdirection of effort. The technical manpower that is wasted could be applied to better use on projects that would become successful. Even a small improvement in efficiency would reap large savings in effort.

According to Booz, Allen and Hamilton, it takes an average of 58 new product ideas to yield one successful new product. Compare Fig. 1 with Figs. 2 and 3; these show that much money and manpower could be saved if methods were improved to devote more of the effort in the **development** stage towards successful products. Some of the most costly errors in the development of new products have resulted because one aspect of research and dvelopment was carried too far before other areas were adequately investigated. If you have a way of early screening and priority assignments, you can allocate budget and talent to the best prospects, and avoid costs on ideas that are not likely to pay their way in the market.[2]

To increase the efficiency of the new product effort, you must establish an effective system. The new product continuum may be divided into seven stages:

1) Exploration
2) Screening
3) Business Analysis
4) Development
5) Testing
6) Commercialization
7) Review

Exploration: setting it up

The exploration phase of new product planning includes the details of setting up a system. As such, it is for both long range planning and specific new product action.

The success of the program is the responsibility of top management. During this phase upper management must perform at least the following six functions: establish goals, formulate a new product policy, set up the new product organization structure, define responsibilities for the various areas of the new product organization, develop a practical procedure, and facilitate the operation of the procedure by proper management.

The problem management faces is how can they make the proper decisions that result in an improved program. To do this, they must have a system that will provide them with clear, concise information.

Specific corporate goals that apply to the formulation of a new product policy are:

• *Desired growth.* The level of growth top management wants will have a great effect on new product policy. A company planning little growth will have a less aggressive policy than will a company expecting to double its sales in five years. Growth can be measured in absolute quantities or in relation to market share.

• *Profit levels.* There is little point in developing a product that will produce a 5% net profit if the company requires at least 10% profit on all products.

• *Expansion.* Most companies will require growth outside their present span of products and facilities if

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*Industrial R&D expenditures for 1965 were $15.5 billion; of this, $8.3 billion was government-supported, and $7.3 billion was company supported.

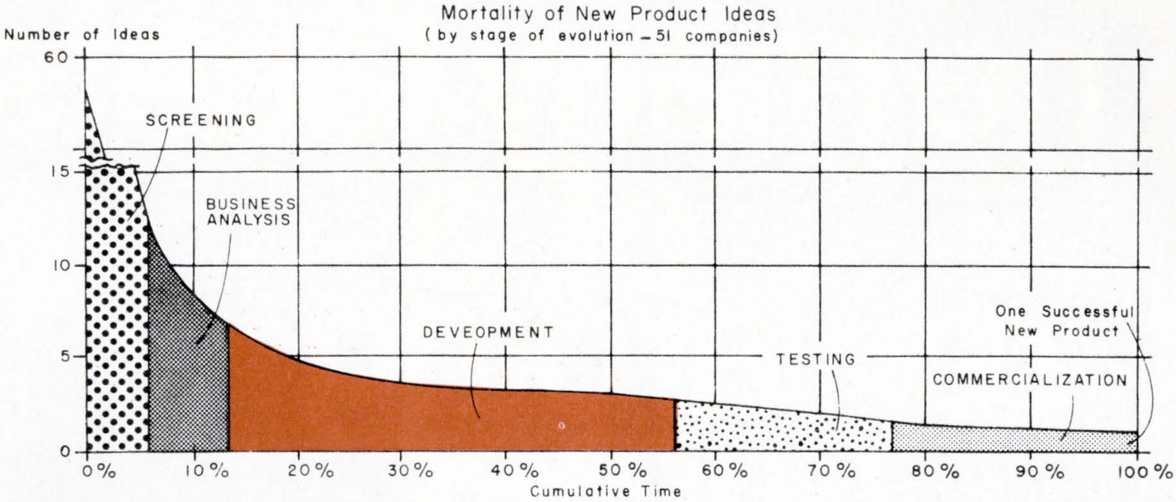

Fig. 1

Source: Management Research Department
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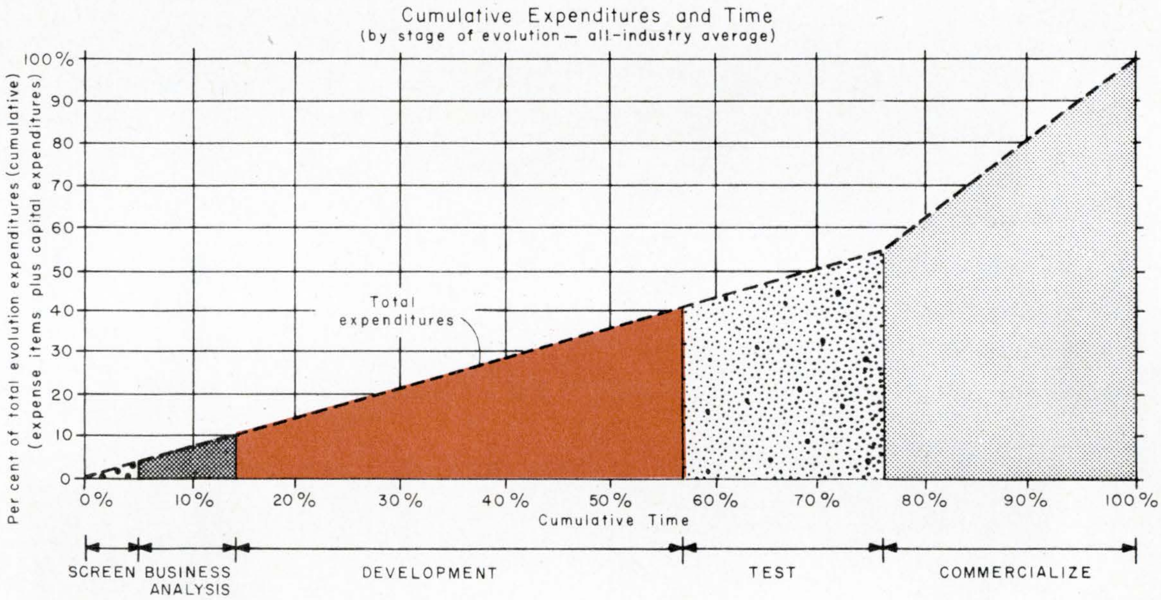


Fig. 2

Source Management Research Department
Booz • Allen & Hamilton Inc.

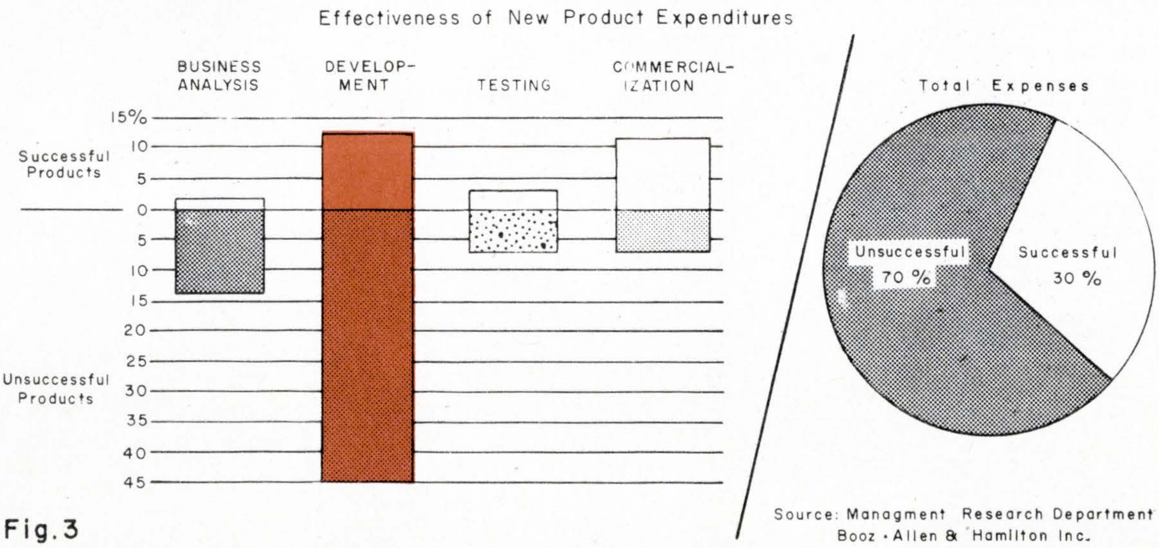
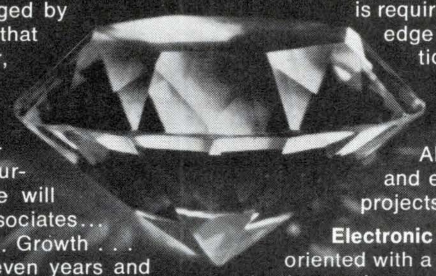


Fig. 3

Source: Managment Research Department
Booz • Allen & Hamilton Inc.

The many facets of a rewarding career.



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they desire a high rate of increase. They can do this by diversifying the line of products horizontally, or by integrating production processes or marketing organizations vertically. Thus goals and policies on expansion by acquisition, foreign operations, or changes from representative to branch office operation will all be relevant to a new product program.

• *Company image and reputation.* A company that makes precision electronic devices, for example, may not want to go into the toy business because of the image involved. This does not mean that company goals would always rule out such a combination. The Lionel Corp., known to the consumer mainly as a toy manufacturer (The Lionel Toy Corp.), consists of six other subsidiaries which make industrial products ranging from precision resistors (Dale Electronics) to geiger counters (Lionel Electronic Laboratories).[3] It should be pointed out that Lionel is known for high quality products in the toy field, so the combination is logical.

• *Stability.* The relative importance of stability as a company goal, both in relation to profits and employment, will also affect new product strategy.

Company objectives in general will include some combination of the following three goals: to protect present earnings and position, to reach beyond competition and improve the company's position in its present field, and to enter new fields and achieve a broader base.[4]

Once you have devised a new product policy, you must set up an **organization structure** for your new product system. Such a structure must provide for three separate functions.

The first of these is the duty of the manager or group responsible for final decisions at various levels. This man (or group) must define responsibilities, etablish goals, and provide resources for projects. At the top level, this function may be carried out by the president, vice-president, or division manager, depending on the size of the company. Or it may be a group effort by a new product department, product teams, or a standing new product committee.

The second function is performed by the operating departments which do the work assigned by management. These include the engineering, finance, marketing, and production departments.

The third function is coordination. This duty may be performed by the same man or group that acts in the management position. In a project manager system, however, coordination is the responsibility of one person, possibly a member of one of the operating departments. This concept of coordination follows a basic principle: one person should be responsible for the details of the overall plan. This person may be given the authority to require plans from each operating department, to require regular reporting on necessary details, and to require some means of coordination and meeting of minds.

An effective system should improve the quality of communication without increasing the volume of paper work. Requirements for both vertical and horizontal communications should be designed to prevent you from discovering later than necessary that a project will not be successful.

Discovering that the development department has just completed the design of a product that the marketing department cannot tell is a costly and often preventable mistake. The earlier such problems can be registered, the less money and manpower will be wasted on projects that will eventually be thrown out.

Judgment cannot be designed out of a new product system. Management cannot expect all their decisions to be based completely on solid verifiable facts. They must make use of prophetic imagination.[5] The system must not require such precise accuracy as to be unrealistic. A system that rigid will discourage creativity.

Management must also keep in mind that a new product program, although an essential element in a healthy and continuing business, is only a means to an end.[6] The program must not become so important that company goals are forgotten.

Idea generation is the final phase of the exploration stage. In this phase, you must first identify idea generating groups, and then give the creative persons in these groups a clear concept of the new product policy. You must also provide a common idea collection point. At this time, it's important to treat the idea man with care. Nothing can stifle the creative process more than critical judgment applied to an emerging idea.

Screening: how the idea measures up

Once the exploration phase has been properly carried out, a company will have a large number of ideas from many sources. At this point, only the originator and possibly his supervisor have evaluated the ideas. To prepare for the screening phase, the ideas must be written into a form that management can evaluate.

The idea should be appraised in relation to its conformance to company and new product policies. Then judge each idea against the following three questions:

• Can we sell this product through our present marketing organization?

• Do we have the skills needed to engineer and manufacture it?

• Does it have a good profit potential?[9]

The transistor is an excellent example of how an idea for a product can be good, but can still be rejected for commercial development based on company policies. When the semiconductor industry began, Bell Labs held basic design and process patents covering the entire field. Bell policy, however, put these patents virtually in the public domain. According to J. A. Morton, Vice-President of Bell Labs, "Bell realized that the transistor industry would be too big for any one company to handle."[7]

Bell Labs is primarily a basic research organization. Due to a series of antitrust suits, it was not interested in involving the American Telephone and Telegraph complex in a monopolistic control of the semiconductor industry.

As it turned out, by 1956 legal action had freed all of Bell Labs' existing patents. It now has an open licensing policy on new patents. The royalty charged to any given company is based on the extent that the licensee is engaged in research and its willingness to cross license. This policy has enabled Bell Labs to stay

fairly well on top of basic semiconductor research, and permits AT&T to have available the latest developments for use in its own systems. This, of course, was the original objective.

In the screening stage it is important to keep decisions at the top levels. Although individuals outside the decision group may be called upon for information, they should not be allowed to destroy the idea. E. J. Tangerman, formerly editor-in-chief of *Product Engineering,* stated this principle very well: "No man should have the authority to criticize, change, or kill an idea who does not also have the authority to okay it."

Business analysis: getting to the specifics

A business analysis must be carried out carefully to insure that money will not be wasted in the product system.

Responsibility for each new product must be assigned in this stage. Generally, if a new product committee system is used, the responsibility will be with the committee, with the ultimate responsibility vested in a division manager or vice-president. This committee, in turn, must appoint coordination responsibility and functional responsibilities to the proper persons.

Market information should be gathered early in this stage. The formality of the analysis will depend on the nature of the product and company experience. If the company has found that it passes a high percentage of its products through the commercialization stage with great hopes, only to have them fail in the marketplace, then it needs a more formal market analysis system. If, however, new products are often stopped in the later stages because they fail to meet market requirements unknown to the designer, the problem is one of communications. Or possibly the marketing department just waits too long before deciding on criteria. You should determine what the customer needs and wants as much as possible during this stage.

The following are all important market criteria:

- Net price the product will have to sell for to be competitive.
- Expected volume, considering general market conditions and price.
- Company position in the market—innovator or follower.
- Capabilities of the present marketing organization to handle the sales and service required.
- Cost of market development, including advertising and additional training of the sales force.
- Quality required.
- Length of product life, taking into account the period of development ahead.
- Effect the new product will have on the sales of existing products.
- Probability of commercial success.

Projected manufacturing cost per unit and investment costs for development, tooling, new machinery, and equipment are also important. Get estimates of these costs from the appropriate department.

You can't determine any of these factors with precise accuracy, especially two or three years in advance. However, you should have the best estimates that can be economically made at this stage, as a starting point is needed.

Be specific with specs

Next, you must make up detailed specifications. It might be argued that the specifications are needed before a market analysis can be made, but much of the data required for the specifications are obtained from the market analysis. Generally, you can resolve this dilemma by evolving the specifications concurrently with the market analysis.

A good set of written specifications is an extremely important link in communications during new product evolution. The specifications inform the design department what requirements its product must meet to conform to the product that the marketing department expects.

The specifications could be written by the new product committee, the project manager, the marketing department, or the engineering department. The individual who writes the specifications is not as important as the requirement that the specs be coordinated among marketing, engineering, and management. Any deviations required later should be carefully reviewed by the groups involved.

Specifications should be written such that they only set down what features are needed, not how a product should be designed, unless certain design methods are required as a sales feature. An example here would be the use of printed circuit boards instead of hand wired circuits, or semiconductors instead of tubes. Reliability as a feature is an important selling point.

The relevant data you get from the market analysis should be translated into product specifications. Estimated volume, price, and quality are all very important to the design of a new product. Financial information obtained internally is also important.

Finally, the specifications should show tentative schedules, because the market analysis has to be based on some release date. In some markets timing can make the difference between success or failure.

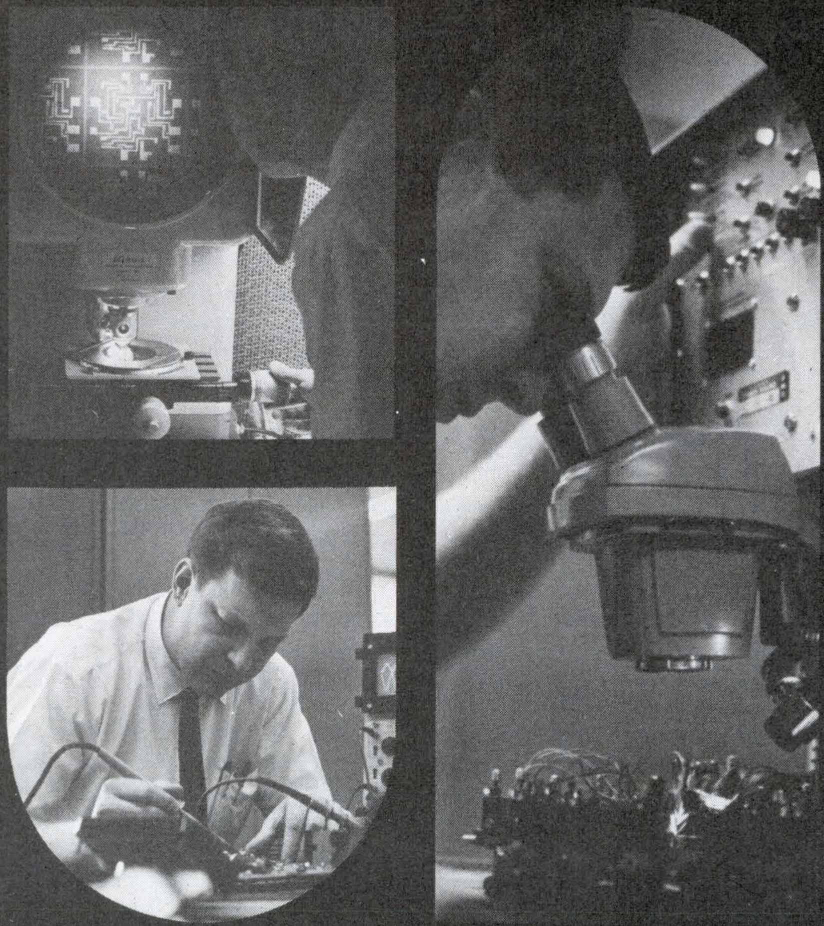
After the specifications are approved, make a specific business analysis. Keep it *simple*—a complicated analysis will discourage its use except on major projects. Besides, a large amount of detail at this stage is impractical as the figures are still rough estimates. A simple analysis will encourage studying the effect of changing specific variables, such as volume, selling price, cost, and investment requirements.

Use a simple formula that will let you quickly work out variations, and yet will include the most important factors. A good formula is:

$$R = \frac{\sqrt{T}\,[V\,(P - C) - D]}{I}$$

Let's explain this formula with an example. Suppose you make an instrument that will sell for \$1000, have a life of nine years, expected sales of 1000 units per year, and a cost per unit of \$500. In this example,

T (9 years) is the estimated life of the product in years. The square root (3) accounts for the time value of money and the decline in market po-



tential in future years.

V (1000) is the estimated average annual sales volume in units.

P (\$1000) is the net selling price per unit in dollars.

C (\$500) is the total cost per unit in dollars, including manufacturing cost and overhead.

D is the estimated average difference in profit to existing products due to the new product. (For example's sake, suppose that the instrument supersedes an older model that also sells for \$1000. costs \$500 to make, and you expect the new model will cut down the sales of the older one by 400 units a year. Thus D would be \$200,000).

I is the total estimated investment required, including marketing costs, development and engineering costs, tooling costs, and the cost of new facilities or machinery. (For our example, assume I = \$300,000.)

R is the value factor of the new product, and will approximate total return on investment. In our example,

$$R = 3\frac{[1000\ (1000 - 500) - 200{,}000]}{300{,}000}$$

$$R = 3.0$$

Depending on the industry, R should at least equal 2. A value factor of 3 is fairly good. A value factor of 1 indicates 0 profit and 3 indicates a fairly good return.

A formula of this type has several advantages. First, it takes into account all of the key numerical factors determined from the market analysis, plus the unit cost and required investment. Second, the formula gives you a quick way to study the effect of changing the variables. Third, the formula gives you a useable figure for comparison with other products. This is helpful both for deciding on the continuation of a project, and for setting priorities. Management could set required values of R for various risk levels.

Once the analysis has been completed and the surviving products reviewed by the new product committee, top management must approve the products before they start into the development stage. Budget approval generally will be required at this point.

Development: engineering the product

Figure 3 shows that the largest portion of effort devoted to unsuccessful products occurs in the development stage. The reason for this lies more in poor preparation in the earlier stages, and poor follow-up during this stage, than in the inability of the engineering department to create a technical success.

In the development stage, the new product must be broken into projects suitable for assigning to specific departments; the responsibility for each of these projects must then be assigned.

You must then make up schedules that fit into the overall timetable, and fit into the work loads of the functional departments.

The next step in the development stage is to design and build a prototype to the product specification. Financial factors such as unit cost requirements must be kept in mind during this phase, without impeding the design freedom of the engineer.

One of the greatest reasons for failure in this stage is the lack of formal communication. Often Marketing fails to note changes which might affect its original figures, and therefore certain points in the specifications. Development, likewise, does not properly communicate findings which might require a change in specifications. The decision whether to use an expensive solution to meet a technical requirement, to change the requirement, or to add time to lower the cost and still meet the requirement should be made at the upper levels between management, marketing, and engineering.

Once a quarter (or whatever time period is appropriate), management or the new product committee should review each project. They should include in this review any technical, cost, or time deviations from the current approved specifications. They should request that Marketing re-evaluate and, if necessary, revise its original estimates in terms of recent information.

The management group should be alert for factors that might bring about failure later. For example, a drop in a competitor's price or a change in the state of the art might be impending. A hint that the project is falling behind schedule or budget guidelines may require further study.

Testing: does it work?

During the testing stage, three forms of evaluation must be made: technical, production, and marketing.

Technical testing will include extensive evaluation under varying conditions. Although some of these tests will be in the laboratory, field tests should also be made. If possible, a different group than the one that designed the unit should handle some portions of the tests.

Also, facilities should be tried to insure that parts can be made and units assembled in production, and market reaction should be tested by a planned program to get opinions from salesmen and users.

From the results of the three types of tests, management should decide whether to complete changes or to drop the project.

Commercialization: putting it across

In the commercialization stage, production and marketing plans and schedules are set up and coordinated. Management or the new product committee must continue to follow the product until it becomes a commercial success. It is important during this stage to insure that slowly rising costs do not cause the planned profit to deteriorate.

New product management
(concluded)

Review: the final step

You must set up some method of reviewing the effectiveness of the new product effort. If a new product committee or other coordinating body is used, it should check the accuracy of schedule, cost, and marketing estimates over a long period. An established routine for review can provide data helpful for improving the whole new product system.

In summary, two assumptions have been made:

- Companies that do not use a detailed new product program waste their resources developing products that never reach the marketplace.
- Most factors which cause a specific new product project to be dropped are of such a nature that they could be determined early enough to save considerable effort.

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Next month

In Part II of this article, we present a detailed study that confirms the above two assumptions, and that suggests ways to manage better your company's new product efforts. For this study, the author analyzed the new product activities of the instrument division of a medium-size midwestern manufacturing company.

The study investigates the percentage of new product dollars wasted on new product projects that were later dropped, and establishes those factors which caused the projects to be discontinued. It then suggests some positive steps you can take to get more products for your engineering dollars.

INFORMATION RETRIEVAL
Project management, Careers

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Charging energy-storage capacitors from low-voltage sources

When you design a dc-dc converter to charge a capacitor, you must consider the rate of energy transfer, oscillation frequency, peak battery drain, and efficiency.

By Lynn T. Rees,
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Rechargeable nickel-cadmium cells are convenient and compact energy sources for portable equipment. But because they have a relatively high cost, your equipment design should use a minimum number of such batteries. This, in turn, implies that you should use a suitable dc-dc converter to boost a low dc battery voltage to a level sufficient for your needs.

An example of such a converter is one that charges a 480 μF energy-storage capacitor of a photoflash power supply to 500 V (60 joules of energy). Two 1.2-V nickel-cadmium cells are the energy source. The energy capacity of this supply is comparable to that of a supply of four or more cells, although fewer flashes (about 25) are available. And it gives you convenience (small size) and economy to a degree not presently available in units with such an energy capacity. Although this discussion concerns itself with a photoflash unit, similar factors apply to circuits in automobile ignition systems, flashing beacons, welding systems, Geiger counters, and so forth.

Converter requirements

Capacitor charging imposes these requirements on a converter circuit (Fig. 1):

- The converter must be capable of starting and operating with its output shorted, because a discharged load capacitor acts as a short circuit.
- The charging source must shut itself off when the capacitor reaches full charge, and must cycle as needed to maintain the capacitor voltage within certain limits.

Our particular photoflash must meet these added design requirements:

- load capacitor—60 joules (480 μF, 500 V)
- power supply—two nickel-cadmium cells in series giving 2.7 to 1.8 V as cells discharge
- capacitor charging time—20 s (3 W output)

You can use a solid-state oscillator to perform the voltage conversion. The low power supply voltage rules out SCRs as power switching elements. It also rules out silicon transistors because of their excessive voltage loss in the ON condition. (The switching device has to conduct from 2 to 10 A when ON, depending on the circuit used). So, the power stage of the converter uses germanium transistors.

You need some type of current limiting to protect the switching transistors from high peak currents when the circuit operates into a short-circuit load. Resistive limiting is inefficient; for example, it can reduce an 80% inverter efficiency to only 40%.

Single-transistor converters

Figure 2 shows a two-transistor basic oscillator as the main converter block. Such an oscillator uses transsistors efficiently, and gives you maximum power output for any given peak current. But it has several disadvantages. One is that it can be difficult to shut off. Another is that there must be a large current-limiting inductor (or some other means of current limiting) in series with the load capacitor. Such disadvantages overrule the advantages, for this application.

But consider the single power transistor converter shown in Fig. 3. In this circuit, the primary of T_1 stores energy when Q_1 is on, and releases it into the load when Q_1 is switched off.

A single-transistor circuit has these advantages:

—You need only one power transistor.

—Low-loss peak-current limiting is inherent in the circuit.

—The circuit is potentially easy to shut off (automatically) when the load reaches the desired voltage.

—And, finally, transformer size is reasonable, if you consider that you don't need auxiliary current limiting.

The drive oscillator of Fig. 3 must

—Supply drive current to the power transistor.

—Supply reverse base drive to turn the power transistor off rapidly and minimize switching power losses.

—Have a controllable duty cycle to allow the energy-storage winding to completely discharge before starting another cycle, and yet never leave excess dead time between discharging and charging the transformer winding.

—Be relatively easy to turn off with a voltage-sensing feedback signal.

—Draw low idle current when shut off.

The voltage-sensor block must:

—Operate on minimum power (because the power it needs discharges the load capacitor).

—Have a voltage reference to compare to the output voltage.

—Show (visually) when the output voltage is at the desired value.

—Allow setting for a range of output voltages.

Circuit operation

Transistor Q_1 (Fig. 3) is a switch that controls the current in the primary winding (L_p) of transformer T_1. The drive oscillator furnishes base drive to Q_1, and sets its ON and OFF times for each switching cycle. For a constant battery voltage, the ON time of each cycle is constant. But the OFF time varies: it is inversely proportional to the voltage V_L on the load capacitor. Thus, the drive oscillator is a variable duty-cycle circuit.

For example, suppose the load capacitor is discharged and you start the converter. The time needed to transfer the energy in the transformer's primary to the load capacitor is many times longer than Q_1's ON time. As the load capacitor charges, the required energy transfer time of each cycle decreases. As the capacitor nears full charge (500 V), the OFF time of each cycle becomes about one-third of the ON time (75% duty cycle). Finally, the oscillator stops when the load capacitor reaches the desired voltage. Switch Q_1 is OFF, and the entire circuit draws only a small amount of standby power from the battery and from the load capacitor. As charge leaks off the load capacitor, its voltage drops until a cut-in point is reached (typically 485 V). The converter then resumes oscillation and brings the capacitor voltage back up to 500 V.

This is what happens in the course of a single cycle of oscillation in the circuit of Fig. 3. Switch Q_1 turns on and immediately saturates. Diode D_1, reverse-biased, open-circuits the secondary winding (N_s) of T_1. The transformer then appears as an inductance (L_p) in Q_1's collector circuit. The collector current (i_P) starts at zero and increases linearly with time until the oscillator pauses and abruptly switches Q_1 OFF. Current i_p no longer can flow through Q_1. But it must flow somewhere, since it is an inductive current. So, as Q_1 turns off, the induced voltage across the transformer secondary winding reverses polarity, forward-biases diode D_1, and current i_S flows through the load capacitor.

In this manner, energy stored in T_1 while Q_1 is ON transfers to the load capacitor while Q_1 is OFF. The peak load current is much smaller than the peak Q_1 cur-

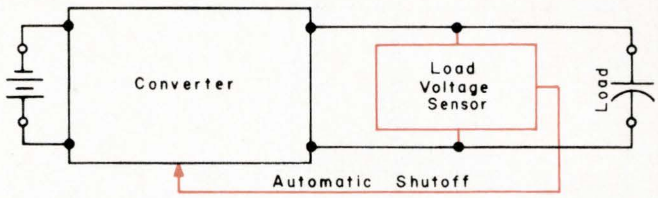


Fig. 1. A capacitor charging system changes the low dc voltage of a battery into high-voltage, unidirectional ac. The energy thus accumulated and stored in the capacitor is useful in such diverse equipments as Geiger counters, welding systems, and photoflash units. The addition of the load-voltage sensor assures you that the capacitor is always at full charge, and extends the battery life as well.

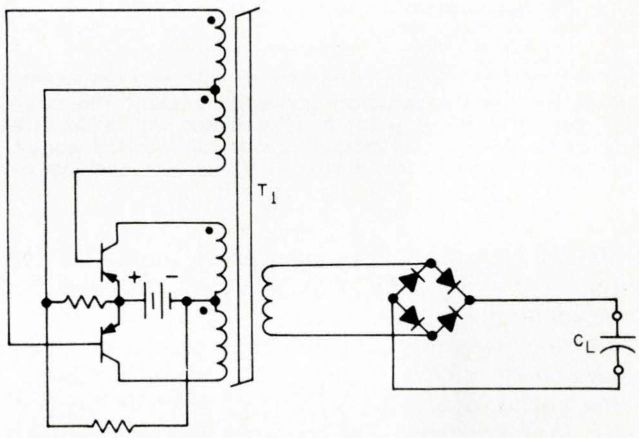


Fig. 2. This two-transistor oscillator could serve as the main converter block. Though efficient, it is not a good choice for several reasons. One reason is that it can be difficult to shut off. Another is that the circuit needs a large current-limiting inductor in series with the capacitor, which adds considerable size and weight.

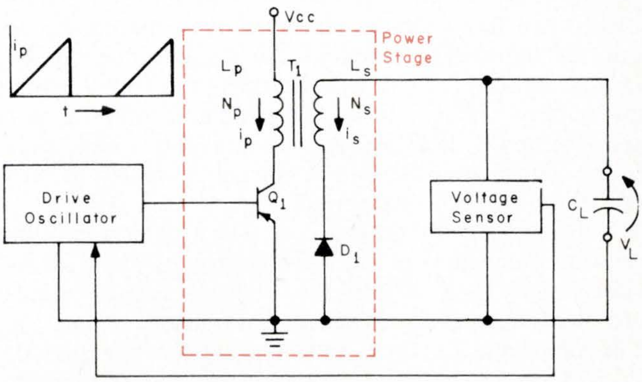


Fig. 3. A single-transistor converter is very suitable for the charger. It is easy to shut off (automatically) when the capacitor reaches full voltage, and the transformer—which first stores energy and then releases it to the capacitor—can be of reasonable size. The circuit has a further advantage in that it has inherent current limiting.

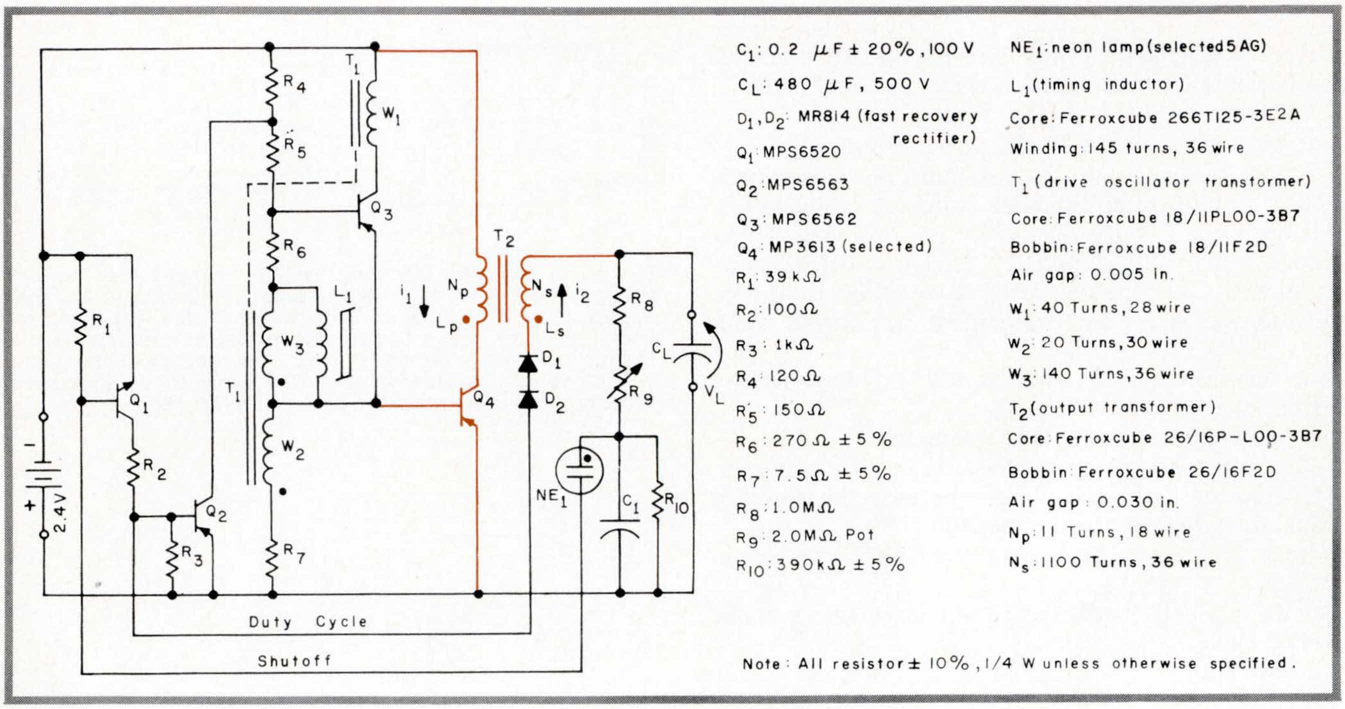


Fig. 4. Here is the complete converter circuit. The drive-oscillator of Fig. 3 is a blocking oscillator with a variable duty cycle. A saturable magnetic core sets the ON period. The load-voltage sensor is a neon bulb oscillator; the inverter pulses OFF each time the bulb conducts. Because the inverter is ON most of the time, the charge on the capacitor keeps accumulating. When the charge is sufficient, the bulb stays on, and the oscillator turns off.

rent (i_P) because N_S has many more turns than N_P, and there is conservation of ampere-turns as Q_1 switches from ON to OFF.

Figure 4 shows the complete converter circuit. It includes energy storage capacitor C_L, which is the converter's load, and a 2.4-V battery, which is the converter's power supply. The converter is a variable duty-cycle circuit; it stops and starts itself to maintain the voltage on the load capacitor within narrow limits. It is also self-compensating for battery voltage variation, and tends to charge the load capacitor in the same length of time, regardless of decreasing battery voltage.

During the ON portion of the cycle, T_2 stores energy in its primary winding, L_P. The energy, U, is equal to $\frac{1}{2}L_P i_1^2$. Then, when Q_4 is switched OFF, the stored energy transfers to the load capacitor, C_L, as $U = \frac{1}{2}C_L V_L^2$, and the cycle repeats.

The driver-stage oscillator has about 75% duty cycle when free-running. However, the time needed to transfer the energy across T_2 to C_L depends on the voltage existing across C_L, the turns ratio of T_2, and the battery voltage. It is undesirable to start a new cycle before T_2 is discharged; Q_2 prevents a new cycle from starting until the output current decreases to zero at the end of each OFF period.

The square-loop timing core (L_1) determines the free-run frequency of the driver-stage blocking oscillator. Switch Q_3 is ON until the "constant voltage" winding, W_3, saturates L_1. When L_1 saturates, it shunts the base drive and Q_3 turns OFF. During the OFF period, W_3 voltage is (initially) several times higher than its ON value, and the timing core resets much more rapidly than it saturates. As soon as L_1 resets and the stored energy in T_1 dissipates, the driver stage is free to start a new cycle. Resistor R_4 supplies the starting current to begin each cycle.

The power stage

The trapezoidal current of T_1 (Fig. 4) drives power transistor Q_4 into saturation during the ON portion of the cycle. The ON voltage of W_2 furnishes only negligible drive to Q_4. But when Q_3 turns OFF, the W_2 reverse voltage is much higher and rapidly switches Q_4 OFF, using part of the energy stored in T_1 during the ON portion of the cycle.

Since the Q_4 saturation voltage subtracts from the battery voltage available for transferring energy to T_2, a low $V_{CE\ (sat)}$ is very important; a $V_{CE\ (sat)}$ of 1V would waste almost half the battery voltage. The required output power, the waveshape of the collector current (i_1), and an estimated efficiency of 50% put the peak collector current in Q_4 at roughly 10 A.

The power transistor, then, should have a saturation voltage of less than 0.5 V (at a collector current of 10 A), and must have a fast turn-off time compared to the operating frequency of the circuit. A silicon device meeting such requirements is costly. You are wiser to choose a germanium device such as the 2N1557 or MP3613.

The driver stage

The driver-stage network (W_2, W_3, R_6, and R_7) provides sufficient ON drive to saturate Q_3. It also forces the T_1 flyback energy to divide in such a manner as to switch off Q_3 and Q_4, and reset L_1 in preparation for the next cycle. With L_1 timing the ON portion of each cycle, you get a relatively constant peak current in Q_4 (and also constant energy in the transformer), even though the battery voltage changes. This tends to compensate for battery voltage drop and, more importantly, makes the timing relatively independent of the current gain in Q_3.

Novel blocking oscillator

The drive oscillator is a blocking oscillator with two interesting features:

- You control the oscillator's duty cycle by varying the OFF portion of the cycle (when it free-runs, the oscillator has a duty cycle of approximately 75%).
- The saturable magnetic core (L_1) sets the ON portion of the oscillator period, without requiring a separate external current source for resetting the core.

The magnetic core controls the ON time of each cycle as follows. From eq. 1 in the box on page 54,

$$i_{1(peak)} = \frac{V_{CC}t_1}{L_P}.$$

Since L_P is constant, if $V_{CC}t_1$ is constant, $i_{1(peak)}$ will be constant. Switch Q_3 turns OFF when L_1 saturates. You can determine the time needed to saturate L_1 from the standard transformer equation, $E_{W3}t_1 = 2NA_mB_{max}10^{-8}$.

This shows that the product $E_{w3}t_1$ is a constant and, consequently, $i_{1(peak)}$ is a constant. Energy transfers at a constant maximum increment per cycle. This gives you full use of the power transistor and the energy-storage transformer, which are the two major circuit components in terms of size and cost.

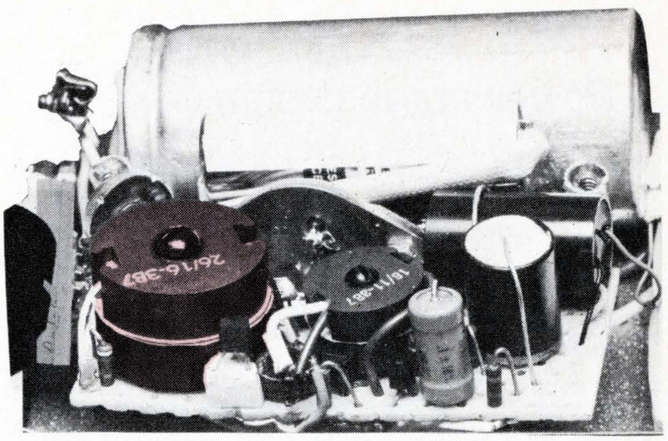
Automatic shutoff

As C_L charges up, the neon lamp (NE_1) starts to oscillate, and the inverter is pulsed OFF during the short time that NE_1 conducts. However, the inverter still operates *most* of the time, and the load voltage continues to increase slightly until the voltage divider (R_8, R_9, and R_{10}) finally supplies holding current to NE_1, thus turning off the oscillator. The inverter now *stays* OFF because starting resistor R_4 is held to ground and Q_3 gets no starting current. The standby current consists of battery drain through R_4, and load-capacitor drain through its internal leakage and the voltage divider.

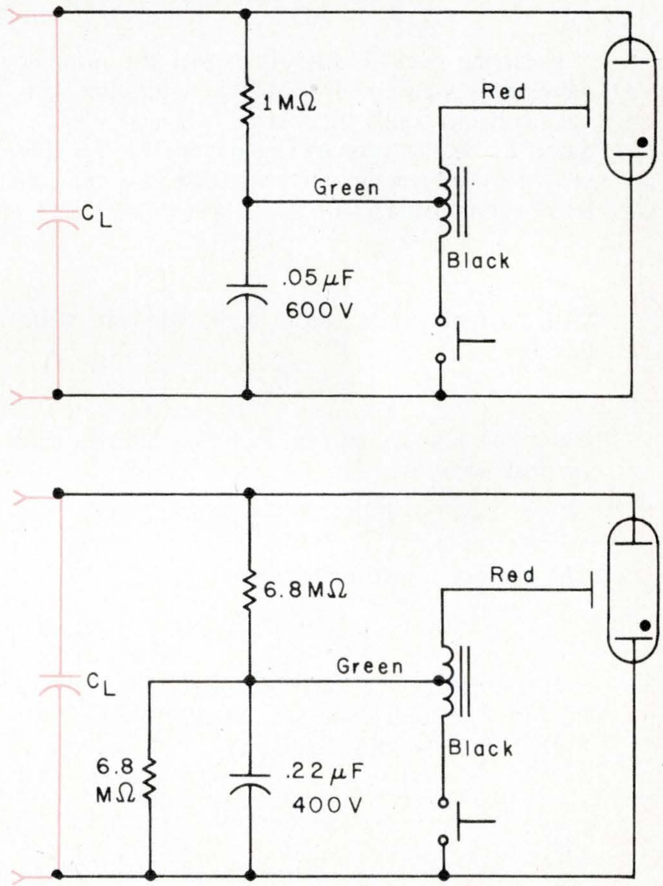
When the voltage across C_L drops enough (a few volts) for NE_1 to stop conducting, the inverter turns on again, and boosts the capacitor voltage back up to the shut off value. The shut-off voltage adjustment gives you a method of calibrating units for constant energy over a range of capacitance values. For example, if the load capacitor is larger than the nominal value, you can set the converter to turn off at a lower load-capacitor voltage.

The complete circuit of Fig. 4 meets all the design goals. It charges a 60-joule capacitor in about 15 s from two high-current size AA nickel-cadmium cells rated at 500 mAh each. The current waveform is compatible with nickel-cadmium batteries. A 10-A peak current gives very good efficiency in such cells, whereas the same waveform gives very poor efficiency when it comes from size AA dry cells. The circuit efficiency is about 40%. This compares favorably with other photoflash converters on the market. You can significantly increase the efficiency of the circuit by operating it at a lower frequency, with a larger T_2. For example, doubling the volume of T_2 gives efficiencies greater than 60%.

INFORMATION RETRIEVAL:
Oscillators, Power supplies
Circuit design



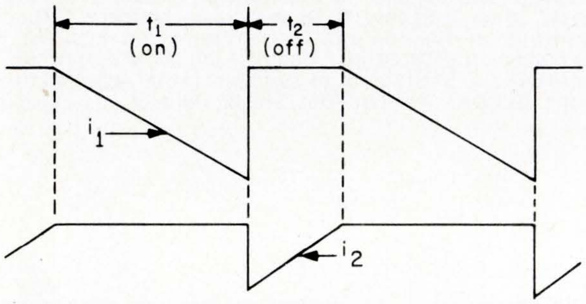
This photograph shows the complete photoflash unit incorporating the converter circuit of Fig. 4. The component shown in color is transformer T_2 which first stores energy, then transfers it to the load capacitor. (The capacitor is at the top of the picture.) You can see the powerstage transistor just behind, and to the right of, T_2. The flashtube itself is out of sight along the right-hand edge of the picture. The batteries are in front of the capacitor.



Here are two trigger circuits for firing the flashtube. The upper one is suitable for push-button switch contacts rated at 500 V. The lower circuit is for switches rated at 250 V. The trigger transformer is a Stancor P-6426, and the flashtube is a General Electric FT 52, FT 118, or FT 120. With these trigger circuits, you can expect about 25 flashes per charge from the 60-joule load capacitor. You can use other flashtubes with different capacitors and voltages (the GE FT 106 is suitable for a 50-joule capacitor at 300V).

Power stage design

In general, you get minimum transformer size when you run the power stage at its highest efficient frequency. The main losses are in the transistor and transformer. You should place primary design emphasis on the efficiency of power conversion. Other considerations are peak collector current, frequency of operation, ON time (t_1), and OFF time (t_2). The relationship between the primary and secondary currents in T_2, and the ON and OFF times, are shown in this sketch:



Referring back to Fig. 4, neglect the primary winding resistance of T_2 and Q_4's saturation voltage; consider only the period when Q_4 is ON. Since L_P is the primary inductance of T_2 (the secondary is open-circuited by diode D_1), the collector supply voltage is

$$V_{CC} = L_P \frac{di}{dt}$$

With current starting from zero, you can write this as

$$V_{CC} = L_P \frac{i_1}{t_1}$$

Thus, the primary current increases linearly, and its peak value is

$$i_{1(peak)} = \frac{V_{CC} t_1}{L_P} \qquad (1)$$

The average transistor current is

$$i_{av} = \frac{t_1}{2(t_1 + t_2)} i_{1(peak)}$$

If you define the efficiency, η, as the ratio of P_{out} to P_{in}, and since the input power, $P_{in} = V_{CC} i_{av}$, then by substitution

$$i_{av} = \frac{P_{out}}{\eta V_{CC}} = \frac{t_1}{2(t_1 + t_2)} i_{1(peak)}$$

Or,

$$i_{1(peak)} = \frac{2(t_1 + t_2)}{\eta V_{CC} t_1} P_{out} \qquad (2)$$

Example. Assume an average duty cycle of 2/3 ($t_1 = 2t_2$), $V_{CC} = 2V$, $P_{out} = 3W$, and $\eta = 50\%$. Then from eq. (2),

$$i_{1(peak)} = \frac{(2)(2t_2 + t_2)(3)}{(0.5)(2)(2t_2)} = 9\ A$$

and

$$i_{1(av)} = \frac{P_{out}}{\eta V_{CC}} = \frac{3}{(0.5)(2)} = 3\ A$$

The requirements for Q_4 and T_2

The prime characteristics of Q_4 are

- a peak-current capability with a low $V_{CE(sat)}$, and a reasonable saturated current gain (20 min., in order to use a small driver transistor, Q_3)
- an adequate collector-emitter breakdown voltage
- rapid fall time during turn-off (storage time is not critical)

The key factors in the design of the storage transformer (T_2) are

- the converter duty cycle, $t_1/(t_1 + t_2)$
- the secondary-to-primary turns ratio, N_S/N_P
- and the primary inductance, L_P (this is set by the operating frequency)

When Q_4 turns off, the core flux cannot change immediately. So the primary ampere-turns immediately *before* the Q_4 turnoff equals the secondary ampere-turns immediately *after* the Q_4 turnoff: $N_P i_1 = N_S i_2$. N_P and N_S are the primary and secondary winding turns, respectively, and i_2 is the peak secondary current.

The OFF time, t_2, is the time needed for the secondary current to go to zero, at which point a new cycle can begin. You determine this by assuming that the load voltage is constant for the duration of one cycle. As an example, suppose you run the converter at 1 kHz. Then, if it takes 20 s to charge the capacitor, you will use 20,000 cycles to raise the load voltage from zero to 500 V. Thus, the voltage increment per cycle is negligible, and you may consider the load voltage constant throughout the cycle.

The turns ratio

The open-circuit output of T_2 is $E = L \frac{di}{dt}$ and the load voltage is $V_L = \frac{L_P i_1}{t}$ at any time t (t starts when Q_4 turns OFF). The secondary current i_2 decreases linearly; the time to decrease from its peak value to zero is $t_2 = \frac{L_S i_2}{V_L}$. This time varies throughout the capacitor charging cycle. It is shortest when the capacitor is fully charged.

Since $L_S = \left(\frac{N_S}{N_P}\right)^2 L_P$ and $i_2 = i_1 \frac{N_P}{N_S}$, then by substitution

$$t_2 = \frac{L_S i_2}{V_L} = \left(\frac{N_S}{N_P}\right)^2 \left(\frac{L_P i_1}{V_L}\right)\left(\frac{N_P}{N_S}\right) = \left(\frac{L_P i_1}{V_L}\right)\left(\frac{N_S}{N_P}\right)$$

From eq. 1, $t_1 = \frac{i_1 L_P}{V_{CC}}$

therefore, $\frac{t_1}{t_2} = \frac{i_1 L_P}{V_{CC}} \times \frac{V_L N_P}{L_P i_1 N_S} = \frac{V_L N_P}{V_{CC} N_S}$

from which $$\frac{N_S}{N_P} = \frac{V_L t_2}{V_{CC} t_1} \quad (3)$$

This expression gives the turns ratio needed to proportion the ON and OFF times for a given duty cycle. The drive-oscillator circuit sets the maximum duty cycle, which in this case is about 75%. Other factors that affect the turns ratio are the collector-emitter voltage and the fall time of the switching transistor during turn-off. These two factors imply that you want the highest turns ratio allowable, provided that it is compatible with the drive-oscillator duty cycle.

Example. Assume a maximum duty cycle of 75%, and substitute the values of the previous example into eq. 3.

$$\frac{N_S}{N_P} = \frac{500}{(2)(3)} \approx 80.$$

With this turns ratio, the maximum collector-emitter voltage is

$$\frac{V_{L(max)}}{80} + V_{CC} = \frac{500}{80} + 2.7 = 9\ V.$$

Selecting the inductance of L_P

L_P, the primary inductance of T_2, has no optimum value. You select it for a given ON time (t_1) determined by the drive circuit. This time, in turn, is based on the specifications of the core materials, the power-transistor switching speed, and so forth. In general, make t_1 as small as possible, while keeping the energy stored in the transformer much greater than the energy lost in the transistor in each cycle. Keep the transformer losses small by selecting the proper core material and wire size. To prevent saturation of the core, it must be air-gapped.

The equations applicable to L_P are:

$$U_L = \frac{1}{2} L_P i_1^2, \quad (4)$$

and $$i_1 = \frac{V_{CC} t_1}{L_P} \quad (5)$$

Substituting (5) in (4), you have

$$U_L = \frac{1}{2} L_P i_1 \frac{V_{CC} t_1}{L_P} = \frac{1}{2} V_{CC} i_1 t_1 \quad (6)$$

U_L is the energy stored in the inductance during each cycle. Since it is desirable to have L_P as small as possible (t_1 small), select the ON time, t_1, on the basis of power stored to power lost during each cycle.

Example. Choose $t_1 = 350\ \mu s$. Then the energy stored is

$$U_L = \frac{(2)(9)(3.5)10^{-4}}{2} = 3.15 \times 10^{-3}\ \text{joules/cycle}.$$

And if you assume an inductor efficiency of 90% min., then the losses per cycle are $0.1 \times 3.15 \times 10^{-3} = 3.15 \times 10^{-4}$ joules/cycle.

Power losses

Power stage transistor losses consist of the saturation-voltage losses during the ON portion of the cycle and the switching losses during turnoff. You can express these on an energy-per-cycle basis as $U_T = U_{sat} + U_{sw}$. Also,

$$U_{sat} = \frac{V_{CE(sat)}\, i_1 t_1}{3}$$

and

$$U_{sw} = \frac{V_{CE} i_1 t_f}{2}$$

where t_f is the transistor fall time.

Example. Substituting into the above equations $V_{CE(sat)} = 0.2\ V$, $V_{CE(max)} = 9\ V$, $t_1 = 350\ \mu s$, and $t_f = 10\ \mu s$,

$$U_{sat} = \frac{(0.2)\ (9)\ (350)\ 10^{-6}}{3} = 2.1 \times 10^{-4}\ \text{joules/cycle}$$

$$U_{sw} = \frac{(9)\ (9)\ (10)\ 10^{-6}}{2} = 4.05 \times 10^{-4}\ \text{joules/cycle}.$$

Again, assume an average duty cycle of ⅔. Then the average period is

$$t_{av} = \frac{(3)\ (350)\ 10^{-6}}{2} = 5.25 \times 10^{-4}\ s.$$

The average frequency is, therefore, 1900 Hz.

You can now estimate the transistor power losses as

$$P_t = (U_{sat} + U_{sw})\ f_{av} = (2.1 + 4.05)10^{-4} \times 1900 = 1.2\ W.$$

This estimate is higher than the actual value, as it assumes maximum switching losses and maximum frequency during the whole capacitor charging cycle.

The only other major losses are in the drive circuit. You can estimate them on the basis of the current required to drive the power stage. The drive-circuit losses during the ON time are

$$U_{d1} = \frac{i_1}{h_{FE}} V_{CC} t_1\ \text{joules/cycle};$$

drive-circuit losses during the OFF portion of the cycle are

$$Ud_2 = \frac{V^2_{CC}}{R_4} t_2\ \text{joules/cycle}.$$

Example.

$$U_{d1} = \left(\frac{9}{18}\right)(2.5)\ (3.5)10^{-4} = 4.4 \times 10^{-4}\ \text{joules/cycle}$$

$$U_{d2} = \left(\frac{2.5}{120}\right)\ (1.75)10^{-4} = 3.65 \times 10^{-6}\ \text{joules/cycle}.$$

dc-dc converter (concluded)

Efficiency

You can define the total circuit efficiency as

$$\eta = \frac{(total\ energy\ stored\ per\ cycle) - (total\ energy\ lost\ per\ cycle)}{total\ energy\ stored\ per\ cycle} \times 100\%$$

The total estimated losses (transistor, inductor, and drive-circuit) are $(6.15 + 3.15 + 4.44)10^{-4} = 1.37 \times 10^{-3}$ joules/cycle; total energy stored per cycle, $U_L = 3.15 \times 10^{-3}$ joules/cycle;

$$\text{estimated efficiency,} = \frac{(3.15 - 1.37)}{3.15} \times 100\% = 57\%.$$

This is a reasonable efficiency for many applications, so the ON time selected appears to be a sound choice. Sacrificing size and weight (to lessen the effect of switching losses), you can lengthen the ON time and increase the efficiency. A faster power transistor (such as the 2N2912) and a more efficient inductor would reduce losses still further.

Standby power losses

When the inverter is shut off, the significant power losses are

- load-capacitor leakage
- voltage-sensing circuit dissipation
- drive-oscillator starting-circuit losses

You can compute the latter two losses, but the first is unknown, as it depends on load-capacitor quality.

The sensing-circuit loss,

$$P_S = \frac{V^2_L}{R_8 + R_9 + R_{10}} = \frac{(500)^2}{2.5 \times 10^6} = 0.1\ W$$

The drive-oscillator losses,

$$P_d = \frac{V^2_{CC}}{R_4} = \frac{(2.6)^2}{120} = 0.05\ W$$

So the total circuit standby losses are

$$(P_S + P_d)3600 = (0.10 + 0.05)3600 = 540\ \text{joules/hour}.$$

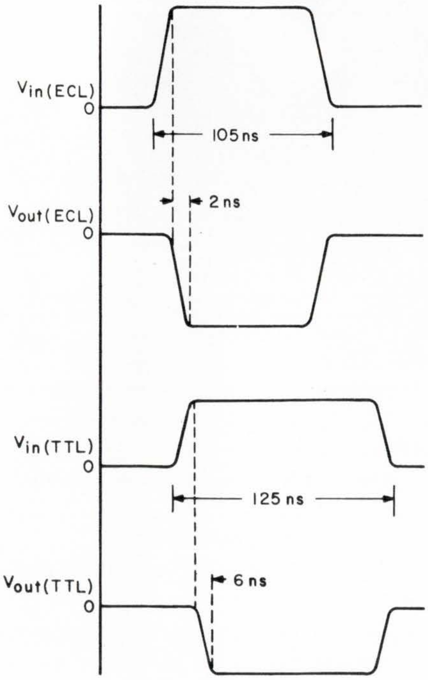
Thus, at 57% efficiency, you waste about five capacitor charges for each hour's operations. Leakage losses for a typical electrolytic capacitor are at least this large; so it probably is not worthwhile to reduce standby losses. Thus, total standby losses are about ten capacitor charges per hour. (Note: The numbers used in these calculations do not reflect the actual performance of the circuit of Fig. 4. This circuit operates at a higher frequency and uses a smaller transformer, T_2.)

EE FANOUT

Mark B. Leeds, Features Editor

TTL padding. Giving further strength to the buyer's market in transistor-transistor-logic (see EE, Dec., p. 73) and wishing to enlarge on its base as the sales leader, Texas Instruments is planning a number of innovations this year. TI will unveil three new families of the dominant digital logic, and plans to alternate source the rival SUHL TTL line. Engineers have modified the basic circuit design to provide: a high-noise immunity TTL; a non-saturating TTL for speeds comparable to emitter-coupled logic; and an ultra-low power TTL that will consume one-fifth the dissipation of current standard low-power TTL (which is 1 mW/gate). Details remain proprietary, as do the market introduction dates.

Various catalog forms of high-noise immunity logic exist—providing from 6 to 80 volts of transient protection—supplied by such IC houses as Motorola, Amelco, and United Aircraft (see EE, Nov., p. 14). A lower low-power TTL form should bite into the slower MOS logic market. And a 1-2 ns propagation delay TTL family will curb some standard ECL growth (which runs from about 3 ns down into the picosecond realm). The total import to users is a greater degree of latitude in system design and product selection.



Faster. Standard ECL is faster than current TTL logic, because the former is non-saturating, and has lower parasitics and impedance levels. Basic gate is more complex and requires additional power.

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KHX	U/L recognized for opposite polarity ratings.
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AMF | POTTER & BRUMFIELD

Highlights of ISSCC

Now, in the twenty-first year of semiconductor electronics, the solid-state technology is showing definite signs of maturity. Semiconductor devotees are abandoning the device-oriented oneupmanship tack—and are instead becoming systems-oriented.

Evidence of the "adult" theme is this year's International Solid State Circuits Conference, considered the premier technical meeting of the industry. The 1969 Philadelphia confab, scheduled for February 19-21, will focus on circuits, subsystems, and systems, concentrating on the solution to specific, practical problems.

Foremost among the many topics are linear integrated circuits, microwave systems, and interfacing with computer technology tools.

For example, the last-mentioned includes computer analysis and simulation of MOS-ICs, topological layout and synthesis, memories, and diagnosis of gate failures in combinational circuits. A panel discussion on CAD will examine the vendor-user interface and modeling dilemmas. Five more papers on the subject cover speed optimization in pulse and switching circuitry, variable-threshold FET performance, and MOS circuitry. Finally, computer graphics in the context of standard vs custom LSI and mask generation wrap up the topic coverage.

Other prominant subjects include memory systems, optoelectronics, digital system implementation, consumer electronics, and power generation and control. The "power" papers cover a new IC for proportional power control, silicon transducers, pressure-sensitive diodes, a Hall-element switching circuit, and phase-sensitive rectifier circuits.

The keynote address, "Strategy and Tactics for Integrated Electronics," will be given by J. A. Morton of Bell Telephone Laboratories. And, continuing the meeting's international flavor, 20% of the 150-odd papers and panel sessions will be conducted by engineers from abroad. Many are truly "state of art," evincing the closing of the technology gap between here and abroad. Among the topics are a 1.5-W monolithic amplifier from R.T.C. Radiotechnique of France, CAD topology from Tokyo-Shibavra of Japan and Technische Hochshule of Germany, and discretionary-wired MOS memories from Mullard Labs (U.K.).

In linears, the dominant themes are operational amplifiers, video circuits, receiver amplifiers, MOS synch separators, tuned circuits, and oscillators; also, proportional power control, transducers, motor switching, regulators, and analog delay lines.

The microwave accent is on bulk-effect and avalanche circuitry, with topics including power generation, amplification, and conversion. Sessions on the computer art will cover systems partitioning and organization, the vendor-user interface, subsystem analysis and synthesis, failure analysis, and memory organization.

Registration for the conference is being handled by H. G. Sparks, The Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, Pa. 19104.

ISSCC PROGRAM

WED (2-19)

A.M. Sessions

New Op Amps
Bulk-effects, Avalanche Devices

P.M. Sessions

Keynote Address
Semiconductor Memories
Optoelectronics

Eve Panels

Microwave Power Generation
Analog ICs
LSI: Custom vs Standard
Artwork Design, Implementation
Memory Impact of LSI
Electroluminescent Displays

THUR (2-20)

A.M. Sessions

Digital Circuits
Microwave Amplifiers, Oscillators
Consumer Electronics

P.M. Sessions

Solid-state Power Control
Hybrid Power Amplifiers
Computer-Aided Design

Eve Panels

MOS-FETs Today
Digital Techniques
Low-Noise Microwave Techniques
Phased Arrays
Computer-Aided Circuit Design
Consumer Electronics

FRI (2-21)

IC Design Technology
Analog Circuits
Circuit, Device Modeling

←Circle 33 on Inquiry Card

Ion implantation: the sock-it-to-'em method to dope semiconductors

There is a new girl on the block. Nobody knows how good she is yet. But she seems to have a lot to offer.

By Stephen A. Thompson, Western Editor

Ion implantation is a newly emerging semiconductor processing technique involving many interrelated phenomena. There has been much confusion, both semantic and technical, in this complex field, but progress toward understanding the process and fabrication of production devices is being made at many companies and research labs both here and abroad.

While it is still too early to tell what the practical limitations of ion implantation are, it is obvious that neither will it replace diffusion, nor is it just another fad. The real promise is in marrying both processes to produce devices that will surely be better than either can produce independently.

Where the action is

Hughes Aircraft Co. makes MOS FETs and IMPATT diodes. The table on page 69 lists the differences between introducing the impurities by diffusion and by ion implantation. Hughes Aircraft Co. takes advantage of these differences to make the improved MOS FETs and IMPATT diodes shown in Fig. 1.

For the two MOS FETs, the fabrication steps are similar except for some dimension changes and the extra implantation step. The gate in the diffused device is necessarily wide to allow for registration tolerances and for the fact that diffusion spreads laterally. The overlap between gate and diffused channels produces a high parasitic capacitance in the diffused MOS FET.

In the implanted MOS FET, the gate can be made to its desired width, which can be almost three times smaller than the gate of the diffused device. A broad beam of boron acceptor ions is then implanted over the entire wafer. Most ions striking the oxide regions penetrate the oxide layer and are deposited in the bulk material, doping the offset channel region. Ions which strike other regions are collected harmlessly in the metallization layers or form p+ regions in the diffused areas.

Alignment of the implanted channel and the gate is automatic, because the gate serves as the mask and there is no lateral spread of ions. Photoresists, oxide layers, metalizations, and metal contact masks have also proven effective as masks in similar situations. Dr. Edward Wolf of the Hughes Research Labs has used a scanning electron microscopy to show that diffused junctions are indeed located far under the gate, while implanted junctions line up perfectly with the gates.

The alignment between gate and source or drain channels produces two to four times lower input capacitance and about 40 times less Miller capacitance than a conventional device for equal g_m. This reduction in parasitic capacitance makes the implanted MOS FETs about five times faster.

According to Robert Bower, Manager of the Applied Solid State Research Department located at Hughes in Newport Beach, Calif., there are other ways to get self alignment. However, they are not as good as ion implantation. These other methods also depart substantially from standard MOS technology by requiring the use of refractory metals, doped insulators, silicon etches, and similar items. At best, they yield devices only half as fast as the implanted ones.

Hughes is making experimental MOS devices for an experimental Air Force system. Both the process and the results are good enough to maintain an active pro-

What is ion implantation?

Ion implantation is simply a method for doping semiconductors. In diffusion—the popular doping method used today—an impurity is presented to the surface of a semiconductor, and under proper temperature treatment it diffuses into the bulk material. In the new method, impurities which are ionized and accelerated to high velocity, penetrate the semiconductor surface and deposit in the interior.

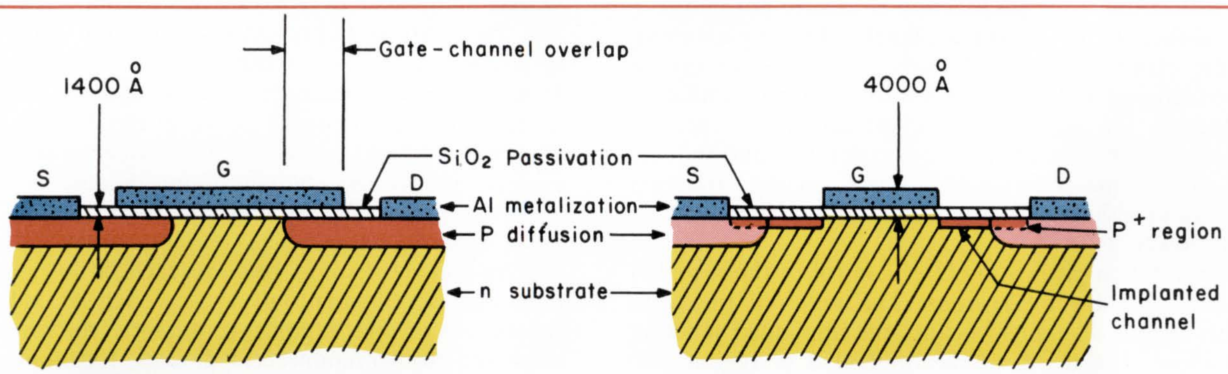
What can ion implantation do for me?

Diffusion and ion implantation are two different physical processes for doing the same job, doping. To oversimplify, diffusion is a temperature dependent phenomenon, while ion implantation depends primarily on kinetic energy. One intuitively expects different end results.

A new approach always suggests the happy possibility that certain jobs can be done better, or that previously impossible tasks can now be performed. Listed below are the main differences between ion implantation and diffusion. Somewhere in the list is a difference that may spell out an advantage for you.

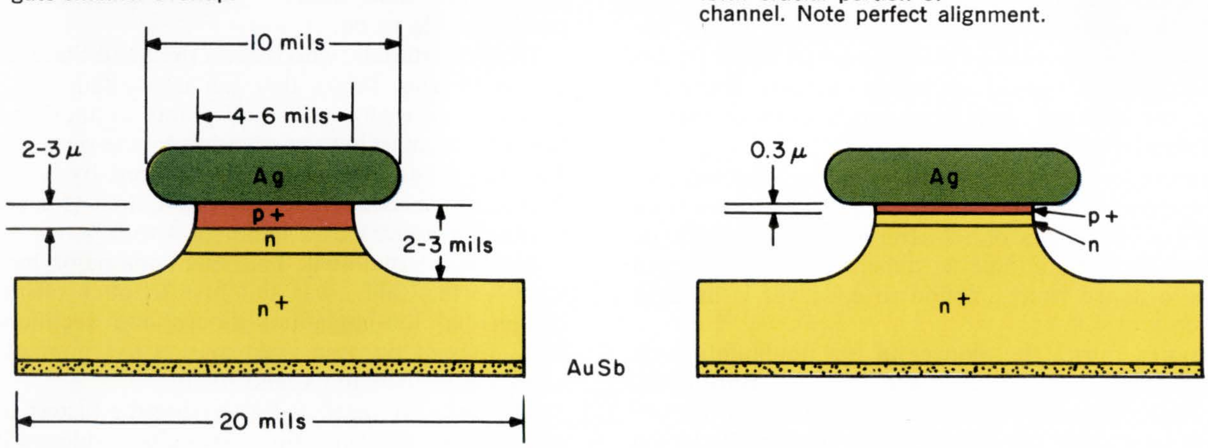
HOW ION IMPLANTATION DIFFERS FROM DIFFUSION

- The two techniques offer wider choice of dopant-substrant combinations.
- Solid solubility or diffuseability do not restrict dopants.
- Ion implantation is a relatively low temperature process.
- Very shallow and/or abrupt junctions can be made.
- Submerged layers of opposite polarity can be made in one step.
- A direct electrical measurement of doping is available.
- Manufacturing steps do not have to follow the same order of diffusion.
- Production steps can be eliminated.
- Purer doping is possible.
- The dopant does not spread laterally.
- Junctions can be formed beneath existing passivation layers.



Diffused, passivated MOS FET. Note the gate-channel overlap.

Diffused, passivated MOS FET using ion implantation to form crucial portion of channel. Note perfect alignment.



Diffused IMPATT device. Note wide p+ region.

IMPATT device with p+ region implanted. Note how thin the layer is. It also makes a more uniform junction.

Fig. 1: **How ion implantation improves semiconductors.** Thanks to the better alignment, the implanted MOS FETs operate five times faster than diffused ones. Implanted IMPATT diodes run cooler, are less noisy.

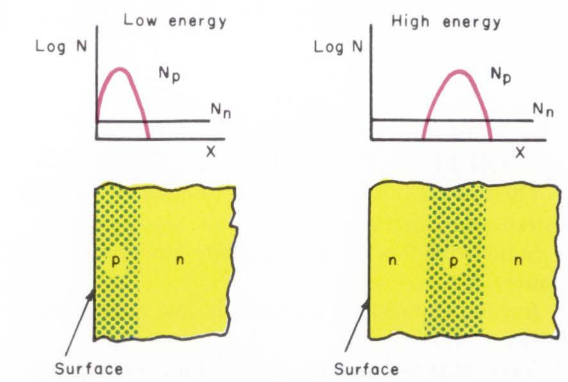
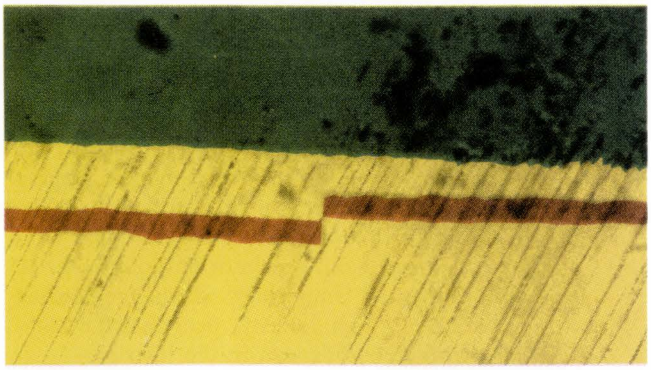


Fig. 2: **Implanted junctions.** Assuming, ideal distribution, the amount of energy provides accurate control of the location of the junction or buried layer.


Buried layers are easy to make with ion implantation. Note also the masking effect of a thin (0.3 μm) gold mask, which brings the buried layer closer to the surface. Implantation energy was 2 MeV. (Photomicrograph courtesy of Roosild, Dolan and Buchanan, AFCRL.)

gram to make ion-implanted semiconductors for digital applications. Ion implanted ICs (probably MOS memories and shift registers) will be the next step.

Another illustration of the advantages of ion implantation is in the IMPATT* diodes shown in Fig. 1. Both structures, the diffused and the implanted, are formed by starting with an n^+ substrate, growing an n-type epitaxy, and doping that with p-type dopants.

Since diffusion is sensitive to crystal imperfections and dislocations, the pn junction is usually not uniform, and neither is the IMPATT avalanche. Ion implantation, on the other hand, is relatively insensitive to crystal imperfections, and produces a more uniform junction.

Because the implanted junction can be so shallow, 0.2 microns versus about 2-3 μm for the diffused device, its thermal resistance is much smaller. Junction temperatures have been reduced by 4°C per watt of input power.

Implantation gives you better control of the n-region thickness for several reasons. The required thickness of this region is smaller because the implanted junction is shallow. The depth of the implanted p^+ region also varies less. The n-n^+ interface does not move during doping because the ions are implanted at a relatively low temperature, 300° to 500°C.

Only the microplasma noise level is seen in the implanted diodes, whereas as many as seven occur in diffused diodes. At typical operating currents, the noise level of the diffused diode is as much as twice that of the implanted diode.

Optimization of these devices is still a long way off, but outputs of 1.5 W of cw power at X-band have been reported at efficiencies of 5%. Improvement in this type of device should continue as dimensions are tightened and the distance from junction to epi layer is brought under control.

Ion Physics Corp., the pioneer in ion implantation. A subsidiary of High Voltage Engineering, Burlington, Mass., this company has been selling phosphorous-implanted solar cells for four years to Wright Patterson AFB, NASA-Goddard, JPL and others. No good economic comparison with diffused cells is available because production quantities have been small.

Ion implantation was first to provide a junction 0.2 micron deep, which increased the blue-light response of the cells. But this advantage no longer exists as low-temperature diffusion (800°C) now also provides shallow junctions. Since junction uniformity is not too important in solar cells, ion implantation today does not offer a clear advantage for them.

Ion Physics Corp. also makes IR detectors of InAs and InSb, and is getting ±2% uniformity from one to another, about 10 times better than with diffusion. GaP, GaAs, and GaSb devices are also being investigated, and the company is presently looking for 2 μm IR response for night vision sensors and other applications.* It has under development a sensor matrix of 16 elements (on 50-mil centers) active in the 3-5 μm region. The goal is to make a 300 x 300 device array on 5-mil centers. IPC is also studying Gunn diodes.

Since 1967, IPC has had a contract with Corning Glass covering three areas: equipment design of ion sources and accelerators basic reseach on ion implantation; and development of devices such as MOS transistors, microwave bipolar transistors, microwave diodes, and electro-luminescent devices. Ion implantation holds the promise for practical electroluminescent devices made with III-V compounds (GsAs) and II-VI compounds (InSe, InSb)— something the diffusion has not been able to do.

Dr. Fred Bartels, who directs the Solid State Division of Ion Physics, thinks that ion implantation is ideally suited to make MOS FETs and points to another advantage of gate masking (in addition to the ones shown in Fig. 1). "Gate lengths can be reduced by a factor of 2 or 3, which reduces the gate active area (for the same transconductance) by a factor of 4 to 9."

Isofilm International. This small company, located in Chatsworth, Calif., was the first to offer off-the-shelf commercial ion-implanted diodes and rectifiers. Isofilm's present purpose is to market ion implanted devices and it plans to expand its line.

The units are marketed as having the fastest forward and reverse recovery time available, independent of pulse width or amplitude. It is doubtful, however, that doping in the conventional chemical sense of the word is responsible for that good performance. Since the forward drop of these diodes is less than 0.6 V (it can

*IMPATT (IMPact Avalanche Transit Time): A microwave diode oscillator that operates on the negative resistance that results from the combination of avalanche and carrier drift.

*Hughes Research Labs also has a program to make photodetectors with ion implantation. They have implanted large-area photodiodes of InSb.

be made as low as 100 mV), they look more like Shottky barrier diodes, rather than like junction diodes. Of course, such low drop brings with it a relatively high reverse leakage.

However, Leonard F. Roman, Vice President of Isofilm, says you cannot use diffusion terms when you think of ion implanted diodes. "The ions find their way into the silicon in two different ways," he says. "Interstitial ions channel deeply and form a junction. Other ions impact-damage an area that lies immediately below the surface. This area serves as contact for the active channel and accounts for the extremely high pulse-handling ability of the diodes."

Isofilm will sell scribed implanted wafers and guarantee an 80% yield. Mr. Roman is so confident about his process that he says "major yield problems are associated with the silicon wafers, not the implantation." George H. Elliott, president of Isofilm, indicates that they can produce up to a half million chips per day, or 4000 packaged diodes.

Other players

Fairchild Semiconductor has had a product on the market for almost a year (their 2500 core driver) which uses ion implantation as a processing step. It feels that the process is proprietary, since it gives the company a competitive edge.

Dr. William J. King, formerly of Ion Physics, has started a new company, **KEV Electronics,** in neighboring Reading, Mass. He hopes to have a few unique products (initially, voltage-variable capacitors and high-frequency devices) by June 1969, sales before the Fall is over and product acceptance within a year. Dr. King thinks ion implantation cannot compete yet with diffusion in silicon digital ICs.

Dr. A. U. MacRae of **Bell Laboratories,** Exploratory Semiconductor Technology Labs, is enthusiastic about the reduction in processing steps that are possible along with the reproducibility, shallow junctions, and low temperature benefits. He contends that processing is fast enough to compete with diffusion.

Roosild, Dolan, and Buchanan at the **Air Force Cambridge Research Lab** have used energies of 1 to 2.5 MeV to implant buried layers in silicon. As shown in Fig. 2, one application of this technique would be to use the buried layer as the gate for a vertical channel junction field effect transistor.

There are several other areas of general interest where progress is being made. Better resistor doping is possible with ion implantation for high-value resistors, because the sheet resistivity can be controlled accurately. Good ohmic contacts can be made thanks to the high surface concentration of impurities that can be obtained. Nuclear particle detectors have been made with alpha particle resolution comparable to that observed in good surface barrier detectors. There is work going on to make implanted bipolar devices, but the problem is complex and no definite results are available yet.

Even though junctions have been implanted in materials such as Ge, CdTe, CdS, and SiC, silicon remains the main one by far. Professor James W. Mayer of Cal Tech, who has worked many years on ion implantation, stresses investigation in silicon because, "if we don't understand it in silicon, we can't understand it anywhere".

Next to silicon, ion implantation seems to hold a promise for GaAs. According to Professor James Gibbons of Stanford University, good isolation can be obtained in GaAs with planar technology. Oxide layers can be formed, etched, and implanted through. With diffusion, on the other hand, GaAs devices must be isolated using mesa technology.

The equipment—how to get turned on

Ion implantation is not as simple as it may first appear, nor are all of its advantages always available. Let us explore its limitation further. Most of the field is completely uncharted for there is no "recipe book." A company investigating a particular application must do its own research. The equipment is sophisticated and expensive, because it must be versatile enough to generate almost any ion in vacuum, accelerate it to a high velocity, separate it by mass and finally implant it at a controlled temperature and/or orientation.

Post acceleration

The decision to pre or post accelerate the ion beam (before or after mass separation, respectively), creates the first price division. Post acceleration is cheaper because the relatively low energy beam from the ion source, about 2 to 10 keV, can be mass separated easily —which reduces the dimensions of the implantation system. The separated low-energy beam (about 100 keV max.) is accelerated in one step to the full target potential.

This approach has two severe drawbacks. First, the single-stage acceleration has an "electrostatic lens" effect on the beam—making large area, uniform implants difficult to obtain. Second, the target chamber instrumentation must float at high voltage, so accurate measurements and control of target are very difficult.

Pre acceleration

The answer to those problems is a pre acceleration system such as shown in Fig. 3. The ion source is at high voltage, so most of the system is grounded. There is, therefore, no "electrostatic lens" effect on the beam, and the target is easy to control.

This type of system produces ion beams of several million electron-volts. However, for energies higher than 300 keV, the high voltage source must be a Van de-Graaff or a Cockroft-Walton type of accelerator. These machines, plus the added mass separation requirements, add to the cost substantially. Is it worth it? "Yes," says Fred Bartels of Ion Physics. "To implant heavy ions into heavy substrates you'll need that type of machine. But equipment is not where the money is spent in a (diffusion or ion implantation) process for semiconductors, so equipment cost is not as important as it first appears."

Robert Bower of Hughes costs out a low voltage pre-acceleration system this way. "A diffused MOS processing line costs about $600,000. The MOS manu-

Ion implantation system

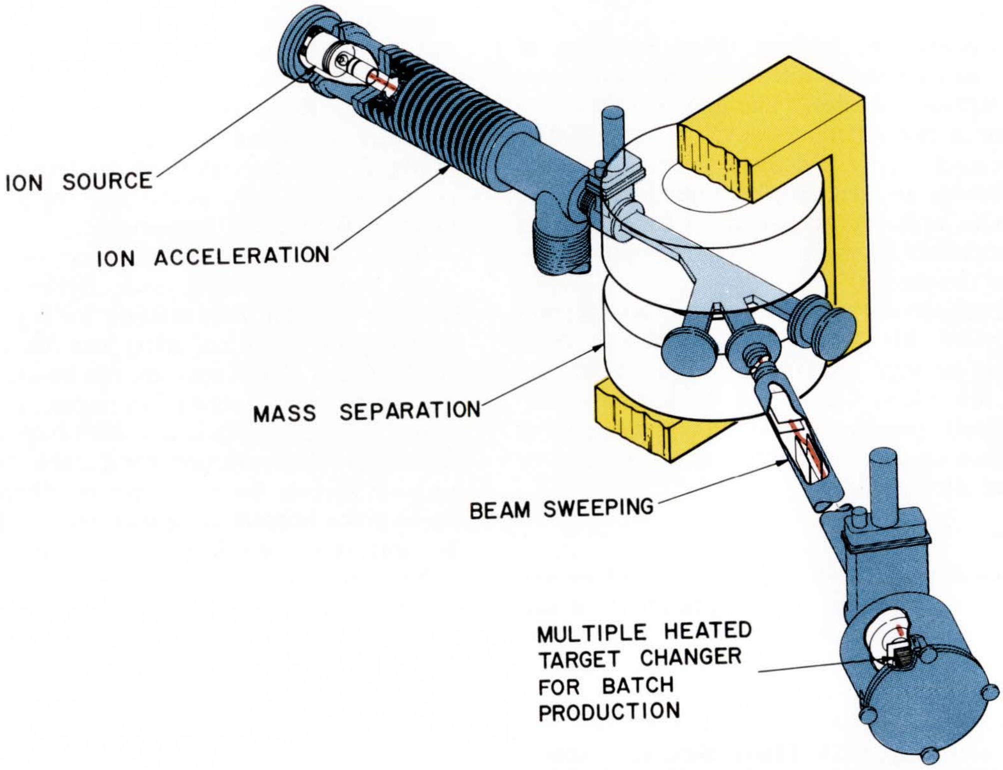


Fig. 3: **Ion implantation system with pre-acceleration.** The ion source, floating at the highest system voltage, generates a plasm that contains the desired dopant. The beam emerges from a lens directly into a multi-stage acceleration column, where it is accelerated to its full potential. From the exit aperture of the accelerating column to the target, the sysetm is grounded, eliminating "electrostatic lens" effects. A large mass-separation magnet deflects the high-energy beam. Beyond this magnet, deflection plates steer or sweep the beam (just as in a CRT) to make uniform, wide-area implants regardless of beam profile. Samples are mounted and manipulated in the temperature-controlled target chamber, which is essentially at ground potential.

facturing station for ion implantation costs about $30,000 additional, so it becomes a 5% cost increase. You must then balance this against the 3 to 5 times better speed-power product that is possible to achieve."

To buy, or not to buy

Ion sources and systems are commercially available. Many of the companies involved in ion implantation, however, design and build much of their own systems—particularly the sources. Source technology is generally proprietary.

A post acceleration system costs around $50,000. An intermediate-voltage, 100 keV, pre-acceleration system is about $100,000. A high energy pre-acceleration system will range upward from there. Roughly, a 2 MeV generator would cost about $100,000, or half the total system price.

It is interesting to note that two companies in the field had particular capabilities that offset some of the initial costs. The Hughes Aircraft Co. had source technology derived from its extensive involvement in ion propulsion. It also has a semiconductor division.

Ion Physics also had considerable know-how in ion beams, as a result of early ion engine work. In addition, it has easy access to Van de Graaff generators through its parent company, High Voltage Engineering.

Isofilm and KEV Electronics are proof that despite the costs, the entrepreneur is not dead. Isofilm has spent four years developing most of their own techniques and equipment for implantation. On the other hand, Dr. King of KEV does not think it is worth designing your own equipment, and has bought most of his.

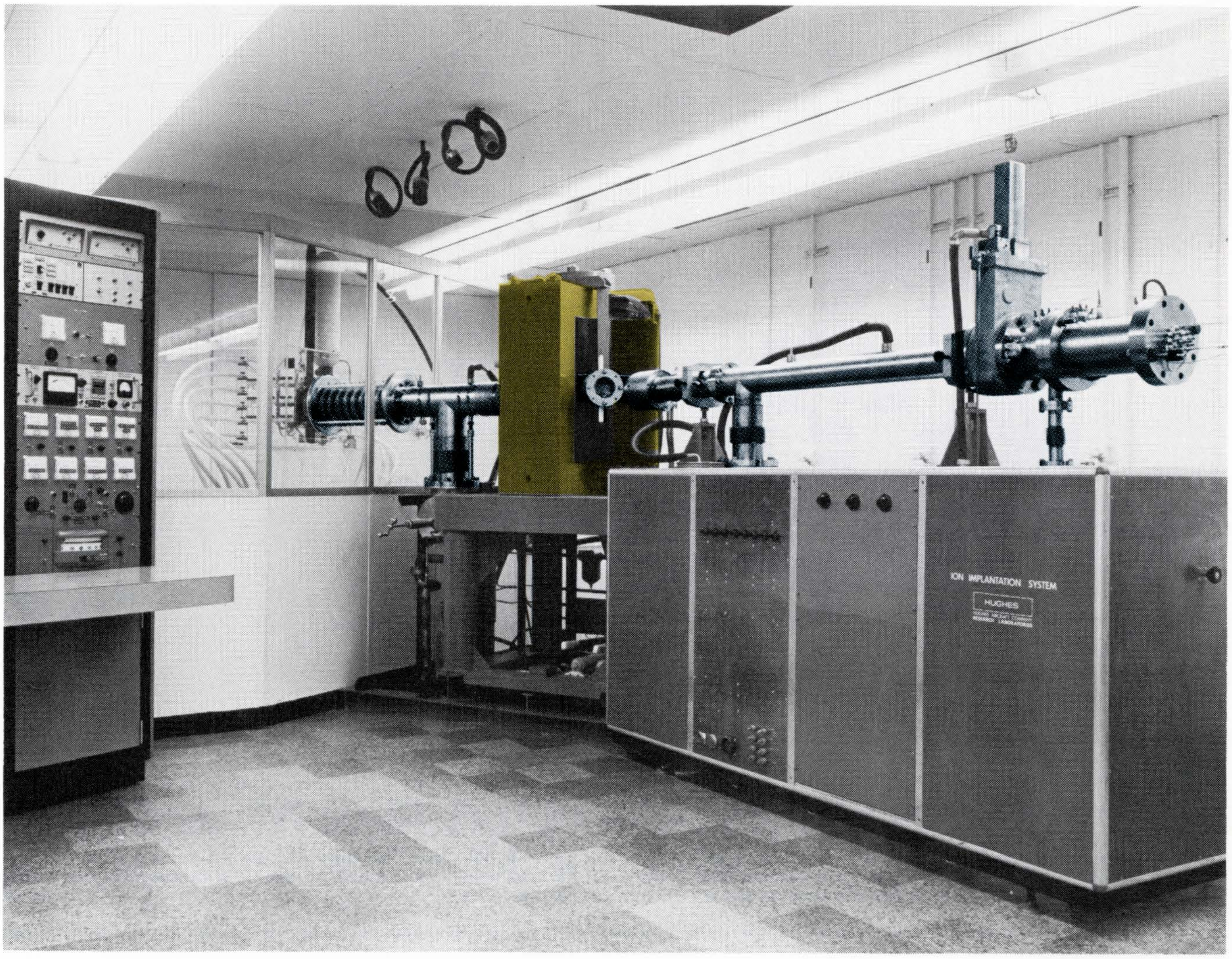
Production systems

Ion implantation equipment for production lines can certainly be simpler and cheaper than research systems, because the optimum implantation parameters would be established.

The source can be very simple, as long as it reliably puts out lots of the desired ion specie. Relatively cheap permanent magnets can accomplish mass separation. Minor adjustments of beam positioning can be made by varying the entrance angle to the magnet instead of providing a variable magnetic field.

A single high voltage supply, with voltage dividers may be sufficient to operate the source, lenses, and accelerating column. Sample handling apparatus will become the most complex part of the system. This is as it should be, because it is the processed wafers that we are after.

Professor Carver Mead of Cal Tech states that, today, a low energy system that will do radiation-damage implants at 20 keV can be built for $20,000.



This ion implantation system at Hughes Aircraft, Newport Beach Facility, can implant virtually any ion up to an energy of 150 keV. Unheated samples can be cycled in less than 5 minutes.

How to implant

It has not proven feasible to diffuse all types of dopants into all semiconductors. Diffusion technology is largely silicon technology, with germanium and gallium-arsenide a poor second and third. On the other hand, any conceivable dopant can probably be ion implanted into any substrate. This reopens the entire Pandora's Box of material combinations for the semiconductor designer to play with. Unlike diffusion doping, implanted ions always penetrate into the semiconductor, but this does not guarantee successful doping.

The first parameter that must be controlled when designing an ion implanted device is the ion distribution, since this will determine the doping profile.

All ions arrive at the surface with practically identical energies, which they dissipate through random interactions with the target nuclei and electrons. The ions scatter, slow down and come to rest, after traveling a distance R, called range. As shown in Fig. 4, the range of interest is the projection R_p of R onto the direction of incidence.

Since all ions randomly interact with target atoms, R_p will follow a statistical distribution characterized by the mean ion range $\overline{R}_p$, and a standard deviation in range $\overline{\Delta R}_p$.

In a paper published in the March 1968 issue of the Proceedings of the IEEE, Professor James F. Gibbons of Stanford University tabulated values of R_p and $\overline{\Delta R}_p$ for conventional dopants (B, N, Al, Pa, Ga, As, In and Sb) into silicon. With the aid of rather simple formulas, those values can be used to convert a total ion dose into an impurity profile for an amorphous (noncrystalline) semiconductor substrate.

What about crystalline substrates?

Unfortunately, all the world is not amorphous, especially the silicon world. It is is highly structured and this is important from the ion's point of view.

What the ion "sees," when it hits the semiconductor, depends crucially on crystal orientation. For example, when a silicon crystal is *tilted* 10 degrees with respect to to the <110> axis, it looks almost amorphous to the ions. If, on the other hand, the ions come into the lattice structure *along* the <110> axis, they see large openings (or channels) down which they can penetrate.

Fig. 4 shows how the distribution of ions varies from pure channeling (into crystal) to random (into amorphous). Well channelled ions can penetrate an average of 2-50 times farther than in amorphous material.

Ions do their thing

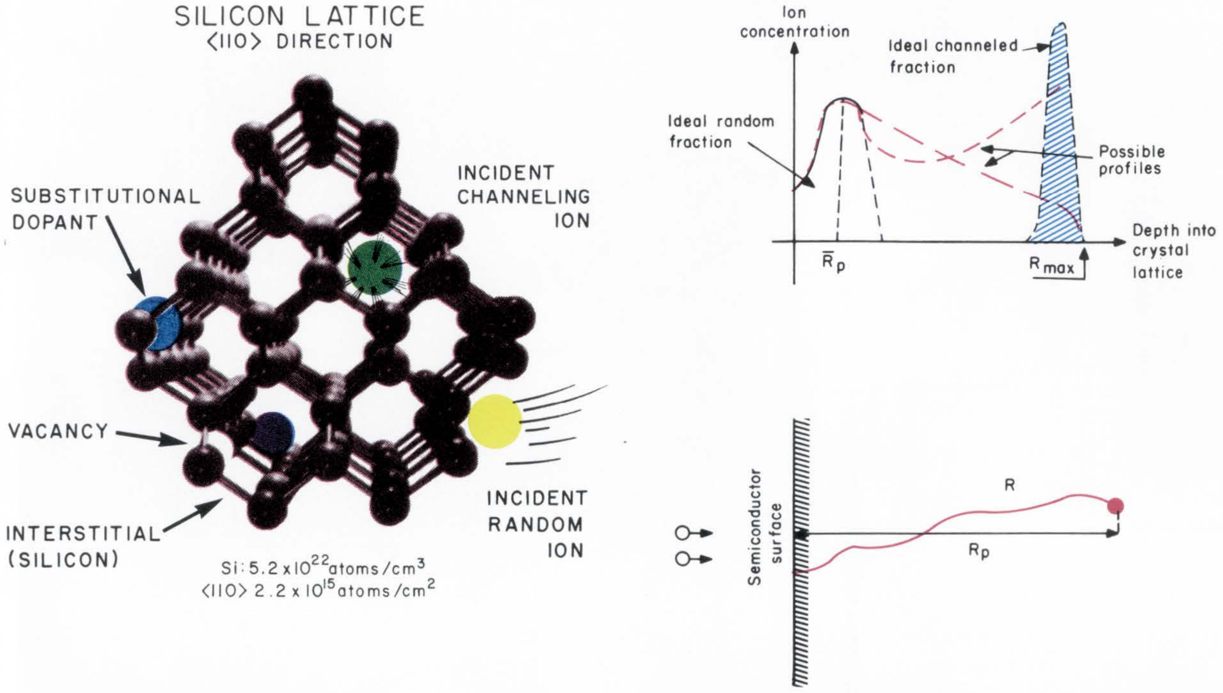
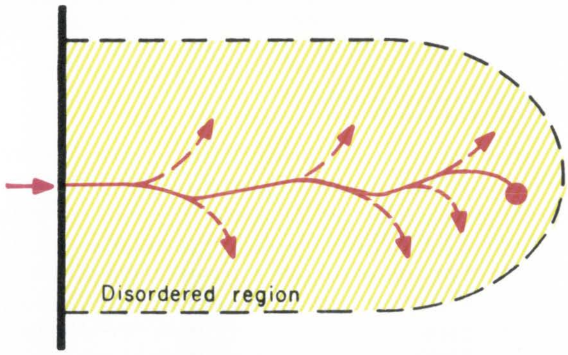


Fig. 4: **View of a silicon lattice** along the $<110>$ direction. Ions going into the paper penetrate deeply into the lattice (channeling). On the other hand, an ion coming at only 10° off the axis sees a closed structure, and scatters at random on the surface or just below it (random ion). Also, some ions fill vacancies in the silicon lattice (substitutional). The graphs (from the paper by Dr. Gibbons) show the possible impurity profiles between 100% random and total channeling, and the definition of ion range and projected range.

Fig. 5: **Non-channeling ions** create lattice disorder around their path, forming a damage cluster about 100 Å in diameter. In an amorphous material, the radiation damage effects are relatively unimportant. In crystalline material, whenever channeling is desired, they are significant.



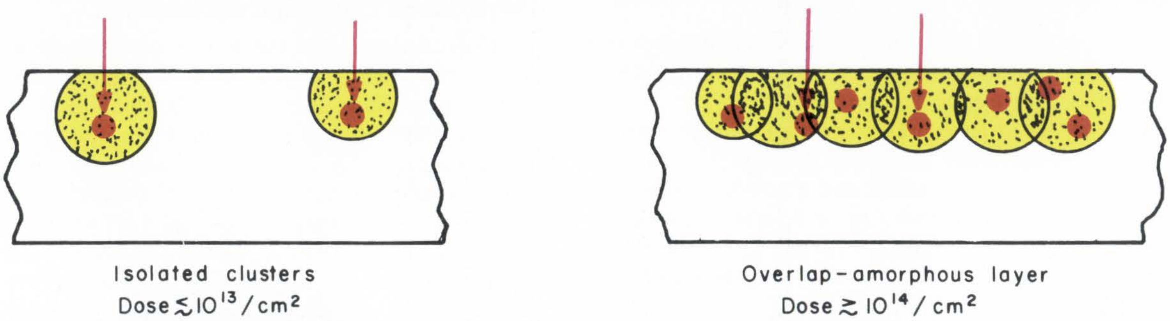


Fig. 6: **The ion dose affects the implanted layer** at room temperature. As the dose approaches $10^{14}/cm^2$, the damage clusters begin to overlap, forming a completely disordered layer. Cluster diameter is relatively independent of energy—higher energy ions simply penetrate deeper.

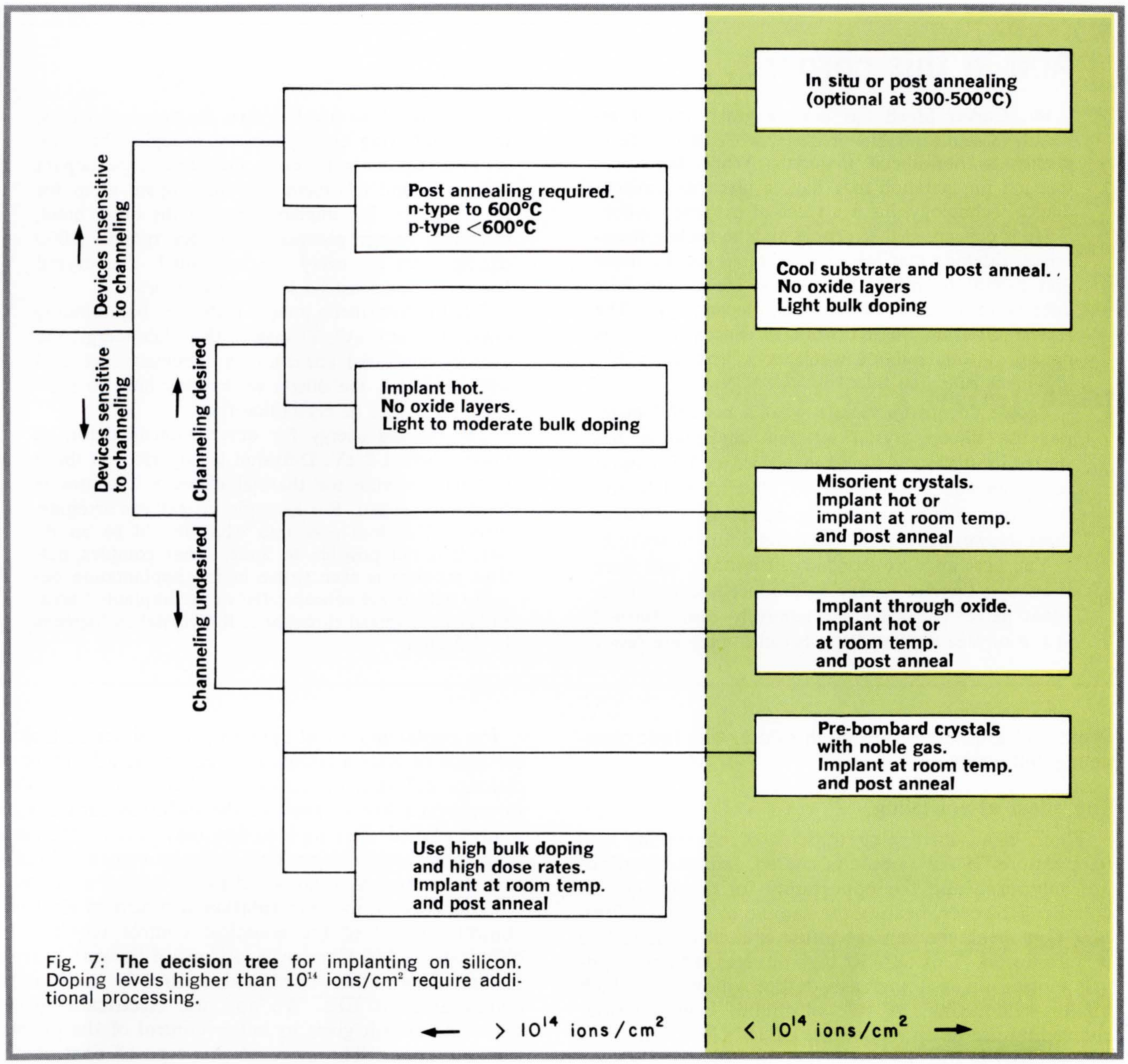


Fig. 7: **The decision tree** for implanting on silicon. Doping levels higher than 10^{14} ions/cm^2 require additional processing.

Complete elimination of channeling is not possible. Some ions will always travel the maximum channeling range in the crystal. Two methods for reducing the effects of channeling are to tilt the crystal off axis, or purposely create an amorphous layer. If the crystal is oriented several degrees off a major channeling axis, channeling can be minimized to useful proportions. Many implants into silicon are made 7° off the <111> axis. Tilting off the axis presumes a knowledge of crystal orientation, and you can find out what this orientation is with a sophisticated technique such as proton backscattering. Good wafers are sliced within a fraction of a degree of the <111> or <100> axis, so tilting them off axis may not be too difficult.

When implants are done through an oxide, channeling is minimized because of the severe dechanneling in the amorphous oxide layer. If there is no oxide, an inert specie such as argon or neon can be implanted first to create a damaged layer that has amorphous properties.

Even when channeling is desired and the best orientation is obtained, lattice atoms occupy a finite area of the space. Some ions will impact in this area and scatter, or dechannel. Thus the doping profile will be some composite of both amorphous and channeling. To complicate matters further, non-channeling ions produce radiation damage, because ion implantation is not an equilibrium process like diffusion. Unchanneled ions stop in a region of heavy crystal disorder that they themselves create, as shown in Fig. 5. When enough ions have been implanted, the damage clusters begin to overlap, as in Fig. 6, effectively creating an amorphous layer where all channels are closed and the surface goes amorphous independent of energy for a given combination of ion and target. This occurs at a doping level of

And in this corner . . .

Dr. Carver Mead has done a great deal of research in semiconductor material while at Cal Tech, mostly in non-silicon materials. While he agrees that ion implantation may have a place in semiconductor technology, his is a voice of extreme caution.

He is concerned that people may be fooling themselves, thinking that lots of new things can be made that cannot be made other ways. He is especially dubious in the areas of non-silicon technology. "The reason diffusion doesn't work is exactly the same reason ion implantation won't work," he states. His argument runs like this:

People do not appreciate what a beautiful material the silicon crystal is. Ion implantation has started in silicon and found some success. It is natural to extrapolate this success to other materials and think that it is only a matter of getting around to them. However, let us review what diffusion really is.

You heat up a semiconductor substrate until there is enough thermal energy to produce vacancy-interstitial pairs. Vacancies are relatively easily formed at the surface of the silicon because there are fewer chemical bonds to break. When the vacancy occurs, the dopant lying on the surface occupies the spot. As other vacancies diffuse to the surface, the dopant diffuses in and fills them up—one dopant atom for each vacancy. Ion implantation, on the other hand, is a high energy process—it creates roughly 1000 damage sites for every ion implanted. The crystal is a mess, and must be annealed to reorder it.

What makes silicon unique is its very high binding energy (about 4 eV). Thanks to this high energy, the vacancy-interstitial attraction is extremely high and when annealed, the silicon works very hard to rearrange itself into its crystalline form.

The binding energy for other semiconductors is lower, about 1-2 eV. Diffusion is imperfect in those materials because the thermal disorder it causes is harder to get out. For example, in gallium arsenide, when a Ga atom goes into what should be an As site, it is not possible to anneal that complex out. This problem is even worse in ion implantation because defects are concentrated in the implanted area, rather than spread throughout the crystal as happens in diffusion.

about 10^{14} ions/cm^2. Beyond this dose, very little channeling will occur.

The effect of annealing

There is an interesting tradeoff of channeling and temperature. If the sample is cooled, lattice vibrations are minimized and the opportunity for channeling increases. However, heating the sample to between 300-500°C, anneals the damage to the crystal out as fast as it is produced. This permits high dosages without channels closing up, but increases lattice vibrations, which hinders channeling. A rule of thumb is to consider channeling useful up to dosages of 10^{14} ions/cm^2.

The chart in Fig. 7 summarizes the discussion above. It lists the main decision points and suggests methods of achieving the desired results. It considers the doping level of 10^{14} ions/cm^2 as the break point for some techniques. Except for the cool substrate case, all methods that work below 10^{14} ions/cm^2 will work at higher doping levels. The reverse, however, is not true.

Where to from here?

How far will implantation go? In the near future, MOS technology will get a lot of attention from ion implantation. Those places where the problems of parasitic effects, uniformity, alignment, and temperature can be overcome will be early battlegrounds.

Although the promise is high, non-silicon technology will develop more slowly, as will devices requiring techniques such as buried junctions or channeling.

Further down the road, some speculate about the possibility of all ion implanted devices. Others toy with the idea of discrete implantation using fine beams, or broad area implantation with discrete area activation by local heating, such as with laser beam.

Ion implantation will have to prove either its technical value or offer a competitive economic advantage to dislodge diffusion processes. Semiconductor manufacturers would like to stick to the diffusion furnaces already installed. Ion implantation may provide the competitive impetus and produce an improvement of diffusion technology as it happened in the case of solar cells.

Others see an ion implantation a return to electrical control, instead of the chemical control required by diffusion. As Mr. Charles H. Alford of Stewart Warner Microcircuits states, "electrical control is much more comfortable for EEs. We now use electrically grown oxides because it gives us better control of the process for thin oxides. The more of this type of control, the better." With ion implantation, ion sputtering, and ion machining all under study, more of this type of control seems almost a certainty.

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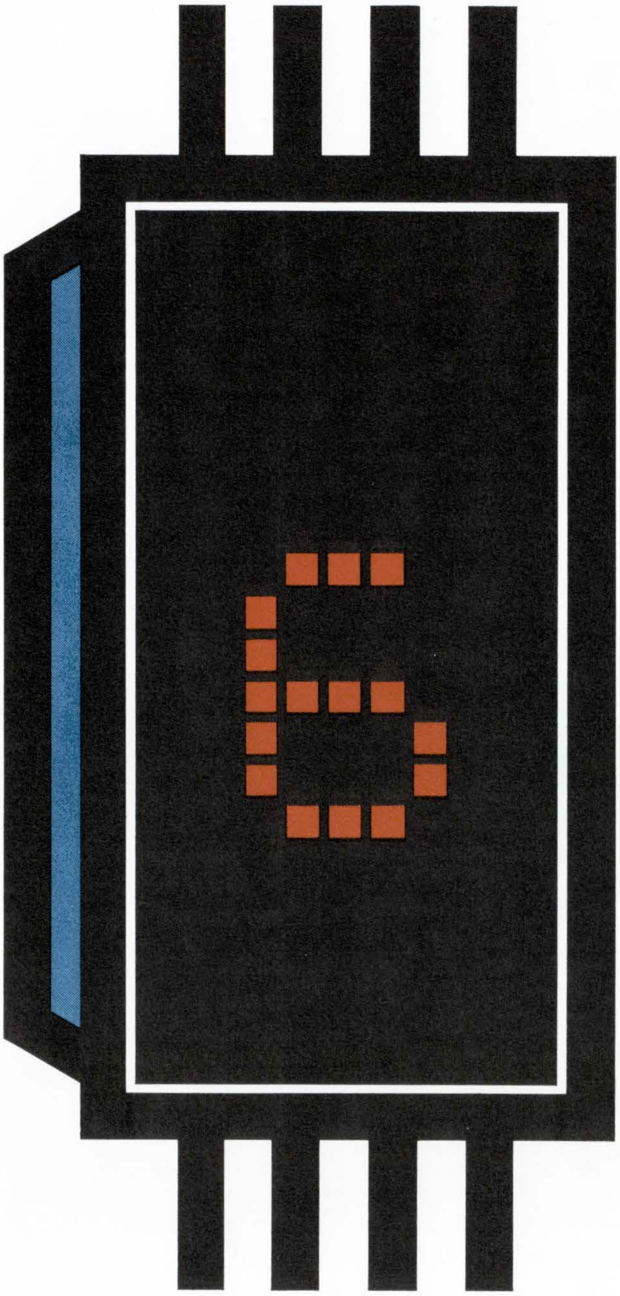
INFORMATION RETRIEVAL
Semiconductors, Integrated circuits, Microwave semiconductors, Materials



LOW PROFILE

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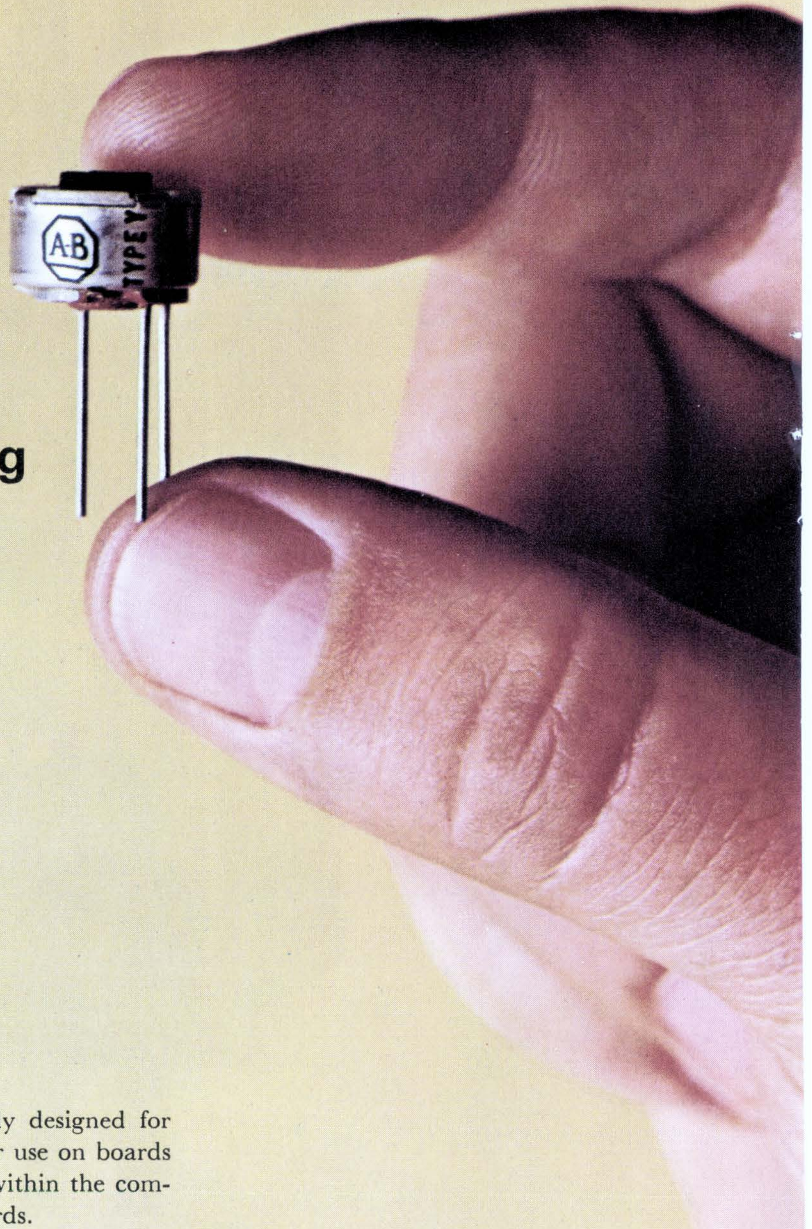

Basic Type Y unit shown actual size

With wheel for side adjustment

With attachment for horizontal mounting and wheel for side adjustment

With attachment for horizontal mounting

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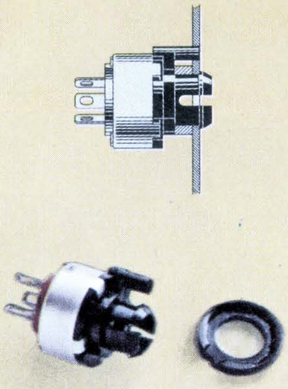

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Learn to live with a filter's reactance

Power line filters draw large reactive currents—but a power factor correction coil can help. Here are some tips on how to use one.

By Robert B. Cowdell,
Technical Director, Genistron Div.,
Genisco Technology Corp., Compton, Calif.

Today's power line filters require 100 dB of insertion loss at 14 kHz. This calls for large filter capacitors and inductors; the higher the line current, the larger those components get.

For very high line currents, the very large inductor cores needed to prevent saturation become very expensive. The filter inductance, therefor, must be reduced and compensated by boosting the capacitance. Such a filter, however, will draw a capacitive current from the line, spoiling the power factor. In this article, we'll show how to correct the power factor by adding a coil as shown on next page.

Large filters spoil the power factor

When large power line filters are placed in power lines, they load the line and draw large reactive currents, as shown below.

For example, a 100-A filter, on a 400-Hz line, draws a reactive current (I_C) of 60.9 A under no load. Such reactive currents can be even larger if the generator source impedance is also reactive, and of different sign than the net circuit impedance. Even with no load, the filter will draw so much reactive current that it may trip the line circuit breakers. At best, the breakers will trip at less than rated loads.

In addition, the capacitive current drawn through a reactive generator impedance will increase the generator terminal voltage to a level which might damage either the regulating equipment or the load. The circuit's power factor will be zero at no load and very low at full load.

A power factor correction coil can solve this problem. The coil inductance is

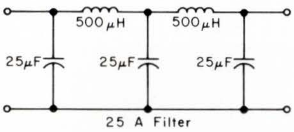
$$L = \frac{1}{(2\,\pi f)^2\,C}$$

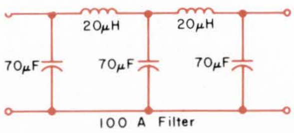
When shunted across the filter, this coil draws about the same current as the sum of the currents through the capacitors. For the 100-A, 400-Hz filter, L is 753.9 μH. Now, the current through the coil will be exactly opposite in phase to the reactive line current, and the reactive current is zero under no load. When a load is connected, the line current will then be the same as the load current, and the power factor will be the same as the load power factor for all loads.

All is not roses . . .

Our coil, however, introduces some complications. For example, it causes a small drop in output voltage at no load and a smaller drop at full load. This happens because coil current cancels the total current of all the capacitors at the input terminals of the filter, but only partly cancels the current in the individual capacitors. Furthermore, individual series inductors in the filter still have a net capacitive current flowing through them, and a resultant voltage drop across them. If we wanted to cancel the individual leading currents completely, we would need several correction coils, one in shunt with each capacitor. But this is not feasible because the heat losses would go up with the number of coils.

A correction coil must be connected at the filter *load* terminals. The voltage rise it produces in the filter then becomes a small voltage drop. As the load in-





f (Hz)	Inductive reactance X_L (Ω)		Capacitive reactance X_C (Ω)		No-load reactive current I_C (A)	
	25 A	100 A	25 A	100 A	25 A	100 A
60	0.377	0.015	35.4	12.6	3.3	9.1
400	2.51	0.10	5.3	1.9	13.1	60.9

Filter power. Typical 25- and 100-ampere filters both have the same insertion loss. Units' inductive reactance, capacitive reactance, and reactive current drawn are as listed in the table.

Frequency	Insertion Loss (dB)	
	with coil	without coil
60 Hz	0.47	0.02
120 Hz	0.48	0.03
400 Hz	0.41	—0.04
800 Hz	0	—0.46
1 kHz	—0.34	—0.80
2 kHz	—2.98	—3.39
4 kHz	0.98	1.13
6 kHz	3.31	3.32

Table of insertion loss for the 100-A filter. Although power factor correction coils will not materially alter the insertion loss of filters in their stop band, they can change the response in the pass band.

A filter's reactance (concluded)

creases (if the load power factor is high), the voltage drop in the filter is reduced. Thus, the power factor correction coil tends to improve the load voltage regulation, since it reduces the full-load voltage drop.

Even if the coil were installed at the filter *input* terminals, it would still produce a unity power factor loading at the generator terminals. The line voltage, however, could rise considerably through the filter, and the size of the filter inductors would have to be increased to prevent saturation by the added current in the capacitors.

Since capacitive current increases with frequency, it is much lower at 60 Hz than at 400 Hz. Also, a 60-Hz filter does not need a very steep insertion loss characteristic to prevent harmonic distortion at 60 Hz, so it requires fewer filter sections. For these reasons, power factor correction coils are seldom needed for 60-Hz filters, but are almost always necessary with heavy current filters for 400 Hz or higher power frequencies.

To each frequency its filter

Since line currents are much smaller in 60-Hz filters than in 400-Hz filters with the same total capacitance, the voltage rating of their capacitors can be lower, and the capacitors smaller. Capacitors in 400-Hz filters must be larger to allow for derating due to the heavier currents. Because of this, do not use a 60-Hz filter on a 400-Hz line. Even if the capacitor dc voltage rating is adequate for 400 Hz, the 60-Hz filter may have prohibitive insertion loss at 400 Hz. On the other hand, a filter designed specifically for 400 Hz may be used safely at any lower power frequency.

We used a computer to calculate the filter output voltage, assuming a 0 Ω source impedance and a 1.15 Ω load (115 V/100 A). At 400 Hz the uncorrected filter would produce a load voltage of 115.55 V for a 115-V input because of the 0.04 dB gain. With the power factor correction coil in place, the load voltage would be 109.7 V for a 115-V input level. Then, the source voltage might have to be raised to 120.6 V to provide 115 V at the filter load.

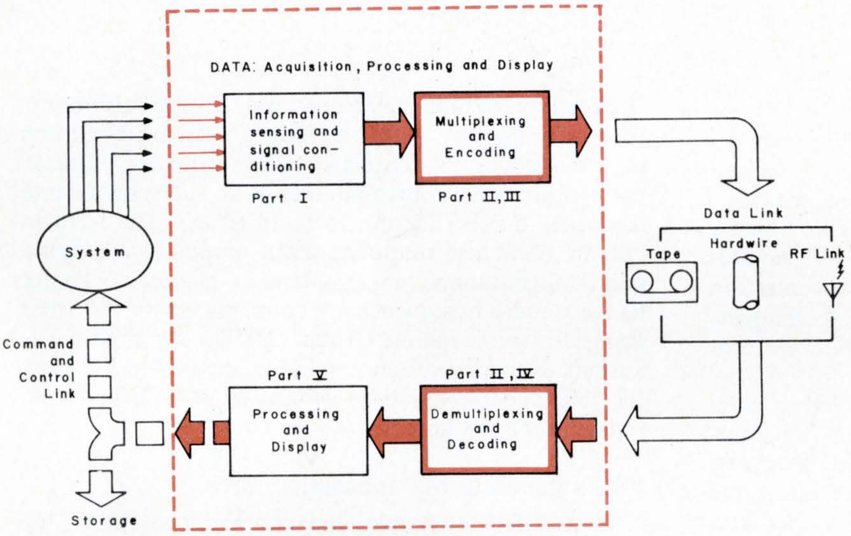
Watch the audio noise

An important disadvantage of 400-Hz correction coils is that, because of eddy currents, the inductor core tends to vibrate at that frequency. The audio noise is usually annoying and occasionally unbearable. It may occur on some new coils and eventually on most older coils as their laminates loosen with age. You can prevent it by tightly clamping the laminates and impregnating them in a semirigid epoxy. You can also neutralize the ringing by mounting the coils on an isolating material which will not conduct the noise.

INFORMATION RETRIEVAL:
Passive components, Magnetic devices, RFI

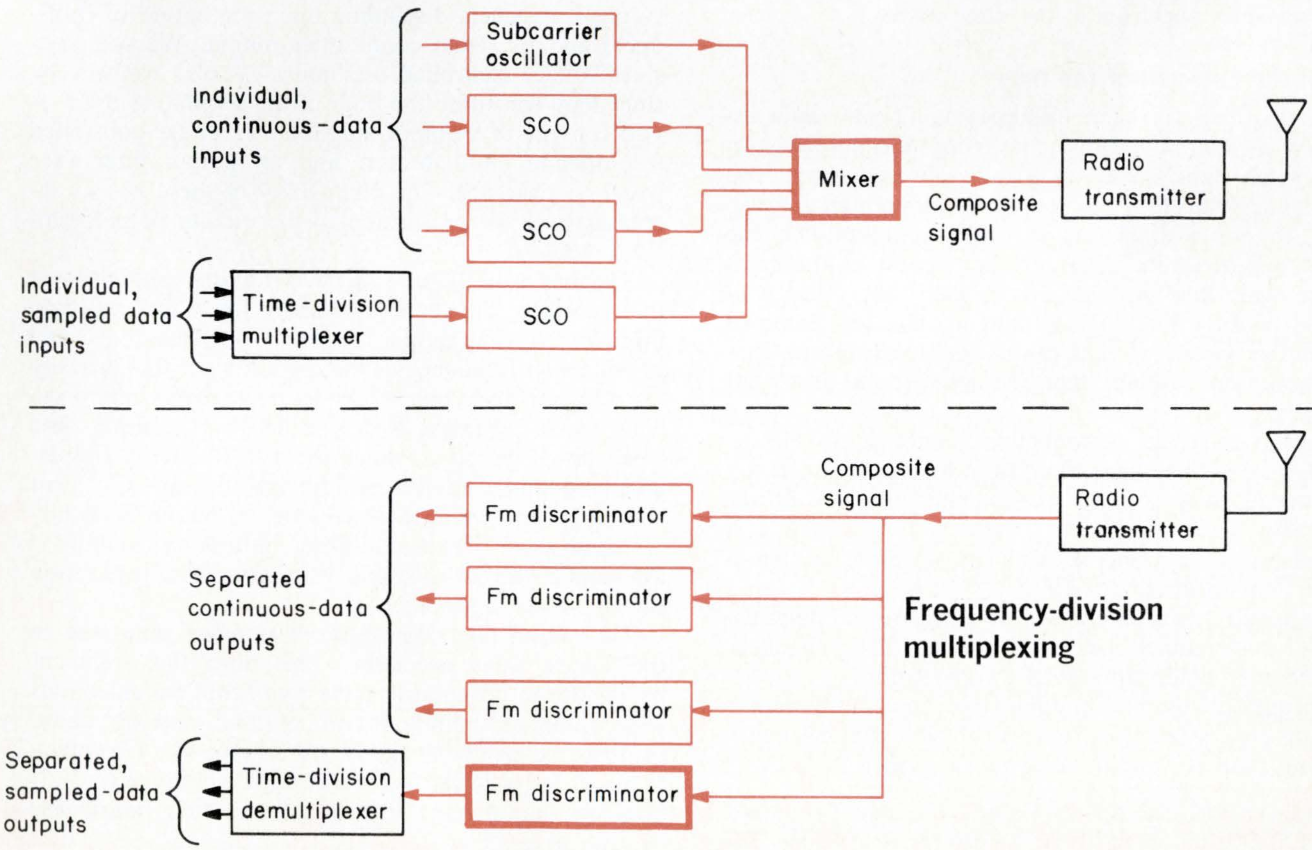
A five-part course

Data:
acquisition, processing, and display



Multiplexing and demultiplexing

Multiplexing and demultiplexing are the subjects of this and next month's part of our course on telemetry. This month, we discuss **frequency/division multiplexing,** used when there are a multitude of data sources and but one channel for handling them. In a typical radio telemetry system, sub carrier oscillators feed the data to a mixer to form a composite signal. On the receiving side, discriminators break up the composite into separate data outputs. This system can accommodate time division multiplexing (and demultiplexing), in one of the channels, where the data is sampled and sent in separate, rather than continuous, data streams. Time division multiplexing is the subject of next month's installment.



Frequency-division multiplexing

Telemetry course—Part II

Frequency-division multiplexing

An economic technique that preserves the integrity of data

By Richard G. Vorce, Section Manager, Analog Products Eng'g. Dept. Electro-Mechanical Research Inc., Sarasota, Fla.

"From many into one" characterizes most data acquisition systems, where the signal sources are many, but the channels for handling them are few. The predominant means of accommodating this concentration employs frequency division multiplexing techniques. Signals are combined into a composite waveform that is transmitted on a single data link.

Whatever the parameters monitored—whether electrical (gain, voltage, current, etc.) or physical (temperatue, pressure, acceleration, etc.)—it would be costly and impractical to use a separate channel of electronic equipment for each parameter to transmit the data from where it is generated to where it is received. But combining the signals into a composite signal can be tricky. The signals cannot occupy the same portion of the frequency spectrum at the same time.

All of the data, all of the time

In frequency division multiplexing (FDM), data integrity is maintained by converting the information from each data source to a different frequency. The frequency bands for each source are far enough apart so they do not overlap. At the receiving terminal, the process is reversed. Different components of the composite signal are separated from each other, and converted back to the original data frequencies. Some of the major system advantages of multiplexing are:

- Continuous rather than sampled data from all sources.
- End-to-end data reproduction accuracy of 1%.
- Maintains close time correlation among channels.
- Accepts time division multiplexing* on one of the channels.
- Preserves dc response with no sacrifice in bandwidth (up to about 10 kHz).
- Reliability, because failure or performance degradation of one channel does not affect remaining channels.
- Accommodates tape-speed compensation.

Frequency division multiplexing, now more than a decade old, is still used extensively in radio telemetry systems (and also in tape-recorded systems).

In a typical radio telemetry system, the information from a transducer (after appropriate signal conditioning) modulates the frequency of a subcarrier oscillator (SCO). Each data source modulates an SCO with a center frequency that is different from all others. The frequencies are chosen so that even when modulated, a "guard band" (separation) exists between channels. Thanks to the standard frequencies recommended by the Inter-Range Instrumentation Group (IRIG) for missile and aircraft telemetry systems, reliable, economic hardware for implementing systems is available "off-the-shelf", reducing the design-effort.

VCO's generate the subcarrier wave

In a practical system, the subcarrier oscillator accepts the data input and generates a carrier frequency that is frequency-modulated by the data waveform. The oscillator can be resistance-, charge-, inductance-, or voltage-controlled, depending upon the nature of transducer and/or signal conditioner output. We will consider voltage-controlled oscillators (VCO's) exclusively, since they constitute the bulk of the oscillators used. A VCO consists of an input amplifier, a voltage-controlled free-running multivibrator, and an output filter (see panel on page 85). The complexity of these blocks increases in direct proportion to the quality of performance required.

The basic oscillator is a free-running multivibrator that generates the center frequency when the VCO data input is zero. The output frequency deviates above and below center frequency as the amplitude of the data signal varies above and below its zero-signal reference. The rate of deviation is determined by the input data frequency. Linearity, voltage input to frequency output, and both time and temperature stability are the most critical parameters in the oscillator. Its output is usually a square wave rich in odd-order harmonics; making it as symmetrical as possible minimizes the generation of even-order harmonics.

The output filter suppresses harmonics generated in the square wave oscillator. This filter has sufficient bandwidth to pass most of the significant fm sidebands with minimum amplitude modulation, and its phase response is ideally linear in the passband of interest. It usually is followed by a wideband amplifier that allows for output level adjustment and that boosts the current drive.

*In Time Division Multiplexing (TDM), information from different sources is kept independent by sampling the different data sources one at a time.

Primer on fm

In a frequency modulation system, the input data waveform modulates the frequency of a sinewave carrier. Carrier variation occurs at the rate of the data frequency, proportionally to the data signal amplitude. The instantaneous carrier frequency, when the modulating signal is a single sinusoid is:

$$\omega_i = \omega_c + \Delta\omega \cos \omega_m t$$

Here ω_c is the unmodulated carrier frequency and ω_i varies at the rate of the modulating signal ω_m with a *peak deviation* $\Delta\omega$.

The phase variation of this instantaneous frequency is

$$\theta(t) = \int \omega_i dt = \omega_c t + \frac{\Delta\omega}{\omega_m} \sin \omega_m t$$

where the constant of integration is ignored.

The expression for the frequency modulated carrier becomes

$$f_c(t) = \cos(\omega_c t + \beta \sin \omega_m t)$$

where β (the modulation index) is the ratio of the peak carrier deviation $\Delta\omega$ to the modulating or data frequency ω_m. For wideband fm, where $\beta > \pi/2$, this equation can be expanded to

$$f_c(t) = \cos \omega_c t \cos(\beta \sin \omega_m t)$$

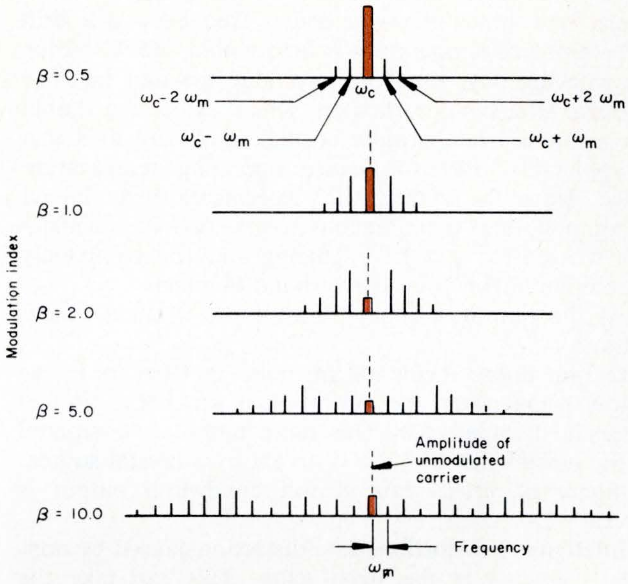
$$- \sin \omega_c t \sin(\beta \sin \omega_m t)$$

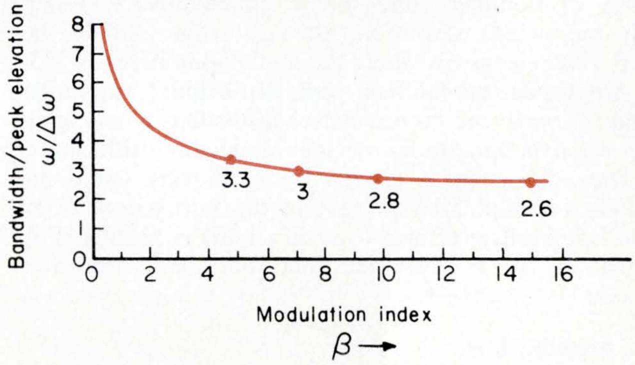
which shows that both $[\cos(\beta \sin \omega_m t)]$ and $[\sin(\beta \sin \omega_m t)]$ are periodic in ω_m and have Fourier series expansions that contain terms of ω_m and all its harmonics. This time function can also be represented and evaluated as a Bessel function of the first kind, mathematically denoted as $J_n(\beta)$.

In the fm spectral distribution shown here, the modulating frequency is held constant and the modulation index (β) is increased by increasing the data amplitude, which increases the deviation $\Delta\omega$. As β increases, the number of sidebands generated increases dramatically. This means a corresponding increase in the bandwidth required by the system.

Alternately, if the peak deviation ($\Delta\omega$) of a channel is kept constant, lowering of the data frequency results in the generation of many more sidebands more closely spaced, with the crowding of these sidebands into a fixed increment of bandwidth.

From the spectral distributions it can be seen that the average power associated with the wave train is independent of the modulating signal, and has the same average power as the unmodulated carrier. As the sideband power increases with β, the power in the carrier term decreases.





The curve shows the channel bandwidth required to pass all the significant sidebands, plotted as a function of β. This curve approaches $\omega/\Delta\omega = 2$ for $\beta >> 1$.

For additional details see M. Schwartz, "Information, Transmission, Modulation, and Noise," McGraw-Hill, 1959, pp. 115, 116.

How to select a VCO

When choosing the VCO optimum for your system and budget, be sure that compatible auxiliary equipment such as signal conditioning, charge- and mixing-amplifiers, a reference oscillator, and voltage calibrators are available as standard items. If they are not, system costs will go up considerably.

First, consider the input stage. It should be floating, guarded, and provide a high common-mode rejection ratio ($\geqslant$120 dB) out to at least 60 Hz, where major interference components occur. The floating input allows the unit to withstand common-mode voltages of 100 V or higher. Input impedance should be high enough so that the data source (whose impedance is typically about 1000 Ω) isn't loaded down.

The frequency response and the deviation of the VCO are also important. Many practical applications have data frequencies as high as 1.5 MHz, others are as low as 10 Hz or less. If your application is at the higher frequencies, consider the response curve (linearity of ±0.05% is readily available in hardware) and check the overload recovery time. Designs that recover in 25 to 50 μs from 1000% overloads are available.

In a laboratory or a data site environment long-term rather than short-term stability is the major concern. Learn how much the VCO center frequency will drift if the ambient temperature is held within ±5°C during the working day. Find out how long the unit takes to stabilize after being turned on. This specification should also contain a temperature coefficient of zero drift that is applicable over the entire operating temperature range. Have the VCO stability specifications explained in complete and unambiguous terms. A drift specification written for a ±15% channel may be completely unacceptable for your narrowband channel.

At the output, examine three types of data degradation:

Output noise: incidental fm noise that occurs in the output signal when the VCO input is grounded through a specified impedance. This noise output is compared to the noise when the VCO is driven by a crystal source. A figure of 0.1% rms of full bandwidth output is typical.

Intelligence distortion: data distortion caused by nonideal elements in the signal path. This can take the form of amplifier nonlinearity, VCO deviation restrictions, or nonlinear filter phase characteristics. Using full bandwidth deviation, the distortion should be < 0.5% in a system where the modulation index is ⩾5.

Amplitude modulation and distortion: Amplitude modulation in the output causes distortion by changing the relative amplitudes of the modulation sidebands. Carrier distortion is caused by harmonics (predominately 3rd and 5th) present in the VCO output after filtering. Control of a-m to within 1 dB is normal. For deviations ⩽ ±15%, the total harmonic distortion should be less than 1%.

The missing link

For transmission, the outputs of all subcarrier oscillators are combined into a composite signal. This signal may be recorded directly on tape for the data processor, sent along a single wire, or used to modulate a radio transmitter.

If an rf data link is used, the system will have a two part designation. The first part defines the subcarrier modulation (or encoding) technique, while the second part describes the method used to modulate the radio transmitter. Thus, in an fm/fm system, both the oscillators and the carrier are frequency-modulated; in an fm/pm system, the carrier is phase-modulated; and in pcm/fm/fm system, the oscillator is pulse-code modulated, while the carrier is frequency-modulated.

Filtering, the key to demultiplexing

Once the data has been sent along the link, individual data channels must be demultiplexed. In fm systems, this is done by the subcarrier discriminator. The discriminator selects a specific fm channel frequency from the input fm multiplex, separates the intelligence signal from the fm carrier with a minimum of distortion, and supplies this signal at its output with sufficient amplitude to drive a monitor.

Bandpass input filters separate the desired fm signal from noise and other fm multiplex signals present at the subcarrier discriminator input. In addition, the filter must pass the desired frequencies with a minimum of distortion. Watch out for excessive signal distortion at the output of the bandpass filter, due to improper amplitude response, and/or nonlinear phase response of the filter to the desired band of frequencies.

The fm signal contains a number of necessary frequency components of different amplitudes: these are called *significant sidebands.* If the intelligence contained in the fm signal is to be reproduced, the filters must maintain the relative amplitude of the signal carrier and these sideband frequencies. It must, therefore, attenuate all frequencies within the bandpass by the same amount, and block all signals outside the passband. In practice, filters cause negligible amplitude distortion of fm signals with a modulation index of five or higher. Although they do not completely attenuate noise and other signals outside the passband, their attenuation is sufficient. The filtering characteristics of the limiter, fm detector, and low-pass output filter that follow the filter will suppress these signals.

In fm, frequency deviation due to modulation produces a linear phase shift over the passband range of the fm signal. Signals produced at the carrier frequency do not have the same phase relationship as signals produced above and below the center frequency. The phase changes occur at a linear rate and the bandpass input filter must present a linear phase response to signals passed by the filter.

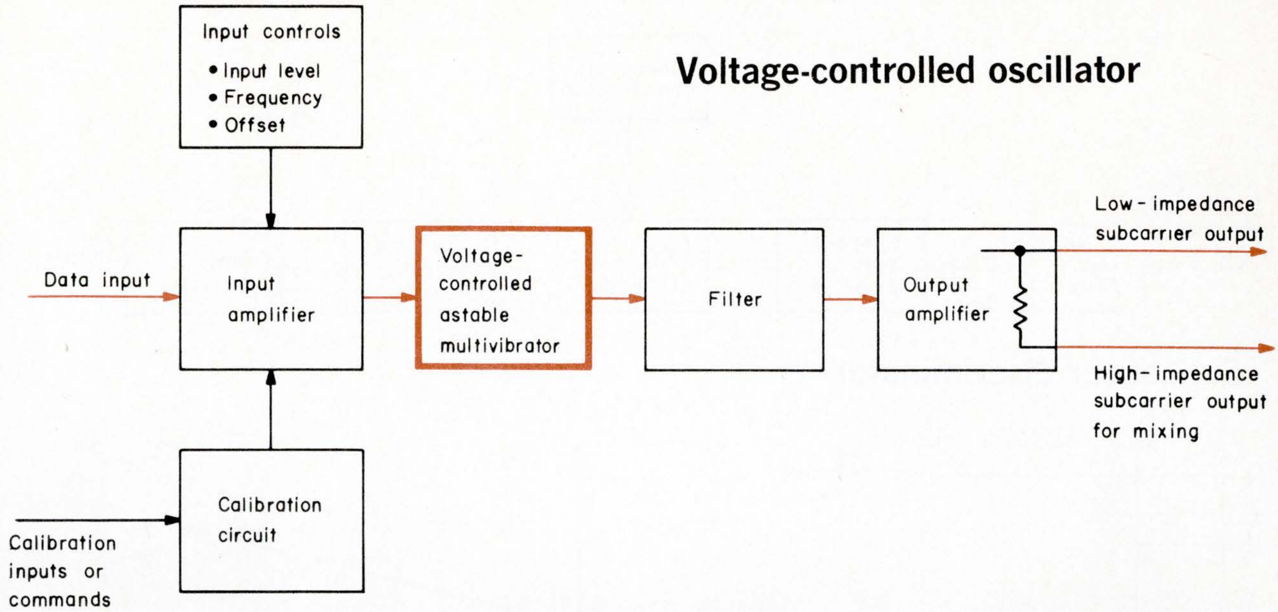
In practice, filters provide negligible phase distortion. An improperly designed filter that does not present constant delay to different frequencies in the pass band however, will alter the linear phase relationship and the upper sideband will experience less delay than the lower sideband. This changes the relative spacing between sidebands, and introduces phase distortion (see panel on page 87.

Demodulation: limiting + detection

After the filters separate the subcarrier frequencies from the composite transmitted signal, the signal must still be demodulated from the subcarrier. Demodulation is accomplished using a limiter and a detector.

Noise and other interfering signals have imposed an amplitude modulation on the fm signal, and this a-m must first be removed. In theory, the detector would respond only to frequency or phase changes (depending on the type of detector used); in practice, detector circuits are responsive to amplitude variations, too. Converting the input signal to a constant-amplitude square wave overcomes this problem.

For detection following the limiter, two common circuits are used today (see panel on page 87). The **pulse-averaging detector** operates on the principle that the frequency of an input signal can be determined by measuring the time between zero crossings. Various circuit configurations are possible, but the basic principle remains the same. The detector generates a fixed length pulse for every zero crossing of the limiter output. An increase in subcarrier frequency results in an increase in the number of pulses per unit time, and hence, in the average output of the low-pass filter. When you use both edges of the limiter output, the subcarrier frequency doubles. This makes subcarrier rejection a



Wave makers. Voltage controlled oscillators (VCOs) are the most popular type of subcarrier oscillators used in telemetry systems to generate a frequency-modulated carrier. In the simplified block diagram, input amplifier isolates the data source from the oscillator. It has wide bandwidth, and provision for sensitivity and offset adjustment; some units also accommodate calibration networks and relays. The oscillator is a free running multivibrator whose frequency depends on the amplitude of the input signal. Filters suppress multivibrator harmonics.

much easier task in the low-pass output filter.

The primary advantage of a pulse-averaging detector over other types of detectors is the relative simplicity of design and operation. The detector has excellent linearity (better than 0.05%) and stability (less than 0.2% drift for a 24-hour period).

Although the pulse-averaging detector has the ability to detect low signal-to-noise ratio signals, the **phase-locked-loop detector** (the second common detector type) is preferable for threshold performance. This detector operates on the principle that an output voltage can be developed which is proportional to the phase difference between the input signal and the output of a VCO. The phase detector compares the limiter output with the output of the VCO, where the latter is quiescently displaced 90° from the limiter output signal.

The 90° between these signals is the reference phase established at center frequency. At the reference phase, the output of the phase detector is such that a zero volt output is developed at the output of the subcarrier discriminator. Any phase error (change from the 90° difference) between the input signal and VCO signal varies the output voltage of the subcarrier discriminator above or below zero volts in response to the phase error. This error signal changes the VCO output frequency an amount equal to the frequency change of the input signal. In other words, the VCO frequency tracks the input signal frequency. However, as the input signal varies about the center frequency, the dynamic phase error between input signal and VCO signal varies linearly.

The loop filter, which sets the maximum rate of change for the VCO, determines the dynamic behavior of the phase-locked loop in response to subcarrier modulation. When the phase error, which is statically zero, reaches ±90°, the discriminator is said to have "lost lock".

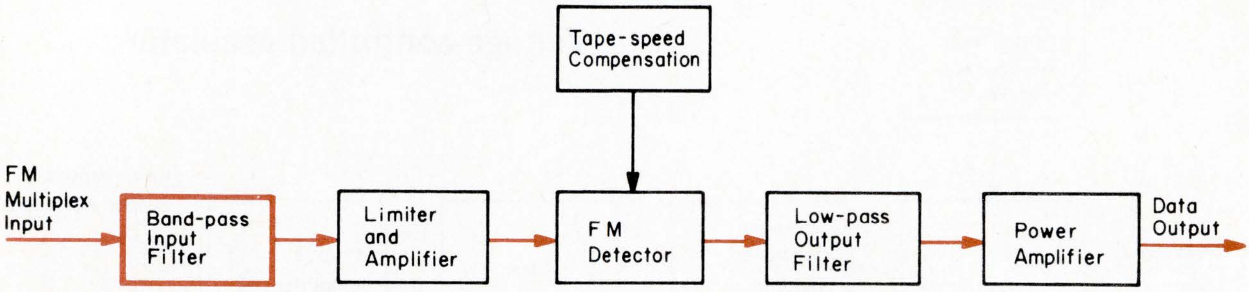
The advantage of a phase-locked-loop detector over pulse-averaging and other type detectors is better signal-to-noise ratio. The phase-locked loop acts as a tracking filter, and as such, supplements the noise rejection provided by the bandpass filter. When the data signal characteristics are known, the operator can adjust the cutoff point of the loop filter and the bandpass of the phase-locked loop. This aids in the rejection of noise errors which fall outside the loop bandwidth.

On the other hand, other subcarrier discriminators (such as the pulse-averaging discriminator) let noise signals throughout the total channel bandwidth reach the detector, and may generate erroneous data.

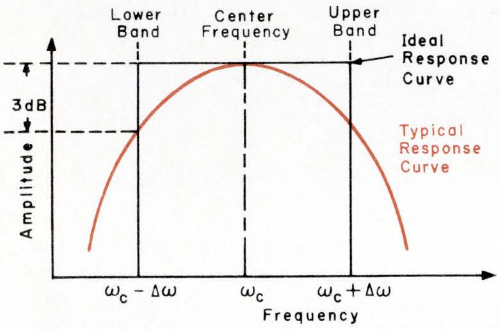
The output filter restores the signal

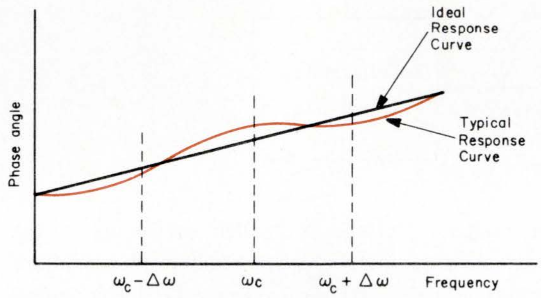
The output of the detector (i.e., the reconstructed transducer data) is next applied to a low-pass output filter. This filter attenuates all frequency components above the data cutoff frequency of the channel. Low-pass output filters are usually classified as either constant-amplitude or constant-delay types, and may even have provisions to permit switch selection of either characteristic, depending upon the data signal.

The discrimination problem



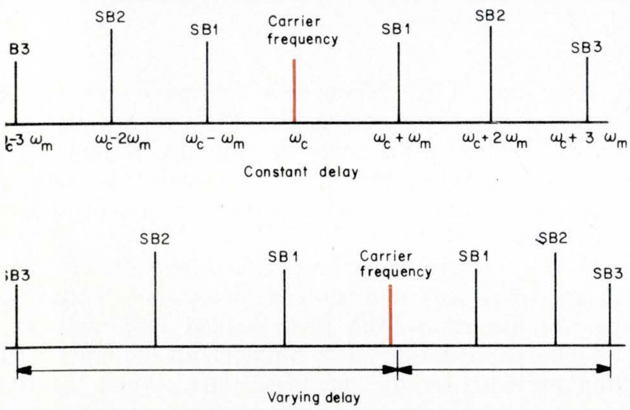
Subcarrier discriminator





Filter response: amplitude . . . . . . and phase

Basic fm subcarrier discriminator contains a bandpass input filter which passes only the desired band of frequencies from the fm multiplex, a detector that separates data signal from the carrier, and an output filter tuned to pass only the detected data frequencies. Ideally, the bandpass input filter would have a rectangular response, passing all the frequencies within the $2\Delta\omega$ band while rejecting all others. This ideal response can be approached only by very expensive filters. In practice, the more typical response curve (shown in color) provides accurate representation of the input data when combined with the filtering characteristics of the circuitry that follows it. Frequency modulation produces a linear phase shift across the pass band. Again, an ideal filter would compensate for this. Practical filters, however, introduce a varying time delay that shifts the frequency components of the output signal.



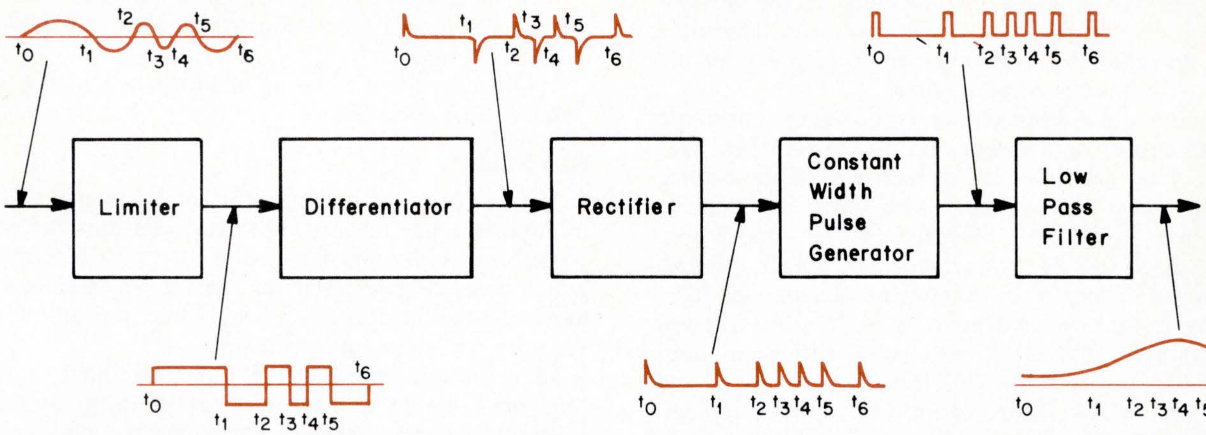
Nonlinear phase shift affects the spectrum

Constant-delay filters are most frequently used where real-time interpretation of data is of significance and where the data is represented by pulses. The constant-delay filter has a Gaussian-response curve. All frequencies in the passband are delayed almost equally, thus permitting excellent time correlation. However, the attenuation factor is not equal at all frequencies, so do not use this filter where relative amplitudes are of prime concern. For such case, use the constant-amplitude Butterworth response filter, which provides nearly equal attenuation to all frequencies in the passband. Its disadvantage is that time delay is not constant enough to obtain good time correlation.

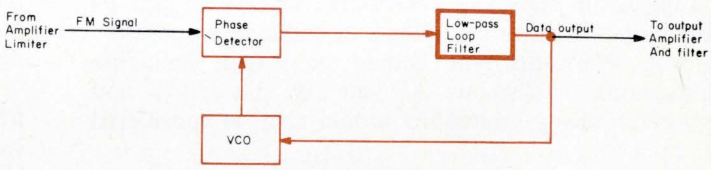
The output amplifier matches and current-drives the output load. In many cases, this dc amp is part of the low pass output filter, i.e., a power output stage is the last stage of the filter. Regardless of the circuit configuration, problems of dc drift are present which, if not compensated for, will distort the output signal.

Watch that tape recorder

Many data acquisition systems record the fm multi-



Pulse-averaging detector



Phase-locked loop detector

A limiter and a detector, together with the filter discussed at left, above, complete the fm discriminator. Two popular detectors are the pulse-averaging detector and the phase-locked loop detector. The former essentially measures zero-crossings of the input waveform whereas the latter measures phase differences between the VCO and the processed input. While phase-locked loop detector provides better signal-to-noise ratio; the averaging type is simpler and has superior subcarrier rejection.

plex signals on tape for future processing, or when the system acquires too much data to process it in real time. The best point in the system to acquire these signals is just before the subcarrier discriminator, as a single tape suffices for many data channels. You can then play back the tape and separate the individual data channels at your convenience.

Since the recorder is another element in the signal path, it can introduce errors. Variations of tape speed during recording or reproduction (respectively called wow and flutter) cause frequency modulation of all channels of the fm multiplex. Unless the effects of tape-speed variations are corrected, wow and flutter modulations produce discriminator output signals indistinguishable from the data.

In fact, tape recorders can seriously limit the overall ability to retrieve data. Major limitations are usually caused by faults in the mechanical systems that transport the tape across the heads, and by the tape itself, rather than by the recorder electronics.

Tape-speed error consists of any variation of the tape speed from its nominal value as it passes over either the *record* or *reproduce* head. Among the more likely causes of tape-speed error are speed variations in the tape drive, expansion or contraction of the tape, or slippage of the tape relative to the head. Any of these variations will cause a reproduced signal to be displaced in time relative to its true recorded time. In fm systems, this error results in both an amplitude and a time base error in the demodulated data.

Fortunately, it is possible to compensate for these errors to a large degree. In the pulse-averaging detector, an error signal derived from the tape speed variations is used to modulate the data output. This technique can yield improvements in tape speed of greater than 36 dB up to a frequency equivalent to a modulation index of five. In the phase-locked loop circuit, the compensating signal retunes the vco to compensate for the speed fluctuations.

How to buy a discriminator

Don't select a commercial discriminator arbitrarily. Follow the guidelines prescribed here, which are keyed to the unit's major specifications and parameters. Check the list before you buy, and you'll get better performance and probably save your company unnecessary expense too. The major intent of this section is to clarify certain key discriminator specifications.

- The **input impedance** specification is provided solely to demonstrate the loading effect of a discriminator or discriminator system on the signal source.
- The **dynamic input signal range** generally indicates limiter performance capabilities. If the limiter is well designed, step changes in input signal amplitude should cause only a small transient at the discriminator output.
- The **amplitude and phase characteristics** of the bandpass input filter affect discriminator performance parameters, particularly harmonic distortion, rejection of unwanted signals, tape speed compensation, and data frequency response. Linear phase or flat group delay response has long been a desirable criteria in constructing bandpass filters. Recently, a technique for achieving flat group delay at finite frequencies was developed. This has resulted in multipole bandpass filters

with group delay variation less than 0.1% across the entire passband of interest. Depending on overall system requirements, the data system user can determine whether he requires a two pole-pair, four pole-pair, or six pole-pair bandpass input filter.

- **Low-pass output filters** eliminate the second harmonic of the subcarrier component and all close-in beat frequencies. They are necessary to reduce the output noise bandwidth, and are available with cutoff frequencies ranging from 1-3 Hz to 1 MHz in 3, 4, 5, 6, and 7 pole versions. Low cutoff frequencies no longer present problems for higher order filters since techniques have been developed for incorporating 4, 5 and 6 poles around a single amplifier. Filter characteristics commonly available are Butterworth, Bessel, Chebishev, and phase-compensated Butterworth. For special applications, filters that exhibit the characteristics of any well-described low-pass polynominal are also available. Some filters can switch between characteristics (Butterworth/Bessel).
- **Long-term zero and sensitivity stability** should be defined within reasonable limits of ambient temperature control. Warm-up time should be stated, including temperature coefficients of stability. Deviation and center frequency limitations should also be considered as applicable.
- **Rms and peak-to-peak** values of output noise should be stated and their reference levels made clear. Also, look for the noise performance at low input signal levels, as well as the applicable range of center frequencies, deviations, and modulation indices.
- **Nonlinearity** refers to deviations from ideal frequency-to-voltage conversion. It is measured by a best-straight-line method and is specified in terms of ±% of full bandwidth output. Again, this spec must state the applicable center frequencies and deviations.
- **Harmonic distortion** is a measure of discriminator dynamic performance and depends to some extent on amplitude and phase of the bandpass input filter. It should be stated as the maximum rms value occurring anywhere within the output data bandwidth and as a percent of full bandwidth output. The modulation index is required to complete this specification.
- **Hysteresis** is an important but seldom-mentioned spec for the discriminator output. It normally shows up when the discriminator output stays at one band edge for a relatively long interval of time. Test for this condition by switching to center frequency after the discriminator dwells for one-minute at either band edge under full load. Excessive hysteresis can cause poor static linearity.
- **Tape-speed-compensation** specs should include the error percentage, the appropriate data modulation index, and the minimum level of correction that can be obtained. The ability to meet this specification is determined by the accuracy with which the delay paths and amplitude-characteristics of the data and reference channel can be known and kept constant or matched.
- **Other features** that are important and desirable include the following:

  —Availability of interchangeable pulse-averaging and phase-locked-loop detectors.

  —Adjustable output level for "zero signal".

  —Front-panel switchable deviation polarity.

  —Built-in crystal calibrator for center frequency and band edge.

  —Independent power supplies per channel.

  —Functional block construction for rapid testing and easy repair.

  —Independent metering of subcarrier input and % band edge deviation.

Band aids

Before taking advantage of what frequency-division multiplexing has to offer, however, consider the bandwidth availability and utilization. Start by determining which piece of equipment in the total system has the narrowest bandwidth. This could be the transmitter, tape recorder, or some other element.

In a ground system which does not have a radio link, for example, it may be desirable to set minimum acceptable performance standards and use only enough bandwidth to handle the necessary number of channels with the required data accuracy. On the other hand, if the system contains a radio link, the rf bandwidth must be considered. It may be the limiting factor on how many channels can be used or how wide the deviation can be.

With a radio transmitter of fixed bandwidth, the problem is how to use this bandwidth to its fullest extent. This may be done by increasing channel spacing for less crosstalk, by increasing the number of channels in the multiplex, or by increasing the deviation ratios for better data accuracy.

Since there are no perfect transmission systems, it is necessary to set limits on the amount of data degradation which can occur between the transducer and the remote monitoring station. For most non-critical applications, a 5% data error can be tolerated; for severe applications, 2% or less may be the limit.

The problem of optimum bandwidth utilization is intimately tied in with system accuracy requirements. To ensure faithful reproduction of the input data signal at the demodulator output, the relative amplitudes and phases of the various spectral components must be preserved. In other words, all filters in the path of the fm wave train must be wideband to preserve sideband amplitude, and must have a linear phase property so that sideband phase relationships are not altered.

In actual practice these requirements are always compromised to conserve bandwidth, and because the components are not ideal. IRIG Document 106-66 recommends using a data bandwidth that is 10% of the deviation bandwidth for nominal operation. This means that the bandwidth of the total channel, from end to end, should be capable of passing the first five sidebands in a system where the modulation index, β, is five. Several ways for accommodating more channels of data in a given bandwidth are: reduce the guard band spacing; reduce the required individual channel bandwidth by reducing β or the subcarrier deviations; eliminate some of the Bessel sidebands by reducing channel filter bandwidths. Note however, that each of these methods requires a tradeoff in system accuracy or performance capability that must also be accounted for.

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EE DRAWER

Are you confused by high di/dt SCR ratings?

High di/dt devices are being looked at as a solution to SCR failures. But are SCR failures really from a high di/dt? Before you decide, examine failure mechanisms and rating philosophy. Also, be aware of the tradeoffs you must make for a higher di/dt.

By Dante E. Piccone, I. Steve Somos,
Custom Power Components Operation
General Electric Co., Collingdale, Pa.

Recently engineers have been flooded with di/dt ratings for thyristors. These ratings have resulted in much confusion. One reason is that the ratings are not all based on a common and sound principle. Also, failures caused by other mechanisms are sometimes thought to be di/dt failures. In addition, it is not made clear that high di/dt ratings sacrifice other device parameters, and that it is senseless to use di/dt ratings higher than necessary when it means compromising other important characteristics.

This article discusses problems associated with high di/dt gate structures which are common today in many versions.[1 2 3 4 5] All high di/dt gate structures known to us use the "field initiated" (FI) principle.[6] This principle achieves turn-on in two steps. First, the gate initiates a turn-on at a point or small area. Second the load current is used as a high energy gate signal to turn-on a long line. Several structures employing this field initiated principle are shown in Figs. 1 and 2.

Figure 1 shows four gate structures. In all four there is a region, indicated in color, which has a controlled lateral resistance. The turn-on action for all four is initiated at the small area near the gate; then in 0.1 to 0.2 μs, the line at the edge of the colored region opposite the gate is turned-on and current flow at the initially turned-on small area ceases. The voltage drop which appears across the colored region in gate structure 4 can be fed to other gates via leads D.

This principle can also be used, as shown in Fig. 2,[6] to enhance the di/dt rating of a thyristor which is fired by forward voltage breakover. In this version, the firing is forced to occur either under or external to the auxiliary region, marked A. Second triggering then occurs along the circumference of the cathode contact, giving you a high di/dt device. The cross-section of this device, and how it operates is shown in Fig. 2b.

Failure modes

There are two di/dt failure modes. One is caused by a thermal fatigue mechanism (the failure occurs at point A, Fig. 1). The second is a thermal runaway failure mode (the failure occurs at point B, Fig. 1). This latter failure point can be anywhere along the second turned-on line.

There is another failure mech which can easily be confused with a di/dt failure of the thermal, runaway mode. This failure is a short-time surge-current failure.

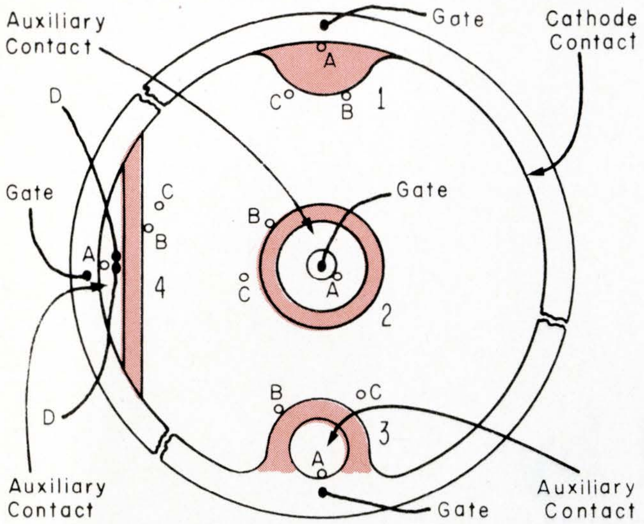

Fig. 1: Four possible gate structures are shown in this one sketch. The region shown in color on each type has controlled lateral resistance. Each configuration uses the field initiated principle where a gate turns on at a point, permitting the load current to start flowing. The load current then acts as a high energy gate signal to turn-on the long line, giving high di/dt devices.

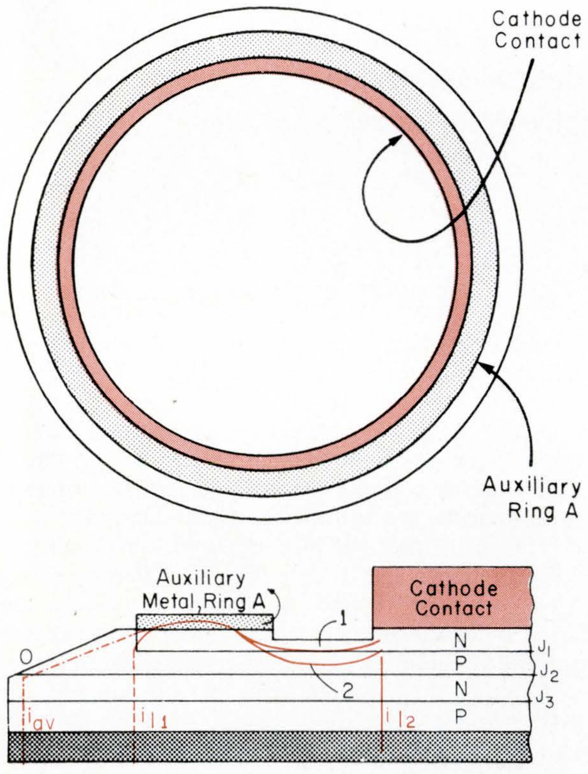

Fig. 2a: The field initiated principle can be used for higher di/dt rating of a thyristor fired by forward voltage breakover. Looking at fig. 2b, a cross-section of the device, the first microplasma due to forward breakover voltage is generated at point O. The avalanche current I_{av} flows to the cathode contacts along the indicated path. It flows through the top junction J_1 and acts as a gate current. The thyristor is triggered and a load current i_{l1} occurs. A part of the current flows along path 2, bringing about a second triggering resulting in load current i_{l2}. At the same time, current i_{l1} will cease. Current i_{l1} is a local current along the path indicated by broken lines. It will become, however, a large area current along the path indicated by the solid lines, flowing through the whole circumference. Thus, the whole circumference of the cathode contact is turned-on.

It results in a failure at point C in the vicinity of the second turned-on line, but within the cathode contact.

Thermal fatigue failure mode

As mentioned above, the second switching occurs in a fraction of a microsecond. The initially turned-on area sees energy during this time. This energy, which can be very high, causes a temperature fluctuation. Though the temperature excursion may not be high enough to instantly destroy the device, it can lead to thermal fatigue. Figure 3 shows a curve of temperature excursion vs time-to-failure for silicon. This curve was determined statistically and shows that if the temperature excursion is cut in half, the time to failure can be increased 500 times.

Thermal runaway failure mode

Failure along the second turned-on line is caused by a thermal runaway action which lasts about 60 seconds.[5] This thermal runaway condition is due to the interaction of two cell characteristics—the thermal resistance of local conducting area to case, and the increase of watts with temperature in the high current density region (see Fig. 4). Figure 4 shows devices A and B with different watts vs temperature characteristics. Cell B, which can only stabilize at the lowest case temperature, would stabilize at D in Fig. 4. (Note that just a slight increase in case temperature can cause a runaway condition.) Device A can stabilize at all three case temperatures, as indicated by points C. The watts which cause this runaway condition are average watts at local conducting areas and not instantaneous watts. Hence frequency can affect the thermal runaway condition.

Short time surge current failure

The di/dt capability is greater for a single pulse than repetitive pulses which raise the average temperature near the conducting area. A current pulse which attains a high peak in a short time, in about 50 to 100 μs, can cause a short time surge current failure. This failure results from instantaneous heating rather than from the slower temperature build-up which is characteristic of thermal runaway. The failure here occurs at a time when the current approaches the peak; it does not occur in the 1 μs or below region as does di/dt failure.

Test methods

As mentioned before, there are two kinds of di/dt failure modes: thermal fatigue and thermal runaway. Accordingly, two test approaches may be possible.

For low di/dt's and for very mild snubber circuits (such as 50 to 200 A/μs and 25 A peak snubber current), the overwhelming failure mechanism is thermal runaway. To guard against this type of failure, the JEDEC[7] test run for 60 seconds is satisfactory (this test is normally run for only 5 seconds). For a realistic test, the snubber circuit equal to that used in the application must be included. The broken line in Fig. 5 shows the snubber current; the solid line shows the test current wave occurring during such a test. Disregard the current scale. Accordingly, the magnitude of the di/dt rating is established by the current I. This is the current value at about 1 μs. The peak of the test current is equal to 2 I. This current waveform of a few microseconds length is too short in duration to cause short time surge current failures and thus avoids this possible confusion. It also avoids the use of too short a current wave, less than a microsecond length, which is inadequate for creating a realistic thermal runaway condition.

For higher di/dt's and more severe snubber duties, the thermal fatigue failure mode will be more significant.[1] At di/dt values in excess of 600 A/μs, it will be the predominant failure mode. In this case, the 60 second test time interval must be extended to a life test which, according to present practice, is run for 1000 hours. However, 1000 hours in most cases is much less than desired operational life. Hence, the thermal fatigue stress during the 1000 hours life test should be increased.

The degree of increase can be determined from Fig. 3. For example, if the desired operation life is 100,000 hours, then the stress must be increased according to Fig. 3 by the ratio of 2 to 1.2. This increase of stress must last for a minimum of 0.25 μs, which is greater than the time required for second switching. To increase the stress, increase the current level by the same ratio for this short time interval.* This is an approximate method based on the assumption that temperature excursions increase proportionally with current increase. We arrived at this assumption by observing the voltage and calculating the turn-on area (which is a function of current density).

Enhancement of di/dt rating

Both failure mechanisms (thermal runaway and thermal fatigue) can be handled adequately and it is our opinion that a device for any di/dt rating can be designed. To increase di/dt rating, current density during the di/dt failure period must be controlled. This can be done by controlling the initial speed of plasma spread and the length of turn-on line for both the first and second triggering.

Methods are available for both types of control. The control of initial speed of spread is beyond the scope of this article. The control of turn-on line length for thermal runaway conditions is comparatively simple and can be done by various configurations of the second turn-on line. These configurations do result, however, in loss of active area.

Figure 6 shows how the di/dt rating, based on thermal runaway, varies with the length of second turned-on line. Increasing this line also results in higher short time surge current rating, since more area will be conducting when the peak of the current occurs.

Increasing the length of turn-on line at the first triggering point is not simple. The length of this line is a function of the gate drive. Although the P type gate does not respond to this increase as much as you would want, any increase in length increases life expectancy.

New gate firing mechanisms have been used to at-

*To increase the current, either alter the snubber circuit or add another snubber circuit.

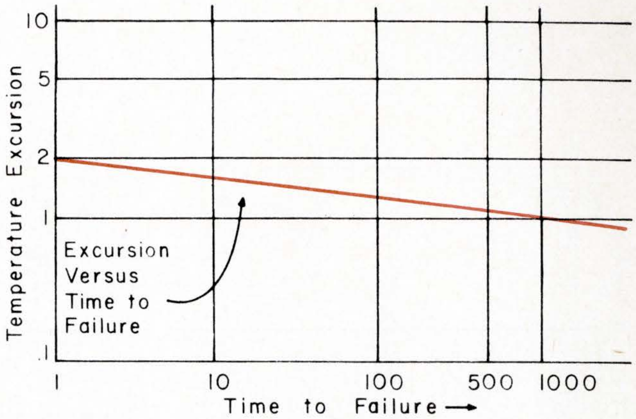

Fig. 3: Curve shows temperature excursion vs time-to-failure for silicon. If the temperature excursion is cut in half, the time to failure can be increased 500 times.

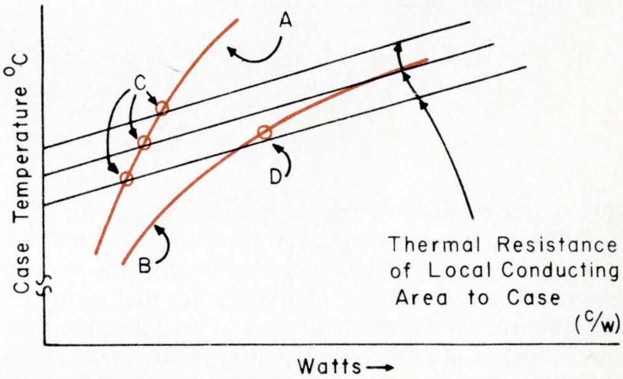

Fig. 4: Two devices, A & B, have different watts vs temperature characteristics. To prevent a thermal runaway condition, cell B would have to stabilize at point D. A light increase in case temperature can cause thermal runaway. Device A could stabilize at all three case temperatures shown.

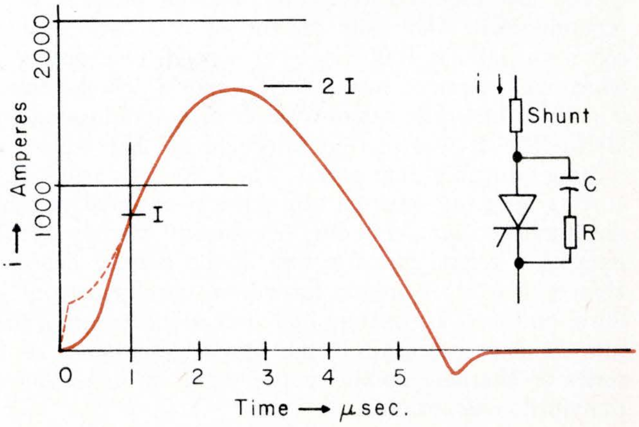

Fig. 5: For a realistic test against thermal runaway, the JEDEC 7 test should be run for 60 seconds. The snubber circuit equal to the one used in the application must be included in the test. Here the broken line is the snubber current while the solid line shows the current wave occurring during the test.

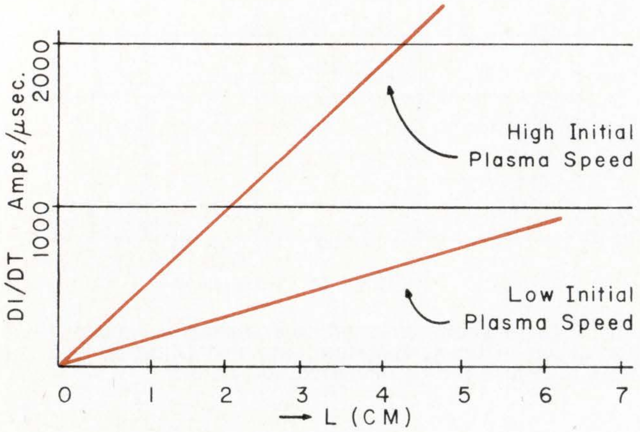

Fig. 6: The di/dt rating, based on thermal runaway, varies with the length of second turn-on line.

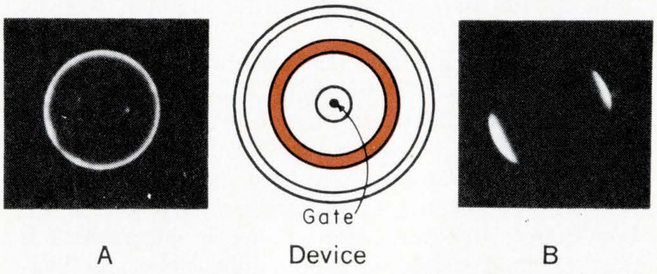

Fig. 7: Here are two devices with slight changes in parameters. Fig. A is an optimized device, with the entire circumference of the second turned-on line ignited. Fig. B, not optimized, has only portions of the second turned-on line ignited. These two devices were tested using infrared.

tain a longer turn-on line at the first triggering point and one has been available for years (emitter gate).[5 8 9]

In device design, you need techniques to measure length of turned-on lines. One is the infrared method. A short current wave of about 5 μs is used and the infrared radiation due to recombination is observed. During this short time, no significant plasma spreading occurs and it is justified to assume that the observed line is really the initial turned-on line. Figure 7 shows two devices with slight changes in parameters. Figure 7A shows an optimized device. The entire circumference of the second turned-on line is ignited (note the glow along the circumference). Fig. 7B shows an unoptimized device with only portions of the second turned-on line being ignited.

The test used for obtaining infrared pictures is a repetitive test. The short current pulse is applied at a repetition rate of 400 cycles per second. One question which can be raised is whether the line which is viewed is really a line rather than a series of points turning-on alternately. It was proven satisfactorily that a line is turning-on rather than points. The recovery current occurring after the short current pulse is an indication of the turned-on area. Lifetime of minority carriers in the internal N region is a function of the current density. Hence, if a larger area is turned-on, current density is lower and recovery current increases as the length of the turn-on line increases. If the observations were of a series of alternate points, recovery current would have remained constant.

Conclusions

In designing equipment, use a device with di/dt ratings adequate for the application, since increased di/dt rating results in smaller active area. A smaller area means lower current ratings, lower surge rating, and higher thermal resistance.

Also, be sure that the rating philosophy takes into account all failure mechanisms and is adequate for the expected operational life. You definitely should know gating conditions during the test since they directly affect thermal fatigue.

It has been our experience that extremely high di/dt ratings are not required in most applications. It is actually difficult, even under laboratory conditions, to achieve 1000's of A/μs. However, there are a few applications where great pains are taken to minimize inductance and in these applications high di/dt devices are a must.

The FI principle, described earlier, has opened the door to higher di/dt ratings, has resulted in the use of lower gate drive, and has increased the reliability of equipments since 1964.

Reference

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2. Gray, Donald I., "This SCR is not burning," Electronics, Vol. 41, No. 20, Sept. 30, 1968, pp. 96-100.
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6. USA Patent #3,408,545.
7. Jedec Suggested Standard No. 7, April 1967, No. 5-1.2.4.
8. Gentry, F. E., Scace, R. I., and J. K. Flowers, "Bi-directional p-n-p-n switches," Proc. IEEE, Vol. 53, April 1965, pp. 355-369.
9. Patent pending.

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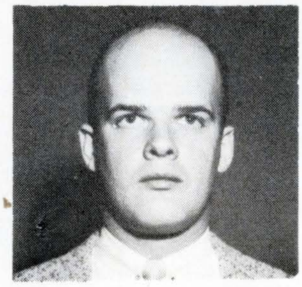
The winning Idea for August 1968 is, "For a square-law transfer function, try this op amp connection." **Robert P. Hennick,** the author, is an Assistant Project Manager in Troposcatter Communications Systems, at Bell Aerosystems in Buffalo, N. Y. Mr. Hennick chose the Simpson 270 multitester as his prize.



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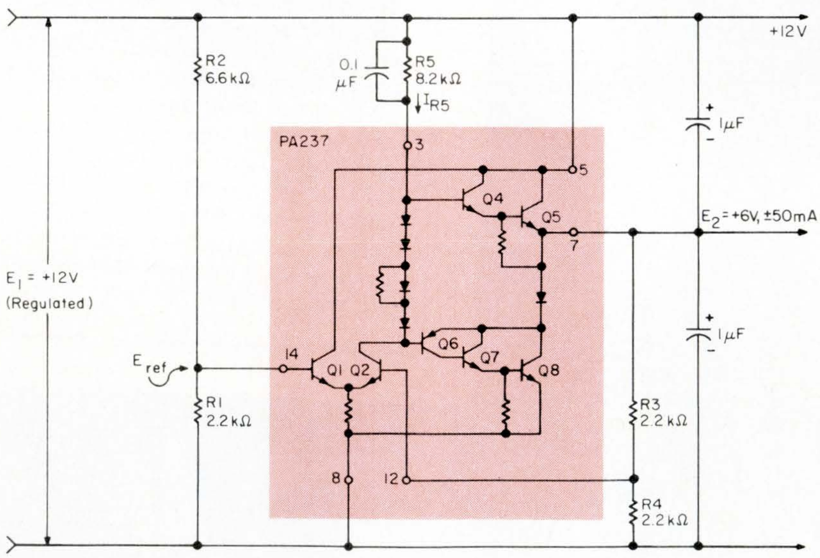
901 Load current flows into or out of voltage regulator

Dan Lubarsky, Moore Assoc. Div.
Rucker Co., San Carlos, Calif.



Suppose that in a system where only one regulated voltage is available, you must use an IC op amp (such as the µA702) that needs two voltages. Simply adding another regulator may not be the complete answer, since current may flow from or to this second source, depending upon the mode of operation.

The circuit shown here solves such a problem. General Electric's PA237 audio IC lets current flow in either direction, while supplying the second regulated voltage. Resistor R_5 supplies the bias current drive (I_{R5}) to the Class B output made up of Q_4, Q_5, Q_6, Q_7, and Q_8. This bias current lets the load current supply source change smoothly from Q_5 to Q_8.

$$R_5 = \frac{(E_1 - E_2) - (V_{be4} + V_{be5})}{I_{R5}}$$

From the PA237 spec sheet, I_{R5} should be 0.6 mA for a 5 mA quiescent current flow through Q_5 and Q_8.

$$E_{ref} = \frac{R_1}{R_1 + R_2} E_1$$

and, $$E_2 = \frac{R_3 + R_4}{R_4} E_{ref}$$

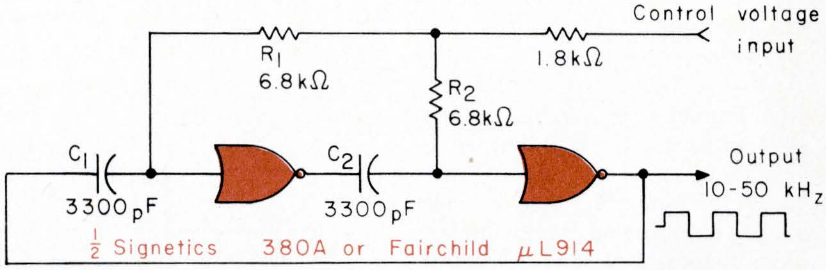
The circuit uses a +12 V regulated source, and supplies +6 V with 0.1% regulation from 0 to ±50 mA.

VOTE: for the one you like best.

902 Two gates = voltage controlled oscillator

Les Toth
Cohu Electronics, San Diego, Calif.

You can build a simple voltage-controlled oscillator with two inexpensive gates and a few external components. This circuit was designed for a TV synchronizing generator that operates at a center frequency of 31.5 kHz. By varying the control voltage from 2.4 to 4.8 V, you can change the output frequency from 10 to 50 kHz. By changing the timing components (R_1, C_1, R_2, and C_2), you can shift the frequency range in either direction.



The circuit operates reliably at rates up to several megahertz. The choice of gates isn't critical, but the Fairchild 914 dual gate is very economical in such a circuit.

903 Digital filter replaces bulky components

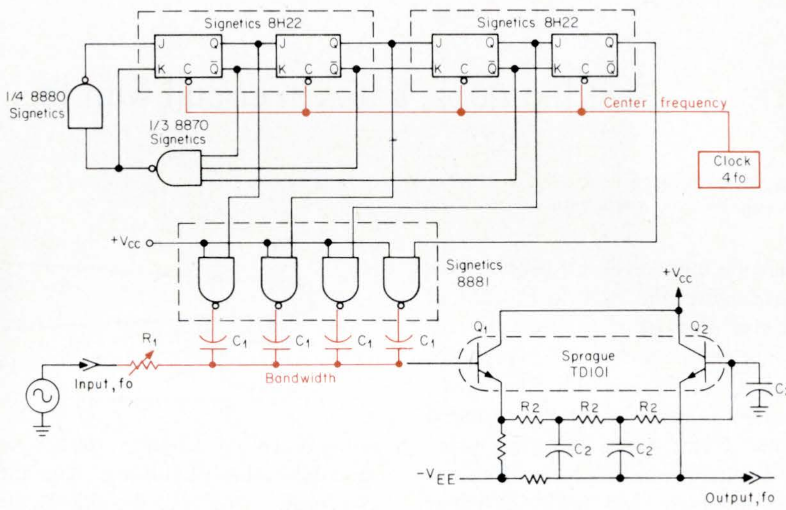
Mario Humberto Acuña
Fairchild-Hiller, Hyattsville, Md.

When you need a narrow-band filter, you should consider using a digital type. At low frequencies, for example, equivalent passive filters are of considerable size, so a digital filter saves you space.

An external clock sets the center frequency of the filter. You can change it without altering the band-pass characteristic. The clock also sets the stability of the center frequency.

Four JK flip-flops with two NAND gates form a self-starting, self-correcting ring counter that drives a four-position sequential switch. A quad 2-input NAND gate (without dc collector returns) makes up this switch. The switch and the counter make up the main filter.

A switched low-pass filter (R_1C_1) sets the digital filter's bandwidth and response curve. The equivalent bandwidth is nR_1C_1, where n is the number of positions of the sequential switch. R_1 adjusts the bandwidth, which is independent of the center frequency.



R_2, C_2, and Q_2 form an active low-pass filter that removes the sampling ripple from the output waveform. Its cutoff frequency is $1/2\pi R_2C_2$, and should be slightly higher than the center frequency of the digital filter.

A filter was built for a center (clock) frequency of 500 Hz, with $R_1 = 51$ kΩ, $R_2 = 5.1$ kΩ, $C_1 = 2.2$ μF, and $C_2 = 0.68$ μF. The measured 3 dB bandwidth was 2 Hz, with an (equivalent) skirt roll-off of 6 dB/octave. The insertion loss was 6 dB.

Note that in filters such as these, if you synthesize the center frequency from the output of the filter itself (instead of using an external clock), you get a tracking filter. Such a filter tracks its center frequency while keeping the bandwidth constant.

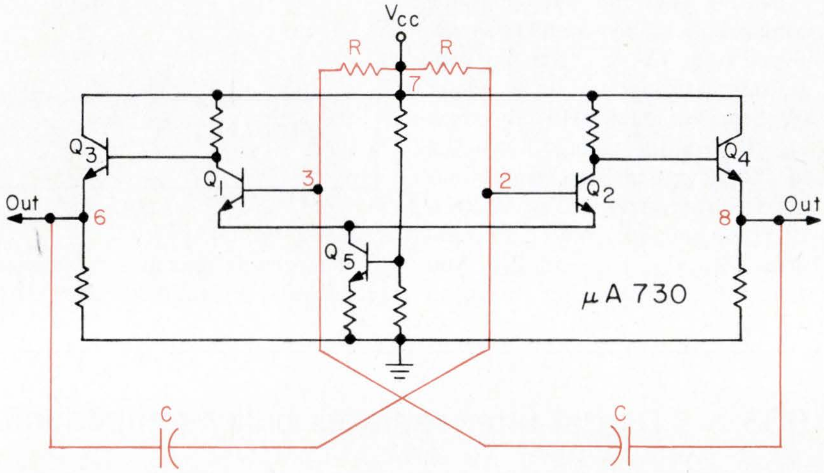
VOTE: for the one you like best.

904 Turn a diff amp into an astable multi

Howard Chiang
Carco Electronics, Palo Alto, Calif.

The Fairchild μA730 has both a differential input and output. Adding the components shown here turns the amplifier into a wide range free-running multivibrator. For instance, with R = 47 kΩ, if you vary C from 6 μF to 500 pF, the output square wave varies in frequency from 4 Hz to 38 kHz.

Q_5 is a stable current source for Q_1 and Q_2, alternately—depending on which one is in conduction. Q_3 and Q_4 are emitter followers that provide a low output impedance.

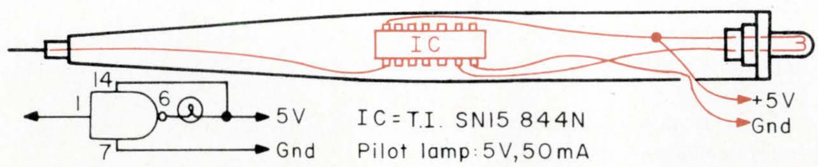


905 Test flip-flops, gates in-circuit with this simple probe

David L. Sporre
Electronix Products, Westport, Conn.

Here's a logic level test probe that's inexpensive and easy to build. Cut all the pins from a Texas Instruments SN15 844N IC, except for pins 1, 6, 7, and 14. To these, solder lengths of #30 stranded wire. Next, clean out the inside of a felt tip marking pen. Remove the metal tip and solder a paper clip to it. The paper clip wire is your probe tip. Remove the top of the pen, and attach the pilot lamp to it.

After you run the wires through the pen as necessary, and complete all connections, press the pen tip back into place. Cement the lamp assembly to the pen with something such as silicone rubber or silicone bathtub caulking. Run the 5-V power wires out the side of the pen.



The probe is useful in checking logic circuitry, especially on high density boards. The SN15 844N is a DTL lamp driver. When the input to the probe is HIGH (> 1.2 V) or not connected, the lamp is on. When the input is LOW (< 1.2 V) or grounded, the lamp is off.

Use the probe to check the operation of flip-flops or gates. When the probe input frequency is less than 15 Hz (alternating between logic levels of 0 and +5 V), the lamp blinks. If the frequency is much less than 15 Hz, the lamp blinks more slowly. If the input is faster than 20 Hz, the lamp stays on, but is only half as bright as before, since the lamp cannot respond to a higher frequency.

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Circuit Design

Practical guide to A/D conversion, part 2, Hermann Schmid, General Electric Co., "Electronic Design," Vol. 16, No. 26, Dec. 19, 1968, pp. 57-76. The continuation of a design guide to analog-to-digital conversion, this section covers two additional converter types—indirect and high-speed, high-accuracy designs. Complete performance criteria and design considerations are detailed for ramp-comparison, up/down integration, cascade, multi-threshold and variable-reference cascade techniques.

Simplifying line-voltage ring counters, Frank McKendry, Signalite, "Electronic Products," Vol. 11, No. 7, Nov. 15, 1968, pp. 48-51. Certain types of gas diodes (neon lamps) have close tolerances and are sensitive to power supply variations. The author discusses ring counter circuits that use difference diodes. The use of such diodes alleviates the sensitivity problems.

***Charging energy-storage capacitors from low-voltage sources,** Lynn T. Rees, Motorola Semiconductor, "The Electronic Engineer," Vol. 28, No. 1, Jan. 1969, pp. 50-56. There are many applications, ranging all the way from the popular photoflash to portable lasers, which require sudden bursts of dc power at a higher voltage than the one available from the batteries that power them. The solution is a dc to dc converter that takes the battery voltages and converts it to a higher voltage, at which it charges a capacitor. This article explains the converter design and gives a specific example applied to a capacitor charger for a photoflash.

Lower an oscillator's frequency drift, Robert R. Meola, Newark College of Engineering, "Electronic Design," Vol. 16, No. 24, Nov. 21, 1968, pp. 50-54. Need an oscillator insensitive to power supply or load variations? This is a tall order, but the article gives some hints. It tells how to get maximum power, how to avoid frequency changes due to transistor parameter variations, and how to minimize the effect of reactive loads on the tuning circuit.

Practical guide to A/D conversion, Hermann Schmid, General Electric Co., "Electronic Design." Vol. 16, No. 25, Dec. 5, 1968, pp. 49-72. Analog to digital converters are key elements of all digital systems. And, they must be compatible in design with the rest of the system. This guide, part I of a three-part A/D series, analyzes both parallel- and serial-feedback A/D converters. Performance, cost, and design details are given for all types.

Speed immittance calculations, Luiz Peregrino, Hewlett-Packard Co., "Electronic Design," Vol. 16, No. 25, Dec. 5, 1968, pp. 74-77. Need to find the impedance or admittance of interconnected networks? Use a computer, says the author. Time-shared computers, using BASIC, make short work of immittance matrices. The article shows how.

Communications

***The Electromagnetic Frequency Spectrum Chart,** Staff, "The Electronic Engineer," Vol. 28, No. 1, Jan. 1969, pp. 57-64. Here is the latest version of the best known among the reference charts published by this magazine. The chart incorporates all the latest revisions by the Federal Communications Commission, plus the detailed specifications of frequency allocations that account for its popularity.

Sweep time delay correlation—a potent test technique, Paul Yu, Yu-tronics, "EDN," Vol. 13, No. 15, Dec. 1968, pp. 68-73. Sweep time delay correlators are excellent for recovering periodic signals buried in noise, and signal enhancement in general. Such devices require accurate, continuously variable time delays. Here's how to build such equipment, along with descriptions of autocorrelation, cross-correlation, point-by-point sampling correlators, etc.

***Telemetry Course, Part II, frequency division multiplex,** R. Vorce, EMR, "The Electronic Engineer," Vol. 28, No. 1, Jan. 1969, pp. 81-88. An economic technique that preserves the integrity of data. In this Part II of the course, the data stays analog and we stop at the point where it is ready for conversion to digital.

Components

***Learn to live with a filter's reactance,** R. B. Cowdell, Genisco Technology Corp., "The Electronic Engineer," Vol. 28, No. 1, Jan. 1969, pp. 79-80. Since most electronic units are powered by line current, one of the most common methods used to avoid radio frequency interferences is to filter the power line, blocking the leakage of rf energy from the electronic equipment through the power line. Even though they should do this without disturbing the line, the authors show that the filters can actually "load" the power line by drawing high currents.

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Suppressing relay transients, Philip W. Koetsch, Consultants and Designers Inc., "Electro-Technology," Vol. 82, No. 6, December 1968, pp. 39-44. Unsuppressed relay transients, as you know, can do a great deal of damage. But, how does one suppress them? This comparative analysis of various methods of suppressing them in ac and dc relays should help you answer that question.

Forum on op amps, Part II—conclusion, George Flynn, Sr. Assoc. Editor, "Electronic Products," Vol. 11, No. 7, Dec. 1968, pp. 18-37. Here are the experts' opinions on such topics as specsmanship, parameter cost compromises, testing, and so forth, as well as possible future improvements in op amps. (The first part appeared in the Nov. 1968 issue.)

Computers and Peripherals

Plated wire: a long shot that's paying off, George A. Fedde, Univac Div. of Sperry Rand Corp.; **Rods look like wires, act like cores,** Donald A. Meier, National Cash Register Co.; **Weaving wires for aerospace jobs,** Richard A. Flores, Singer-General Precision Inc.; "Electronics," Vol. 41, No. 23, Nov. 11, 1968, pp. 124-133. A three-part article, this second installment in a series is devoted to memory technology. It presents the "A-Z" of the emerging plated-wire technology, and constrasts it with the dominant technique, core memories. Alloyed, isotropic, and woven plated wire are the main topics. The content includes current state-of-art efforts and recent case histories, as well as advantages and present limitations.

Z transform applications using digital computers, John D. Markel, Motorola, "Electro-Technology," Vol. 82, No. 6, December 1968, pp. 21-36. The author reviews Z transform techniques, using easy to follow (if you are still conversant with Laplace transforms) examples. He shows how you can program the method on digital computers, enabling rapid solution of non-linear and time-varying problems in circuit design and analysis.

Digital Design

Design better sequential circuits, Kevin McDonagh, ITT Semiconductors, "Electronic Design," Vol. 16, No. 26, Dec. 19, 1968, pp. 80-85. Want to cut the number of logic elements in your counter designs? Timing diagrams are *not* the answer. For a guaranteed minimum-element logic design, an approach combining flow tables and Karnaugh maps will turn the trick. A decade counter design serves as an example.

The design and use of IC preset counters, Don Jones, ITT Semiconductor, "Electronic Products," Vol. 11, No. 7, Nov. 15, 1968, pp. 54-56. Preset counters are finding wide use in a variety of applications such as programmed events counting, programmed time-interval generation, mathematical operations in electronic calculators, and so forth. In such counters, the modulus is programmable to a number of different values. This article shows you how to do it.

Plot II Karnaugh maps in parallel. George E. Goode, Assoc. Prof., SMU, "EDN," Vol. 13, No. 15, Dec. 1968, pp. 50-62. This article is based on a chapter from the author's textbook, "Design of synchronous sequential logic circuits," to be published by McGraw-Hill in 1969. The author presents a special worksheet and a construction for a template (a parallel map plotter). This new method saves much time and improves accuracy in deriving input/output functions for synchronous sequential logic circuits.

Instant logic conversion, S. P. Asija, National Cash Register Co., "IEEE Spectrum," Vol. 5, No. 12, Dec. 1968, pp. 77-80. The conversion of one logic gate into another was formerly a long and time-consuming process that required a thorough understanding of Boolean algebra, logic circuits, and related topics. But the introduction of two simple concepts of logic design makes it possible for the neophyte in computer design to convert one type of gate into another with relative ease.

To optimize TTL performance . . . , Howard Bonner, Texas Instruments, "Electronic Products," Vol. 11, No. 7, Dec. 1968, p. 52. This is a listing of frequently asked questions regarding standard TTL usage. The answers are strictly rule-of-thumb, and are useful as design guidelines.

EMI

Switch out power supply RFI, Leonard Roman, Isofilm Int'l., "Electronic Products," Vol. 11, No. 7, Dec. 1968, pp. 60-62. Switching regulator power supplies, especially those running at 20-40 kHz, are sources of RFI. By replacing the ordinary rectifier diodes with Isodiodes (that have fast rise/fall times and low stored charge), and using ferrite beads, you can reduce the RFI problem.

Integrated Circuits

LSI and computer design, Special Report, "Electronic Design," Vol. 16, No. 24, Nov. 21, 1968, pp. 80-88. Computer designers are still hedging on the use of LSI in their designs. This special report, based on four technical articles, tells why. Sections cover memories, discretionary wiring, ECL logic, and a discussion of development costs from the vendor's point of view. News stories and a product roundup are keyed to the Fall Joint Computer Conference.

Materials

An engineer's guide to precious metal plating, Robert L. Cooley, Burton Research Labs., "Electronic Products," Vol. 11, No. 7, Dec. 1968, pp. 64-69. This survey of electroplating tells you when to plate and with what material, and how to test the result.

Design guide to shrinkable tubing, Chuck Henningsen, Insulectro, "EDN," Vol. 13, No. 15, Dec. 1968, pp. 64-65. This survey of shrinkable tubing describes a variety of types and their characteristics, for users.

Oscillators

Synchronous Wein bridge oscillator, Dr. Veljko Milenkovic and Carl Zaander, General American Transportation Corp., "Electro-Technology," Vol. 82, No. 6, December 1968, pp. 54-57. Sinusoidal-output oscillators normally exhibit large phase shifts when they are driven even slightly off their tuned frequencies. The oscillator described here overcomes this tendency. The key to its success is that it is reset to a unique initial state every cycle.

Remember the blocking oscillator, Henry D. Olson, Stanford Research Inst., "Electronic Products," Vol. 11, No. 7, Dec. 1968, pp. 54-58. Here is a description of several blocking oscillators that use FETs and bipolar transistors. The author's point is that ICs are not always the best or cheapest solution.

Semiconductors

MOS multiplexer switches can do well at high frequencies, Per Morgensen and Wallace Chan, Fairchild Semiconductor, "Electronics," Vol. 41, No. 23, Nov. 11, 1968, pp. 152-156. Field-effect devices, both function and MOS have been steadily increasing their application in multiplexers. But thus far, MOS use above 1 kHz switching rates has been limited by feedthrough, transient, and frequency effects. The author generates a set of mathematic models which show how to design around these obstacles. He proves his case with actual performance examples that underline the effectiveness of the method.

***Are you confused by high di/dt SCR ratings?** Dante E. Piccone & I. Steve Somos, General Electric, "The Electronic Engineer," Vol. 28, No. 1, Jan. 1969, pp. 89-92. High di/dt devices are being looked at as a solution to SCR failures. But are SCR failures really from a high di/dt? Before you decide, examine failure mechanisms and rating philosophy. Also, be aware of the tradeoffs you must make for a higher di/dt.

***The sock-it-to-'em method to dope semiconductors,** Stephen A. Thompson, Western Editor, "The Electronic Engineer," Vol. 28, No. 1, Jan. 1969, pp. 68-76. Diffusion, the process commonly used today to make transistors, diodes and integrated circuits, has dominated the semiconductor industry for the past 10 years. It consists of introducing impurities (or dopants) into semiconductor materials at temperatures above 1000°C. Ion implantation, on the other hand, is a new process which has, in only a few cases, left the laboratory for the production line. It inserts dopants into semiconductor materials by driving them in an electromagnetic field, much as the electron gun of a TV picture tube drives electrons onto the faceplate to form an image. Since this process takes place at relatively low temperature, ion implantation promises devices with very fine control of geometry, and characteristics not attainable with diffusion.

Systems

A new method of driving synchro receivers, Martin Kanner, Grumman Aircraft, "Electronic Products," Vol. 11, No. 7, Dec. 1968, pp. 44-50. In certain applications, it would be desirable to drive the torque receiver directly as a function of a dc input signal. Such a capability would eliminate the cumbersome electromechanical aspects of servo applications. A study of the feasibility of doing this shows that you can indeed use dc to drive (normally) ac operated synchro torque receivers.

Test and Measurement

Testers for thyristor-family devices, David A. Zinder, Motorola Semiconductor, "Electronic Products," Vol. 11, No. 7, Nov. 15, 1968, pp. 22-27. Many component testers are complex and require skilled operators. The testers described here test important parameters of thyristor-family devices on a GO/NO-GO basis. They are simple, inexpensive, and are suitable for production-line testing by unskilled personnel.

Instrumentation and measurement issue, "EDN," Vol. 13, No. 14, Nov. 25, 1968. This issue consists of a collection of thirty charts and nomographs, either published in previous issues of "EDN," or reprinted from other sources.

Hardware—software tradeoffs in testing, James E. Stuehler, International Business Machines, "IEEE Spectrum," Vol. 5, No. 12, Dec. 1968, pp. 51-56. The manufacturing and aerospace industries are finding wider use for the digital computer in reliability testing. In some cases, computers are replacing or supplementing special hardware that in the past has provided the test capabilities. The problem is that arbitrary decisions are sometimes made as to hardware—software tradeoffs. Before you make such decisions concerning the total system, you should analyze the needs of the information, control, and interface subsystems.

Miscellaneous

Laser display technology, Charles E. Baker, Texas Instruments Incorporated, "IEEE Spectrum," Vol. 5, No. 12, Dec. 1968, pp. 39-50. There has been much progress in the development of operational experimental systems, but low efficiency of presently available lasers prevents them from competing seriously with cathode ray tube displays. The widespread application of laser display technology depends on the development of improved lasers.

Information access catches up with the designer, A. F. Novak, Databank Editor, "EDN," Vol. 13, No. 15, Dec. 1968, pp. 89-94. More engineers are turning to libraries and other information centers, rather than to their own books or files, or those of their friends, for design information and background. To cope with the information explosion and make as many sources as possible available to those who need them, libraries are turning to computerized information retrieval systems.

***New product management, Part I: how to get more products for your engineering dollars,** Eugene Parry, Hewlett-Packard, Vol. 28, No. 1, Jan. 1969, pp. 38-46. Only 30% of new product expenditures will result in successful products. But with improved management techniques, you can weed out the failures early—and thus concentrate your resources on the probable successes.

Circle 38 on Inquiry Card ⟶

EE NEW PRODUCTS

Power IC audio amp. race tightens

Fledgling firm follows Westinghouse withdrawal with one-watt monolithic

How does a small firm get into the integrated circuit business?

How does a large firm get out of the integrated circuit business?

If you've been taught not to answer one question with another, try again. In this case, the swan song of Westinghouse's Molecular Electronics Division signals the debut of Trans-Tek Mfg. Co. as an IC supplier.

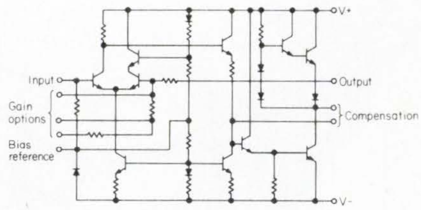
What's in a name?

The product in question is a one-watt monolithic audio amplifier. It's called the WC334, or the TT-1, depending on whom you are speaking to.

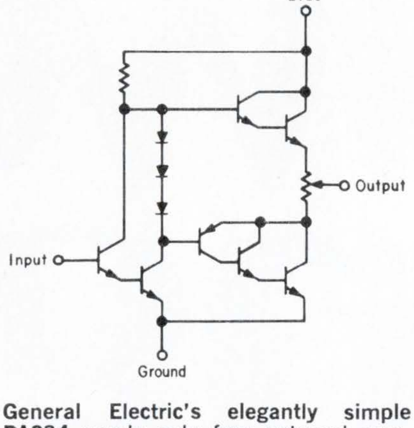
Lawrence Massaro, president of the South Plainfield, N. J.-based Trans-Tek, candidly admits that his devices are Westinghouse-designed. But, what with the Westinghouse announcement that it is leaving the commercial IC marketplace, Massaro hopes to manufacture the devices under his own roof, if sales warrant. The 6-year old company's previous semiconductor experience consists of second-sourcing of "bullet" diodes and rectifiers, and small-signal silicon transistors.

The big boys

Massaro faces stiff competition from some familiar names—General Electric, Motorola, Amperex, and Westinghouse itself. At the present time, the TT-1 is priced about 25% less than the WC334 in small quantities. But price is not the entire story with the other devices.



Motorola's premium MC1554 leads the pack in number of transistors, circuit and pinning complexity, price, and performance. Unit will amplify to 400 kHz, delivering its one watt to a direct or capacitively coupled load. Package is a low-profile similar to a TO-5, and available to Mil specs.



General Electric's elegantly simple PA234 needs only four external components: three resistors and one capacitor, plus any coupling capacitors needed for source or load. Package is a plastic dual-in-line with a tab for heat transfer to a printed circuit board.

The General Electric, Westinghouse, and Trans-Tex devices are all general-purpose, consumer/industrial circuits. The GE PA234 needs a higher input voltage for full output (600 mV vs. 50 mV), and has a lower input impedance (100 kΩ vs. 400 kΩ). On the other hand, its frequency response curve is flat to 100 kHz (10 kHz for the others) and its distortion is lower. Its pinning is much simpler, and its price in quantity can be almost half that of the WC334/TT-1.

The Amperex entry needs a mere 10 mV for full output. Aside from its somewhat lower input impedance, its price and performance are comparable.

Motorola has the Cadillac device of the bunch. Its MC1554 gets out to 400 kHz, boasts 0.4% total harmonic distortion and conforms to Mil specs in package and temperature specs. You don't get this kind of performance for nothing, however. Small quantity prices run up to \$14.25. Motorola doesn't see much of a consumer market for its unit. One possible use, however, would

Device	Supply (Vdc)	Sensitivity (mV)	Z_{in} (kΩ)	Z_{out} (Ω)	Frequency response[2]	THD (% at 1 W)	Package type	Price[3]
Amperex TAA 300	4.5 to 10.5	10	15	—	800 Hz-10 kHz	3 (0.5 W)	10-lead TO-74	$2.96 (1-24) $1.77 (1k)
Motorola MC1554	−8 to +8	—	10	0.2	30 Hz-400 kHz	0.4	10-lead low-profile TO-5	$14.25 (1-24) $9.50 (1k)
General Elec. PA234	9 to 25	600	100	2	30 Hz-100 kHz	3	8-lead plastic DIP with tab	$1.38 (1-99) 75¢ (10k)
Westinghouse WC334	6 to 20	—	50 400[1]	0.3	50 Hz-10 kHz	5	8-lead TO-78	$3.00 (1-49) $2.15 (1k)
Trans-Tek TT-1	6 to 20	50	50 400[1]	0.3	20 Hz-10 kHz	5	8-lead TO-78	$2.25 (1-9) $1.30 (100k)

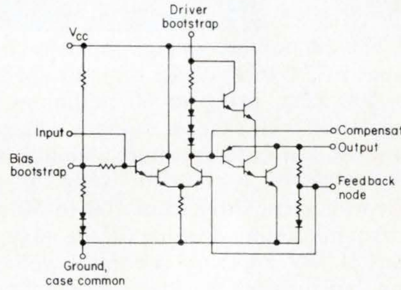
Notes:
(1) With external bootstrap capacitor added.
(2) To 3-dB point, in optimum gain configuration.
(3) Distributor stock, except Trans-Tek (50% stock, 50% 6 wks. in large quantity).

be in portable stereo units calling for high-fidelity performance.

Typical specs and prices on all devices are given in the table. For further information, circle the following numbers on the Inquiry Card:

Amperex—Circle number 201
Motorola—Circle number 202
General Electric—Circle number 203
Trans-Tek—Circle number 204

Westinghouse/Trans-Tek device is a temperature-compensated, Darlington-input diff-amp followed by a quasi-complementary emitter-follower output stage. Input impedance is boosted with capacitor between feedback and bias pins. Package is a TO-78. Required heat sink is Wakefield 207 or equivalent.



Audio IC delivers 5 watts

Discussed at ISSCC (International Solid State Circuits Conference) last February, it has finally arrived—a five watt IC audio amplifier by General Electric. Device comes in a plastic package requiring metal plates for a heat sink.

We saw one in operation at the National Electronics Conference held in Chicago on December 9, 10, & 11. And the operating unit's output looked pretty good on a scope at about 4W. Semiconductor Specialists, a rep for General Electric, had a hastily breadboarded circuit powered with a supply capable of only four watts output. For cooling they had attached two copper fins. These fins had a measured temperature of 68°C.

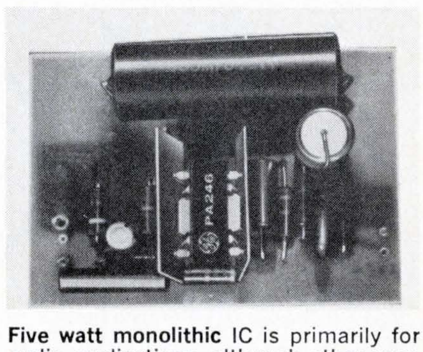
Designed for audio amplifiers, the monolithic PA 246 comes in a modified DIP to provide lower thermal resistance. Two wide tabs, centered on each side of the package, are for attachment of a heat sink. Heat sinking must be used.

The power IC will operate from a wide range of power supply voltages up to 37 V. Frequency response extends from 30 Hz to 100 kHz with noise output typically −70 dB, relative to five watts. At 5 W output, input sensitivity is 180 mV and output harmonic distortion is under 1% at 1 kHz. The 5 W rating is based on a 34 V supply and a 16 ohm load.

While primarily for audio applications, the IC will be useful as a voltage supply regulator, servo motor driver, relay and lamp driver, and an op amp booster, to cite a few examples.

Prices range from $3.84 in quantities of 1 to 99 to $2.56 for 100 to 999. Engineering sample quantities should be available now. For additional information contact A & SP Distribution Services, General Electric Co., Building 705, Corporations Park, Scotia, N. Y. 12305.

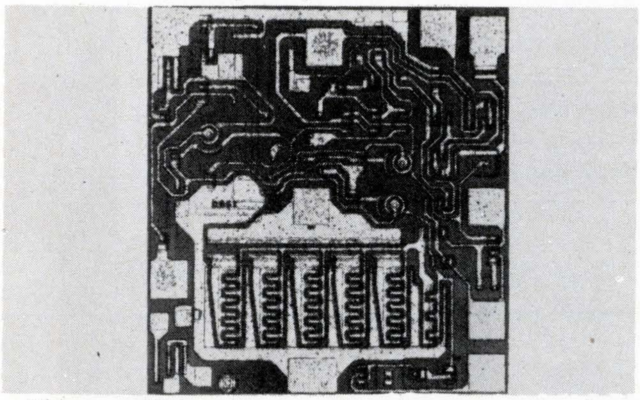
Circle 239 on Inquiry Card



Five watt monolithic IC is primarily for audio applications, although other uses will be found for the device. IC requires heat sinking. In this photo two metal plates are affixed to built-in tabs for cooling.

VOLTAGE REGULATOR

Has 0.5 A output capability.



This monolithic voltage regulator has an output voltage range of 2.5 to 17 V. Its output impedance is 20 milliohms to 100 kHz, rising to 60 milliohms at 1 MHz. Typical regulation with changes in input voltage is only 0.002%/V. The MC1560's temperature stability is 0.002%/°C. Transient response is excellent: only 50 ns recovery time for a load current drop from 100 to 50 mA.

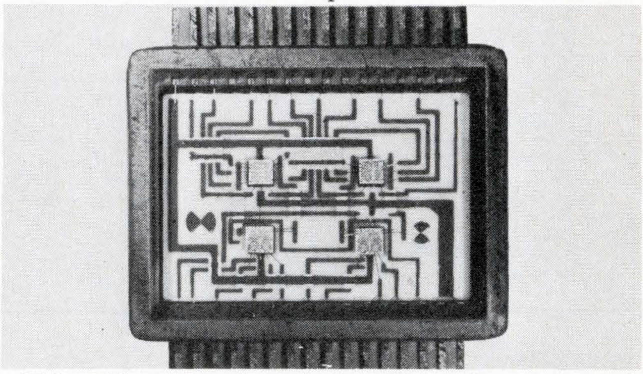
An interesting feature of the regulator is a shut-down control. By applying a control voltage to this terminal, you can turn off the load and regulator bias currents. Besides reducing system power consumption, such a control gives you remote on/off switching, a squelch for communications circuits, and a dissipation control to protect the regulator during sustained short-circuits. RTL, DTL, TTL, and HTL logic levels actuate the shut-down circuit.

The MC1560R, in a 9-pin TO-66 case, can dissipate 10 W at a 65°C case temperature, and regulates 500 mA loads (or 10 A with an external pass transistor). It costs $20 ea. in 100-up lots. The MC1560G, in a 10-pin TO-5 housing, regulates to 200 mA, and can dissipate 1.8 W at a 25°C case temperature. Its price is $15, 100-up. Limited temperature (0 to 75°C) versions with relaxed specs are available as the MC1460G ($3.50, 100-up) and MC1460R ($4.50, 100-up). Technical Information Center, Motorola Semiconductor Products, Inc., P. O. Box 20924, Phoenix, Ariz. 85036.

Circle 223 on Inquiry Card

MULTIPLE MSI HYBRID

Arithmetic unit uses four chips.



This 4-bit arithmetic unit introduces the concept of multiple MSI circuits within a single package. The SH8080, which combines a ripple carry adder and a holding register, is the industry's first hybrid to incorporate four MSI chips. With an advanced packaging technique, two TTμL 9020's and two TTμL 9304's are interconnected by a multilayer thick-film substrate. This gives higher reliability than the usual wired connections. (The chips themselves—the 9020 dual JKK flip-flop, and the 9304 dual full adder—have been in use for more than a year.) Two-layer metalization separated by a ceramic dielectric greatly enhances packing density while keeping power requirements low.

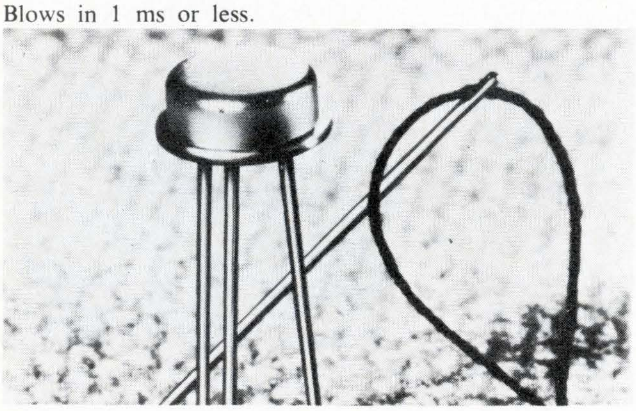
Compatible with current-sinking logic, the SH8080 performs with a carry propagation time of only 32 ns typ., and has a noise margin of 1 V. Chief applications for the circuit are in airborne computers, desk calculators, and high speed data processing and ground support equipment. Such systems can realize substantial savings in assembly costs, because the SH8080 reduces package count.

Available from distributors in a hermetically sealed, 32-lead flatpack, the device costs $120 in quantities of 1-24 (for the military temperature range of −55 to 125°C); $96, 25-99; and $79.25, 100-999. The industrial unit (0 to 70°C) sells for $46, $35.80, and $30.80 in the same respective quantities. Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, Calif. 94040. (415) 962-3562.

Circle 224 on Inquiry Card

HIGH SPEED FUSE

Blows in 1 ms or less.



Designed specifically to protect ICs and power transistors in digital microcircuits, this fuse is available with ratings of 0.5, 0.75, and 1.5 A. All three units blow in 1 ms with small overloads. And they will blow as fast as 50 μs with 30 A overloads.

Packaged in a TO-46 can, the Series 817 High Speed Fuse features 40 V at 50 A circuit interruption, and an insulation resistance of 10 MΩ at 150 V. It has a −55 to 125°C operating temperature range.

The fuse costs $1 ea., 1-9 pcs.; 95¢, 10-24; 90¢, 25-49; and 85¢, 50-99. Ask the factory for a quote on quantities of more than 100 pcs. Technical Information Section, Helipot Division, Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, Calif. 92634. (714) 871-4848.

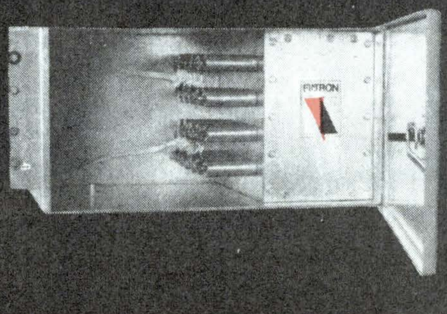
Circle 225 on Inquiry Card

Circle 41 on Inquiry Card ⟶

Ever wonder how you keep a secure line from being bugged?

When the security of your teletype, telegraph, telephone and other signal lines is critical the solution is to guard them with Filtron Fil-Tel® filters.

Used in conjunction with protected and shielded facilities, Filtron Fil-Tel filters for voice, digital, light, and controlled circuits provide the required intelligence security you need. They remove spurious energy, and provide a continuous RF-tight shield for every signal transmitted or received. As with all Filtron shielding and filtering products, construction of the Fil-Tel line is of the highest quality. All units are hermetically sealed, and housed in hot-tinned steel cases ready for fast mounting. Assemblies of any combination of filters are available, completely pre-wired to standard terminal strips and enclosed in an RF-tight cabinet.



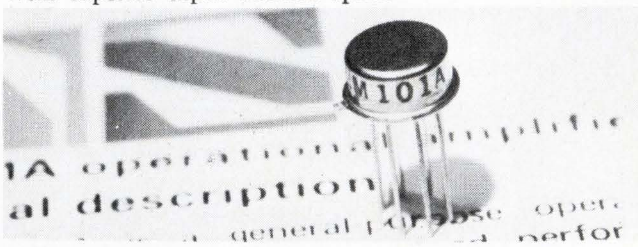
The Red / Black insignia on Filtron's "Fil-Tel" line is our guarantee of superior communications security performance. For a complete, informative listing of our Red/Black secure communications devices and shielded enclosures, write for our new 24-page catalog, No. P-68.

FILTRON COMPANY, INC.
131-15 Fowler Avenue,
Flushing, N.Y. 11355 (212) 445-7000
Subsidiary of
Liquidonics Industries, Inc.

FILTRON

OP AMP

With superior input current specs.



Here's a monolithic op amp that guarantees bias currents of 100 nA and offset currents of 20 nA, from -55 to 125°C. Offset voltages of 3 mV, offset voltage drifts of 15 μV/°C, and offset current drifts of 0.2 nA/°C are also guaranteed over the full military temperature range. Such superior input characteristics result from improved processing for better transistor current gains (especially at low temperatures), and an improved input stage current source that compensates for temperature variations of the current gain in the input transistors.

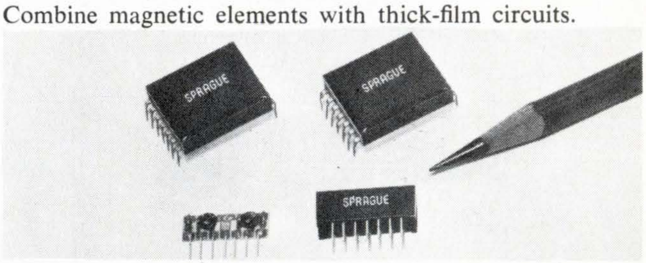
Interchangeable with the LM101 and the 709, the LM101A has overload protection on its input and output. You can frequency compensate it with a single 30 pF capacitor, and it will not oscillate with capacitive loads or loose supply bypassing. There are no latch-up modes.

You can get the LM101A from any National stocking distributor. The OEM prices are $45 (1-24 pcs.), $36 (25-99), and $30 (100-999). A limited temperature (0 to 70°C) version, the LM201A, is priced at exactly 40% of these figures. National Semiconductor Corp., 2950 San Ysidro Way, Santa Clara, Calif. 95051. (408) 245-4320.

Circle 226 on Inquiry Card

MEMORY-DRIVE MODULES

Combine magnetic elements with thick-film circuits.

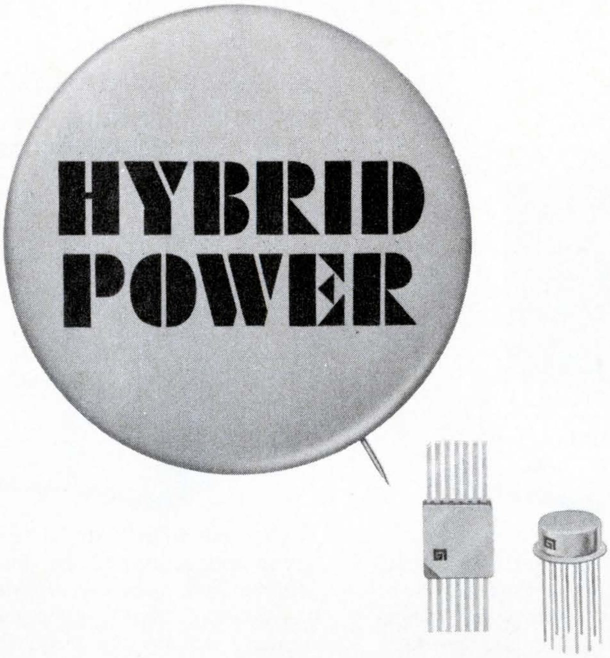


These circuit assemblies are made up of miniature inductive elements and metal-film resistors on ceramic substrates. Type 905Z is in a jumbo dual in-line package, while the 906Z is a DIP assembly. Component complements in the Moduline Memory-Drive modules are expandable to include other components such as diodes, capacitors, and so forth.

With these modules you get, in one package, the pulse characteristics you need for functional operation. You do not have to develop a system of guard-band tolerances on individual components, such as has been needed for discrete component assemblies used in computer memory-drive circuits.

You can realize substantial savings by using these memory-drives because you eliminate the cost of individual purchase orders, incoming inspection, component assembly, and final inspection of conventional discrete component circuits. You can order burn-in to your specifications. Technical Literature Service, Sprague Electric Co., Marshall St., North Adams, Mass. 01247. (413) 664-4411.

Circle 227 on Inquiry Card



General Instrument, the "#1 Power" in hybrid microcircuitry adds the NC/PC-260 Hybrid Power Amplifier to the industry's original and broadest line of hybrid ICs. The NC/PC-260 does more and costs less* than any other hybrid power amplifier.

The NC/PC-260 Hybrid Linear/Pulse Power Amplifier is a complementary symmetrical current amplifier exhibiting exceptional linearity in the entire output voltage range without crossover distortions; power efficiency approaching theoretical maximum; high output current; high input impedance; low output impedance and wide bandwidth. This unique combination of performance characteristics is made possible by the V_{BE} pairing and thermal feedback of the four transistors which keep the bias current constant, thereby preventing thermal runaway.

The NC/PC-260s are designed for use as linear, T^2L, and MOS buffers. They are immediately available from your authorized General Instrument distributor in TO-5 (NC-260) and ⅜" square flat packs (PC-260).

TYPICAL CIRCUIT PERFORMANCE RATINGS:

$V_{CC} = V_{EE} = 12V$, $R_L = R_S = 1K$
$T_{OP} = -55°C$ to $+125°C$

Voltage Gain	0.99
Bandwidth (3 dB), $R_S = 100\Omega$, $V_{IN} = 1V_{PP}$, DC to	40 MHz
Input Resistance	1 MΩ
Output Impedance	12 Ω
Total Harmonic Distortion V_{in} (1—5 V_{rms})	0.2 %
Power Efficiency ($R_L = 240\Omega$, $18V_{PP}$ Swing)	53%

*at quantities 1-24, NC-260 @ $17.50 ea.; PC-260 @ $20.30 ea.

Write for complete information. (In Europe, to General Instrument Europe S.P.A., Piazza Amendola 9, 20149 Milano, Italy.)

GENERAL
INSTRUMENT

GENERAL INSTRUMENT CORPORATION • 600 WEST JOHN STREET, HICKSVILLE, L. I., NEW YORK

IC TESTER

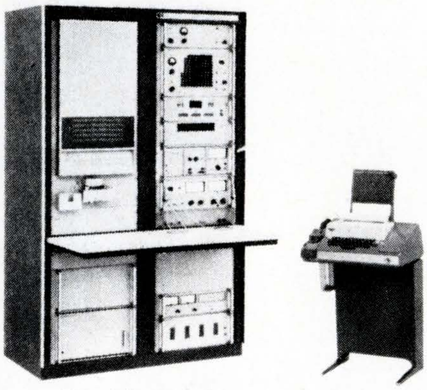
High speed, 20 lines.

CDC 9545 provides a custom, high thru-put, low-cost IC modular testing system. It can be adapted to one of four sequencer units; from a manual switch with panel meter, to automatic electronic scanning with automatic go-no-go detectors, stop on failure commands and print commands for auxiliary data acquisition systems. The tester contains the forcing functions and programming capabilities for 20-tests. It will test all form of analog digital logic elements, including ICs, discrete circuits and printed circuit cards. Options include: IBM card programming; disc programming; auto sequencing; print all data; print fail data, and is expandable in groups of 20 lines and tests. Price from $5,500 to $9,500. Contact Marv Paller, Manager, Apparatus Div., Continental Device Corp., 12515 Chadron Ave., Hawthorne, Calif. 90250.

Circle 234 on Inquiry Card

COMPUTER CONTROLLED TEST SYSTEM

Uses off-the-shelf instruments.

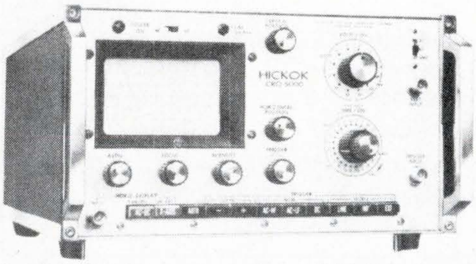


The system, HP Model 9500A, asks only that the user devise connections to the units tested, and set up the test program. The system is programmed in BASIC, an English-like language that can be learned in a few hours. With standard options the frequency range is from dc to 100 kHz or as high as 500 MHz controllable in levels from 0 to 132 dB. The 9500A consists of the computer (HP Model 2116B) a teleprinter input/output, a punched tape reader, a programmable dc power source (HP Model 613OB) an integrating voltmeter (HP Model 2402A) and a distribution switch to connect the system to any of 16 test points. Options for place measurements, 200-line measurement scanning, frequency and ohms measurements. Price of the system is from $54,000 to $125,000 depending on options. Inquiries Mgr., Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304.

Circle 236 on Inquiry Card

OSCILLOSCOPE

Bandwidth of dc to 25 MHz.

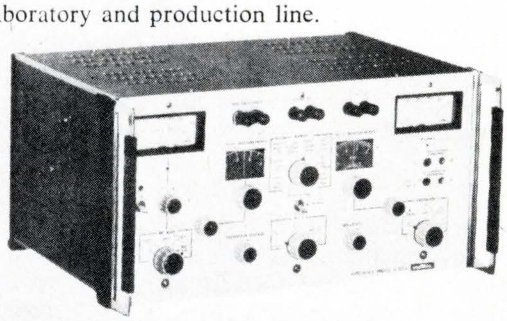


Model CRO-5000 response above 25 MHz is essentially Gaussian for optimum pulse reproduction and is usable to 50 MHz. A 4 in. flat-faced CRT with 3.8 kV accelerating voltage provides a bright, crisp trace. Horizontal amplifier response is from dc to over 5 MHz. A built-in vertical delay line provides nearly 50 ns of baseline prior to start of the pulse display. Vertical sens. is 10 mV/div. in 12 steps from 10 mV/div. to 50 V/div. Sweep delay will delay the waveform continuously up to 40 divisions, allowing the operator to obtain full presentation of small portions of the input waveform. Twenty-four calibrated sweep ranges from 50 ns/div. to s/div. with an accuracy of 3%. The price is $650. The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, Ohio 44108.

Circle 235 on Inquiry Card

IMPEDANCE BRIDGE

For laboratory and production line.



Designated Model IX 307A, the bridge is capable of performing the following measurements: dc resistance; resistance, capacitance, inductance at 100 Hz, 1 kHz, 10 kHz or 60 Hz to 10 kHz using an external source (a variable bias is available to simulate true operating conditions); loss angle tangent and Q factor for a capacitor or inductor; and comparison of a component with an external standard. Its ranges are: resistance 0.01 Ω to 10 MΩ in 8 ranges, capacitance 0.1 pF to 10,000 μF in 8 ranges, loss factor, direct reading of Q factor from 0 to 15 and the loss angle tangent 0.004 to 0.15. The unit is priced at $832, delivery in ten days. Advanced Technology & Systems Corp., 199 Sound Beach Ave., Old Greenwich, Conn. 06870.

Circle 237 on Inquiry Card

potential unlimited

Our little DT-360 digital voltmeter/multimeter looks portable. It is.

And, it doesn't cost an arm or leg to own one. So at first glance, we wouldn't be surprised if you regarded it rather lightly (especially when you pick it up and find it only weighs 42 oz.).

Take a second look. Then you see why we call it a system for measuring potential with unlimited potential.

Take for example, **Accuracy.** The DT-360 gives 0.1% of reading ±0.1% of full scale; over a temperature range from 10° to 40° C for a six months' period.

Versatility. The DT-360 can be used anywhere: On the bench, mounted on the rack, or held by hand. It's portable, so you can use it in the physician's lab or the mechanic's garage.

Input?

The DT-360 takes separate single-end inputs for voltage and current/resistor measurements—floating from power ground.

Anything else? Well, you notice we call it a voltmeter/multimeter. Which we did for a reason: The 360 is a voltmeter with multimeter flexibility. You can select any one of 5 ranges of DCV, ACV, DCMA, ACMA or KΩ by pushbutton switch. The dual slope integration technique performs the analog-to-digital conversions. In short, the DT-360 has just about everything you need for portable potential measurement. All in one brief (8½" x 5¾" x 3") case.

Data Technology Corporation
1050 East Meadow Circle
Palo Alto, California 94303
Phone (415) 964-2600, TWX (910) 379-6467

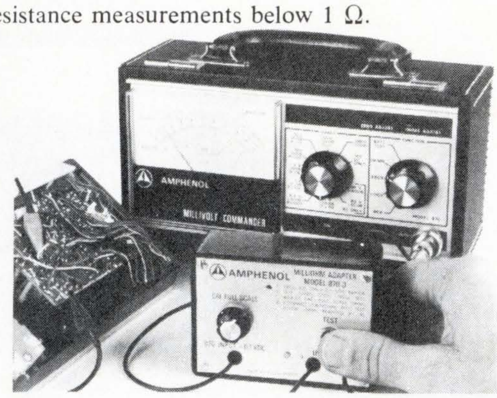
Circle 44 on Inquiry Card

Circle 39 on Inquiry Card

EE NEW LAB INSTRUMENTS

METER ATTACHMENT

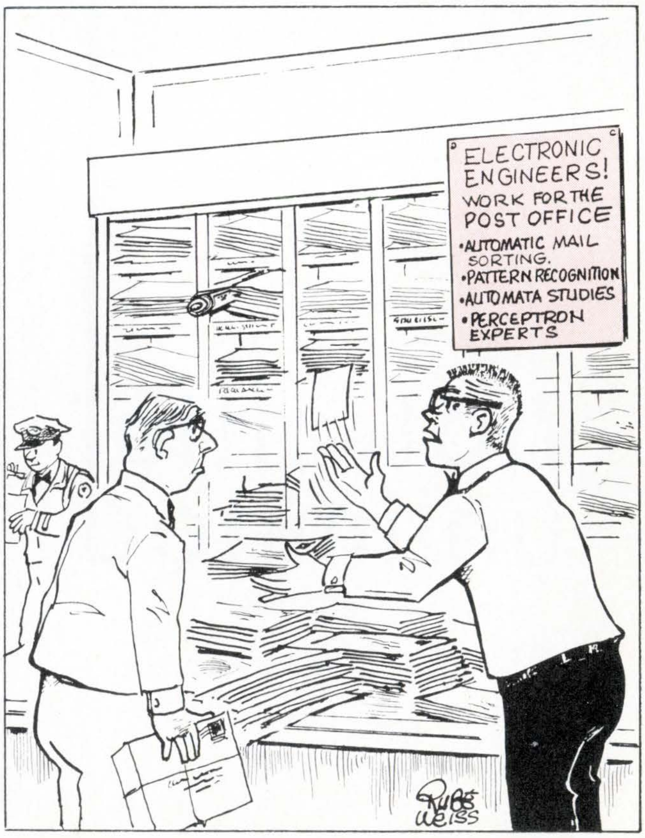
For resistance measurements below 1 Ω.



The meter attachment is capable of converting Millivolt Commander instruments and other 10 ohm center-scale meters to read resistance of 1 Ω or less. The 870-3 is of particular value for checking voltage dropping resistors in solid state power supplies as well as for testing transformerless transistorized audio power amplifiers. The device under test is fully protected against accidental burnout since the current is limited to 100 mA across 1 Ω. Operationally the meter is switched to 0.1 Vdc range and the adapter cable is connected to the meter input. After some calibrations the measured resistance is observed on the meter and divided by ten. Amphenol Distributor Div., The Bunker-Ramo Corp., 2875 S. 25th Ave., Broadview, Ill. 60153.

Circle 238 on Inquiry Card

ELROY



"Are you sure this is an engineering position?"

Circle 45 on Inquiry Card ⟶

EE NEW LAB INSTRUMENTS

DECADE INDUCTOR

Inductance from 0.111 H to 11.1 H.

Type 1491 decade inductor is an assembly of several 940 decade-inductor units in a single metal cabinet. Six ranges are provided in 0.1 mH steps. The decades are convenient elements for use in wave filters, equalizers, and timed circuits throughout the range of audio and low frequencies. They are also useful during preliminary circuit design when it is necessary to vary circuit elements over relatively wide ranges. Price of the decade inductors varies from $515 to $915, depending on range and mounting. General Radio Company, 300 Baker Ave., Concord, Mass. 01781. (617) 369-4400.

Circle 228 on Inquiry Card

PULSE MODULATOR

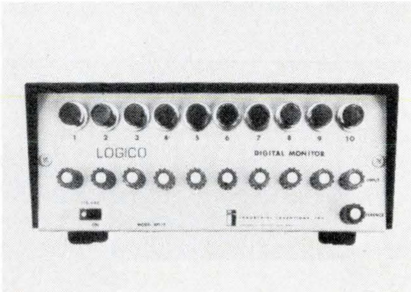
Output voltage from 0 to 3 kV at 3 A.

Model 10299 features peak output voltage readout; pulse characteristics of 0.5 to 10 μs, adjustable; pulse droop of 5% max. at 10 μs pulse width; and rise and fall time of less than 0.4 μs into a 1 kΩ load. Pulse repetition rate is adjustable, 150 Hz to 10 kHz. Duty cycle readout is from 0.001 to 0.01. Output modifications will provide voltages up to 6 kV at average power levels to 100 W. Input power is 115 Vac, 50/60 Hz at 300 W. Weight is approximately 45 lb. Robert E. Morgan, President, Microwave Cavity Laboratories, Inc., 10 North Beach Acenue, La Grange, Ill. 60525.

Circle 230 on Inquiry Card

DIGITAL MONITOR

Saves breadboarding and testing time.

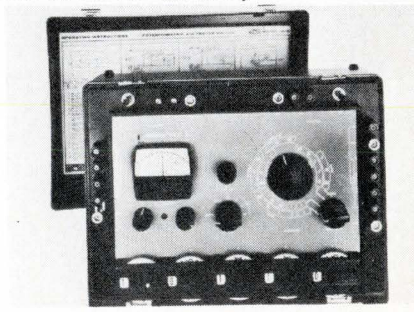


The Logico Digital Monitor provides simultaneous visual indication of the logic states of up to 20 digital or binary circuits. It will not affect the circuit under test and can be used with any logic or voltage system commonly in use today. With each logic system a reference potential is determined and connected to the reference terminal; the other inputs are connected to the circuit points to be observed. Two models are offered, the Model BPL10 with 10 indicators and an internal supply ($79.50) and the Model BL10 with just 10 indicators ($69.50). Industrial Inventions, Inc., RD2 463, US1, Monmouth Junction, N. J. 08852. (201) 329-6000.

Circle 229 on Inquiry Card

VOLTMETER-BRIDGE

Offers 0.01% accuracy.



A newer, higher-accuracy version of the Model 300 Potentiometric Voltmeter-Bridge is the Model 300A. Its accuracy of 0.01% in all its measurement and ratio functions provides the desired 10:1 accuracy ratio for calibrating 0.1% instruments. The 300A has five dc-voltmeter ranges to 511.10 V with 1 μV min. steps, eight ammeter ranges to 5.1110 A with 10 pA min. steps, and 10 resistance ranges to 511.10 MΩ with 10 microhm min. steps. It is portable and operates from a battery power source. Price is $995; availability is stock to 30 days. Electro Scientific Industries, Inc., 13900 N. W. Science Park Dr., Portland, Ore. 97229. (503) 646-4141.

Circle 231 on Inquiry Card

LASER DIODE PULSER

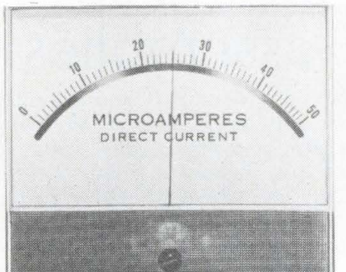
Has pulse amplitude of 0 to 75 A.

This all solid state unit is suited for general laboratory use in pulsing laser diodes. The Type LDP-3 provides continuously adjustable repetition frequency (1 to 1000 Hz with single pulse mode), pulse amplitude of 0 to 75 A, and pulse width of 50 to 200 ns. The rise time is typically less than 5 ns and the fall time is less than 9 ns. The pulser is housed in cabinet 6.5 x 11 x 11 in. and operates from a standard 115 V, 60 Hz line. The price is $975 F.O.B. St. Charles, Mo. Delivery is 30 days. Savant Engineering, Inc., 825 North Second, St. Charles, Mo. 63301. (314) 291-5205.

Circle 232 on Inquiry Card

PANEL BOARD METERS

Full-scale accuracy is 1.5%.



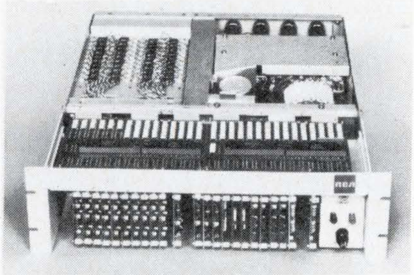
The meters are available in either dc D'Arsonval or ac Repulsion wave movements. They come in three case sizes: 3.5, 4.5, and 5.5 in. widths. The dc mechanism is a self-shielded core magnet design with either pivot-jewel or taut-band suspension. DC ranges of 10 μA to 30 A, and voltage from 15 mV to 300 V, are standard. The ac meters have ranges from 10 mA to 30 A and from 5 V to 300 V. Higher ranges of both types are available. The meters are fitted with clear acrylic plastic faces. Cases may be mounted on panel fronts, or used in rear-of-panel mountings. Colorado Hickok Corp., 2897 North Avenue, Grand Junction, Colo. 81501. (303) 243-2124.

Circle 233 on Inquiry Card

EE SYSTEMS EQUIPMENT

CORE MEMORY

Prices range from $5,000 to $35,000.

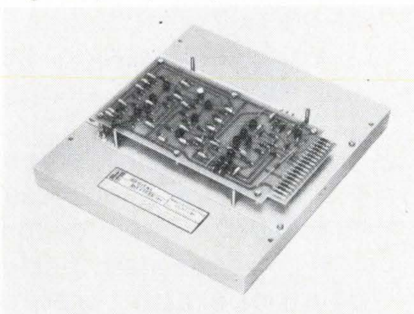


The MS3370 memory system is a 750 ns 3-wire 3D, coincident-current core memory system packaged in a 5½ high to 21 in. high (depending on capacity) sliding drawer mountable in an EIA 19 in. cabinet. System capacity includes 4,096 words x 4 bits to 16,384 words x 40 bits using a standard "building block" approach. Capacities up to 131,072 words are provided by paralleling 16,484-word modules. Integrated circuits make up the memory address register, memory information register and control and timing circuits. Availability is 15 to 90 days. RCA/Electronic Components, Memory Products Div., 150 "A" St., Needham Heights, Mass. 03195. (617) 444-7200.

Circle 205 on Inquiry Card

DELAY LINE

High capacity magnetrostrictive

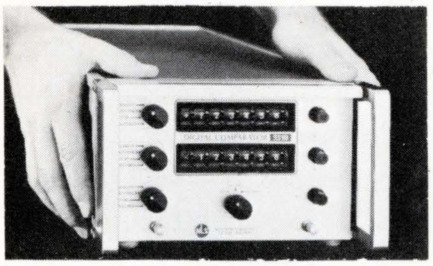


Delay line has a storage capacity of 30,000 bits. The cost per bit is around 1 cent, in small quantities. The unit provides a 15 ms delay, and a 2 MHz data rate over the range 60°F to 90°F. All silicon circuitry is used, and interfaces compatible with ICs are available. The new high capacity delay line has application in cathode ray tube displays, digital TV displays, and communications terminals. The package carries the nomenclature 613E-1015. Digital Devices Div., Tyco Labs, 200 Michael Dr., Syosset, L. I., N. Y. 11791.

Circle 206 on Inquiry Card

DIGITAL COMPARATOR

Five decades plus overrange.

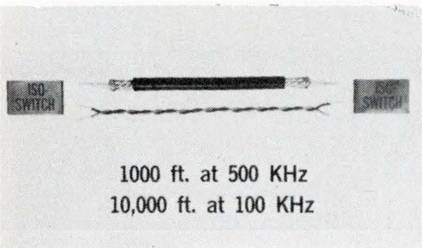


The Model 5510 digital comparator accepts parallel input of up to 5 digits plus overrange; compares the input to locally or remotely set limits; and outputs Hi-Lo-Go information via a rear connector. Individual mode controls for each limit (Hi-Lo-Go) allow flexibility. Each limit is controlled remotely, or manually set to issue an Advance pulse to other equipment, or it may be set to Stop other equipment when an "out of limits" is encountered. High speed operation is through "time-sharing" and a 1 μs compare time. Price is $2000, with delivery in 90 days. Non Linear Systems Inc., P. O. Box N, Del Mar, Calif. 92014. (714) 755-1134.

Circle 207 on Inquiry Card

ISOLATING DATA LINK

Reduces the cost of data transmission.



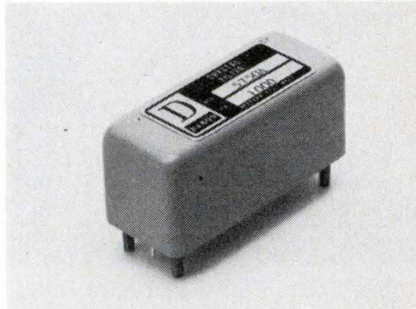
The Iso-Switch brings the cost of data transmission, including transmitter and receiver, to $50/line. Device transmits data at bit rates up to 500 kHz over a distance of 1000 ft. and up to 100 kHz over 10,000 ft. Major applications are in time-shared computer systems. Unit is virtually immune to common mode noise and can be operated with as much as 500 V offset between input and output. Input voltage can range from ±15 V. Output is up to 150 mA. Any logic signal level conversion can be accomplished. Prices for quantities of 100 range from $20.70 to $26.30. Iso-Switch Corp., 2956 Randolph St., Costa Mesa, Calif. 92626. (714) 540-3244.

Circle 208 on Inquiry Card

EE NEW PRODUCTS

GAUSSIAN CRYSTAL FILTERS

Provides 4-pole selectivity.



Model 5750A is for FM communications or radar systems where flat time delay is a requirement. In a coherent pulsed radar system, for example, it can minimize return-pulse over-shoot. The filter has a center freq. (f_o) of 10.240 MHz $\pm 0.005\%$. Bandwidth at 3 dB: 10 kHz nominal. Pulse response: ringing at least 25 dB below main response, with input pulse of 100 μs. Source and load impedance: 95 Ω. Insertion loss: 3 dB max. Other filters cover a center freq. range of 100 kHz to 35 MHz. Damon Engineering, Inc., 115 Fourth Ave., Needham, Mass. 02194. (617) 449-0800.

Circle 209 on Inquiry Card

RESIN DISPENSER

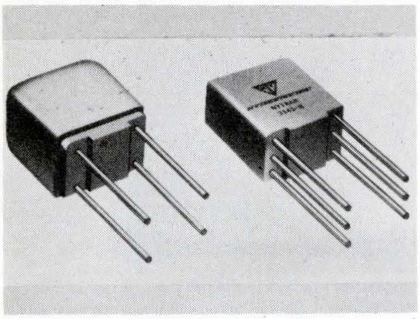
Simplifies component potting.

New 3-compartment Unipak dispensing unit contains Scotchcast polyurethane resin No. 225, a black, pigmented, room temperature curing material. To use the dispenser, you rupture a seal between the two resin parts and mix the resin by kneading the plastic bag. You then rupture the seal into the third compartment and dispense the resin by squeezing it into the compartment and through the plastic nozzle. There are three sizes of dispensers. Size A contains about 2¾ oz. of resin, size B about 6¼ oz., and Size C about 12½ oz. Dept. Di8-30, 3M Company, 3M Center, St. Paul, Minn. 55101.

Circle 210 on Inquiry Card

MINIATURE TRANSFORMERS

Input, output, and interstage.

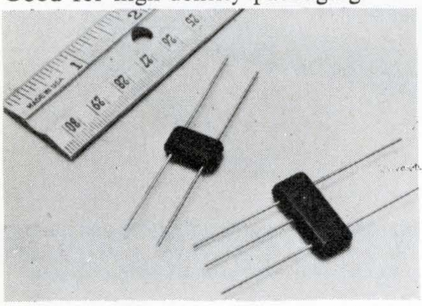


Units are a tiny 0.31 x 0.41 x 0.465 in. package. Most of the series have both centertapped input and output windings. Audio chokes also included with inductances from 0.1 H to 6 H. A mu metal shield case is offered as an optional slip-on. Useful operating range is 100 to 100,000 Hz. Normal freq. response is ±2 dB from 300 Hz to 100,000 Hz. Power levels of 50 mW can be obtained at 300 Hz. They weigh about 0.1 oz. Delivery is 2 weeks. Price ranges from $4 to $10 in small quantities. Contact Frank Liebermann, Transformer Div., Nytronics, Inc., Philipsburg, N. J. (201) 454-1143.

Circle 211 on Inquiry Card

SILICON BRIDGE RECTIFIERS

Good for high-density packaging.

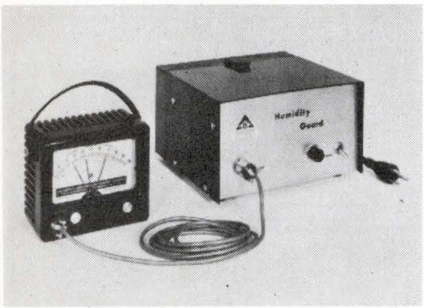


A complete line of subminiature medium power and 3-phase full wave bridge rectifiers are designated (SBR series). High temp. compounds provide excellent mechanical, thermal, and electrical reliability, and easily satisfy stringent requirements. Specifications: full-wave bridges range from 1.5 A, 50-1000 V to 360 mA, 1500-3000 V; 3 θ full-wave bridges range from 2 A, 50-1000 V to 500 mA, 1500-3000 V. Also available in the "Compac" series are fast recovery bridges from 50 to 600 V with reverse recovery of 150 ns and 1 μs. Immediate delivery. Contact William Krause, Semtech Corp., 652 Mitchell Rd., Newbury Park, Calif.

Circle 212 on Inquiry Card

HUMIDITY ALARM

Accuracy is ±3% RH.

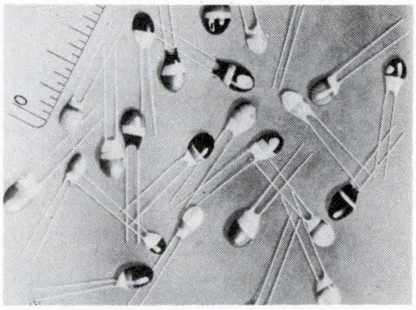


New humidity alarm system is comprised of a Serdex Humidity Indicator with a precisely calibrated animal membrane sensor which reacts instantly to any fluctuation of humidity level. This reaction is translated into electrical impulses which control the visual and audible alarm components of the system. The new "Humidity Guard" operates on 110 Vac, is lightweight and portable, and may be operated on a continuous basis. Ambac Industries, Inc., Div. Bacharach Instrument Co., 625 Alpha Dr., Pittsburgh, Pa. 15238.

Circle 213 on Inquiry Card

TANTALUM CAPACITORS

Revised to conform to IEC spec.

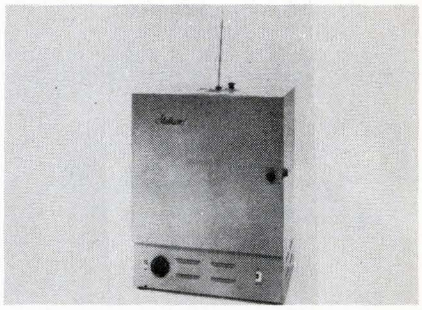


Complete revision has been made to standard line of miniature solid tantalum epoxy-dipped fixed capacitors. Capacitance and voltage values have been changed, along with color coding, to conform to the new specification recently promulgated by the International Electrotechnical Commission (IEC). Tantalum capacitances now range from 0.1 μf to 100 μf with max. working voltages of 3, 6.3, 10, 16, 25 and 35 V. The color coding has been simplified. JFD Electronics Co., Components Div., 15th Ave. at 62nd St., Brooklyn, N. Y. 11219.

Circle 214 on Inquiry Card

DRYING OVEN

For general purpose use.

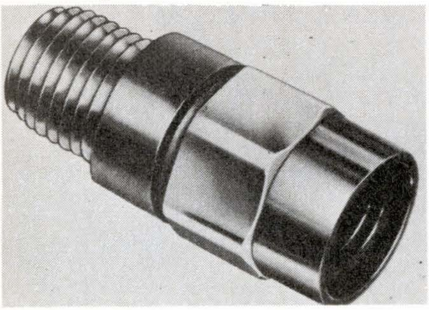


An electric thermal drying oven (Model 409) of cold-rolled steel is built to MIL Specs. This oven has a temperature range of 100° to 392°F. The 1050 W electric heater is thermostatically regulated. The oven has a fresh air intake and an adjustable, rotating vent cover to regulate air flow. Two welded trays are adjustable at ½ in. intervals in a specimen area of 17 x 11.5 x 16.5 in. Miss Daisy W. Kay, Mgr., Mktg. Services, Statham Instruments, Inc., 2230 Statham Blvd., Oxnard, Calif. 93030. (805) 487-6321.

Circle 215 on Inquiry Card

COAX ATTENUATOR

Max. length is 0.750 in.



The Series 4400 miniature coaxial fixed attenuators provide low VSWR of not more than 1.5 in the dc to 12 GHz range. They have attenuation values from 1 to 20 dB, and weigh 6 grams or less. Standard units have a plug and jack which mate with all of the common 3 mm connectors. Bodies and nuts are gold-plated stainless steel, while the captured pins are gold-plated beryllium copper. Price is $15 each in quantities of 100, with 6-week delivery. EMC Technology, Inc., 1300 Arch St., Philadelphia, Pa. 19107. (215) 563-1340.

Circle 216 on Inquiry Card

HIGH-VACUUM SYSTEM

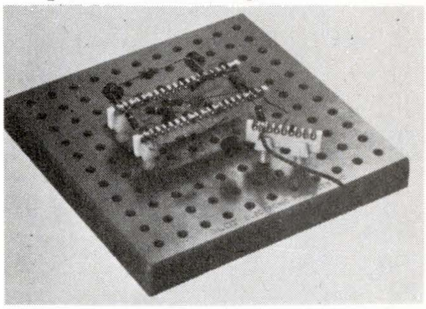
It's fully automatic.

This fully automatic fast-cycle high-vacuum system is for such thin-film production processes as vacuum evaporation and sputtering. It has an ultimate pressure capability of 5 x 10^{-10} Torr. Automatically sequenced by a single pushbutton, the Model VI-460 achieves 5 x 10^{-7} Torr in less than 10 min. consistently over day-long production shifts. Using ion pumping, it is contaminant-free and has pump-down speeds five times faster than most oil-diffusion systems. Vacuum Div., Varian Associates, 611 Hansen Way, Palo Alto, Calif. 94303.

Circle 217 on Inquiry Card

CIRCUIT BOARD KIT

Simplifies circuit design.



The Design Board is a 5 x 6 in. deck with pre-punched openings spaced in parallel rows on 0.250 in. centers. These holes are designed to hold MEP-NB Alcostrips which may be quickly inserted and removed to simplify circuit design when broad-boarding. There are 121 single board perforations. The complete ceramic terminal strip kit includes 16 strips (eight sizes) and one design board. The CB-2 kit is available from stock at $10.95. Robert Laffey, Sales Mgr., Alco Electronic Products, Inc., Lawrence, Mass. 01843.

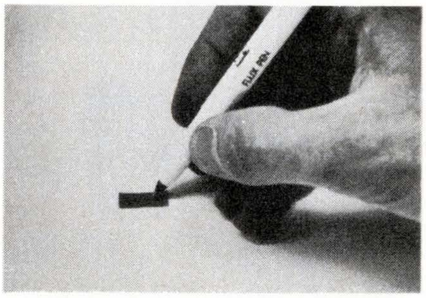
Circle 218 on Inquiry Card

Circle 55 on Inquiry Card

EE NEW PRODUCTS

FLUX PEN

For soldering small connections.

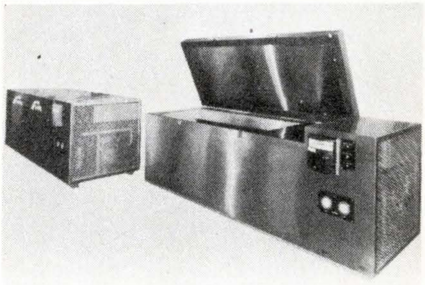


This nylon-tipped pen makes it easy to apply flux when soldering. It is for any soldering task involving small connections and precise control of the amount of flux required. The liquid in the pen contains a special carrier which retards evaporation and provides even flow. In normal use and with proper care, a pen will last up to one year. It can be used with any conventional soft solder. J. C. Lowrey, BLH Electronics, Inc., 42 Fourth Ave., Waltham, Mass. 02154. (617) TW 4-6700.

Circle 219 on Inquiry Card

ENVIRONMENTAL CHAMBER

Capacity of 12 cubic feet.

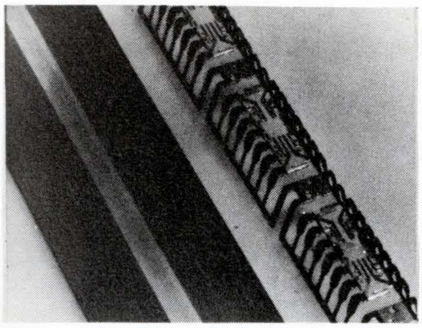


An all stainless steel environmental chamber, the Model AT-12-40 can test parts at any temperature from +80° to −40°F. It has a top opening and 2 in. porthole for cables or cords. The refrigeration system is mechanical and air cooled. Its capacity is such that it can cool 300 lbs of batteries in 4 hours or less. Interior forced air circulation maintains less than 1° stratification. Robert C. Webber, Webber Manufacturing Co., Inc., Box 217, Indianapolis, Ind. 46206. (317) 357-8681.

Circle 220 on Inquiry Card

LEAD FRAME MATERIAL

Cuts cost, increases yield of ICs.



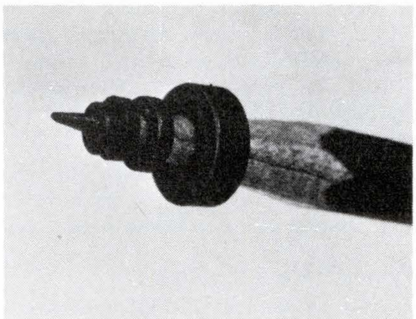
F-15 alloy selectively clad with aluminum stripe (left) is for lead frames (right) of ceramic IC packages.

A new lead frame material—ASTM F-15 alloy—selectively clad with an aluminum stripe—reduces the number of fabrication steps needed to mount and package IC chips. This is because the aluminum can be vapor-deposited on the F-15 (iron-nickel-cobalt glass-sealing alloy) before stamping and forming rather than after. The metallurgical bonding process provides an accurately located, uniform layer of low-porosity aluminum. Frames produced from aluminum-clad F-15 meet fatigue requirements of MIL-STD 750, method 2036.1, test condition E and other important criteria. Texas Instruments Incorporated, Materials Div., 34 Forest St., Attleboro, Mass. 02703.

Circle 221 on Inquiry Card

FERRITE MATERIAL

Provides improved temp. stability.



New ferrite material, 3B7, is primarily for use in pulse transformers. It comes in four small toroid sizes and has greater temperature stability than previously available materials. Significant properties are an initial permeability of 2500 and a low variation in permeability with temperature of $-6\% < \mu < 10\%$ from 0 to 60°C. Samples are available. Ferroxcube Corp., Saugerties, N. Y. 12477.

Circle 222 on Inquiry Card

EE LITERATURE

MOS shift registers

MOS shift registers are now the most popular type of MOS digital integrated circuit. A 20-page application report will acquaint you with the static MOS shift registers available from TI and will give you information on clocking and interfacing with DTL/TTL bipolar

logic. Bulletin CA-114 emphasizes the selection and application of MOS shift registers rather than their internal circuitry. There are sections on fundamentals, power requirements, data input and output, and so forth. Technical Information Services, Texas Instruments Incorporated, Box 5012, MS/980, Dallas, Tex. 75222.

Circle 321 on Inquiry Card

Silicon rectifiers

This 4-page Designers™ data sheet will give you the information you need to design most circuits using the 1N-4001-1N4007 silicon rectifiers. These are subminiature, axial lead mounted devices for general purpose low-power applications. They are offered at reduced OEM prices (up to 57%). Motorola Semiconductor Products, Inc., Box 955, Phoenix, Ariz. 85001.

Circle 322 on Inquiry Card

Connectors and contacts

The prime factors in the selection of connectors are outlined in a 53-page reference, Catalog No. 940. Updated specs, plus application and dimensional data, are given for an expanded series of rectangular pin and socket connectors for rack and panel/cable applications. Other useful data include tooling, contact, and plating information; a hardware selection guide; and a numerical index. AMP Incorporated, Harrisburg, Pa. 17105.

Circle 323 on Inquiry Card

Antenna reference

A 200-page catalog contains a listing of antenna and rf transmission line products. Included are military and industrial type antennas, aluminum elliptical waveguide, rigid and semi-rigid copper and aluminum coaxial transmission line, and communication antennas. Catalog 688 gives specs, engineering data, and installation procedures for the various devices. Prodelin, Inc., Box 131, Hightstown, N.J. 08520.

Circle 324 on Inquiry Card

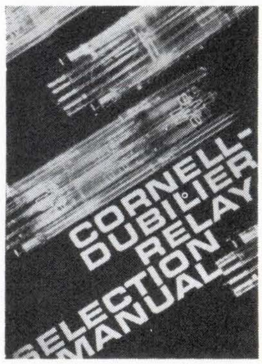
Recorder/reproducer

The PT-501 series of video recorders is designed to meet the requirements of aircraft, submarines, ships, ground vehicles, or other portable configurations. It is available in a configuration suitable for any type of wideband instrumentation application. A description of the unit, a diagram showing its various controls, features, and applications are given. Mgr., Mktg. Dept., RCA/DEP, Defense Communications Systems Div., Bldg. 1-3, Camden, N. J. 08102.

Circle 325 on Inquiry Card

Relay buying guide

A 12-page guide to relay buying contains information on trade-offs in relay selection, showing you how to save money. Included is an ordering checklist designed to answer most of the basic questions asked in fitting a



relay to a particular application. Printed circuit miniature relays, general purpose relays, program relays, power relays, and timers and time delay relays are covered. Marketing Services Dept., Cornell - Dubilier Electronics, 50 Paris St., Newark, N. J. 07101.

Circle 326 on Inquiry Card

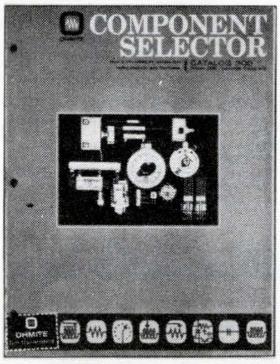
Telemetry systems

A colorful 14-page brochure gives a general description of the company's systems capabilities. Discussed are spaceborne PCM telemetry systems, ground digital telemetry systems, voice/data digital systems, and wideband data systems. Dynatronics, Box 2566, Orlando, Fla. 32802.

Circle 327 on Inquiry Card

Components catalog

A variety of components are described in this 35-page application-ordering guide. Catalog 300 covers



resistors, rheostats, potentiometers, transformers, capacitors, solid-state power controls, light dimmers, rf chokes, and relays. Ohmite Mfg. Co., 3601 W. Howard St., Chicago, Ill. 60076.

Circle 328 on Inquiry Card

Displays and controls

Catalog 629, an 8-page booklet, will provide you with data on display panels, annunciators, indicators, switches, readouts, and CRT terminal systems. Featured is a reference table which lists indicator and switch specs. Transistor Electronics Corp., Box 6191, Minneapolis, Minn. 55424.

Circle 329 on Inquiry Card

Precision instruments

A comprehensive 22-page catalog describes various precision instruments. Resistance decades, decade voltage dividers, potentiometer circuits, resistance bridges, and a variety of Wheatstone bridges for general use are among the products covered in Catalog 600. Shallcross, 24 Preston St., Selma, N.C. 27576.

Circle 330 on Inquiry Card

Transistor and diode data

A 1969 condensed catalog (52 pages) contains a complete listing of the manufacturer's discrete devices. Each of the products discussed is of planar construction. The devices are conveniently listed numerically within specific categories. These categories are: diodes, small signal transistors, dual transistors, FETs, power transistors, communication devices, silicon controlled rectifiers, specialty diode products, and electro-optical devices. Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, Calif. 94041.

Circle 331 on Inquiry Card

Power supplies

A 64-page catalog, No. 691, discusses the use and specification of power supplies. Several lines of ac-dc and dc-dc supplies and two lines of overvoltage protectors are listed. Also included is a discussion of power supply thermal characteristics. Technipower, Inc., Benrus Center, Ridgefield, Conn. 06877.

Circle 332 on Inquiry Card

Shaft encoders

"A Primer on Shaft Encoders," a 6-page booklet, will familiarize you with these devices. It discusses what they are, how they work, the tasks they can perform, and their advan-

tages. It compares optical vs brush techniques and absolute vs incremental encoders. Also included are shaft encoder applications and a glossary that will give you some understanding of encoder jargon. Theta Instrument Corp., 22 Spielman Rd., Fairfield, N. J. 07006.

Circle 333 on Inquiry Card

EE LITERATURE

Capacitors

Engineering Bulletin No. 2142A covers paper-dielectric capacitors for dc applications. Clorinol® "T" capacitors meet the requirements of EIA Specification RS-218 and offer the equipment designer a wide range of ratings. Case size and bracket dimensions, standard ratings, and performance characteristics are listed in the 8-page bulletin. Technical Literature Service, Sprague Electric Co., Marshall St., North Adams, Mass. 01247.

Circle 334 on Inquiry Card

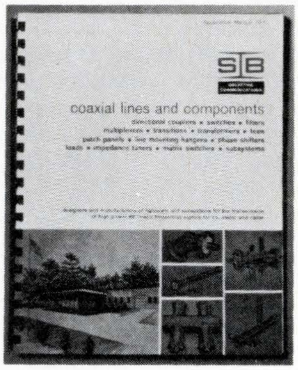
Recording oscillograph

A direct-recording, light-beam oscillograph, Model 801, is featured in this 6-page folder. The unit offers high volume data acquisition and a range of recording capabilities for both system and laboratory applications. Bulletin 1041-A lists accessories, specs, options, and physical data. Midwestern Instruments/Telex, 6422 E. 41st St., Tulsa, Okla. 74135.

Circle 335 on Inquiry Card

Coaxial components

Application Manual 70-1 presents design data for selecting coaxial lines and components. The 72-page reference covers directional couplers, switches, filters, multiplexers, transi-



tions, transformers, tees, patch panels, phase shifters, impedance tuners, and so forth. Diagrams, graphs, photos, and ordering information are included. Dielectric Communications, Raymond, Me. 04701.

Circle 336 on Inquiry Card

Log application note

Design engineers will be interested in this 4-page application note, which discusses the theory and applications of log elements. The note illustrates the use of log elements with op amps in circuits to perform log and anti-log functions, including multiplication and division. Logs of a single variable, logs of a ratio, anti-logs, and multipliers and dividers are covered. Data Device Corp., 100 Tec St., Hicksville, N. Y. 11801.

Circle 337 on Inquiry Card

Electronic components

This 100-page condensed catalog lists a wide range of standard electronic components and devices. Highlighted in Bulletin SF68 are High Level Transistor Logic (HLTTL) digital monolithic circuits. Also listed are linear ICs, silicon planar plastic-packaged transistors, LID packaged transistors, germanium diodes, silicon diodes, zener diodes, and precision voltage references. In addition, you will find some helpful data on silicon rectifiers, fast recovery rectifiers, high voltage assemblies, numerical displays and counters, neon indicators, time delay relays, and other products. A 20-page section covers a broad line of hermetically sealed thyristors in the low and medium power range. Transitron Electronic Corp., 168 Albion St., Wakefield, Mass. 01880.

Circle 338 on Inquiry Card

Miniature chart recorders

DC and ac recorders, event recorders, dc and ac amplifiers, battery packs, and temperature recorders are some of the products listed in this 20-page catalog. Catalog No. 16809 also describes

pressure recorders, temperature indicators, an ac voltage recorder, a multi-purpose recorder, a strain gage recorder, as well as other products. Rustrak Instruments Div., Gulton Industries Inc., Manchester, N. H. 03103.

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Circle 64 on Inquiry Card

Circle 65 on Inquiry Card

EE LITERATURE

Filters

Highpass, lowpass, bandpass, and band reject filters are the subjects for discussion in this 1968-69 catalog. Signal conditioning networks for frequency ranges from 10 Hz to 200 kHz for a wide range of source and load impedances are listed. The catalog contains filter specs, response curves, case drawings, test procedures, and prices. TT Electronics, Inc., Box 180, Culver City, Calif. 90230.

Circle 340 on Inquiry Card

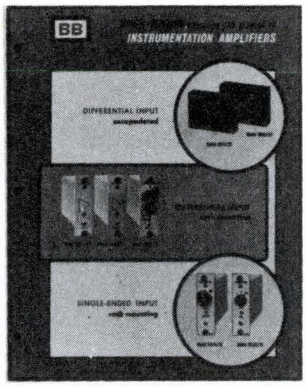
Recording system

An instrumentation tape recorder that covers IRIG bandwidths for such applications as high precision test and telemetry recording is the subject of a 10-page brochure. The Model FR-1900 handles direct data from 50 Hz to 2 MHz and fm data from dc to 500 kHz. Publication D103 gives further details. Ampex Corp., 401 Broadway, Redwood City, Calif. 94063.

Circle 341 on Inquiry Card

Instrumentation amplifiers

Design engineers will find 32 pages of data on instrumentation amplifiers in this handbook and catalog. The publication discusses the various parameters for choosing an amplifier for instrumentation. A section on instrumentation design and application covers topics such as transducer and

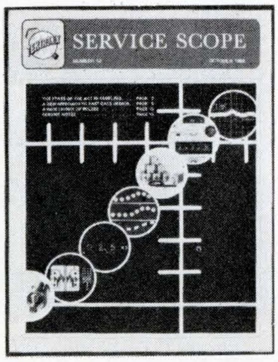


bridge circuits, sources of error, a resistor matching circuit, linearizing a nonlinear bridge output, a power measurement circuit, and a buffer-amplifier linearity tester. Also included are specs, performance curves, and prices for a line of encapsulated and rack-mounting instrumentation amplifiers. Burr-Brown Research Corp., International Airport Industrial Park, Tucson, Ariz. 85706.

Circle 342 on Inquiry Card

Sampling technology

The October 1968 issue of "Service Scope" contains a 6-page article on the state of the art in sampling. Another article entitled "A New Approach to Fast Gate Design" describes a sampling gate that eliminates risetime dependency upon strobe width.



Still another article discusses the company's entry into the medium price, general purpose pulse generator market. How to optimize system risetime is detailed in a service note section of the 16-page issue. There is also a guide to reading capacitor codes. Tektronix, Inc., Box 50, Beaverton, Ore. 97005.

Circle 343 on Inquiry Card

Coaxial switches

A 9-page catalog contains a rundown of the company's various coaxial switches. Specifications for frequency range, insertion loss, temperature range, operating life, etc. are given for each series. A handy ordering guide is included. Electronic Specialty Co., Los Angeles Electronics Div., 4561 Colorado Blvd., Los Angeles, Calif. 90039.

Circle 344 on Inquiry Card

Magnetic recording tape

"Recording Basics" is the title of a 24-page guide to effective use and better understanding of magnetic recording tape. The construction and manufacture of tape, how to select the right tape for individual needs, and how to calculate recording time for the various tapes are some of the topics discussed. Also in the guide is an explanation of different recording formats. There's helpful information on splicing, editing, recorder maintenance, and the care and handling of tape. 3M Company, Magnetic Products Div., Market Services Dept., 3M Center, St. Paul, Minn. 55101.

Circle 345 on Inquiry Card

IC sockets

An 8-page catalog covers test sockets for TO-5 case size ICs and transistors, packaging sockets for TO-5 case size ICs, and breadboard and test panels for flat pack and TO-5 ICs. Catalog No. 364 also describes test sockets for flat pack ICs and various accessories. Augat, Inc., 33 Perry Ave., Attleboro, Mass. 02703.

Circle 346 on Inquiry Card

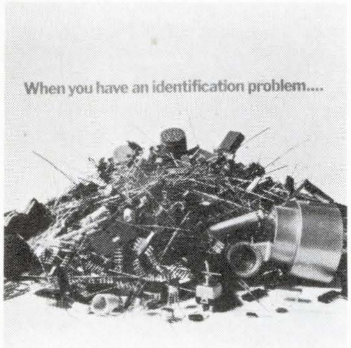
Regulated power supplies

Listed in General Catalog 146 is a line of regulated power supply modules with outputs from 0 to 400 V, 50 mA to 25 A. Modules are short circuit proof and designed for full load operation at 71°C. They are available off-the-shelf. Power/Mate Corp., 163 Clay St., Hackensack, N. J. 07601.

Circle 347 on Inquiry Card

Components marking

Have you ever had the problem of not being able to identify your electronic components after they have been manufactured? An 8-page brochure discusses services available to help alleviate this situation. It outlines



the advantages of taking a systems approach to product marking. Also described are machines for marking diodes, tubes, transistors, ICs, cable, transformers, and various other components. Markem Corp., Keene, N.H. 03431.

Circle 348 on Inquiry Card

Power conversion components

Control, telemetry, and power conversion components are discussed in an 8-page catalog. Each of the devices was designed to meet rigid electrical and environmental specs, mainly for military airborne and ground applications. Included are specs, applications, outline drawings, and photographs. Raven Electronics, Inc., 101 W. Alameda Ave., Burbank, Calif. 91502.

Circle 349 on Inquiry Card

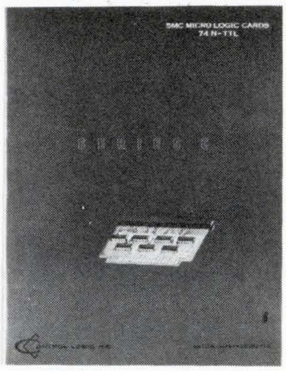
Panel meters

A 16-page catalog, No. DA68, describes panel and switchboard instruments. There's data on ac and dc ammeters, ac and dc voltmeters, ac wattmeters, varmeters, power factor meters, and frequency meters. Tachometers, external tach/generators, and expanded scale meters are covered also. Voltron Products, Inc., 403 S. Raymond Ave., Pasadena, Calif. 91101.

Circle 350 on Inquiry Card

Circuit cards

Designers will be interested in this 44-page catalog, which presents a line of micro-logic circuit cards and accessories. Specifications and logic diagrams are given for specific card types.



These include clock flip-flops, input NAND gates, input power gates, level inverters, pulse shapers, clock sources, differential amplifiers, line drivers, storage resistors, OR gates, and others. Control Logic, Inc., 3 Strathmore Rd., Natick, Mass. 01760.

Circle 351 on Inquiry Card

EE LITERATURE

Silicon controlled rectifiers

A handy 7-page booklet contains an article on a new series of high performance silicon controlled rectifiers. The article provides design information, schematics, charts, and waveshapes. Another article discusses inrush current testing of SCRs. There is also a page of new products, complete with reader service numbers. International Rectifier, Dept. 781, 233 Kansas St., El Segundo, Calif. 90245.

Circle 352 on Inquiry Card

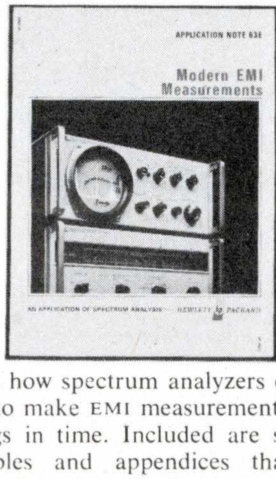
Sensor selection guide

Operating principles of temperature sensors are discussed in a 10-page guide entitled "Temperature Measurement and Sensor Selection." Filled thermal systems, resistance thermometers, thermistors, thermocouples, and radiation pyrometers are described and their specific applications are given. A 2-page table lists the characteristics of temperature sensors and another table compares temperature scales and temperature sensor ranges. Honeywell Inc., MS 436, Industrial Div., Fort Washington, Pa. 19034.

Circle 353 on Inquiry Card

EMI measurements

A 26-page application note, No. 63E, begins with a summary of EMI principles. Next it describes methods for making standardized EMI measurements and tells how they can be made during the design stage so that electromagnetic compatibility can be designed into equipment. It then discusses how spectrum analyzers can be used to make EMI measurements with savings in time. Included are several examples and appendices that list some of the important EMI specs and recommended equipment for MIL-STD-826A. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304.



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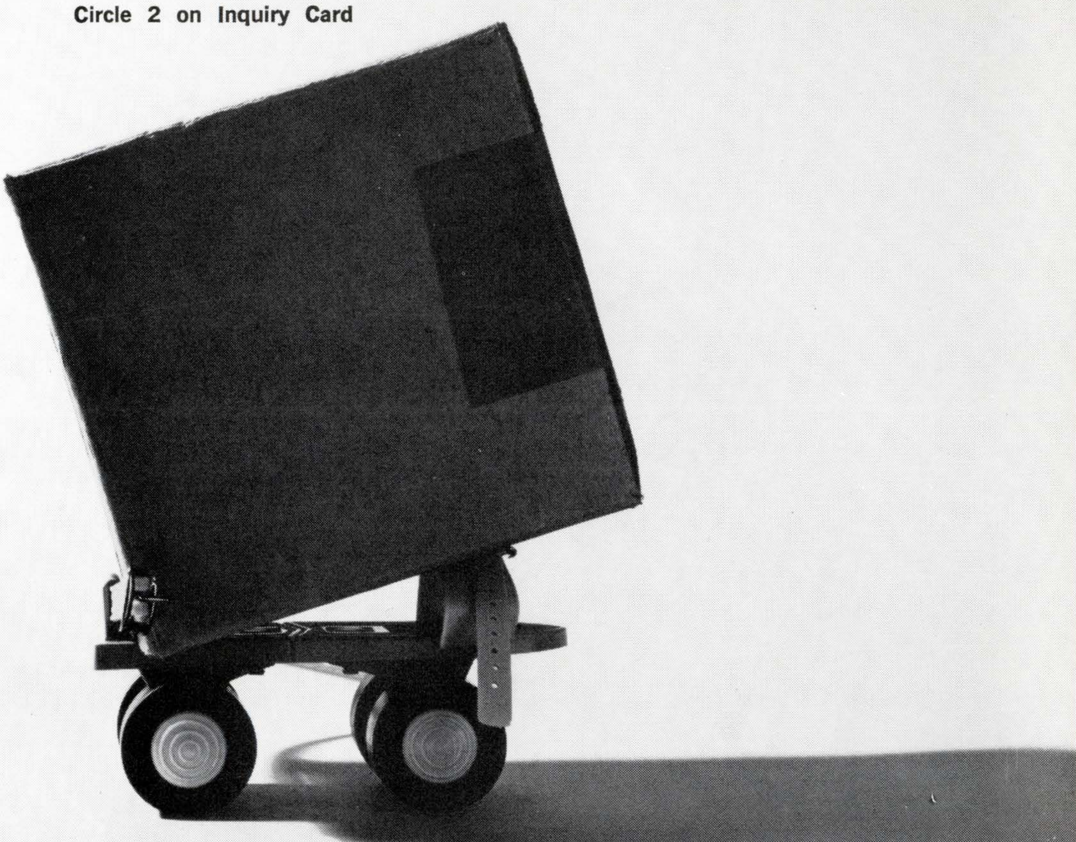

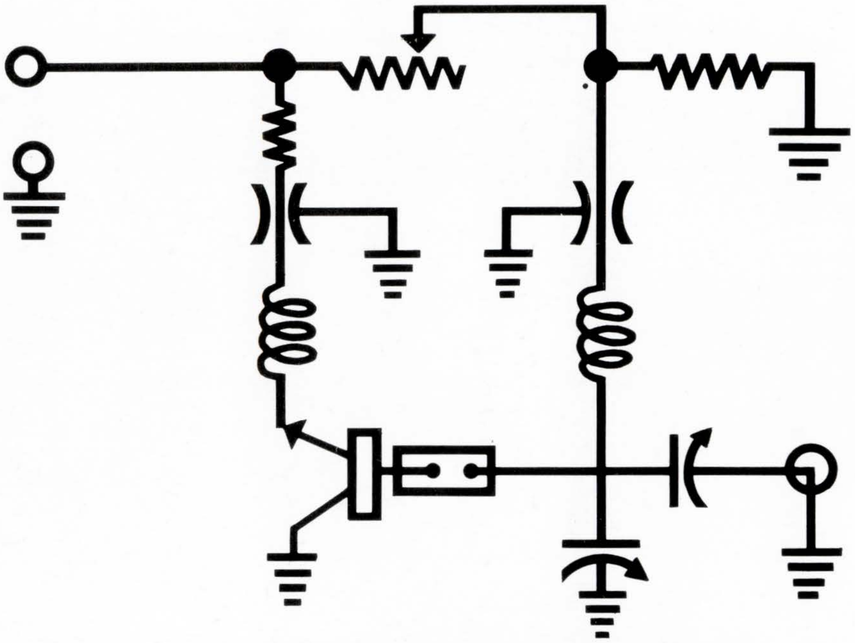

A Microwave Fundamental Frequency Oscillator Circuit is as simple as RCA-TA7403 "overlay" can make it

TA7403 is a new configuration... designed especially to simplify oscillator circuitry. Featuring 0.5 watt output at 2 GHz (at 21 V operation), this all-new RCA epitaxial silicon n-p-n transistor will be especially attractive to designers looking for a device that acts as a superior self-excited oscillator at L-band and higher microwave frequencies.

Incorporating all the advantages of the RCA-developed "overlay" structure, RCA developmental type TA7403 is a compact unit in a hermetically-sealed ceramic-to-metal coaxial package... a package that features very low inductances and low parasitic capacitances. This is the industry's first unit that lends itself to cavity, stripline, and "lumped" constant circuits.

Here, then, is definitely a transistor intended primarily for simple oscillator circuits. TA7403 will find applications in such areas as: local oscillator for receivers, microwave power source—low power klystron replacement, sonde oscillator.

For more information on RCA-TA7403, see your RCA Representative. Ask him, too, about RCA-2N5470 for your UHF and microwave amplifier applications. For technical data, write: RCA Electronic Components, Commercial Engineering, Section P-J-A, Harrison, N.J. 07029.

RCA