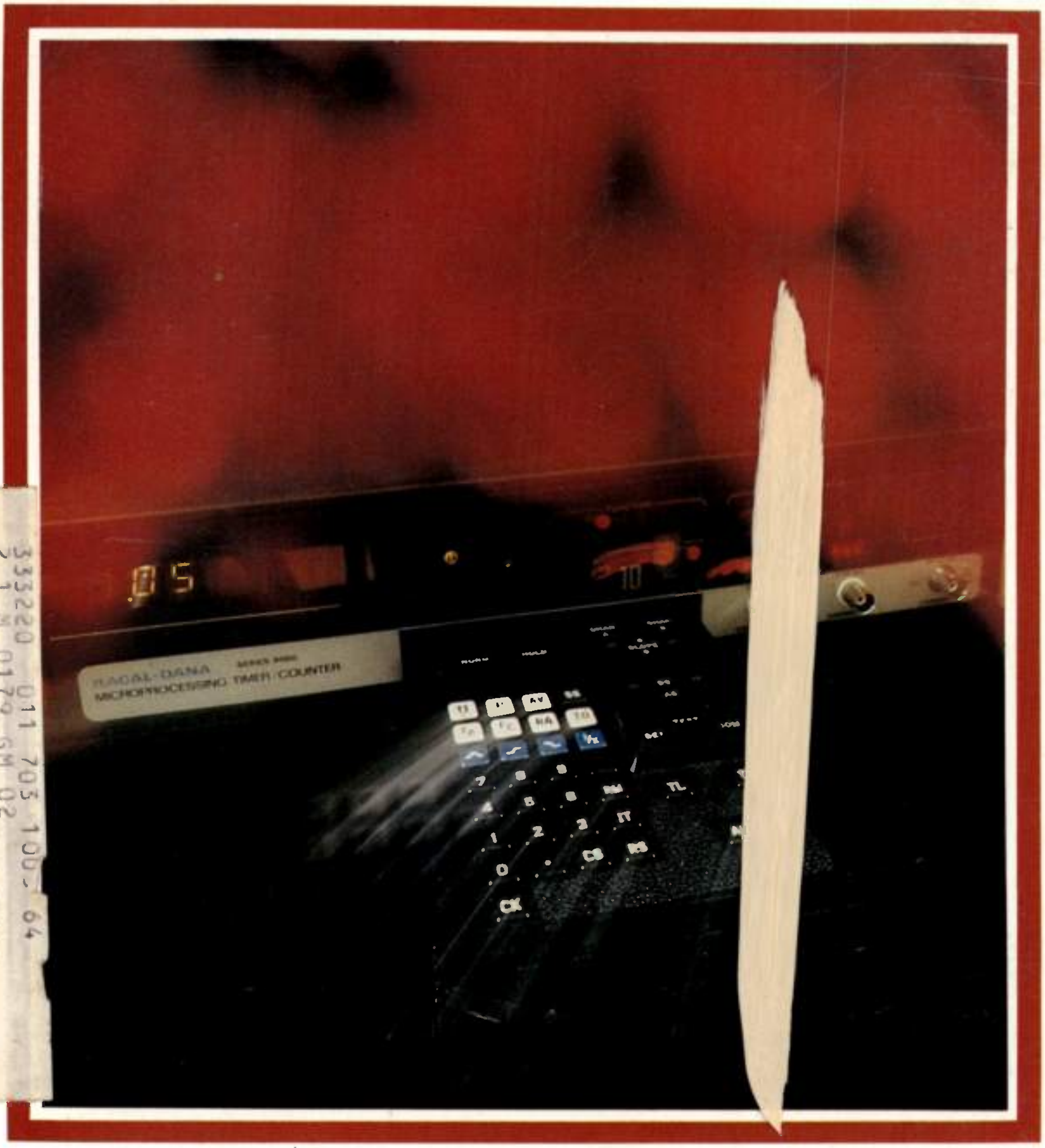
May/June 1979

A Cardiff Publication

rf design



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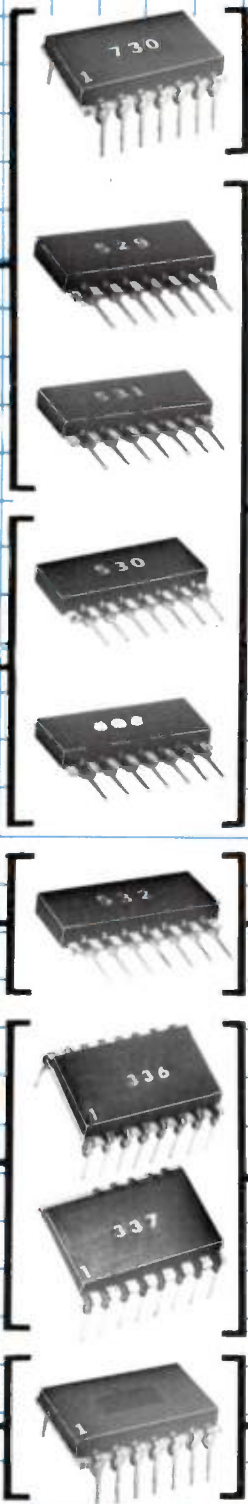

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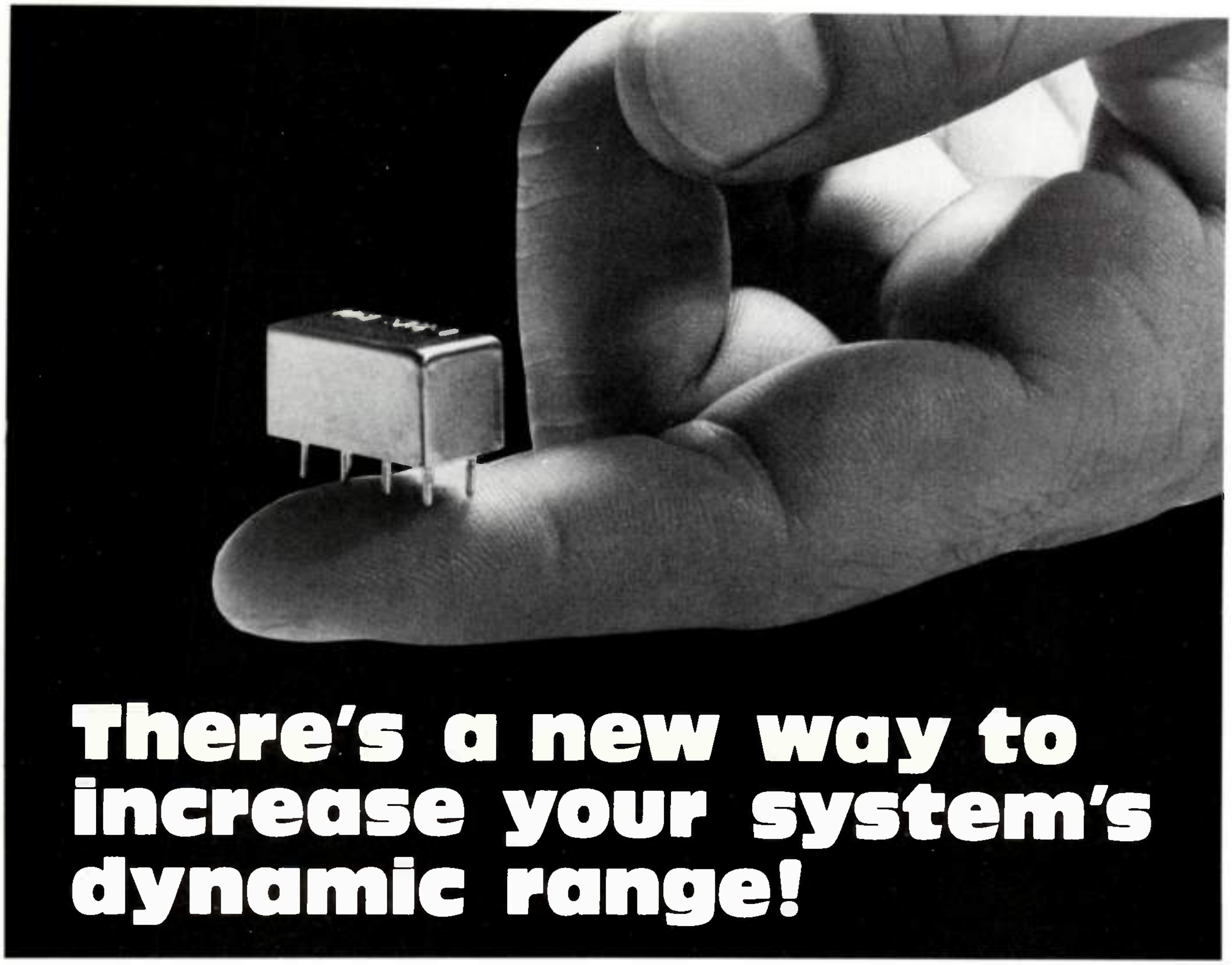

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SAY-2	0.1-1000	9.5	+20	8 pins	0.4 x 0.8 x 0.4	$59.95
SAY-11	10-2400	10.0	+18.5	8 pins	0.4 x 0.8 x 0.4	$64.95
ZFY-1	0.1-500	7.5	+20	•BNC, TNC, SMA, N	1.25 x 1.25 x 0.75	$74.95
ZFY-2	0.1-1000	9.5	+20	•BNC, TNC, SMA, N	1.25 x 1.25 x 0.75	$79.95
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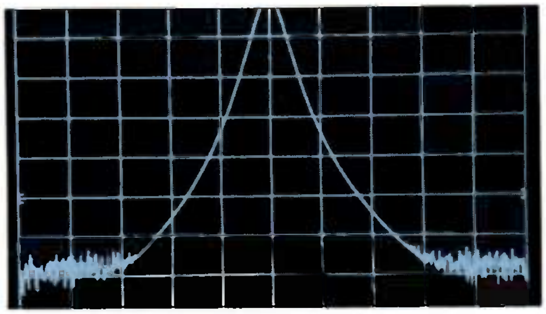
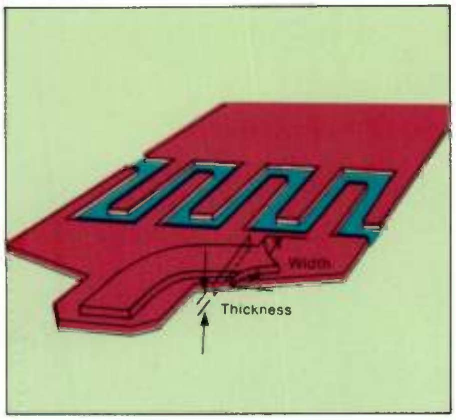
38/Rev/A

r.f. design

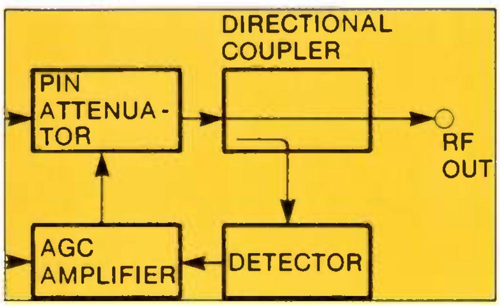
May/June 1979



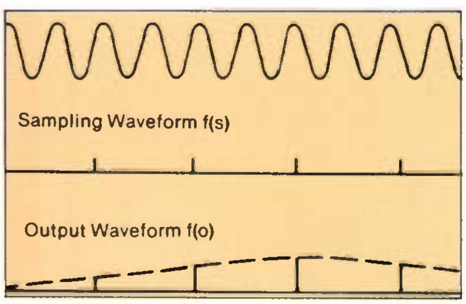
Spectrum Analyzer Performance p. 28



1 GHz Bipolar Transistor p. 34



PIN Diodes p. 40



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Help us service you by returning the r.f. feedback card on page 67.

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For complete specifications, performance curves and application information, refer to 78-79 MicroWaves' Product Data Directory (pgs 161-352) or EEM (pgs 2890-3058).

Model No.	Freq. (MHz)	Conv. loss (dB max.)	Signal 1 dB compr. level (dBm min.)	Connections	Size (in.) (w x l x ht.)	Price (Qty.)
TFM-1H	2 — 500	8.5	+14	4 pins	0.21 x 0.5 x 0.25	$23.95 (5-24)
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TFM-3H	0.1 — 250	8.5	+13	4 pins	0.21 x 0.5 x 0.25	$23.95 (5-24)
TAK-1H	2 — 500	8.5	+14	8 pins	0.4 x 0.8 x 0.25	$19.95 (5-24)
TAK-1WH	5 — 750	9.0	+14	8 pins	0.4 x 0.8 x 0.25	$23.95 (5-24)
TAK-3H	0.05 — 300	8.5	+13	8 pins	0.4 x 0.8 x 0.25	$21.95 (5-24)
ZAD-1SH	2 — 500	8.5	+14	BNC TNC	1.15 x 2.25 x 1.40	$40.95 (4-24)
ZAD-1WSH	5 — 750	9.0	+14	BNC, TNC	1.15 x 2.25 x 1.40	$44.95 (4-24)
ZAD-3SH	0.05 — 300	8.5	+13	BNC, TNC	1.15 x 2.25 x 1.40	$42.95 (4-24)
ZLW1SH	2 — 500	8.5	+14	SMA	0.88 x 1.50 x 1.15	$50.95 (4-24)
ZLW-1WSH	5 — 750	9.0	+14	SMA	0.88 x 1.50 x 1.15	$54.95 (4-24)
ZLW-3SH	0.05 — 300	8.5	+13	SMA	0.88 x 1.50 x 1.15	$52.95 (4-24)
ZFM-1H	2 — 500	8.5	+14	BNC, TNC SMA, N	1.25 x 1.25 x 0.75	$53.95 (1-24)
ZFM-2H	5 — 1000	10	+14	BNC, TNC SMA, N	1.25 x 1.25 x 0.75	$61.95 (1-24)
ZFM-3H	0.05 — 300	8.5	+13	BNC, TNC SMA, N	1.25 x 1.25 x 0.75	$54.95 (1-24)

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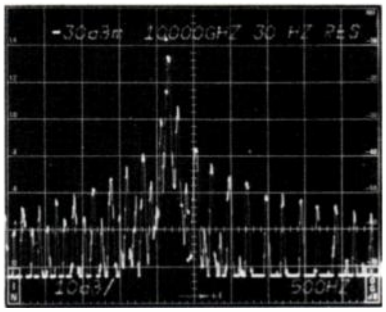
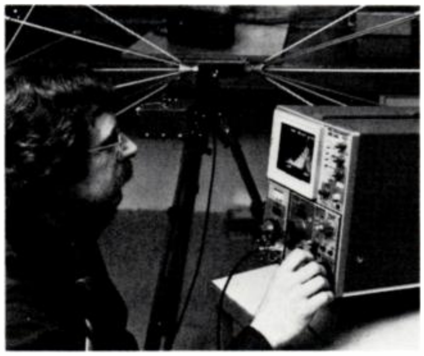


like this sample of 240 Hz sidebands at 10 GHz.

And other features like digital storage and digital signal processing are easy to use with the 7L18's microprocessor-aided controls... plus a built-in tracking preselector, automatic and fully calibrated. In application after application, you get flicker-free traces, even at slow sweep speeds. And you can compare waveforms or make a long series of measurements with repeatable accuracy.

The 7L18 is ideal for testing and evaluating new microwave systems, including ECM, satellite communication systems, and microwave links. All this performance costs under $17 thousand.

Communications measurements without the jitters: 7L13 (1 KHz to 1.8 GHz)



Now you can make every important communications measurement accurately and conveniently for EMI, FM, TV, navigation, avionics, two-way and many other applications.

The 7L13 features jitter-free displays even at 30 Hz resolution with designed-in 10 Hz fm stability. This provides the ultra-critical accuracy necessary for design and proof-of-performance measurements.

The 7L13's top performance costs under $13 thousand.

Put a Tektronix Tracking Generator in tandem with the 7L13, and you can make precise swept frequency measurements, too. All parameters, including center frequency, are read out on the crt itself for easy referencing.

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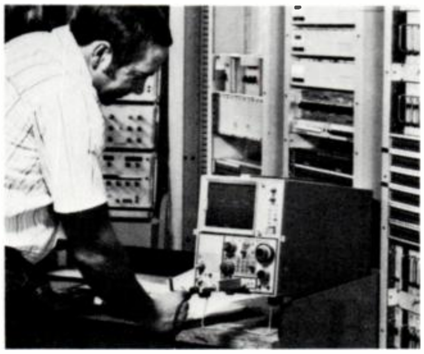

Sweep your baseband for spurious response, leakage, noise, shifts, distortion and transient bursts with the certainty of 10 Hz resolution.

Comparing baseband channel performance is easy because the 7L5 switches from a single channel to a 60-channel supergroup without retuning. You see all channel amplitudes at a glance, side-by-side. And, you get frequency accuracy that resolves an individual channel frequency down to 10 Hz, including signals at −140 dBv.

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Poynting to a Solution

About noon, during the hustle bustle of the recent Electro in New York, I stopped in one of the coliseum pubs for a beer. I struck up a conversation with an engineer from RCA, who had brought his wife along, evidently to carry all the literature he had received. It turned out that he designed HF direction finding antennas.

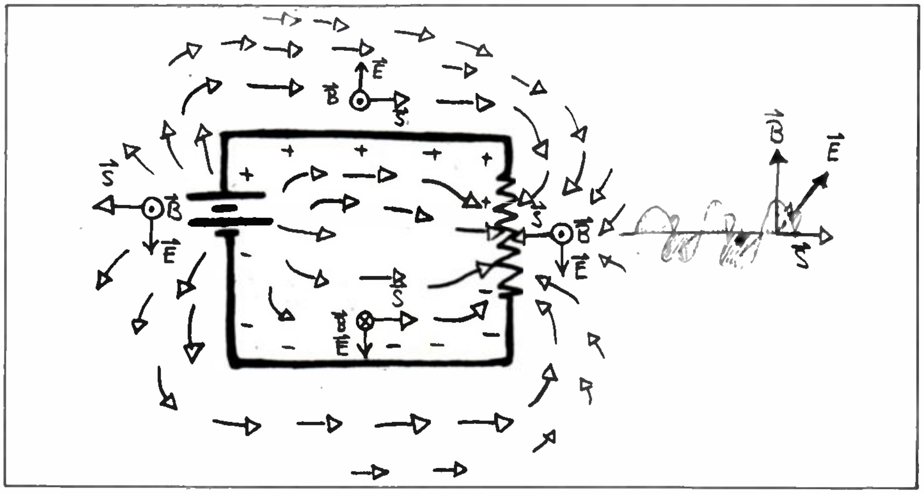
He made an interesting statement, "I'll bet there aren't ten people at this whole show that could explain how the energy gets from the battery to the filament, in a simple flashlight."

Wanting to impress him and his wife, I explained how the electron gas in the conductor drifted under the influence of an electric field, and the electrons collided with the molecules in the filament, producing heat.

But unfortunately, I was not one of the ten. He explained that the energy really wasn't carried by the electrons, but by the fields that accompanied (or produced) their redistribution. He said something about the Poynting vector, and shortly thereafter, we went our separate ways.

So I did some thinking about flashlights, and he's right, the Poynting vector, $\vec{S} = 1/\mu_o\ \vec{E}\mathrm{x}\vec{B}$, gives some surprising insight. It shows that as a charge distribution is changed, it is the surrounding fields that carry the energy out of the battery, and ultimately into the resistor. Thence, the resistor heats up, and emits light. (The propagation of light can again be understood in terms of $\vec{S} = 1/\mu_o\ \vec{E}\mathrm{x}\vec{B}$). And, as you probably know, $\vec{S}$ can be used to gain insight into energy transfer for everything from co-ax, to antenna arrays.

So, is the bottom line that I returned from Electro with a firm theoretical grasp of flashlights? For me, the bottom line is two-fold. As an end in itself, there is a beauty in the eloquence and universality of some ideas, even though they may have been around a long time. Second, finding and applying eloquent answers, to imaginative questions, about simple systems, seems to be the way man has advanced from hot plates to microwaves.



If your wife and friends get that "distant look" when the subject turns to flashlights and the like, then tell us your insights, that's why we're here.

Bart Gates

GPS is On The Ground

Army and Marine foot soldiers as well as jeep and other mobile ground vehicle drivers can now look forward to being able to use the NAVSTAR Global Positioning System to find their location and route. This is because the world's first GPS Manpack has been delivered to the Department of Defense by Magnavox.

The Magnavox Manpack, while still an advanced development model, weighs just 14 kg. (not including batteries), consumes only 29 watts and occupies less than 6,000 cc. However, this model is the first self contained NAVSTAR user equipment. It was designed for man portable applications and for use in vehicles such as jeeps, trucks and tracked vehicles.

This particular GPS set sequentially tracks precise signals from NAVSTAR satellites in order to determine a user's position and velocity even in the presence of enemy jamming.

Position can be read out in conventional latitude/longitude/altitude or in the Military Grid Reference System.

A unique feature of the Manpack not shared by the other GPS sets under development is its ability to transmit fixes automatically over a standard army radio.

NAVSTAR Global Positioning System

The NAVSTAR Global Positioning System is a space-based radio positioning and navigation system that provides extremely accurate three-dimensional position data, velocity information and system time to suitably equipped users anywhere on or near the earth. The Global Positioning System consists of three major segments: space system segment, control system segment, and user system segment. The manpack is in the user system segment.

The operational space system segment deploys three planes of satellites in circular 10,898 nautical mile orbits. Each satellite has an orbital inclination of 63° and a 12-hour period. Each plane has eight satellites. This deployment provides the satellite coverage for continuous three-dimensional positioning, navigation, and velocity determination. Each satellite transmits a composite signal at two L-band frequencies consisting of a precision (P) navigation signal and a course acquisition (C/A) navigation signal. The navigation signals contain satellite ephemerides, atmospheric propagation correction data, and satellite clock bias information provided by a master control station. In addition, the second L-band navigation signal permits the user to correct for the ionospheric group delay or other electromagnetic disturbances in the atmosphere.

In the control system segment, four widely separated monitor stations, located in U.S. controlled territory, passively track all satellites in view and accumulate ranging data from the navigation signals. The ranging information is processed at a master control station located in the continental United States to use in satellite orbit determination and systematic error elimination.

The orbit determination process derives progressively refined information defining the gravitational field influencing spacecraft motion, solar pressure parameters, location, clock drifts, and electronic delay characteristics of the ground stations, and other observable system influences. An upload station located in the continental United States transmits the satellite emphemerides, clock drifts, and propagation delay data to the satellites as required.

Each of the satellites and ground transmitters in this system emit a carrier which is modulated with a pseudorandom noise code of very low repetition rate. The generation of this code is synchronized to the satellite clock time reference. The manpack receiver also maintains a time reference used to generate a replica of the code transmitted by the satellite. The amount of time skew that the receiver must apply to correlate the replica with the code received from the satellite provides a measure of the signal propagation time between the satellite and the manpack.

This time of propagation is called the pseudorange measurement since it is in error by the amount of time synchronization error between the satellite and receiver clocks. The receiver also measures the doppler shift of the carrier signals from the satellite. By measuring the accumulated phase difference in this doppler signal over a fixed interval, the receiver can infer the range change increment. This measurement is called the delta pseudorange measurement and is in error by an amount proportional to the relative frequency error between the emitter and receiver clocks. Since the carrier wavelength is short, the delta pseudorange is a finely quantized measurement.

Measurements from four satellites provide the manpack with sufficient information to solve for three components of user position, velocity and user clock errors. To accomplish the navigation function, pseudorange and delta pseudorange measurements are used to update a running estimate of user position.

The NAVSTAR GPS Program is currently undergoing testing at the Yuma Test Range utilizing satellite like transmitters on the desert floor as well as the three available satellites. During this Concept Validation Phase (ØI), a total of six satellites will be launched to provide several hours a day of coverage in the Yuma area and over Naval oceanic test ranges.

If testing is successful, it is expected that ØII of the GPS Program for full scale engineering development will begin in mid 1979.

Magnavox heads one of four contractor teams currently doing pre-design work for Phase II user equipment. It is expected that two contractor teams will each build about 40-50 Phase II user sets each for testing in the early eighties. If operational testing is successful, a decision to deploy NAVSTAR could come as early as late 1982 in which case 24 Shuttle launched satellites will be in place by about 1987 along with initial deployment of thousands of military production user equipments.

The envisioned ØII effort includes provisions for participation by NATO nations. Civil usage is also expected to materialize in the mid 1980's.

Wescon

Heavy demand for exhibit space coupled with limited facilities in San Francisco have forced Wescon to impose restrictions on exhibiting at the 1979 high-technology convention and show, September 18-20. The restrictions apply only to this year.

The Wescon organization said the booth limitation procedure will have the effect of excluding some companies from exhibiting, curtailing the number of booths exhibitors may occupy and narrowing choices for exhibit hall locations.

William C. Weber, Jr., Wescon general manager, said the limitation policy was adopted by the board of directors because "there is simply no alternative." He noted that there are 300 fewer booth spaces in 1979 than were available in Los Angeles last year and "even more companies seeking to exhibit than in 1978."

FM Quadraphonic Sound (FCC Docket 21310)

The Commission said that comments indicated there is a substantial interest in FM quadraphonic broadcasting and added that technical comments received as well as the FCC's own analysis of technical data submitted indicated that 4-4-4/4-3-4 quadraphonic systems could be accommodated within the present frequency assignment plan without objectionable degradation to monophonic and stereophonic radio service.

For further information contact Albert Jarratt, Sr., FCC Broadcast Bureau, (202) 632-7792.

Computer Club

Increased software support is now provided to users of the Hewlett-Packard System 35 and System 45 desktop computers through the Basic Users' Club recently established by HP's Desktop Computer Division. The System 35 and 45 computers, both announced in the last 18 months, use an enhanced version of ANSI Standard Basic, hence the name of the new user club. The club offers free program and information exchange, as well as support of area meetings, a software catalog, and a newsletter.

Through the program exchange, Basic Users' Club members can take advantage of software that has already been developed by other members. The club library makes available user-submitted programs on a three-for-one basis (submit one and receive three in exchange).

Every member receives a software catalog which has a one-page description of each program in the club library. The description includes program title, mainframe configuration, language in which the program documentation is available, associated ROMs and peripherals, number of program lines and comments. Updates to the catalog are sent out periodically to all members.

The Basic Users' Club newsletter, which is sent to members world-wide, acts as a channel of communication in keeping members informed of area meetings, new Basic language programs and related HP equipment. The newsletter also forwards software information from suppliers to users of the System 35 and 45.

Those interested in joining the Hewlett-Packard Basic Users' Club, may contact: Basic Users' Club, Hewlett-Packard Company Desktop Computer Division, 3404 E. Harmony Road, Fort Collins, Colorado 80525.

Midcon/79

Complementing this year's event is a wide-ranging professional program which was tailored to cover topics of greatest interest to engineers and managers alike. Subjects included: Microprocessors, computers, fiber optics, communications, semiconductor technology, automated manufacturing and testing, energy, medical electronics, avionics, automotive, reliability, and quality control.

Midcon/79 will be held November 6-8, at the O'Hare Exposition Center, Hyatt Regency O'Hare. Contact Jerry Fossler, 999 North Sepulveda Boulevard, El Segundo, California 90245, (213) 772-2965.

ECM & Automobiles

Spectrum's only business is Electromagnetic Compatibility (the science of electronic systems working in harmony), and the Automotive Industry is one of their largest clients.

For example, after initial introduction of anti-lock brake systems it was discovered that the systems were susceptible to electromagnetic interference created by citizen band radios, police radar, mobile radios, television and radio broadcast stations, as well as other sources of man-made and natural electromagnetic interference. This electromagnetic compatibility problem was solved by using a total design approach.

In the first phase of the program the original electronic design of the anti-wheel lock system was tested in the shielded room in fields as high as 200 volts per meter over a frequency range of 500 kHz to 1.0 GHz. From these tests it was verified that the problem could be solved by filtering the power and the sensor lines in the system. The electrical parameters of the filter elements were established and prototype systems were produced. These systems were subjected to susceptibility testing both in the laboratory and under field conditions utilizing static and dynamic test procedures.

After the electrical design was finalized and verified the mechanical design featuring filters built into the system connectors was prototyped and finalized. The total design was subjected to a full environmental and electrical qualification test in the laboratory and under field conditions in both high temperature desert climates as well as sub-zero winter climates.

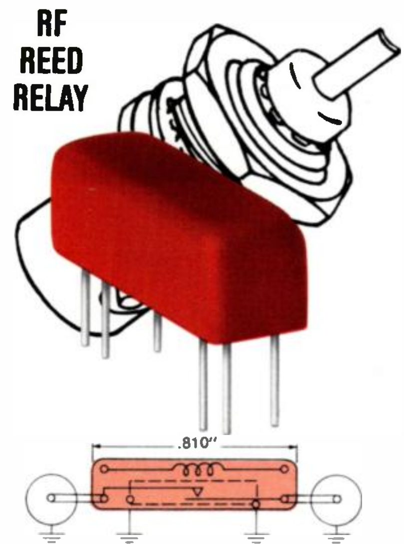
The electromagnetically compatible anti-lock brake system is now in full production and is termed the most successful in the entire industry. □

Amplifier Article

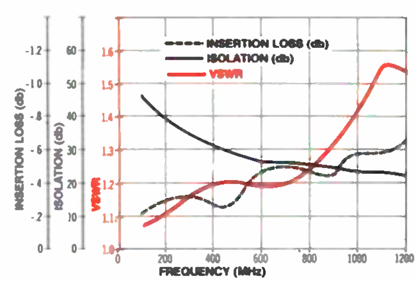
I would like to apologize to Dave Hollander, RF Circuits Engineering Motorola Semiconductor, for not giving him a by line in the March/April issue of *r.f. design*. Mr. Hollander wrote the article entitled **A Practical 60-Watt 225-400 MHz Amplifer,** appearing on page 32.

Bart Gates
Managing Editor
r.f. design

RF REED RELAY



Controls Low-Power VHF, UHF and Fast Digital Pulse Signals



Typical rf Performance in a 50Ω Microstrip Circuit

- Micro-Miniature RF Reed Relay
- Switches Sub-Nanosecond Pulses DC to 1.2 Ghz
- Low VSWR
- Low Insertion Loss and High Isolation
- Short Switching Path
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INFO/CARD 6

Spectrum Analyzer Analysis

The participating manufacturers of spectrum analyzers were asked to contribute editorial material that would answer the following questions. Why buy a spectrum analyzer? And, what kinds of capabilities should the analyzer have? Models produced are listed and specified on the last page of this article.

According To Tektronix

By Morris Engelson
Tektronix

Do You Need One?

Like any other tool, the Spectrum Analyzer is useful only to the extent that it matches the application. Any area that calls for a frequency spread, or distribution is a likely candidate for Spectrum Analysis.

Spectrum Analyzer applications can be separated into two basic types. The most obvious is the area where the information sought is of a frequency nature. Checking the frequency distribution of a transmitter output is such a case. The second category is where an intermediate step is a frequency distribution, even though the desired end result is not a frequency distribution. Using a Spectrum Analyzer to determine the on/off ratio of a pulse modulator is an example.

The Spectrum Analyzer is a general tool that appears at all levels of modern technological life. In research, production, or service —, in electronics, medicine, or mechanics —, anytime an electronic representation of a signal can be generated; there you will find the Spectrum Analyzer.

What Performance Do You Need?

Once one has decided that the problem fits one of the application types discussed — frequency distribution in the answer or frequency distribution as a means to the answer — it becomes necessary to consider a specific instrument. Frequency range is usually the first parameter of interest. Nothing else matters if the frequency range is wrong.

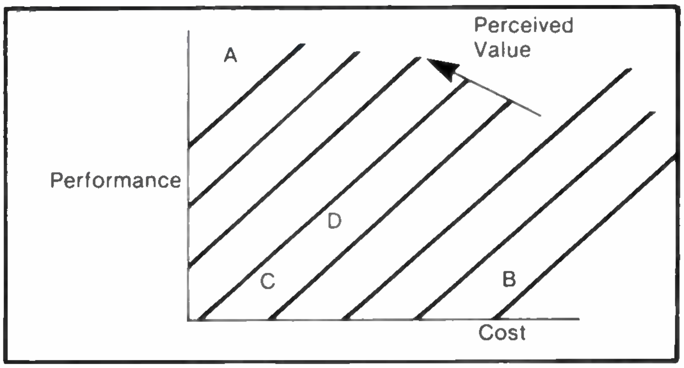
Other performance specifications that should be matched to the need are:

- Resolution and Stability — What is the minimum frequency separation between adjacent signal components? What degree of frequency shift is to be observed?
- Sensitivity — How small a signal is to be detected?
- Dynamic Range — What is the maximum amplitude difference or ratio that needs to be measured?
- Availability of amplitude calibration — Do you need to measure amplitude levels as well as observe spectrum shape?

Many other specifications relate to how easy it is to get the sought for information. A preselector in a microwave Spectrum Analyzer eliminates spurious responses thus making life easier for the user. Internal control optimization via microprocessor or hard wired logic reduces the number of controls that have to be manipulated. The presence or absence of such convenience features as digital storage or CRT parameter readout should be considered.

Is It Worth The Price?

Usually, you get what you pay for and pay for what you get. The user needs to weigh the cost/performance implications to find the best value instrument. One way of quantifying the decision is to draw a price/performance/value chart, such as below.



The price is available from the manufacturer. Performance is more difficult to quantity, but a comparison of specifications will usually lead to a clearly defined hierarchy. Clearly, item A, at high performance and low cost is the best value while item B, at high cost and low performance, is a poor value. Items C and D, though differing in cost and performance carry the same perceived value.

Besides the individual instrument, the user should consider the philosophy behind the product line offered. How does it fit in with other instruments and other uses. Some manufacturers choose to go for low cost and low performance, while others might offer equal perceived value at higher cost and higher performance. Assuming equal value can you afford the price to get better performance?

A major difference exists in physical construction. Primarily, plug-in versus monolithic. Each has its proponents. At Tektronix we offer a line of plug-in instruments covering the frequency range from 20 Hz to 60 GHz. We believe that plug-ins offer a high degree of flexibility in that the same mainframe may be turned into an oscilloscope, Spectrum Analyzer, Logic Analyzer or whatever. Use of a common mainframe offers economic advantages and the small lightweight plug-in can easily be carried from site to site.

At Tektronix we offer application notes, specification sheets and catalogues. The prospective user should take advantage of this free literature, as well as by discussion with our applications Specialists Field Force, to arrive at the best value for the intended application.

According To Polarad

By Edward I. Feldman
Polarad Electronics, Inc.

When Do You Need One?

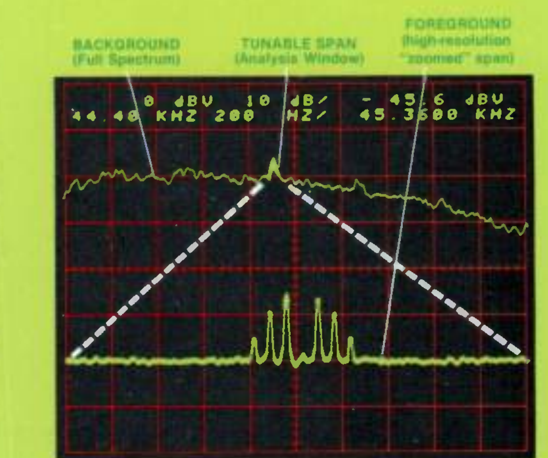
Spectrum analyzers have emerged during the past quarter century as indispensable instruments for RF and microwave industries. Generally, a spectrum analyzer is needed whenever the frequency contents of a waveform are of interest or have to be measured.

For example, the communication spectrum is crowded with many closely spaced signals. To avoid interference, all those who generate signals must maintain their own signals strictly within the prescribed spectrum space so as to avoid interfering with other users of the radio frequency spectrum. Those who inadvertently generate interfering radiation must keep their output levels within stringent FCC standards for levels vs frequency.

Spectrum analyzers display and plot level vs frequency so that the signals can be measured vs their rated characteristics. Design engineers and manufacturers use spectrum analyzers in testing experimental and production communications equipment, military systems and other devices which emit radio frequency energy. Manufacturers of appliances, toys, microwave ovens, motors, automobiles, etc. are examples of those who use spectrum analyzers to measure the residual emissions of their devices to ensure their acceptability.

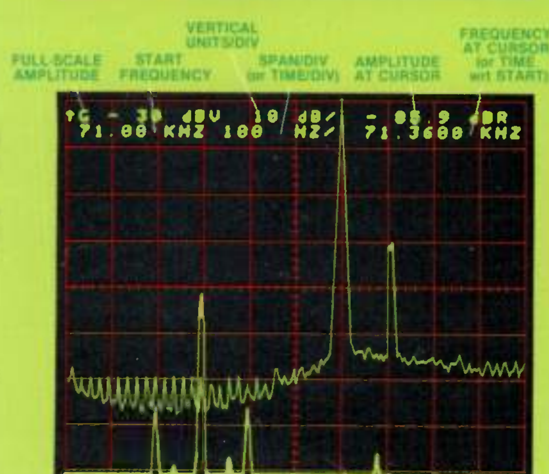
Modern spectrum analyzers are directly calibrated and have excellent frequency resolution and wide measurement dynamic range. They are used to measure signals rather than merely display them.

Get an extra dimension in High-Resolution Spectrum



The Extra Dimension is provided after you have *stopped* tuning... after you have positioned the adjustable span to the spectral region of interest. Then (and only then) the interface computer causes the "zoomed" high-resolution spectrum to pop up, brighter than the background, in the "foreground" position.

The Same 3-Knob Simplicity of operation provided by conventional swept analyzers. 1... 2... 3... READ! After the usual once-per-run setup operations, you rarely touch anything but the Sensitivity, Span, and Tuning knobs. If you've ever used a swept-filter analyzer, you're already checked out on the Model 7530A!



All spectrum data displayed directly on screen, for both spectra. All range, gain, and offset adjustments are automatically included in the annotated display.

Never before...

Never before has there been a spectrum analyzer anything like the new Rockland Model 7530A. At any price. In any physical format. Try one and you'll agree.

Look at that panel. Simple. Familiar to anyone who's ever used a conventional swept-filter analyzer. Yet infinitely more precise and quantitative. The Model 7530A is a true FFT-based, signal-processing instrument, with many exclusive *new* capabilities and features. The secret? Behind-the-panel microcomputer-based automation using very advanced interpretive algorithms. The heart of this exciting new design is its unique new "foreground/background" display. You *always* see the entire 0—100KHz spectrum (background), you *always* know what part of it you have selected for detailed study (intensified background segment), and you then see a full-screen presentation of the high-resolution span (foreground). And *every* parameter of the setup is annotated on-screen, in large, clear alphanumerics... automatically.

FFT-Based Analysis

Just plug the new ROCKLAND Model 7530A High-Speed, DC–100KHz General-Purpose Spectrum Analyzer into any Tektronix® Series 7000

An "extra dimension" indeed! But foreground/background is just one of *many* unique convenience and performance features... extra dimensions of value only in the Rockland Model 7530A. Check these, for example...

- Up to 90dB dynamic range at rated accuracy. Unprecedented! Noise "floor" $-160\text{dBV}/\sqrt{\text{Hz}}$!
- A full range of smoothing, storage, and triggering facilities, including single-transient capture and external triggering.
- Directly calibrated measurements of every point (amplitude *and* frequency) on every spectrum displayed, in Volts, Power Density, dBV, and dBR. (relative to selected reference).
- Excellent resolution: 1Hz at 100KHz.

Get the complete story on the newest and best thing to happen to spectrum analysis in a decade. Call the factory for a demonstration of this remarkable new instrument... or write for the Model 7530A brochure, and we'll send you our 48-page Spectrum Analysis Handbook *free* — a mini-textbook on FFT-based instrumentation!

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ROCKLAND

Rockland Systems Corporation, Rockleigh Industrial Park, Rockleigh, N.J. 07647, (201) 767-7900, TWX 710-991-9852

INFO/CARD 7

Typical applications include distortion analysis, interference and noise measurements, spectrum occupancy, modulation tests, response plotting with tracking generator, system stability studies, etc.

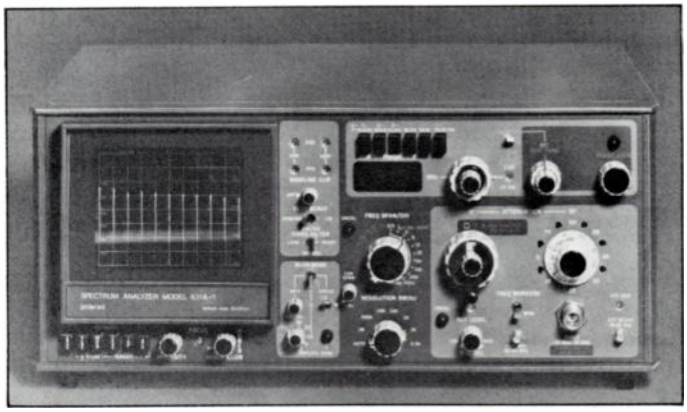
What Capabilities Should it Have?

Polarad produces several spectrum analyzers which are widely used in the RF and microwave industries.

The 600 Series consists of spectrum analyzers having an overall frequency range of 100 kHz-40 GHz. Recent design refinements in Polarad's 600 Series provide greater sensitivity, improved response flatness, and greater usable dynamic range. The upgraded models have an "A" suffix; e.g. 630A, 632A, etc.

The 600 Series' internal digital memory and data interface provides versatile long term display storage, continuous display updating without flicker or smearing, on-screen display comparisons, envelope plots, and other types of signal processing. The input/output interface is used with external data storage and computing accessories. The talker-listener interface can be adapted to the IEEE-488 Buss.

Polarad has recently introduced a new Model 6488 IEEE-488 Buss Interface Adaptor. It interconnects the digital memory of any 600 Series Spectrum Analyzer to accessory devices such as computers, calculators, data loggers, recorders and other data storage and processing devices which are also compatible with the GPIB IEEE-488 Buss. This interface facilitates use of the 600 Series analyzers for data acquisition, storage of any number of displays and recall at will, comparison of stored displays with incoming signals, statistical signal processing, normalization of the analyzer's response to obtain uniform sensitivity, and correlation of spectral data with other parameters such as time and antenna azimuth.



Polarad's Spectrum Analyzer Model 631A-1

According To Ailtech

By David Krantheimer
Ailtech

When Do You Buy A Spectrum Analyzer?

A spectrum analyzer is bought to perform certain types of measurements. There are four basic measurements for which we use with a Spectrum Analyzer. These are relative frequency, absolute frequency, relative amplitude and absolute amplitude. Because of the designs of most Spectrum Analyzers the accuracy of the measurement is a function of both the instrument and the care taken in the set up of the measurement. Some of the basic measurements that a user would make would be:

(a) Amplitude
(b) Frequency
(c) AM
(d) FM
(e) Pulsed RF
(f) Intermodulation distortion
(g) Noise
(h) Spectral purity

It is obvious that these cover just a small part of the many uses of a Spectrum Analyzer.

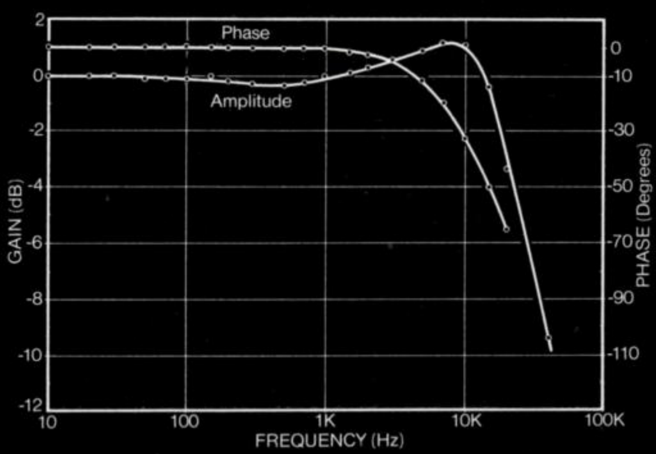
Spectrum Analyzer Capabilities Needed by User

(a) Largest on screen dynamic range
(b) Ease of use
(c) Built-in preselector
(d) IF filters with small shape factors defined by 60 dB to 3 dB ratio 5:1 or less
(e) Video filtering down to 10 Hz
(f) Automatic selection of IF bandwidth
(g) Largest sensitivity/kHz
(h) Unit able to take large input signal
(i) Unit that is maintainable
(j) Company that offers good service
(k) Error free measurement
(l) Good intermodulation product performance
(m) Storage display-digital preferred
(n) Tracking generation capability up to 12 GHz
(o) One complete unit without plug-ins that cover the audio to microwave spectrum

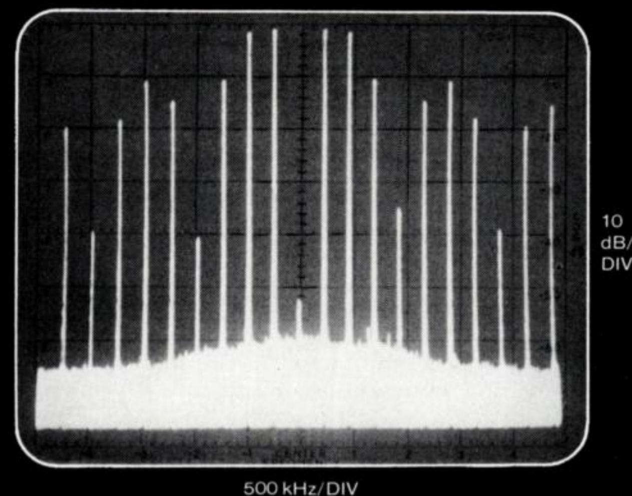
(Continued on Page 20.)

LOOK:

1. Characterize phase lock loops.
2. Generate digital phase modulation.
3. Program signals 10kHz to 2600MHz.



1. A complete Bode Plot of a phase lock loop can be generated with 8660C phase modulation capability.



2. A QPSK phase modulation signal is shown with 1 MHz clock rate and 50 dB carrier null.

3. 8660C Synthesized Signal Generator under 9825A Desk Top Computer Control provides fully programmed signals from 10 kHz to 2600 MHz with AM, FM, phase or pulse modulation.

Look how the HP 8660 Synthesized Signal Generator makes a lot of things easy. Its phase modulated signals allow you to test a wide variety of phase lock loops in their closed loop, operating condition. And low frequency drift gives good results even with narrow band PLL's. We've discussed it in detail in our Application Note 164-3.

You can use the HP-86634-35 Modulation Sections with their analog phase capability to generate discrete phase states for binary and quadra-phase shift keyed (BPSK & QPSK) signals. Such signals will prove valuable for applications such as communications receiver testing, military secure links and time domain multiple access satellites. Our Application Note 164-4 tells how to build the simple interface circuit.

You can also use it as a programmable signal simulator. Application Notes 164-1 and 164-2 show how to program the 8660A/C for automatic test systems or signal simulation.

The versatile 8660A/C Synthesized Signal Generator and its family of three RF output plug-ins (10 kHz to 2600 MHz) and 5 modulation plug-ins (AM, FM, ØM, and pulse modulation) are made even more valuable with the information in these application notes:

AN 164-1 BCD Programming
AN 164-2 Calculator Programming
AN 164-3 Phase Lock Loop Testing
AN 164-4 Digital Phase Modulation

Contact your nearby HP field sales office or write for your free copy.

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According To

Rockland

By Engineering and Marketing Staffs
Rockland Systems Corporation

The spectrum analyzer has been around for 30 years. The digital FFT-based spectrum analyzer is at least 10 years old. What then, is new about analyzing wave forms by means of a frequency-domain display?

- The design engineering "population is now made up largely of engineers who have had thorough training in the significance of the Fourier spectrum, and who are familiar with frequency components and signal characteristics such as: modulation, spurs, distortion, S/N ratio, jitter, flutter, etc. Figure 1 is one example of what can be learned by measuring a single spectrum.
- The price, size, and complexity of recently developed digital spectrum analyzers has been greatly reduced. It is now clear that the FFT-based spectrum analyzer can be called a "general-purpose" instrument. Figure 2 shows a recently introduced all-digital, general purpose FFT analyzer, in the form of a scope plug-in.
- With the wide general availability of ultra-stable, laboratory-grade frequency synthesizers, the technique of "down conversion" can be used to *extend* the frequency range of any low-frequency, wide-dynamic-range, precision analyzer to *high frequencies*. . . well into the microwave region, if necessary. With minimal care, down conversion can be accomplished with a tolerably small increase in distortion and virtually no added noise contribution — and the measurements made on the heterodyned signal are *directly* related to the parameters of the original high-frequency signal. . . usually by simple arithmetic. Figure 3 shows the basic block diagram for a down-converted measurement of phase noise.

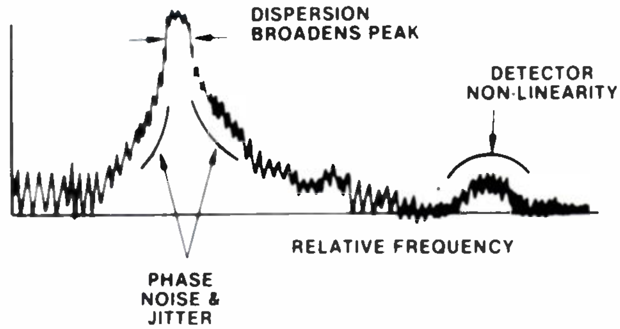


Figure 1. Spectrum analysis of this typical Doppler-radar output spectrum exposes three critical parameters otherwise virtually hiden or revealed only by slow, painstaking point-by-point measurements after some kind of recording to freeze the phenomena under observation.


Figure 2. Rockland Systems' new Model 7530 General-Purpose DC-100 kHz Spectrum Analyzer plug-in module for Tektronix Series 7000 oscilloscope mainframes.

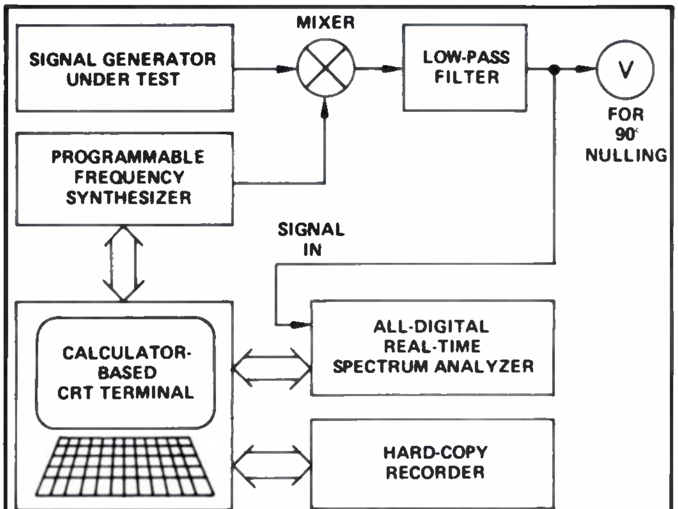


Figure 3. Automated Phase-Noise Measurement. Inset is actual hard-copy recording from CRT screen.

Characteristics and Capabilities

There are six characteristics that separate a modern, high-performance spectrum analyzer from the older "swept frequency" analyzer. Although modern FFT-based designs provide widely varying degrees of efficiency with respect to these parameters, they always provide at least an order of magnitude better performance than even the best of the swept-filter designs. The six key parameters are: resolution, absolute accuracy (in both amplitude and frequency calibrations), linearity, dynamic range, frequency range, and ultimate sensitivity (usually determined by the "noise floor").

The resolution of the most advanced modern analyzers is greatly enhanced by the use of "frequency zoom," in which any portion of the original analysis bandwidth may be selected and expanded to fill the entire displayed frequency scale. (The zooming, like all the other measurement functions in a modern spectrum analyzer, is accomplished entirely by digital means.) Typical modern resolution is 1 Hz out of a 100 kHz frequency span.

The absolute accuracy of the best of the modern analyzers corresponds to that attainable from the highest quality 12-bit A/D converters. The linearity of modern analyzers is also severely restricted by distortion in the A/D converter. In particular, the differential linearity is so poor that significant spurious frequency components are created and displayed. For signals over the 100 kHz band, the distortion products are typically at − 55 dB for high-quality commercial converters. Special designs improve performance so that the distortion products are better than − 75 dB.

The ultimate sensitivity of a modern analyzer is usually of the order of 500 microvolts full scale or better, so that one would think that signals as small as 20-50 microvolts would be easy to measure and display; however, the noise floor of the analyzer input circuitry usually obscures such small signals. The recently introduced analyzer depicted in Figure 2 is exceptional because it has a noise floor of − 160 dB/$\sqrt{}$Hz (about 10 nanovolts/$\sqrt{}$Hz!) This gives it a dynamic range of up to 90 dB.

Probable Implementation

We believe that the instrument shown in Figure 2 is the first of a new class of compact, simplified, low-cost FFT-based designs that will appear (as both scope plug-ins and as stand-alone instruments) over the next few years. We believe that eventually moderate priced general-purpose oscilloscopes will be equipped with signal-processing circuitry that will bring the cursor-directed, alphanumerically displayed digital readout to time-domain measurement. We also believe that the spectrum analyzer will someday be as widely used as the oscilloscope.

Finally, we believe that being able to move confidently from the time to the frequency domain and back will significantly increase the analytical capability of the electronic design engineer.

According To Hewlett-Packard

Engineers involved in the design or manufacture of communications systems, control systems, radar and navigation systems or components of any of these and other circuits all think in terms of the frequency domain. Basic measurements such as modulation, distortion analysis, frequency response measurement, stability and spectral purity measurements are all frequency domain measurements.

Although there are numerous instruments which measure these parameters independently-tuned RF voltmeters, power meters, counters, distortion and wave analyzers, for example — they all present information on a discrete frequency, point-by-point basis. A spectrum analyzer can present this same information as a continuous, broad-band view of the frequency domain.

Why Should I Buy a Spectrum Analyzer?

A spectrum analyzer is a swept tuned receiver that displays absolute amplitude as a function of a frequency on a CRT. It differs from the common superheterodyne radio receiver primarily in the mode of data presentation. The spectrum analyzer is a basic instrument as general purpose and useful as the oscilloscope, but which surpasses the oscilloscope in its ability to present important signal information that a time domain instrument cannot. Despite its general utility, however, the spectrum analyzer has the power to make measurements made by specialized instruments such as distortion analyzers and wave analyzers. The spectrum analyzer is many instruments combined into one. Most important, it gives the engineer the capability to see signals as he thinks of them — in the frequency domain.

What Capabilities Should A Spectrum Analyzer Have?

The capabilities of today's spectrum analyzer can be categorized into three areas: RF performance (i.e. resolution, stability, etc.), user convenience, and automatic measurement capabilities. In addition to offering state of the art RF performance, Hewlett-Packard Company's latest spectrum analyzers have significantly expanded the areas of user convenience and automatic measurement capability with the introduction of the new generation of microprocessor based spectrum analyzers.

User Convenience

Although RF performance heads the list of analyzer capabilities, manufacturers and customers alike have recently placed increased emphasis on convenience features and ease of operation.

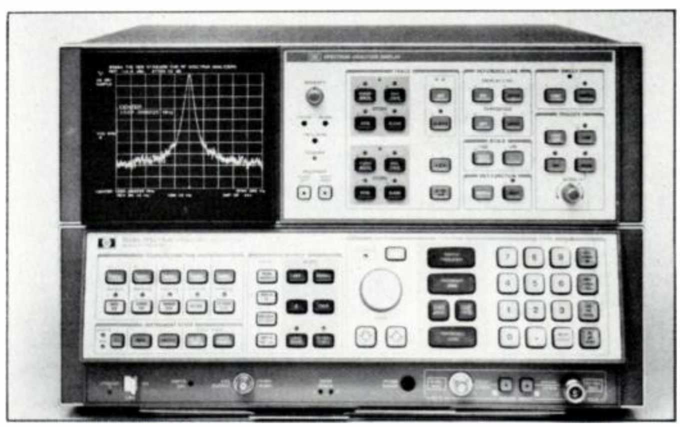
- *Swept response measurements* of filters, amplifiers and other active and passive devices can be made with ease using a tracking generator with the spectrum analyzer. A built-in tracking generator is featured with the new HP 3585A spectrum analyzer and provides swept response frequency coverage from 20 Hz to 40 MHz. Companion tracking generators used with the HP 140 and HP 180 series of spectrum analyzers extends frequency coverage into the microwave region.
- *Modularity* is one answer to the problem faced by customers whose needs include frequency coverage over extended ranges. The HP 140 modular series of analyzers offers high performance extending from 20 Hz to above 18 GHz in overlapping bands.
- *Coupling "dependent controls"* such as IF bandwidth, video bandwidth and sweep time to user adjusted independent controls such as frequency span results in simplification of operation of a spectrum analyzer. The "three knob operation" of the HP 8557A and 8558B analyzers requires the user to tune, reduce frequency span and adjust the amplitude level for most measurements.
- *Microprocessor control* of HP's new generation of spectrum analyzers, models 8568A and 3585A, simplifies operation by placing powerful firmware in control of routine measurement procedures such as zooming in on a displayed signal and performing trace data manipulations. Other benefits include accuracy improvement through automatic error correction and a significant reduction in time ordinarily spent in manually setting up the analyzer to take data.

New innovations in applying *frequency stabilization* techniques to analog swept instruments such as the spectrum analyzer continues the trend toward simplification of operation. It has made possible the synetheisizer like frequency accuracy of the HP 8568A and 3585A spectrum analyzers.

Automatic Measurements

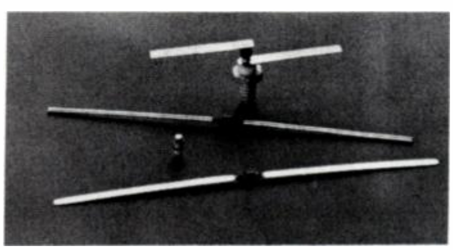
Although IEEE-488 programmable instruments first appeared on the market some time ago, measurements utilizing programmable spectrum analyzers have generally been limited to costly and complex computer based specialized systems. This was principally due to the lack of precision frequency control of the analyzer's tuning and the consequential sweep-to-sweep non-repeatability. Routine automatic spectrum analysis of complex measurements such as multi-channel communications and wideband pulsed RF is now possible with the 8568A spectrum analyzer under design control.

Automated production testing has likewise become an economical practical reality. Operating under program control the 8568A analyzer can be means of



CRT graphics instruct an inexperienced technician how and when to connect the spectrum analyzer and other test equipment and then automatically collect, format and output the test results to give the operator a go/no-go indication or supply a detailed test data output. Practically any degree of operator/controller interface can be built into the system to allow the technician to interject at any point and perform whatever adjustments are necessary and then continue with programmed testing.

In addition to the increased accuracy, reliability and test rate, it's possible to catalog test results for future trend recognition and to identify developing problems before they occur. *(Continued on Page 26.)*



PIN DIODES FOR RF APPLICATIONS

Unitrode's PIN Diodes for low distortion performance in RF switch and attenuator circuits are constructed with thick I-layer and long carrier lifetime.

IN5767 (3080) and UM9301 are designed for receiver AGC, CATV, and other applications requiring low intermodulation distortion.

UM4300 and UM7300 are made for higher power transmitter usage requiring low harmonic distortion and linear modulation. Average power dissipation to 18W enables power handling over 1KW.

For Unitrode's new "PIN Diode Designers Handbook and Catalog," contact Unitrode Corporation, 580 Pleasant Street, Watertown, MA 02172, 617-926-0404.

UNITRODE

With the new improved bandstacking feature in our Model 2002A sweeper, you can now cover the entire 1 to 2500 MHz range in one fell swoop. You can also start and stop anywhere in between. Anywhere.

Try to find another stand-alone sweep-signal generator that has this capability. Or one with a front-panel meter on which you can easily set and read the output over its +13 to −77 dBm range.

Flatness is ±0.5 dB at the 20-milliwatt output; display linearity is ±1%. For compensation of frequency-dependent variations in test set-ups, a ±2 dB slope adjustment is right there on the front panel. There's also a provision for external leveling.

Besides all this standard equipment, the 2002A has options. Like a deluxe harmonic marker system that provides 1, 10, 50 and 100 MHz markers over the entire frequency range. Or you can order specific single-frequency markers when you buy your 2002A, or whenever a specific application comes along.

But the important thing to remember is that the Model 2002A gets you from 1 to 2500 MHz in a single sweep. And you can't get this anywhere for just $3,400. Not anywhere. Wavetek Indiana, P.O. Box 190, Beech Grove, Indiana 46107. (317) 783-3221. TWX 810-341-3226.

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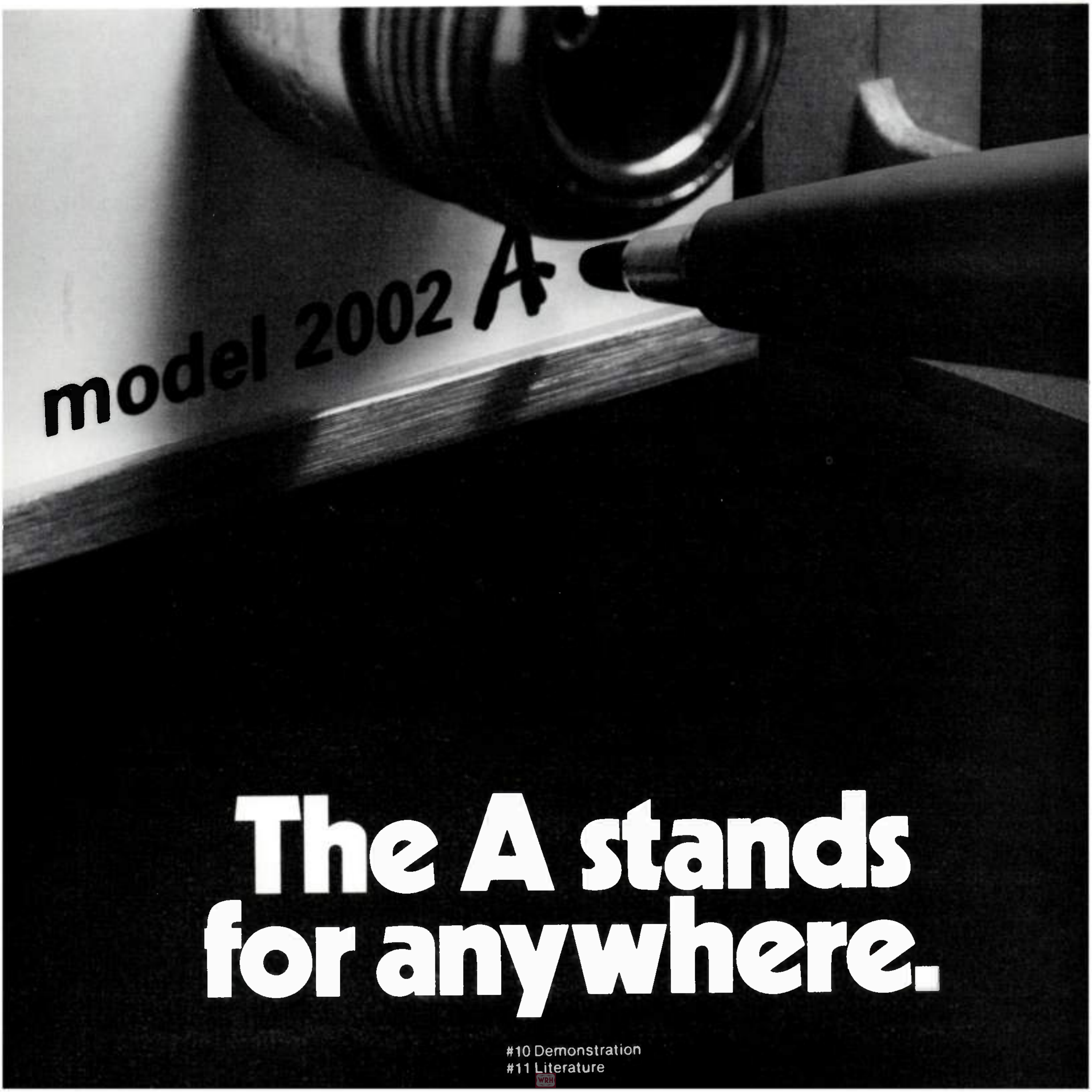

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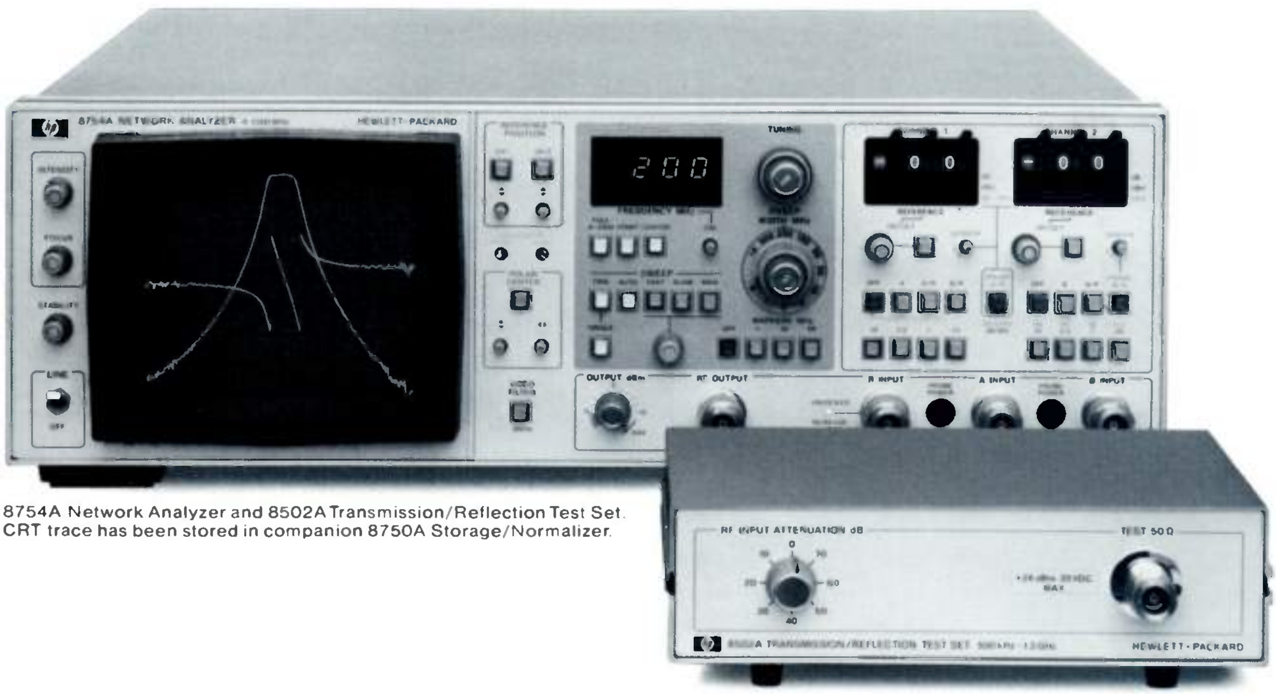

8754A Network Analyzer and 8502A Transmission/Reflection Test Set.
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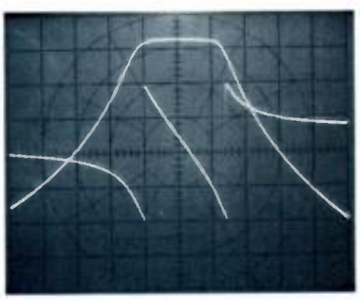

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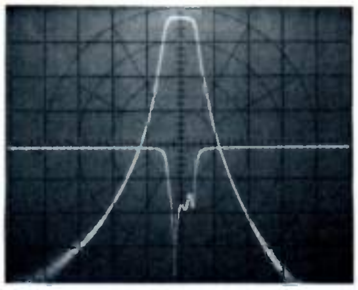

Using the 8502 Test Set ($1850) you can see the trade offs between transmission gain or loss and input match in a single test setup. For complete two-port characteristics of networks, including devices like transistors, an S-parameter test set is available.

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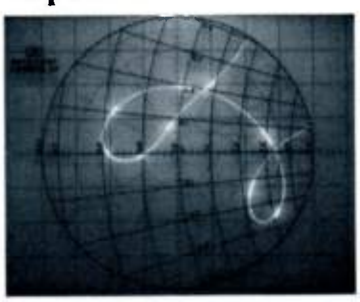

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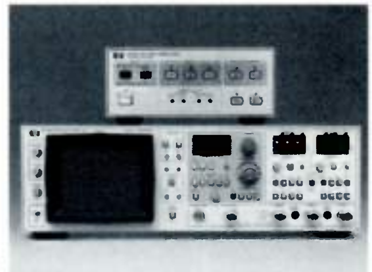

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Model	Frequency Range	Best Sensitivity	Resolution Bandwidth	Dynamic Range On Screen	Price
7L18 Plug-in 7603 Mainframe	1.5 GHz to 18 GHz 60.5 GHz with Optional Mixers.	– 128 dBm	30 Hz to 3 MHz	80 dB	$14,600 2,260
7L13 Plug-in 7613 Mainframe	1 kHz to 1800 MHz	– 128 dBm	30 Hz to 3 MHz	80 dB	$ 9,500 3,430
7L12 Plug-in 7613 Mainframe	100 kHz to 1800 MHz	– 115 dBm	300 Hz to 3 MHz	70 dB	$ 6,500 3,400
7L5/L3 Plug-in 7603 Mainframe	20 Hz to 5 MHz	– 135 dBm	10 Hz to 30 kHz	80 dB	$ 7,575 2,260
491 Portable	10 MHz to 40 GHz	– 100 dBm	1 kHz to 100 kHz	40 dB	$10,700
5L4N Plug-In 5111 Mainframe	20 Hz to 100 kHz	– 134 dBm	10 Hz to 3 kHz	80 dB	$ 3,150 1,490

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Model	Frequency Range	Price
TR501 Tracking generator	100 kHz to 1800 MHz	$ 4,000
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1405 Sideband Adapter	to 1 GHz	3,300
7K11 CATV Preamp	30 MHz to 890 MHz	675
AM511 CATV Preamp	30 MHz to 890 MHz	675
2701 50 Ω Step atten.	DC to 1 GHz	350
2703 75Ω Step atten.	3 kHz to 1 GHz	375

Polarad Spectrum Analyzers

Model	Frequency Range	Resolution Bandwidth	Sensitivity Avg. Noise @ 1 kHz BW	Dynamic Range On Screen	Price
630A (Option-1)	10 MHz-40 GHz	300 Hz-1 MHz	– 116 dBm	70 dB	$ 9,975 (11,425)
640A (Option-1)	10 MHz-40 GHz	300 Hz-1 MHz	– 116 dBm	70 dB	$12,950 (14,400)
632A-1	100 kHz-2 GHz	300 Hz-1 MHz	– 126 dBm	70 dB	$ 8,250
CSA 290-A	10 Hz-43 MHz	6 Hz-3 kHz	2μV	70 dB	$12,525
Option-1		digital memory and data interference			$ 1,450

Ailtech Spectrum Analyzers

Model	Frequency Range	Resolution Bandwidth	Sensitivity Noise Figure	(Screen) Dynamic Range	Price
707	1 MHz-12.4 GHz	1 kHz-1 MHz	110 dBm/kHz* (125)	100 dB	$15,495
727	1 MHz-20 GHz	1 kHz-1 MHz	110 dBm/kHz (125)	100 dB	16,775
757	1 MHz-22 GHz	1 kHz-1 MHz	110 dBm/kHz (125)	100 dB	19,975
70726 70727	10 kHz- 2 GHz 10 kHz-12.4 GHz	Tracking Generator Tracking Generator			3,800 5,250

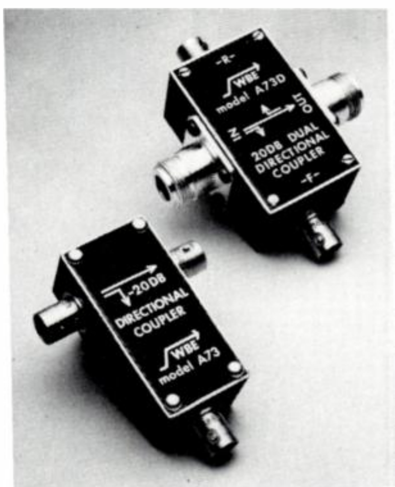
Rockland RF Spectrum Analyzer

Model	Frequency Range	Resolution Bandwidth	Equivalent Input Noise	Linear Dynamic Range	Price
7530-A	DC-100 kHz	1 Hz (200 Hz span)	– 160 dBV/√Hz	70 dB (90 dB)	$ 7,900

Hewlett-Packard RF Spectrum Analyzers

Model	Frequency Range	Resolution Bandwidth	Sensitivity (BW) Noise Figure	Dynamic Range	Price
3580A	5 Hz-50 kHz	1 Hz-300 Hz		>80 dB	$ 4,775
8557A	10 kHz-350 MHz	1 kHz-3 MHz	– 117 dBm (1 kHz)/27 dB	>70 dB[5]	$ 3,950
8558B	100 kHz-1500 MHz	1 kHz-3 MHz	– 117 dBm (1 kHz)/27 dB	>70 dB[5]	$ 4,950
8556A[1]	20 Hz-300 kHz	10 Hz-10 kHz	– 142 dBm (10 Hz)/22 dB	>70 dB	$ 9,150[1]
8553B[1]	1 kHz-110 MHz	10 Hz-300 kHz	– 140 dBm (10 Hz)/24 dB	>70 dB[5]	$ 9,975[1]
8554B[1]	100 kHz-1250 MHz	100 Hz-300 kHz	– 122 dBm (100 Hz)/32 dB	>65 dB	$11,600[1]
8555A	10 MHz-18 GHz	100 Hz-300 kHz	– 125 dBm (100 Hz)/29 dB	>63 dB[6]	$14,725[1]
8565A	10 MHz-22 GHz	100 Hz-3 MHz	– 122 dBm (100 Hz)/32 dB	>70 dB[5]	$19,700[7]
3585A	20 Hz-40 MHz	3 Hz-30 kHz	– 137 dBm (3 Hz)/32dB	>80 dB[5]	$17,500
8568A	100 Hz-1500 MHz	10 Hz-3 MHz	– 135 dBm (10 Hz)/29 dB	>85 dB	$27,800

[1]With 141T mainframe and 8552B IF
[2]10 MHz-2.05 GHz
[3]Frequencies >10 kHz
[4]Frequencies >1 MHz
[5]Degrades approximately 10 dB at low end of frequency range
[6]10 MHz-6 GHz
[7]100 Hz option included



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A73-20GA				30	40			
A73-20GB				40	45			
A73-20P	1-100	single	50W cw (75 ohm limited to 10W cw)	35 dB min		.15	±.1	1.1:1 max
A73D-20P		dual		40 dB min typical		.3		
A73-20PX		single		45 dB min		.15		
A73D-20PX		dual				.3		
A73-20PA	10-200	single		35 dB min		.15		1.04:1 typical
A73D-20PA		dual		40 dB min typical		.3		
A73-20PAX		single		45 dB min		.15		
A73D-20PAX		dual				.3		

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Spectrum Analyzer

By Ralph Fowler
Application Engineer
Hewlett-Packard

To engineers designing or evaluating oscillators, amplifiers, mixers or other components, the primary requirement is RF performance. The job presented to the analyzer, in the simplest terms, is to discern the signal and display its amplitude and frequency with as much fidelity as possible. Resolution and sensitivity directly affect the ability to discern the presence of signals while distortion characteristics and instrument accuracy determine the fidelity of the data presented. Since the specifications which describe these parameters are frequently confusing, it is worth reviewing them here.

Resolution

Resolution is the ability of a spectrum analyzer to accurately separate and display two or more signals in the frequency domain. The usual measure of an analyzer's resolution is its minimum IF bandwidth and as a general rule this bandwidth must be less than or equal to the frequency spacing of the signals to be resolved. If the signals are unequal in amplitude, the IF bandwidth must be considerably less than the signal spacing. The resolution of 60 Hz power line related sidebands, for example, may require an IF bandwidth of 10 Hz or less. See Figure 1.

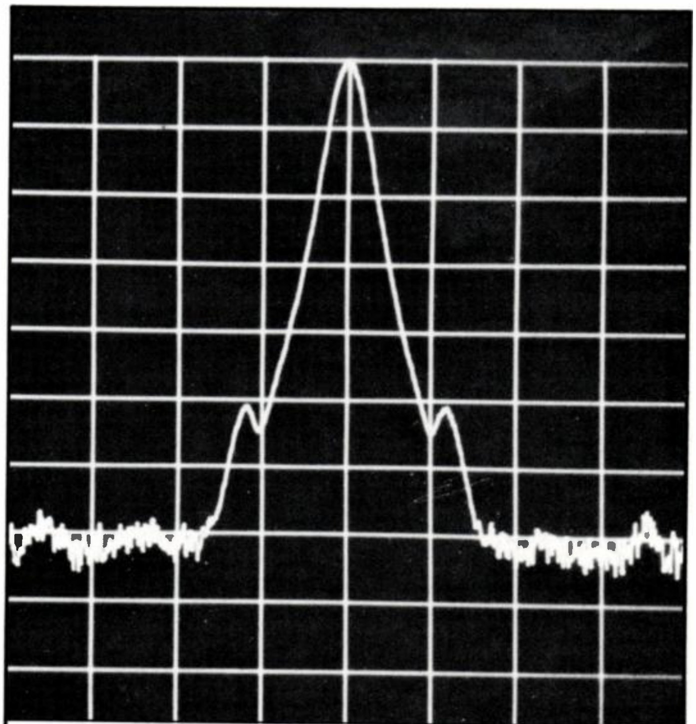

Figure 1. 60 Hz line related sidebands on an RF carrier. IF bandwidth = 10 Hz. Shape factor 10:1.

Performance

A good IF bandwidth *shape factor* must complement the actual IF bandwidth, however, or the advantages of the narrow bandwidth may be lost. See Figure 2. Shape factor, the ratio of the 60 dB and 3 dB bandwidths, is a measure of the "skirt selectivity" or how well the analyzer can resolve signals which are small and close in to larger signals. Shape factors can vary from analyzer to analyzer. Typical values range from 20:1 to 5:1 or less.

Although a small shape factor is advantageous, it should not be achieved by compromising other performance. Using rectangular shaped IF filter passbands, for example, can induce ringing and cause a loss of phase linearity. Phase linearity is important, particularly when measuring phase coherent signals such as EMI. Using synchronously tuned Gaussian filters is one way to avoid these problems while still maintaining a good shape factor.

The use of narrow IF bandwidths, however, presupposes certain stability traits. Narrow IF bandwidths are all but useless unless analyzer residual FM and spectral purity are commensurate with these bandwidths.

Residual FM manifests itself by producing jitter on the observed signal. It makes frequency measurement difficult and prevents the effective use of narrow IF bandwidths. See Figure 3. Generally, the analyzer

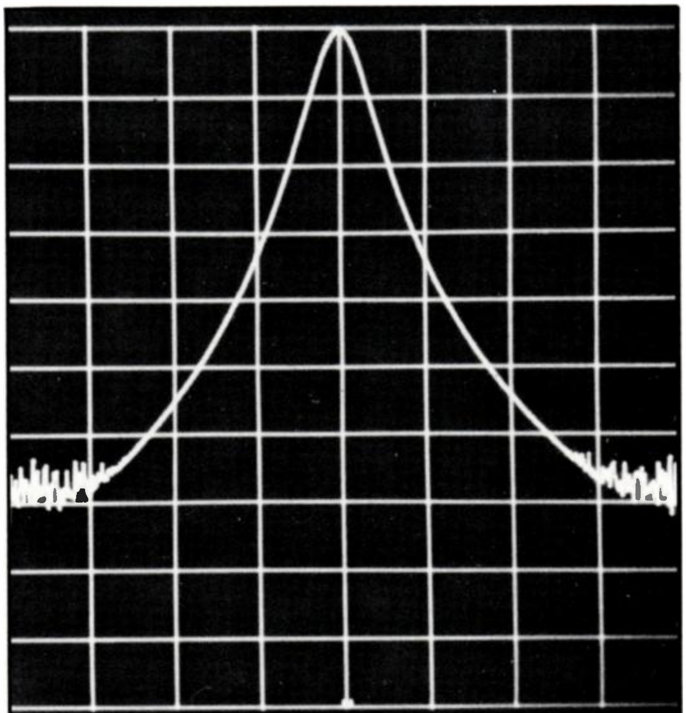

Figure 2. Same signal as in Figure 1. IF bandwidth = 10 Hz. Shape factor degraded.

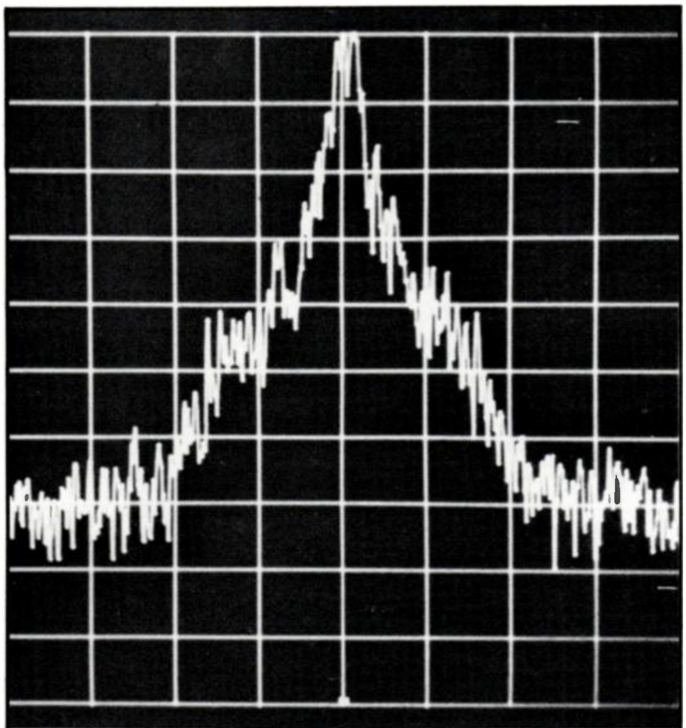

Figure 3. Same signal as in Figure 1. Analyzer residual FM degraded.

residual FM peak-to-peak deviation determines the smallest usable IF bandwidth, although in some instances using smaller bandwidths will give acceptable results. Phase locking local oscillators is one technique employed to decrease analyzer residual FM and permit the use of very narrow IF bandwidths.

Spectral purity is a measure of how clean and noise free the spectrum analyzer local oscillators are. Any impurities will generally show up as noise sidebands superimposed on the observed signal. They can easily obscure signals originating from the test device, such as the 60 Hz line related sidebands cited before. See Figure 4.

Sensitivity

The need for analyzer sensitivity (i.e. to measure signals near the thermal noise level) is self evident. There are two factors which influence an analyzer's sensitivity.

Using *narrow IF bandwidths* increases sensitivity to CW and other non phase coherent signals by reducing the amount of random (white) noise reaching the spectrum analyzer's detectors.[1] For example, decreasing the IF bandwidth by a factor of ten improves the sensitivity by 10 dB. As mentioned before, however, stability and spectral purity provide the foundation necessary to make narrow bandwidths practical and, therefore, available sensitivity is to an extent influenced by these factors.

Analyzer *noise figure* is independent of IF bandwidth and is generally determined by the design of the front end mixer and preamp stages. Poor analyzer noise figures can usually be improved by cascading low noise preamplifiers ahead of the spectrum analyzer input, but dynamic range of measurement is reduced by an amount somewhat less than the preamp gain. More on dynamic range later.

Manufacturers usually combine the effects of IF bandwidth and noise figure on sensitivity and specify the noise power level in a given bandwidth. All signals below this power level will not be measurable (in the given bandwidth) by the analyzer.

Accuracy

For some applications accuracy is the qualifier which determines whether a spectrum analyzer can do the job. Despite the importance of accuracy it is possibly the least understood of all specifications.

Both frequency and amplitude accuracy suffer from two general sources of uncertainty: (1) uncertainties arising from poor operator technique such as using the analyzer outside of its limits (e.g. overdriving the input, sweeping too fast, etc.) or using non optimum measurement procedures and (2) hardware uncertainties resulting from mixer flatness, switching of attenuators and IF filters, linearity and others. Technique derived uncertainties are not easily specified and consequently most manufacturers limit specifications to hardware derived uncertainties and publish other information to address the problems associated with technique errors.[2]

Hardware uncertainties affecting *frequency accuracy* include center frequency and frequency span uncertainties. Reduction in these errors normally comes as a result of improved technology, although there are other ways to minimize their influence. The spectrum analyzer tracking generator was developed to provide swept response measurement capability, but as a by product improvements in

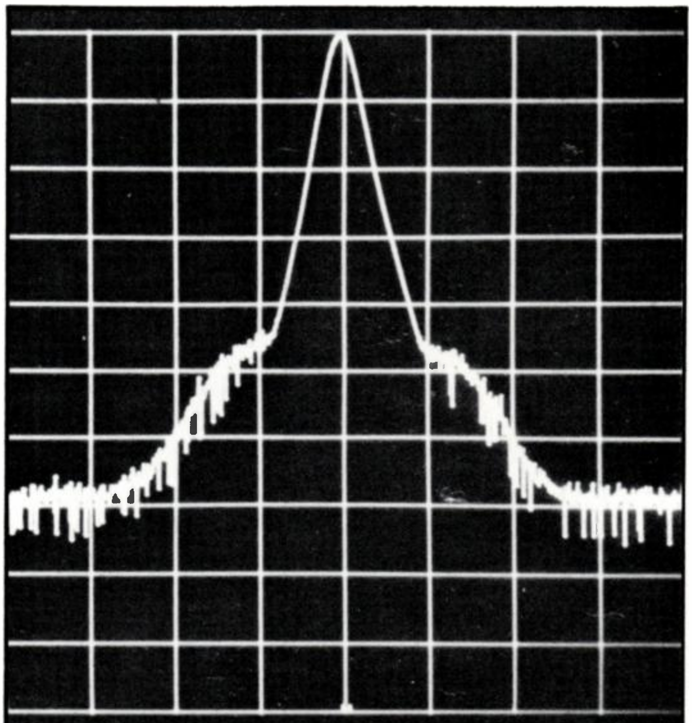

Figure 4. Same signal as in Figure 1. Analyzer L.O. noise obscuring 60 Hz sidebands.

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frequency accuracy resulted. Since the "restoration" or the reproduction of the frequency to which the analyzer is tuned is actually the spectrum analyzer down conversion process in reverse, it's possible to generate a signal which is equal, hertz for hertz, to the input signal, but at an amplitude suitable for counting.

Amplitude accuracy is likewise affected by technique and hardware uncertainties. Hardware uncertainties include flatness, calibration uncertainty, attenuator switching uncertainty, IF bandwidth switching uncertainty and display logging errors to name a few. Manufacturers generally specify each separately to allow the user to add up those which are appropriate to the measurement procedure used. This number then becomes the measurement uncertainty. These uncertainties decrease as technology develops, but they too can be minimized by certain techniques. Fortunately, many of the hardware uncertainties are characterizable and repeatable and can, therefore, be measured and normalized (subtracted) out. The power of microprocessor technology has made it possible to create "error tables" within the memory of a spectrum analyzer and use these to correct for hardware limitations.

Distortion Immunity

Freedom from analyzer distortion is critical, particularly when measuring mixers, amplifiers or other non-linear distortion producing devices. In cases where both the spectrum analyzer and the device generate distortion, the user must determine whether the displayed responses originate from the test device or the analyzer itself.

Harmonic distortion (HD) and *intermodulation distortion* (IMD) are measures of a spectrum analyzer's immunity to generation of internal distortion due to the input of high level signals. HD and IMD state how far down the distortion products are relative to the distortion causing signal (.e.g. 70 dB an input level of −40 dBm). See Figure 6.

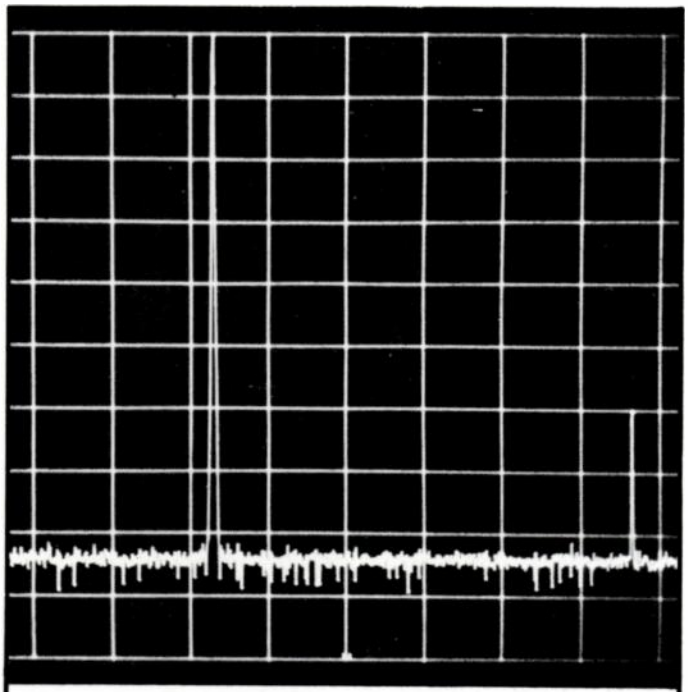

Figure 5. Fundamental and second harmonic of a source. Analyzer dynamic range / 70 dB.

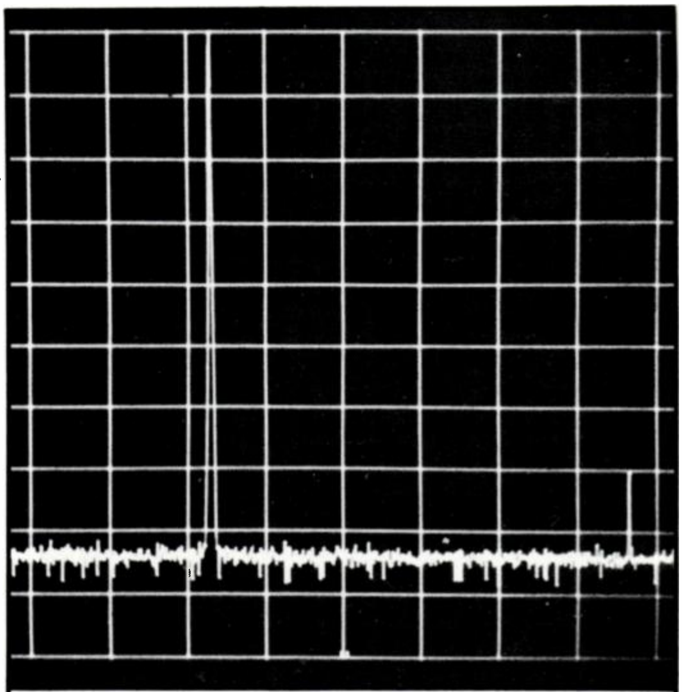

Figure 6. Same signals as in Figure 5. Analyzer distortion obscures harmonic, dynamic range degrades to 60 dB.

Although decreasing the input level reduces the level of distortion even more, a point is reached where the distortion products equal the noise level in the analyzer. The input level corresponding to this condition marks the analyzer's distortion threshold. This level is from −30 to −50 dBm at the mixer input for most analyzers. Under this condition, the distortion threshold and the noise level (in the specified bandwidth) define the amplitude boundaries of a region over which all signals will be detectable, but not distortion producing. The difference between these two amplitude levels is the *maximum achievable spurious free dynamic range* (or simply dynamic range) in the specified bandwidth. Although preselection can extend this range, it is generally limited to frequencies at UHF and above. Dynamic range information is very useful since it qualifies the analyzer's ability to accurately measure high level and low level signals simultaneously — a realistic situation.

Figures 5 and 6 illustrate the practical importance of dynamic range. Note the spectrum analyzer distortion in Figure 6. □

References

1. Hewlett-Packard, "Spectrum Analysis...Signal Enhancement," No. 150-7.
2. Hewlett-Packard "Spectrum Analysis...Accuracy Improvement:, No. 150-8.

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How Good is Your 1 GHz Bipolar Power Transistor?

By Lloyd Hackley
RF Transistor Design Engineer
Thomson CSF — SSM Division

That segment of the RF transistor market that is currently receiving a large interest is the silicon power transistor used in high-power 800 MHz land-mobile, UHF radars, L-band short-pulse, and L-Band long-pulse applications. Equipment designers are actively soliciting and receiving devices from transistor manufacturers to initiate the design phase of new solid state transmitters. Initial samples usually achieve minimum standards with respect to their RF functional tests, package configuration, and projected cost. Following this initial screening, it becomes necessary to narrow the field down to, say, two suppliers who will support the program through the advanced design, pre-production, and production phases.

It is the intention of this article to focus on four important criteria that may be helpful in judging the relative merits of a new transistor. Easily done with the aid of equipment normally available to users of 1 GHz power transistors, the OEM designer may wish to examine in a quantitative manner:

I. Resistance to Metal Migration Failure
II. Integrity of Thermal Design
III. Parasitic Capacitance
IV. Voltage and Current Saturation; Overvoltage and Overdrive

I. Resistance to Metal Migration Failure

Electromigration in metal thin films has been the subject of numerous investigations during the last few years. Scientific interest seemed to peak in the 1970 to 1975 time period, centering on an aluminum versus gold comparison relative to electromigration in microwave transistors. Since then, most manufacturers have developed a gold metal process rendering the controversy somewhat academic. Nevertheless, electromigration poses a long-term potential threat to reliability due to metallization discontinuities occurring in the feeder paths that emanate from the emitter wire bond pads. See Figure 1.

High current densities are encountered in all 1 GHz silicon power transistors because of the necessity to minimize device parasitic capacitance and thereby achieve usable gain and efficiency. The emitter metal conducts a net direct current nearly equal to the average collector current measured during the functional RF test. It is necessary to determine what fraction of the total DC current flows in each emitter feeder by dividing the total current by the number of feeder paths. It will be necessary to use the filar eyepiece on a high power microscope and to measure the width of a feeder element. Assume the thickness of the metal film is 1.0 to 1.6μm. Calculate the current density:

$$J\,(\text{amperes/cm}^2) = \frac{\text{Average DC Current in each Emitter Metal Feeder}}{\text{Measured Width x Thickness}}$$

The degree of metal electromigration is determined by current density, time, temperature, and an activation energy peculiar to the particular metal and its

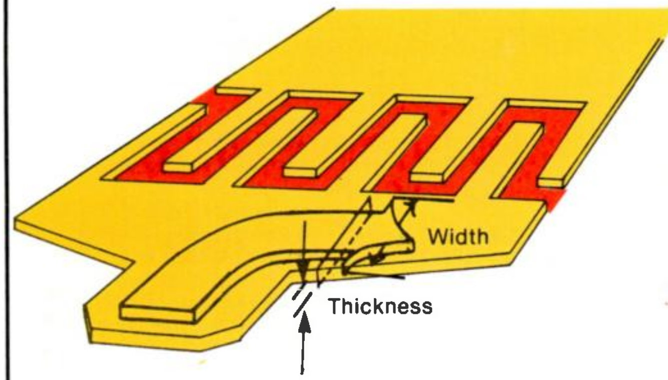


Figure 1.

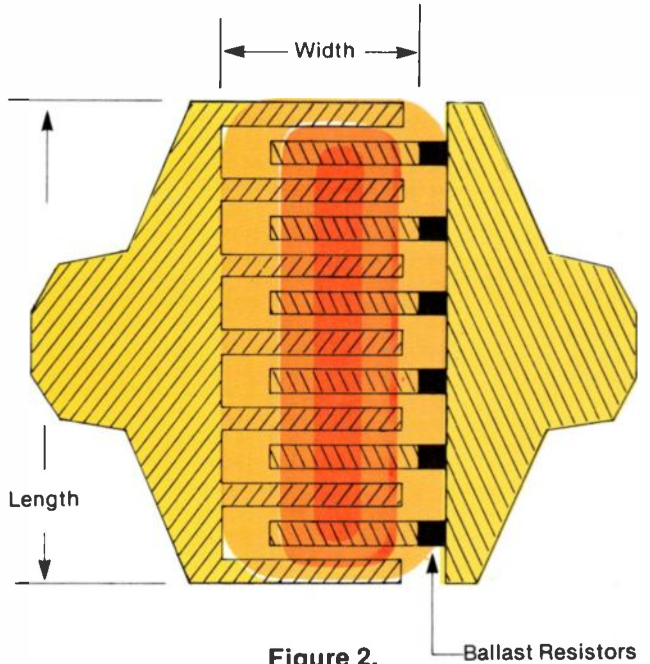


Figure 2.

polycrystalline grain structure. For example, a test at Thomson CSF-SSM Division has shown that gold metallized transistors will sustain current densities of 2 x 10^6 amperes/cm^2 at 200°C for at least 1,000 hours before a failure occurs due to a discontinuity.

Assume that you are designing your amplifier with near state-of-the-art 1 GHz transistors and are using them at rated power. You want to minimize the cost per watt and build a cheaper, better power amplifier than your competition. It is almost certain that the maximum silicon junction temperature is between 150° and 200°C if the heat sink temperature is 50° to 100°C. This is because power performance at 1 GHz today, is limited by thermal dissipation — by a 200°C maximum junction temperature. A 500 W, 1090 MHz, 10μsec pulse transistor and a 50 W, 870 MHz CW transistor are both limited equally by thermal dissipation. Using this argument, we contend that current densities greater than 2 x 10^6 amperes/cm^2 for gold and 2 x 10^5 amperes/cm^2 for aluminum should concern you, especially if your power amplifier is going to be on for more than 1 percent of the time.

II. Integrity of Thermal Design

The overwhelming largest single cause of 1 GHz transistor failure is burnout. This usually occurs during load VSWR stress when some part of the transistor reaches an unknown critical temperature when irreversible damage occurs. Electrical energy stored in the capacitive elements of the transistor and test circuit is dumped into this damaged region where the collector-base field has collapsed. The result is the all-too-familiar, melted, blackened silicon. The art of making a 1 GHz transistor that has a tolerance to the dissipation levels encountered during extreme VSWR stress requires a multicell layout that allows adequate space between each of these heat generating cells. This decreases the overall thermal resistance of the transistor. But, even more important are control of: (1) epitaxial layer thickness and resistivity, (2) discrete resistors in series with each emitter element. These two design features are employed to offset the tendency of a bipolar transistor to form hot spots. Hot spots tend to become hotter due to a localized reduction in the emitter-base forward voltage drop with increasing temperature. More current becomes injected there. The heating is regenerative. Advocates of V-FET RF power devices refer to this troublesome habit of bipolars as "current-hogging." Most manufacturers of 1 GHz power transistors have, therefore, provided undepleted, resistivity-buffered epitaxial silicon layers and emitter ballast resistors. These provide degenerative feedback of RF drive to any developing hot spot.

But, most manufacturers have, up to now, ignored a design feature which makes a large difference between a transistor being fragile or rugged with respect to high VSWR conditions. They ignore the *width* of each active cell. See Figure 2.

The geometric center of the cell runs hotter than at the edges, where heat can flow laterally as well as vertically toward the heat sink. This normal thermal imbalance becomes magnified by the hot-spot current-regeneration effect which focuses RF drive at the geometric center. The wider the cell, the greater the temperature gradient between center and edge. Aggravating this thermal regenerative effect is the decreasing thermal conductivity of the silicon at the cell center. Silicon loses its ability to conduct heat with increasing temperature. We have found a striking correlation between cell width and VSWR tolerance and have arranged an approximate table of allowable cell width versus pulse width. The heat buildup at the cell centers is a function of cell width, pulse width, power dissipation per unit area, thermal conductivity of silicon, and the spreading resistance of the epitaxial layer. The cell width, which profoundly affects VSWR tolerance, is easy to measure with a filar eyepiece. Examine the cell widths of your transistor.

Table I — Recommended Cell Widths vs. Pulse Width

Pulse Width (μseconds)	Maximum Cell Width (μm)
1-5	Any Width
5-15	80
15-50	60
50-200	45
>200	35
CW	35

Note 1: Off time between pulses at least 100 μsec which allows significant cooling between pulses.
Note 2: Case temperature $\leqslant$ 100°C.
Note 3: If the manufacturer has provided vertical emitter side ballasting instead of conventional emitter finger ballasting, he provides control against cell-center heat buildup and this table is not applicable.

III. Parasitic Capacitance

Parasitic output capacitance feeds back output power to the emitter and base. This undesirable capacitance reduces isolation between input and output, decreases bandwidth and efficiency. In particular, the MOS capacitance (C_{MOS}) part of the total output capacitance (MOS, junction, and package) can be significantly reduced by careful layout and thick collector oxide. See Figure 3. Reducing this parasitic capacitance will increase bandwidth, efficiency, and output impedance without penalty. It is possible to separate MOS capacitance from junction capacitance by a simple technique. Measure the output capacitance as a function of collector-base reverse voltage. Plot C_{cb} versus $1/\sqrt{V_{cb}}$ and you will see a straight line that begins to curve at higher voltages. See Figure 4. A graded junction formed by diffusion or ion implantation has an inverse square root dependence. If a straight line is drawn between, say, the 3 to 10 volt points and extrapolated to the Y-axis, this intercept will be the MOS capacitance. Higher voltage points should be ignored in making this extrapolation because the voltage-widened depletion region "subtracts" MOS capacitance as it spreads under the base and emitter metal.

Before proceeding further, it should be mentioned that the internal shunt inductor wires on collector-matched transistors have to be removed for the purposes of this analysis; otherwise, the large-valued bypass capacitors appear as part of the MOS capacitance.

Since we want to develop a figure of merit to compare similar transistors and judge how careful the designer was in laying out base and emitter metallization, we wish to measure emitter periphery (Ep). Then we'll see how much RF power capability the designer has managed to get for every pico-Farad of parasitic capacitance. Measuring emitter periphery is tedious. Instead, it can be estimated by assuming that 1 GHz transistors have 1.65 to 1.9 cm of Ep for every ampere of average DC collector current they draw during the functional RF test. This is at the point in the P_{in}/P_{out} curve where the transistor is in current saturation. See Figure 5(a) for example. This transistor is in current saturation at about P_{out} = 360 watts (peak) drawing 16.7 amperes (peak) as measured. Its Ep is, in fact, 30.7 cm total. This is calculated to be 1.84 cm per ampere.

Use 1.65 cm/ampere for 12.5 volt CW transistors and 1.9 cm/ampere for 28 volt CW and 45 volt pulsed transistors. Calculate Ep/C_{MOS} for your transistor and rate it using Table II.

Table II — Figure of Merit for Parasitic Capacitance of 1 GHz Silicon Bipolar Transistors

Ep/C_{MOS} (cm per pF)	Rating
Less than 0.25	Unacceptable.
0.25 to 0.50	Designer gives away 10 percent efficiency.
0.50 to 0.75	Barely adequate parasitic control. OK for narrowband and low power applications.
0.75 to 1.00	Good transistor.
1.00 and Greater	Excellent. This geometry could be used at 2 GHz.

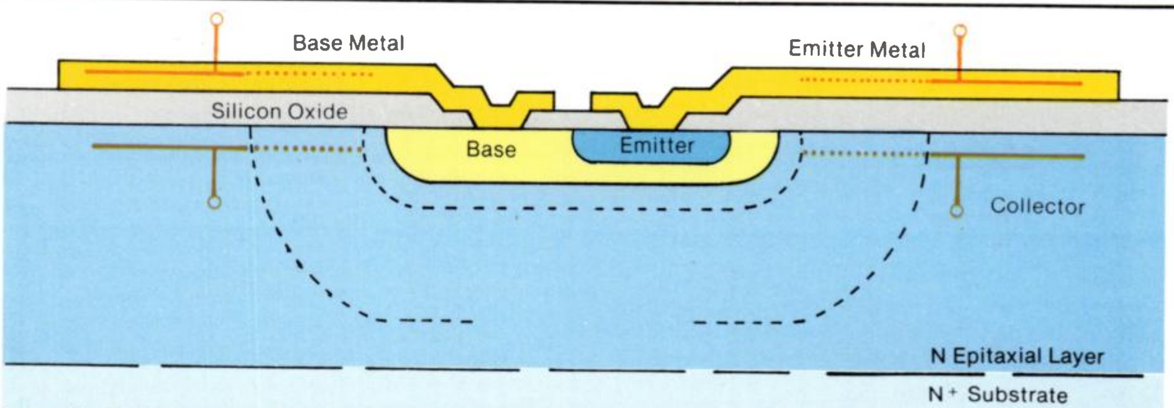


Figure 3. The parasitic MOS capacitance resulting from the emitter and base metals and the collector epitaxial layer is symbolically depicted in blue. As can be seen, when the collector-base voltage (V_{CB}) is increased the depletion region expands, thereby reducing the value of C_{MOS} (which is assumed to be a constant of the transistor).

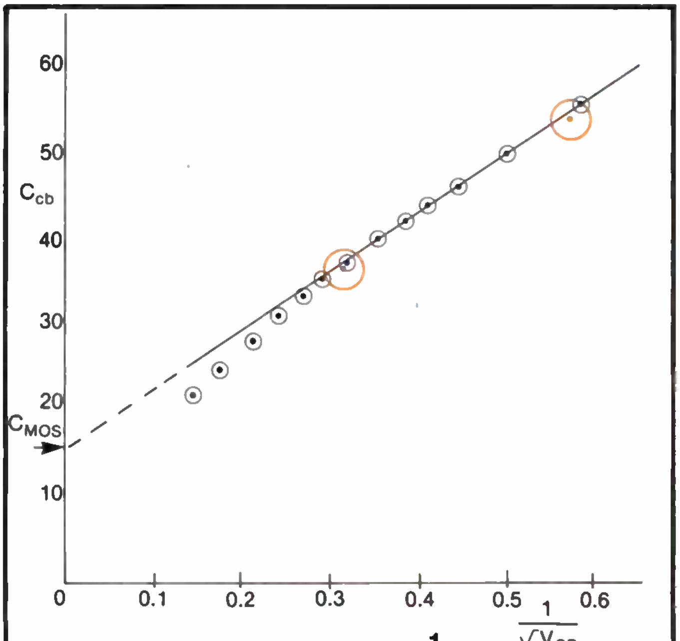


Figure 4. C_{CB} versus $\frac{1}{\sqrt{V_{CB}}}$

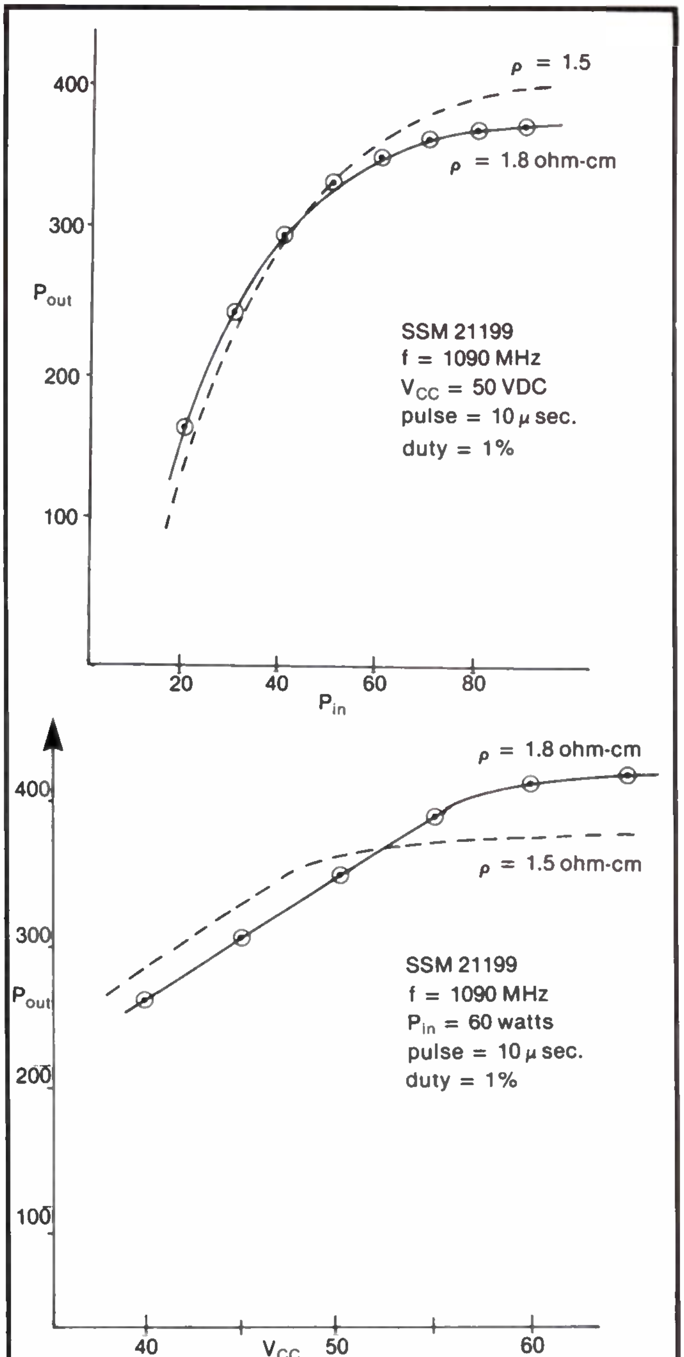
It is seen that the designer must compromise between the above figure of merit and cell width. Long, narrow cells are better thermally and sustain more VSWR abuse, but require more base and emitter metallization to feed them. This tends to increase the MOS capacitance. Also, if the designer chooses to narrow the width of the metal feeders to reduce MOS capacitance, the current density increases which, as we have seen, may have a deleterious effect on long-term reliability due to electromigration.

IV. Voltage and Current Saturation

Worse case design prompts the user to examine current and voltage saturation limits of performance to avoid overspecifying the transistor. Typical current and voltage saturation curves are shown in Figures 5(a) and 5(b). Observe how normal manufacturing variations, such as epitaxial resistivity (ρ), alter device performance. Other manufacturing variations (such as base diffusion depth, image size, base dopant level, metal to silicon contact resistance) will affect device parameters. We suggest imposing a 10 percent guard band on the Pin/Pout curve that you generate with new sample transistors. Conversely, if your required Pout (at a given Pin and Vcc level) falls within 10 percent of observed Pout, the transistor may be too marginal, eventually leading to potential problems with fixture correlation, delivery, and final test yields.

After you have satisfied yourself that the transistor has enough margin to allow for a 10 percent loss in Pout due to manufacturing variations (and another 10 percent loss in Pout under worst case heat sink temperatures, say at 100°C), try overdriving the device by 50 percent. Does the device latch up or power sag? Common emitter transistors may latch into a $f_o/2$ oscillation due to improper phase balancing at the chip level, and CW (and long pulse) transistors may power sag if the entire geometry is not driven and loaded in phase or the epitaxial layer is much too thick. Now return the device to normal drive and raise the voltage by 25 percent. The Pout should increase by at least 10 percent or you are too close to voltage saturation. See Figure 5(b). If the device becomes destroyed at either condition, then the manufacturer has not provided adequate epitaxial thickness or has used a geometry with too wide a cell-width for your application, or both.

Now how good is your 1 GHz bipolar power transistor? □



Figures 5 (a) and (b). Current and Voltage saturation where ρ = collector resistivity.

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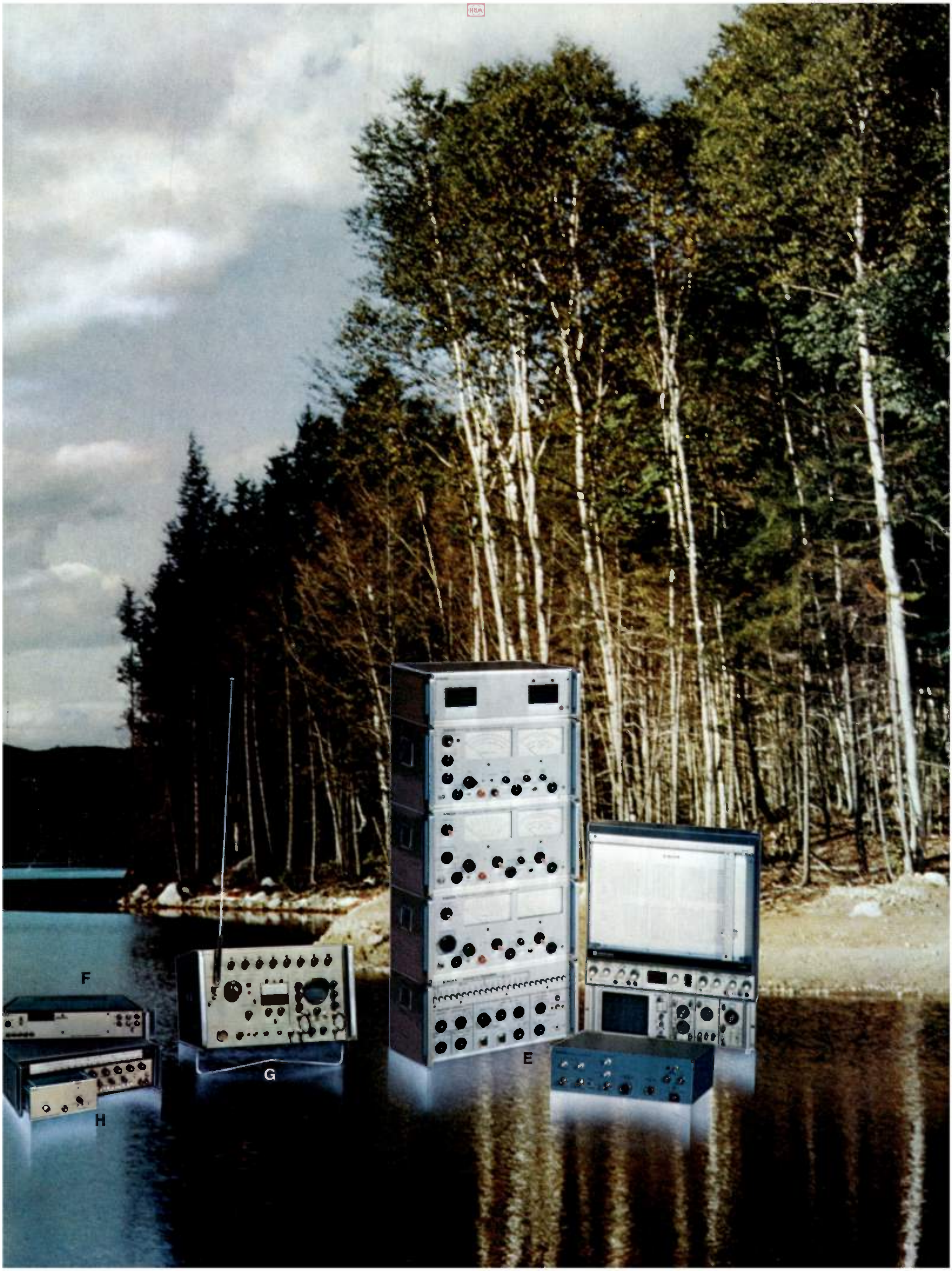
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Design with PIN Diodes, Part II

By Gerald Hiller
Unitrode Corporation

Part I of this article described the PIN diode model and discussed the design of various types of RF switches. This article describes the design of PIN diode attenuator and phase shifter circuits. The distortion model of the PIN diode is introduced and a discussion of techniques to reduce distortion in PIN diode circuits is presented.

PIN Diode Attenuators

In an attenuator application the resistance characteristic of the PIN diode is exploited not only at its extreme high and low values as in switches but at the finite values in between.

The resistance characteristic of a PIN diode when forward biased to I_F, depends on the I-region width (W), carrier lifetime (τ), and the hole and electron mobilites (μp, μn) as follows:

$$R_S = W^2/(\mu_p + \mu_n)\, I_F \tau. \qquad \text{ohms} \qquad (1)$$

For a PIN diode with an I-region width of typically 250μM, carrier lifetime of 4μS, and μ_n of .13, μ_p of .05 m²/v-s, Figure 1 shows the R_S vs current characteristic.

In the selection of a PIN diode for an attenuator application the designer must often be concerned about the range of diode resistance which will define the dynamic range of the attenuator. PIN diode attenuators tend to be more distortion sensitive than switches since their operating bias point often occurs

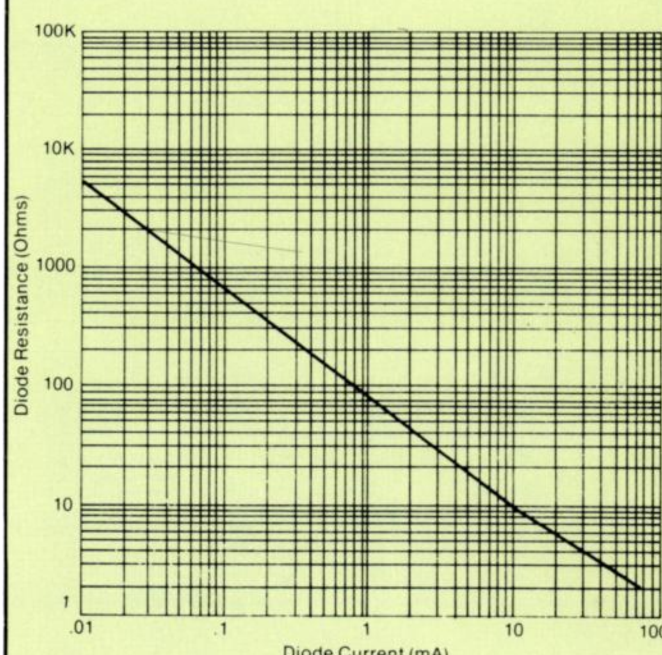

Figure 1.
Typical Diode Resistance VS Forward Current

at a low value of quiescent stored charge. A thin I-region PIN will operate at lower forward bias currents than thick PIN diodes but the thicker one will generate less distortion.

PIN diode attenuator circuits are used extensively in automatic gain control (AGC) and RF leveling applications as well as in electronically controlled attenuators and modulators. A typical configuration of an AGC application is shown in Figure 2. The PIN diode attenuator may take many forms ranging from a simple series or shunt mounted diode acting as a lossy reflective switch or a more complex structure that maintains a constant matched input impedance across the full dynamic range of the attenuator.

Although there are other methods for providing AGC functions, such as varying the gain of the RF transistor amplifier, the PIN diode approach generally results in lower power drain, less frequency pulling, and lower RF signal distortion. The latter results are especially true, when diodes with thick I-regions and long carrier lifetimes are used in the attenuator circuits. Using these PIN diodes, one can achieve wide dynamic range attenuation with low signal distortion at frequencies ranging from below 1 MHz up to well over 1 GHz.

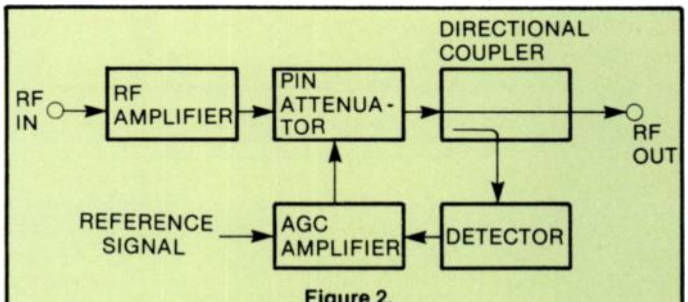

Figure 2.
RF AGC/Leveler Circuit

Reflective Attenuators

An attenuator may be designed using single series or shunt connected PIN diode switch configurations as shown in Figure 3. These attenuator circuits utilize the current controlled resistance characteristic of the PIN diode not only in its low loss states (very high or low resistance) but also at in-between, finite resistance values. The attenuation value obtained using these circuits may be computed from the following equations:

Attenuation of Series Connected
PIN Diode Attenuator

$$A = 20 \log \left(1 + \frac{R_S}{2Z_0}\right) \quad dB \qquad (2)$$

Attenuation of Shunt Connected
PIN Diode Attenuator

$$A = 20 \log \left(1 + \frac{Z_0}{2R_S}\right) \quad dB \qquad (3)$$

These quations assume the PIN diode to be purely resistive. The reactance of the PIN diode capaci-

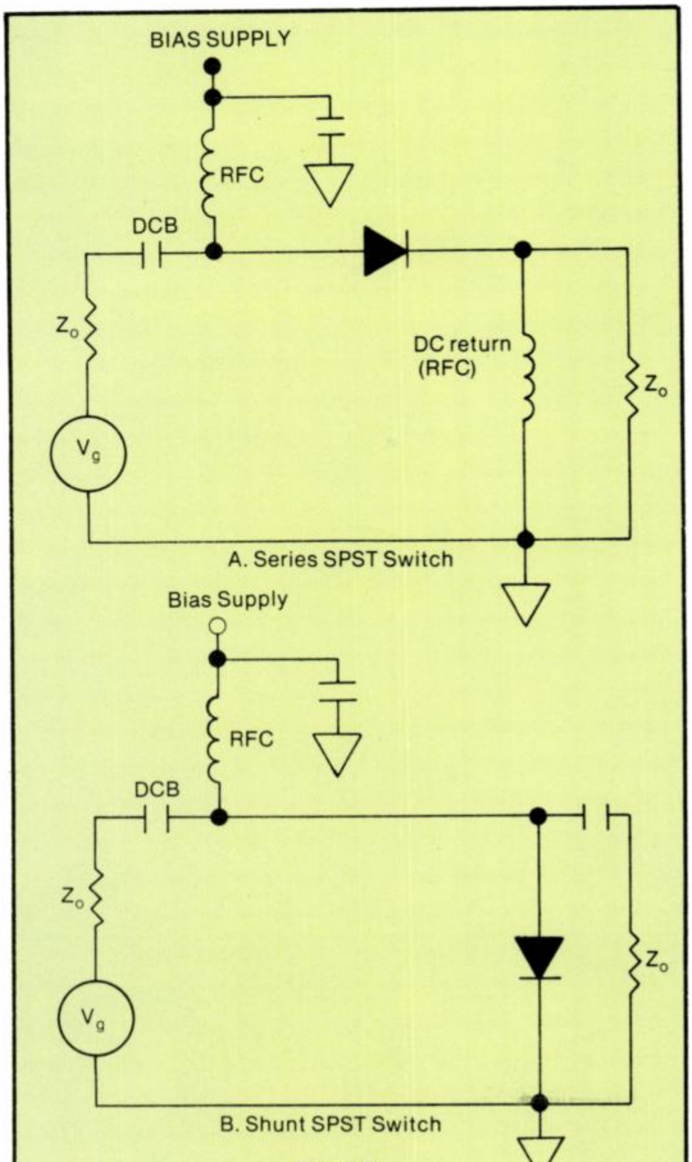

Figure 3.
SPST PIN Diode Switches

tance, however, must also be taken into account at frequencies where its value begins to approach the PIN diode resistance value.

Matched Attenuators

Attenuators built from switch design are basically reflective devices which attenuate the signal by producing a mismatch between the source and the load. Matched PIN diode attenuator designs, which exhibit constant input impedance across the entire attenuation range, are also available which use either multiple PIN diodes biased at different resistance points or bandwidth-limited circuits utilizing tuned elements. They are described as follows:

Quadrature Hybrid Attenuators

Although a matched PIN attenuator may be achieved by combining a ferrite circulator with one of the previous simple reflective devices, the more common approach makes use of quadrature hybrid circuits. Quadrature hybrids are commonly available at frequencies from below 10 MHz to above 1 GHz, with bandwidth coverage often exceeding a decade. Figures 4 and 5 show typical quadrature hybrid circuits employing series and shunt connected PIN diodes. The following equations summarize this performance:

Quadrature Hybrid
(Series Connected PIN Diodes)

$$A = 20 \log \left(1 + \frac{2Z_0}{R_S}\right) \quad dB \qquad (4)$$

Quadrature Hybrid
(Shunt Connected PIN Diodes)

$$A = 20 \log \left(1 + \frac{2R_S}{Z_0}\right) \quad dB \qquad (5)$$

The quadrature hybrid design approach is superior to the circulator coupled attenuator from the standpoint of lower cost and the achievement of lower frequency operation. Because the incident power is divided into two paths, the quadrature hybrid configuration is also capable of handling twice the power of simple series and shunt diode attenuators. It can be shown that the maximum power dissipated in each diode will be only one quarter of the incident power and this occurs at the 6 dB attenuation point. Each load resistor, however, must be capable of dissipating one half the total input power at the time of maximum attenuation.

Both of the above types of hybrid attenuators

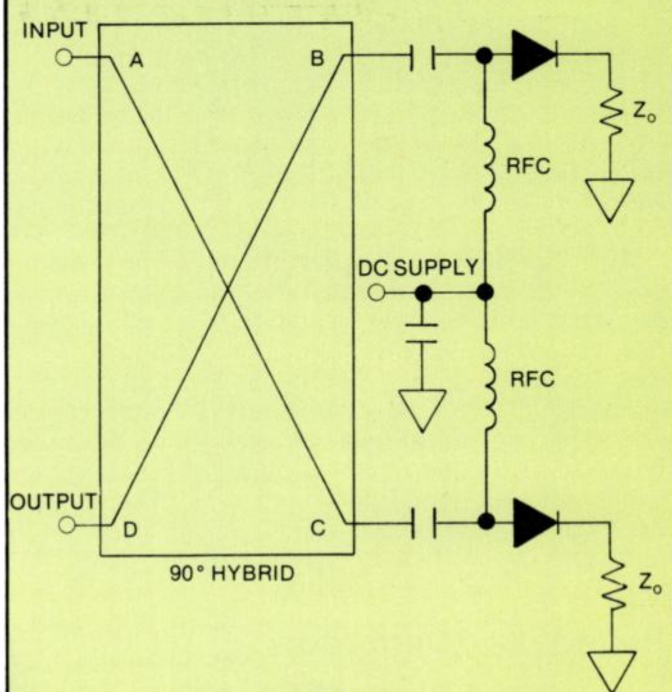

Figure 4.
Quadrature Matched Hybrid Attenuator
(Series Connected Diodes)

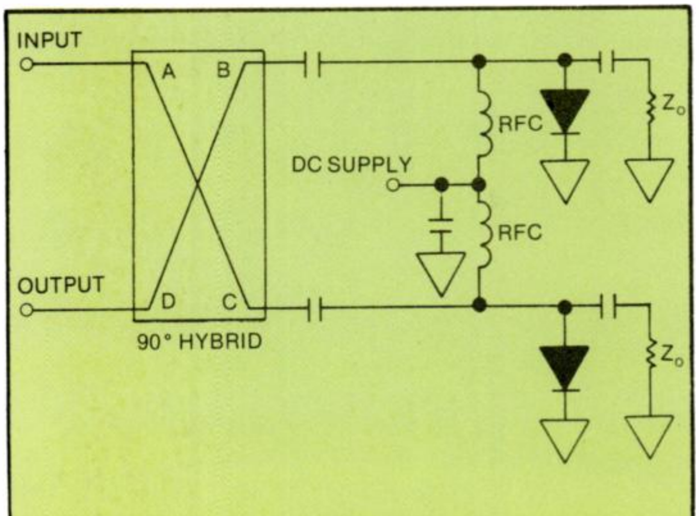

Figure 5.
Quadrature Hybrid Matched Attenuator (Shunt Connected PIN Diodes)
Constant impedance attenuator circuit. The power incident on port A divides equally between ports B and C, port D is isolated. The mismatch produced by the PIN Diode resistance in parallel with the load resistance at ports B & C reflects part of the power. The reflected power exits port D isolating port A. Therefore A, appears matched to the input signal.

offer good dynamic range. The series connected diode configuration is, however, recommended for attenuators used primarily at high attenuation levels (greater than 6 dB) while the shunt mounted diode configuration is better suited for low attenuation ranges.

Quadrature hybrid attenuators may also be constructed without the load resistor attached in series or parallel to the PIN diode as shown. In these circuits the forward current is increased from the 50Ω, maximum attenuation, R_S value to lower resistance values. This results in increased stored charge as the attenuation is lowered which is desirable for lower distortion. The purpose of the load resistor is both to make the attenuator less sensitive to individual diode differences and increase the power handling capacity by a factory of two.

Quarter-Wave Attenuators

A matched attenuator may also be built using quarter-wave techniques. Figures 6 and 7 show examples of these circuits. For the quarter-wave section a lumped equivalent may be employed at frequencies too low for practical use of line lengths. This equivalent is shown in Figure 8.

The performance equations for these circuits are given below:

Quarter-Wave Attenuator
(Series Connected Diode)

$$A = 20 \log \left(1 + \frac{Z_0}{R_S}\right) \quad \text{dB} \qquad (6)$$

Quarter-Wave Attenuator
(Shunt Connected Diode)

$$A = 20 \log \left(1 + \frac{R_S}{Z_0}\right) \quad \text{dB} \qquad (7)$$

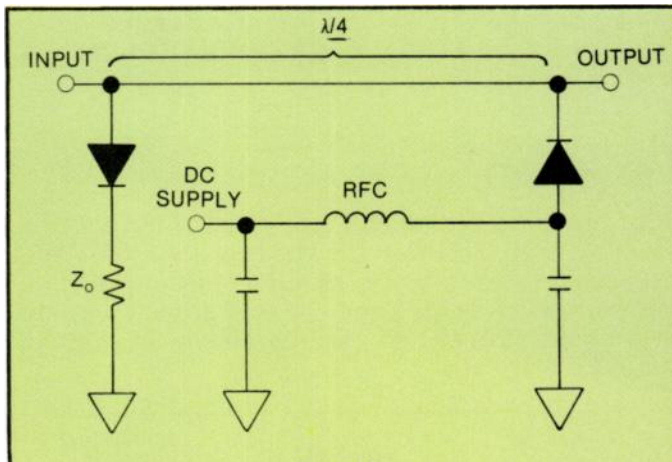

Figure 6.
Quarter Wave Matched Attenuator (Series Connected Diode)

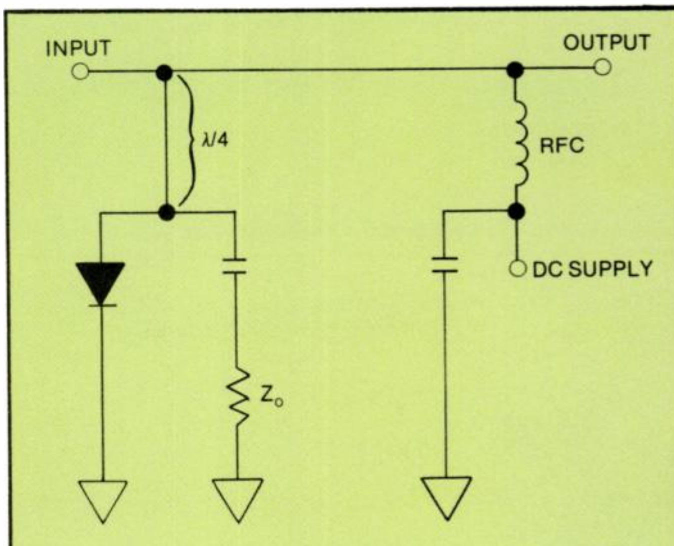

Figure 7.
Quarter Wave Matched Attenuator (Shunt Connected Diode)

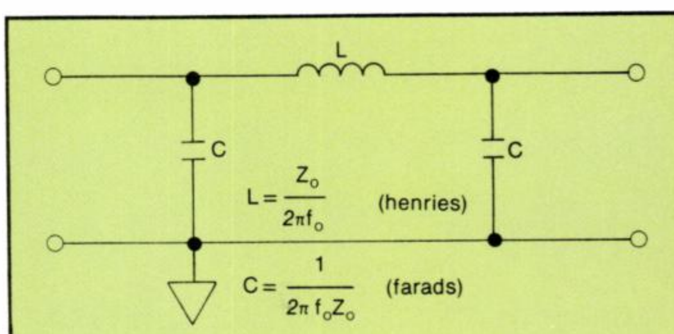

Figure 8.
Lumped Circuit Equivalent Of Quarter Wave Line

A matched condition is achieved in these circuits when both diodes are at the same resistance. This condition should normally occur when using similar diodes since they are DC series connected, with the same forward bias current flowing through each diode. The series circuit of Figure 6 is recommended for use at high attenuation levels while the shunt diode circuit of Figure 7 is better suited for low attenuation circuits.

Bridged TEE and PI Attenuators

For matched broadband applications, especially those covering the low RF (1 MHz) through UHF, attenuator designs using multiple PIN diodes are employed. Commonly used for this application are the bridged TEE and PI circuits shown in Figures 9 and 10.

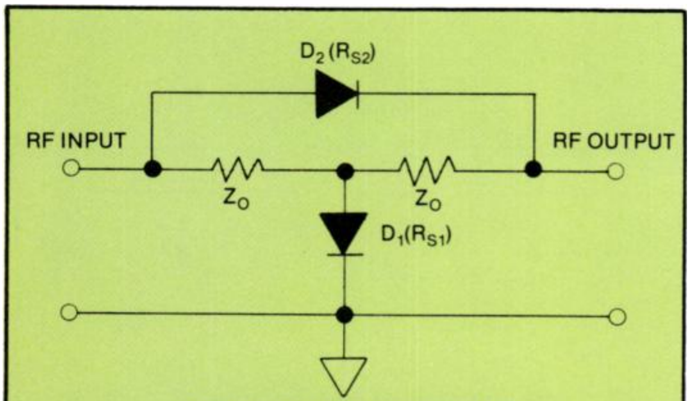

Figure 9. Bridged Tee Attenuator

The attenuation obtained using a bridged TEE circuit may be calculated from the following:

$$A = 20 \log \left(1 + \frac{Z_0}{R_{S_1}}\right) \quad dB \qquad (8)$$

Where:

$$Z_0^2 = R_{S_1} \times R_{S_2} \quad ohms^2 \qquad (9)$$

The relationship between the forward resistance of the two diodes insures maintenance of a matched circuit at all attenuation values.

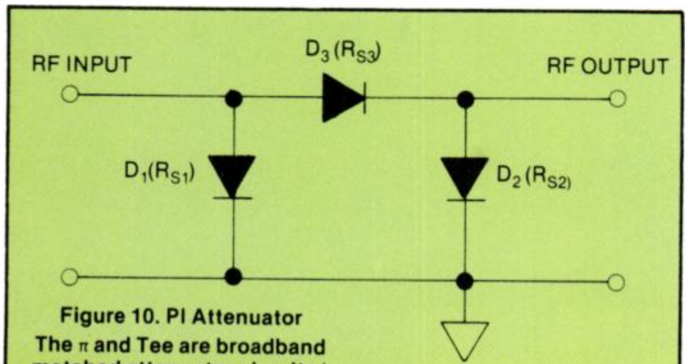

Figure 10. PI Attenuator
The π and Tee are broadband matched attenuator circuits.)

The expressions for attenuation and matching conditions for the PI attenuator are given as follows:

$$A = 20 \log \left(\frac{R_{S_1} + Z_0}{R_{S_1} - Z_0}\right) \quad dB \qquad (10)$$

Where:

$$R_{S_3} = \frac{2R_{S_1} Z_0^2}{R_{S_1}^2 - Z_0^2} \quad ohms \qquad (11)$$

$$R_{S_1} = R_{S_2} \quad ohms \qquad (12)$$

Using these expressions, Figure 11 gives a graphical display of diode resistance values for a 50Ω PI attenuator. Note that the minimum value for R_{S_1}

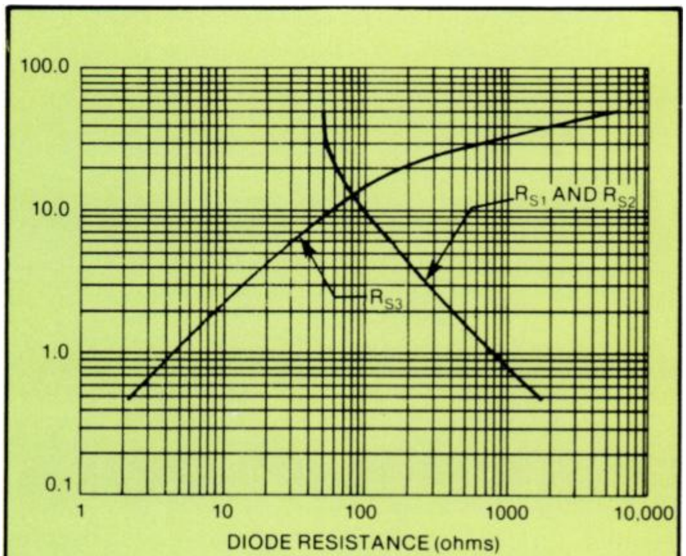

Figure 11.
Attenuation of PI Attenuators

and R_{S_2} is 50Ω. In both the bridged TEE and PI attenuators, the PIN diodes are biased at two different resistance points simultaneously which must track in order to achieve proper attenuator performance.

PIN Diode Modulators

PIN diode switches and attenuators may be used as RF amplitude modulators. Square wave or pulse modulation use PIN diode switch designs whereas linear modulators use attenuator designs.

The design of high power or distortion sensitive modulator applications follows the same guidelines as their switch and attenuator counterparts. The PIN diodes they employ should have thick I-regions and long carrier lifetimes. Series connected or preferably back-to-back configurations always reduce distortion. The sacrifice in using these devices will be lower maximum frequencies and higher modulation current requirements.

The quadrature hybrid design is recommended as a building block for PIN diode modulators. Its inherent built-in isolation minimizes pulling and undesired phase modulation on the driving source.

PIN Diode Phase Shifters

PIN diodes are utilized as series or shunt connected switches in phase shifter circuit designs. In such cases, the elements switched are either lengths of transmission line or reactive elements. The criteria for choosing PIN diodes for use in phase shifters is similar to those used in selecting diodes for other switching applications. One additional factor, however, that must often be considered, is the possibility of introducing phase distortion particularly at high RF power levels or low reverse bias voltages. Of significant note is the fact that the properties inherent in PIN diodes which yield low distortion, i.e., a long carrier lifetime and thick I-regions, also result in low phase distortion of the RF signal. Three of the most common types of semiconductor phase shifter circuits, namely: the switched line, loaded line and hybrid coupled designs are described as follows:

- **Switched Line Phase Shifter**

A basic example of a switched line phase shifter circuit is shown in Figure 12. In this design, two SPDT switches employing PIN diodes are used to change the electrical length of transmission line by some length. $\Delta \ell$. The phase shift obtained from this circuit varies with frequency and is a direct function of this differential line length as shown below:

$$\Delta\varnothing = 2\pi\Delta\ell/\lambda \quad \text{radians} \quad (13)$$

The switched line phase shifter is inherently a broad-band circuit producing true time delay, with the actual phase shift dependent only on $\Delta\ell$. Because of PIN diode capacitance limitations this design is most frequently used at frequencies below 1 GHz.

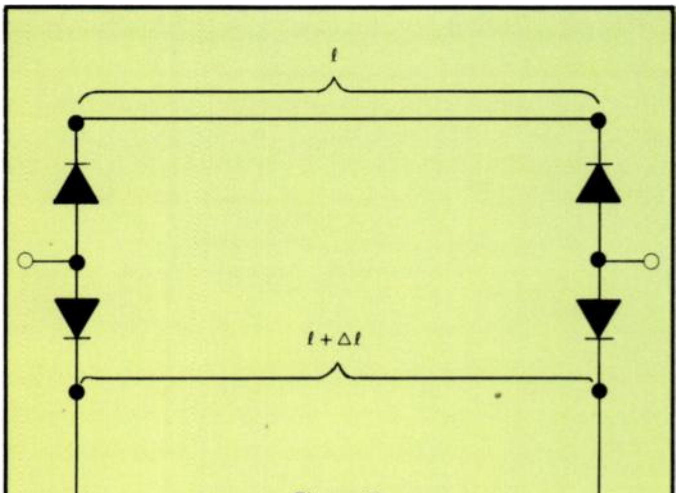

Figure 12.
Switched Line Phase Shifter

The power capabilities and loss characteristics of the switched line phase shifter are the same as those of a series connected SPDT switch. A unique characteristic of this circuit is that the power and voltage stress on each diode is independent of the amount of differential phase shift produced by each phase shifter. Thus, four diodes are required for each bit with all diodes having the same power and voltage ratings.

- **Loaded Line Phase Shifter**

The loaded line shifter design shown in Figure 13 operates on a different principle than the switched line phase shifter. In this design the desired maximum phase shift is divided into several smaller phase shift sections, each containing a pair of PIN diodes which do not completely pertubate the main transmission line. A major advantage of this phase shifter is its extremely high power capability due partly to the use of shunt mounted diodes plus the fact that the PIN diodes are never in the direct path of the full RF power.

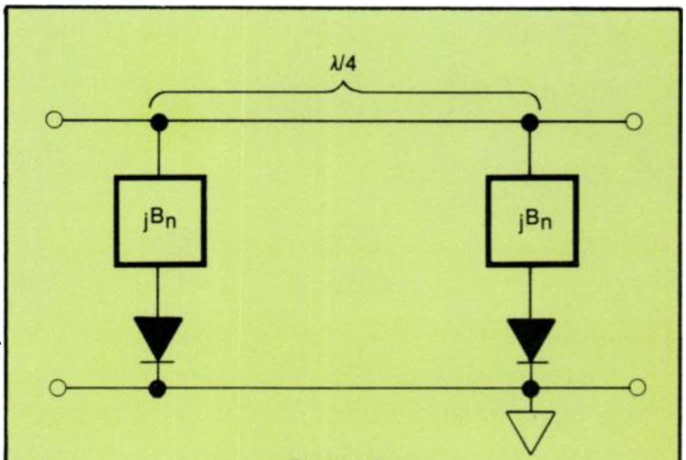

Figure 13.
Loaded Line Phase Shifter

In loaded line phase shifters, a normalized susceptance, B_n, is switched in and out of the transmission path by the PIN diodes. typical circuits use values of B_n, much less than unity, thus resulting in considerable decoupling of the transmitted RF power from the PIN diode. The phase shift for a single section is given as follows:

$$\varnothing = 2\tan^{-1}\left(\frac{B_n}{1-(B_n^2/8)}\right) \quad \text{radians} \quad (14)$$

The maximum phase shift obtainable from a loaded line section is limited by both bandwidth and diode power handling considerations. The power constraint on obtainable phase shift is shown as follows:

$$\varnothing max = 2\tan^{-1}\left(\frac{V_{BR}I_F}{4P_L}\right) \quad \text{radians} \quad (15)$$

Where:
$\varnothing max$ = maximum phase angle
P_L = power transmitted
V_{BR} = diode breakdown voltage
I_F = diode current rating

The above factors limit the maximum phase shift angle in practical circuits to about 45°. Thus, a 180° phase shift would require the use of four 45° phase shift sections in its design.

- **Reflective Phase Shifter**

A circuit design which handles both high, RF power and large incremental phase shifts with the fewest number of diodes is the hybrid coupled phase shifter shown in Figure 14. The phase shift for this circuit is given below:

$$\Delta\varnothing = 4\pi\Delta\ell/\lambda \quad \text{radians} \qquad (16)$$

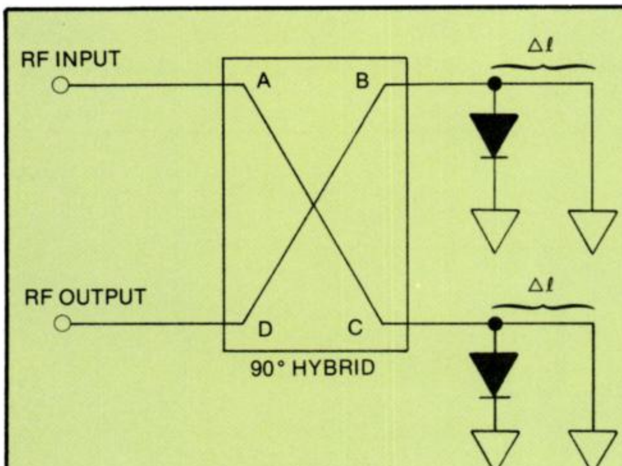

Figure 14.
Hybrid Coupler Reflective Phase Shifter

The voltage stress on the shunt PIN diode in this circuit also depends on the amount of desired phase shift or "bit" size. The greatest voltage stress is associated with the 180° bit and is reduced by the factor $(\sin\varnothing/2)^{1/2}$ for other bit sizes. The relationship between maximum phase shift, transmitted power, and PIN diode ratings is as follows:

$$\varnothing max = 2\sin^{-1}\left(\frac{V_{BR}I_F}{8P_L}\right) \quad \text{radians} \qquad (17)$$

In comparison to the loaded line phase shifter, the hybrid design can handle up to twice the peak power when using the same diodes. In both hybrid and loaded line designs, the power dependency of the maximum bit size relates to the product of the maximum RF current and peak RF voltage the PIN diodes can handle. By judicious choice of the nominal impedance in the plane of the PIN diode, the current and voltage stress can usually be adjusted to be within the device ratings. In general, this implies lowering the nominal impedance to reduce the voltage stress in favor of higher RF currents. For PIN diodes, the maximum current rating should be specified or is dependent upon the diode power dissipation rating while the maximum voltage stress at RF frequencies is dependent on I-region thickness.

PIN Diode Distortion Model

The sections in Part I of this article concerned with large signal operation and thermal considerations allows the circuit designer to avoid conditions that would lead to significant changes in PIN diode performance or excessive power dissipation. A subtle but often significant operating characteristic is the distortion or change in signal shape which is always produced by a PIN diode in the signal it controls.

The primary cause of distortion is any variation or non-linearity of the PIN diode impedance during the period of the applied RF signal. These variations could be in the diode's forward bias resistance, R_S, parallel resistance, R_P, capacitance, C_T, or the effect of the low frequency I-V characteristic. The level of distortion can range from better than 100 dB below, to levels approaching the desired signal. The distortion could be analyzed in a fourier series and takes the traditional form of harmonic distortion of all orders, when applied to a single input signal, and harmonic intermodulation distortion when applied to multiple input signals.

Non-linear, distortion generating behavior is often desired in PIN and other RF oriented semiconductor diodes. Self biasing limiter diodes are often designed as thin I-region PIN diodes operating near or below their transit time frequency. In a detector or mixer diode the distortion that results from the ability of the diode to follow its I-V characteristic at high frequencies is exploited. In this regard the term "square low detector" applied to a detector diode implies a second order distortion generator. In the PIN switch circuits discussed in Part I and the attenuator and other applications discussed here, methods of selecting and operating PIN diodes to obtain low distortion are described.

There is a common misconception that minority carrier lifetime is the only significant PIN diode parameter that affects distortion. This is indeed a major factor, but another important parameter is the width of the I-region, which determines the transit time of the PIN diode. A diode with a long transit time will have more of a tendency to retain its quiescent level of stored charge. The longer transit time of a thick PIN diode reflects its ability to follow the stored charge model for PIN diode resistance according to:

$$Q = I_F\tau \quad \text{coulombs} \qquad (18)$$

and

$$R_S = \frac{W^2}{(\mu_p + \mu_n)Q} \quad \text{ohms} \qquad (19)$$

Where:

I_F = forward bias current
τ = carrier lifetime
W = I region width
μ_n = electron mobility
μ_p = hole mobility

rather than the non-linear I-V characteristic.

The effect of carrier lifetime on distortion relates to the quiescent level of stored charge induced by the DC forward bias current and the ratio of this stored charge to the incremental stored charge added or removed by the RF signal.

Distortion in PIN Diode Switches

Although no analysis has yet been presented to clearly identify the exact magnitude of distortion produced relative to PIN diode and other circuit parameters there are some general guidelines that the circuit designer should follow.

In a distortion sensitive RF switch circuit, the PIN diodes selected should have wide I-regions(W) and long carrier lifetimes. Since stored charge depends on the product of forward bias current and carrier lifetime, the diodes should be both forward biased to as high a current as feasible and reverse biased at the highest voltage possible. A high reverse bias allows the RF voltage swing to remain in the region where there is less incremental charge of the diode capacitance, parallel resistance and DC characteristic. The maximum limit of reverse bias is where the peak signal voltage exceeds the RF breakdown voltage.

Distortion produced in the PIN diode circuit can be reduced further by adding another PIN diode in series with the first which increase the effective I-region width of the diode. In addition, if the diodes are connected in a back-to-back orientation (cathode to cathode or anode to anode), an additional decrease in distortion will occur due to cancellation effects of distortion currents. This cancellation should be total but the distortion produced by each diode is not exactly of the same magnitude and is in anti-phase. Approximately 20 dB distortion improvement may be expected by this back-to-back configuration.

Distortion in Attenuator Circuits

In attenuator applications, distortion is directly relatable to the ratio of RF to DC stored charge. In such applications, PIN diodes operate only in the forward bias state and often at high resistance values where the stored charge may be very low. Under these operating conditions, distortion will vary with changes in the attenuation level. Thus, PIN diodes selected for use in attenuator circuits need only be chosen for their thick I-region width, since the stored charge at any fixed diode resistance, R_S, is only dependent on this dimension.

Consider a UM4301B PIN diode used in an application where a resistance of 50Ω is desired. The UM4300 data sheet indicates the 1mA is the typical diode current at which this occurs. Since the carrier lifetime specification for this diode is 5μS (minimum), the minimum stored charge for the UM4300 diode at 50Ω is 5 nC. If two UM4300 PIN diodes, however, are inserted in series, to achieve the same 50Ω resistance level, each diode must be biased at 2mA. This results in a stored charge of 10 nC per diode or a net stored charge of 20 nC. Thus, adding a second diode in series multiplies the effective stored charge by a factor of 4. This would have a significant positive impact on reducing the distortion produced by attenuator circuits.

Measuring Distortion

Because distortion levels are often 50 dB or more below the desired signal, special precautions are required in order to make accurate second and third order distortion measurements. One must first ensure that the signal sources used are free of distortion and that the dynamic range of the spectrum analyzer employed is adequate to measure the specified level of distortion. These requirements often lead to the use of fundamental frequency band stop filters at the device output as well as pre-selectors to clean up the signal sources employed. In order to establish the adequacy of the test equipment and signal sources for making the desired distortion measurements, the test circuit should be initially evaluated by removing the diodes and replacing them with passive elements. This approach permits one to optimize the test set-up and establish basic measurement limitations.

Since harmonic distortion appears only at multiples of the signal frequency, these signals may be filtered-out in narrow band systems. Second order distortion, caused by the mixing of two input signals, will appear at the sum and difference of these frequencies and may also be filtered. As an aid to identifying the various distortion signals seen on a spectrum analyzer, it should be noted that the level of a second distortion signal will vary directly at the same rate as any change of input signal level. Thus, a 10 dB signal increase will cause a corresponding 10 dB increase in second order distortion.

Third order intermodulation distortion of two input signals at frequencies F_A and F_B often produce in-band, nonfilterable distortion components at frequencies of $2F_A - F_B$ and $2F_B - F_A$. This type of distortion is particularly troublesome in receivers located nearby transmitters operating on equally spaced channels. In identifying and measuring such signals, it should be noted that third order distortion signal levels vary at twice the rate of change of the fundamental signal frequency. Thus a 10 dB change in input signal will result in a 20 dB change of the third order signal distortion power observed on a spectrum analyzer. □

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Sampling Uses For RF Measurements In Instrumentation

Derek R. Gittins
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Many measuring equipments require some form of frequency convertor which will convert a wide range of input signals to a lower frequency, without adding to or detracting from the original information present on the input signal. This is usually achieved by introducing a local oscillator to mix with the input signal and produce the necessary low frequency output. Although a conventional mixer may take many different forms, it will rely on the non-linearity of a diode or similar device to provide frequency subtraction as shown below:

Frequency of output = frequency of input − frequency of local oscillator.

Since the output frequency is low (say 100 kHz) it follows that the local oscillator frequency must track the input frequency with a 100 kHz offset. Moreover, it is desirable that the performance of the local oscillator be better than the input signal so that it does not degrade the converted input signal upon which the actual measurement processing occurs. The design of the local oscillator is therefore critical and the high performance required cannot be maintained over a wide frequency range with a single oscillator. In practice a wide spectrum is only covered using a number of oscillators, each with about an octave of frequency range.

It is possible to use fewer oscillators and range switch the frequency determining components, but the result is still unattractive in both size and cost.

An alternative approach presented here is to use a multiple response, sample-and-hold type mixer. This not only considerably eases the problem but even makes possible the design of certain equipments which have been impractical before.

Basic Sampling Techniques

The technique of sampling can be sub-divided into two classes, that of real time sampling and that of extended time sampling. The fundamental difference lies in that for real time sampling the input frequency f(in) is always less than 1/2 the sampling frequency f(s), whereas with extended time sampling f(in) must be greater than 1/2 f(s). It is, however, extended time sampling which can be made to exhibit the characteristics of a wide band mixer, and for this reason it is of particular interest to the instrument designer.

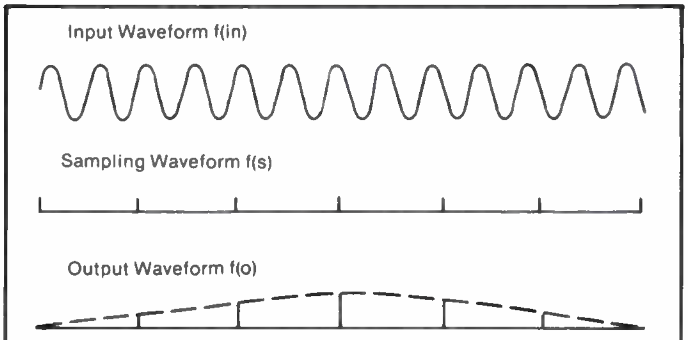

Figure 1. Extended Time Sampling converts frequency and retains wave shape of input signal.

Figure 1 shows a sinusoidal waveform, consisting of many cycles being sampled at a lower frequency than f(s). The example shows f(in) at a little over twice f(s), but this ratio could be many times greater, in which case there would be many more unsampled input cycles between each sample. The envelope of the output is a replica of the input wave shape and can be simply reconstituted by filtering with a low pass filter.

In the example, one period of the output frequency, time relates to 12 sampling periods or 25 periods of the input signal, i.e.

$$\frac{1}{f(o)} = \frac{12}{f(s)} = \frac{25}{f(in)}$$

$$\therefore f(0) = f(in) - 2.f(s)$$

In general, f(o) = f(in) – N.f(s) eqn. 1,

where N.f(s) is that harmonic nearest in frequency to f(in).

Unlike real time sampling, extended time sampling requires a number of input cycles to produce one cycle of output. The cut-off frequency of the low pass filter, however, must be less than 1/2 f(s) in order to achieve suitable mixing action, as in Figure 2.

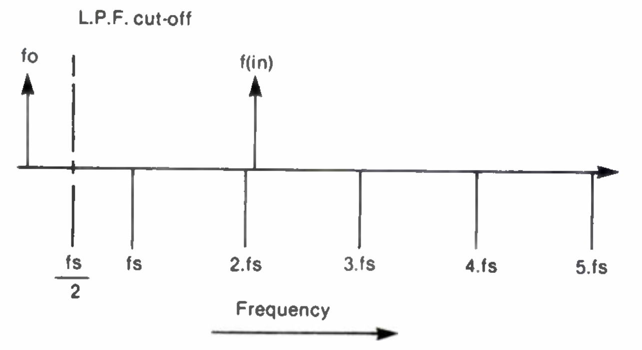

Figure 2. The mixing action of sampler shown in the frequency plane.

In practice f(in) mixes with all the harmonics of f(s) and a multiplicity of output frequencies exist. However, f(o) is the only one which can be less than 1/2 f(s) and is, therefore, the only one selected by the low pass filter. As already explained, f(o) is equal to the difference between f(in) and 2.f(s) (eqn. 1). If f(in) is changed so as to approach 2.f(s), f(o) will also change to approach zero frequency. This is the special case of synchronous sampling and occurs whenever f(in) is equal to a harmonic of f(s).

Consider now the case where it is required to produce an output signal at some specific low frequency, for presentation to a measurement circuit for example. Although the sampling mixer must be able to accept input signals over a wide frequency range, the sampling frequency need only cover a narrow band.

Figure 3 illustrates such a situation where where f(s) lies anywhere in the range 2 to 3MHz. The

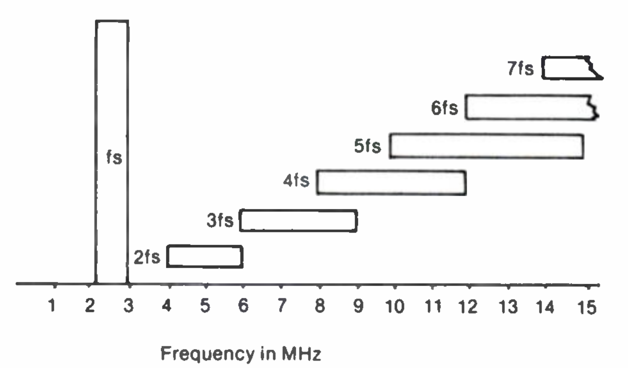

Figure 3. Sampling frequency of 2 to 3 MHz gives full band coverage from 4 MHz upwards.

second harmonic, therefore, will cover the range 4 to 6MHz, the third harmonic 6 to 9MHz, the fourth harmonic 8 to 12MHz, and so on. Full coverage of the input signal is now obtained from 4MHz upwards, with bands of frequencies being overlapped many times at the higher end of the spectrum. A sampling mixer, then, can cover a wide input bandwidth with one single local oscillator operating over a relatively narrow bandwidth — a considerable advantage over the conventional mixer. To be of practical use, however, the efficiency of the mixer over a wide input frequency spectrum must be characterized.

The Sample-and-Hold Mixer

The operation of the sampler may be simulated by a simple switch S1, as shown in Figure 4. An input signal of amplitude Vi is connected to the input and the sampling action is affected by closing the switch S1 for a period τ seconds every T seconds. This example uses a T/τ ratio of 1000:1.

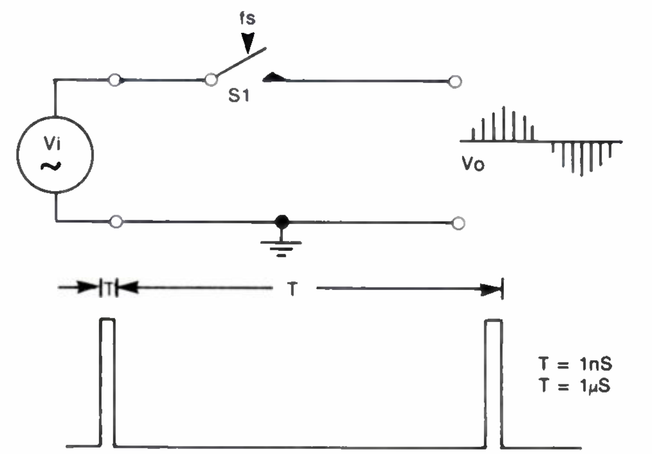

Figure 4. Theoretical simulation of a simple sampler showing switching action of S1

The amplitude of f(o) decreases rapidly as the input frequency increases through the higher harmonics of f(s). In fact analysis shows the response follows a [sin (x)]/x curve, identical to that which was obtained by plotting the harmonic content of the sampling waveform shown in Figure 4.

As might be expected, Figure 5 also shows that even at low input frequencies the output amplitude

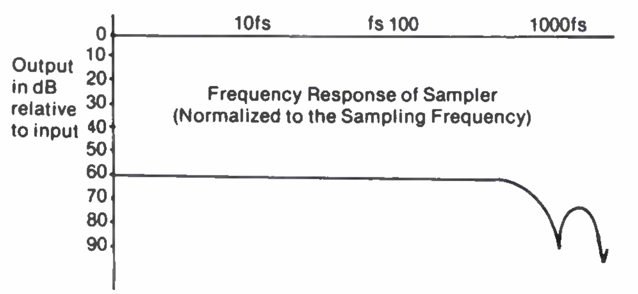

Figure 5. Sampler of Figure 4 gives mixing loss of 60 dB.

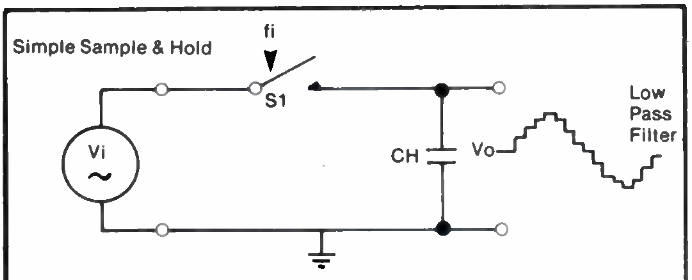

Figure 6. Theoretical sample-and-hold circuit restores mixing efficiency.

is only 1/1000 of the input amplitude — a catastrophic loss of 60dB.

Fortunately the simple addition of a single capacitor, across the output of the circuit shown in Figure 4, improves the performance dramatically.

The revised circuit operates as a sample-and-hold mixer, and as shown in Figure 6 the capacitor 'holds' the value of the instantaneously sampled input waveform until the next sample occurs. It does not require any complicated mathematics to appreciate that when this waveform is subjected to filtering a considerably larger amplitude of f(o) will be obtained. The mathematical analysis of the waveform, however, gives even better results than might be envisaged. The results (Figure 7) show that this capacitor provides 100 percent efficiency regardless of input frequency, even when the harmonic output of the sampling waveform is zero.

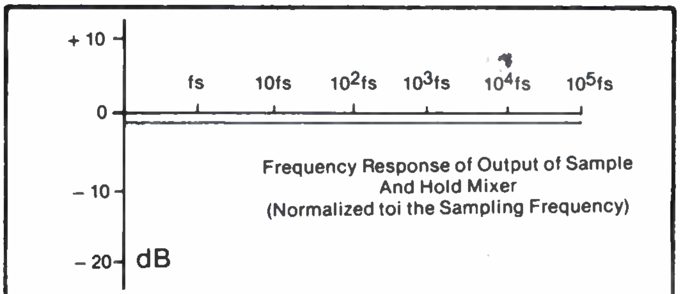

Figure 7. Theoretical Sample & Hold.

In a real life situation there are many constraints which seldom enable the designer to achieve theoretical perfection. Even with a relatively modest sampler operating with T of say 1μS and τ of 1nS, it is impossible to produce a perfect rectangular pulse. The input signal will be driven from some source impedance — usually 50Ω, and there will be some shunt resistance across the hold capacitor. In addition, all the circuit components, particularly the active switch, will be subject to stray inductance, capacitance etc. which will add to the dilemma. Nevertheless, by careful design and with the aid of modern technology, it is possible to produce an efficient, linear mixer which has constant sensitivity over a wide range of input frequencies using one single octave tuned local oscillator.

Figure 8 shows a simplified circuit of such a high efficiency sampler which will operate over the frequency range from 1MHz to 1GHz.

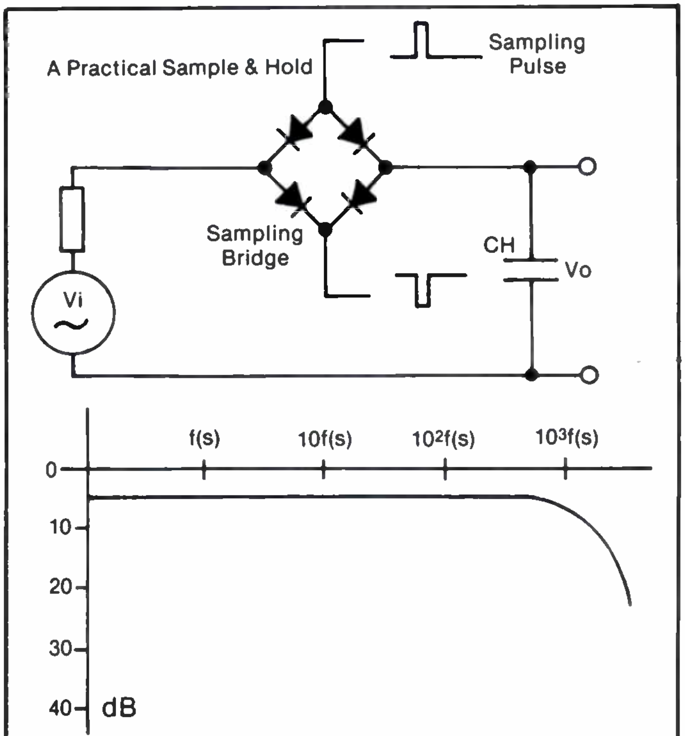

Figure 8. Practical Realisation of Sample-and-Hold operating with sampling pulse width of 1nS at a 1 MHz rate.

Samplers for Instrumentation

Although sampling has been used for many years by oscilloscope manufacturers to extend the frequency range of this equipment, it is perhaps somewhat surprising that this technique is not more widely used in the field of instrumentation.

Nevertheless, some designers have successfully exploited the sampling mixer in a number of measuring instruments. The automatic modulation meter for example (which has significantly simplified the making of modulation measurements) owes its existence to this technique.

The Automatic Mod Meter

The basic requirement of an automatic mod meter is that it be able to lock to an input signal, which may lie anywhere in the range, say, 4MHz to 1GHz, and such as to produce one IF of say 500kHz for processing by the measuring circuits.

A simplified block diagram, Figure 9 shows how this may be accomplished using sampling techniques.

The voltage controlled oscillator is assumed to have a range of 2-3MHz, as previously described in order to cover the complete band from 4MHz upwards.

The VCO drives a pulse generator which provides the narrow pulses required for the sampling bridge. The action of the sampler produces a low frequency signal lying somewhere between DC and half the sampling (VCO) frequency. This IF is extracted by the LPF and presented to the frequency discriminator.

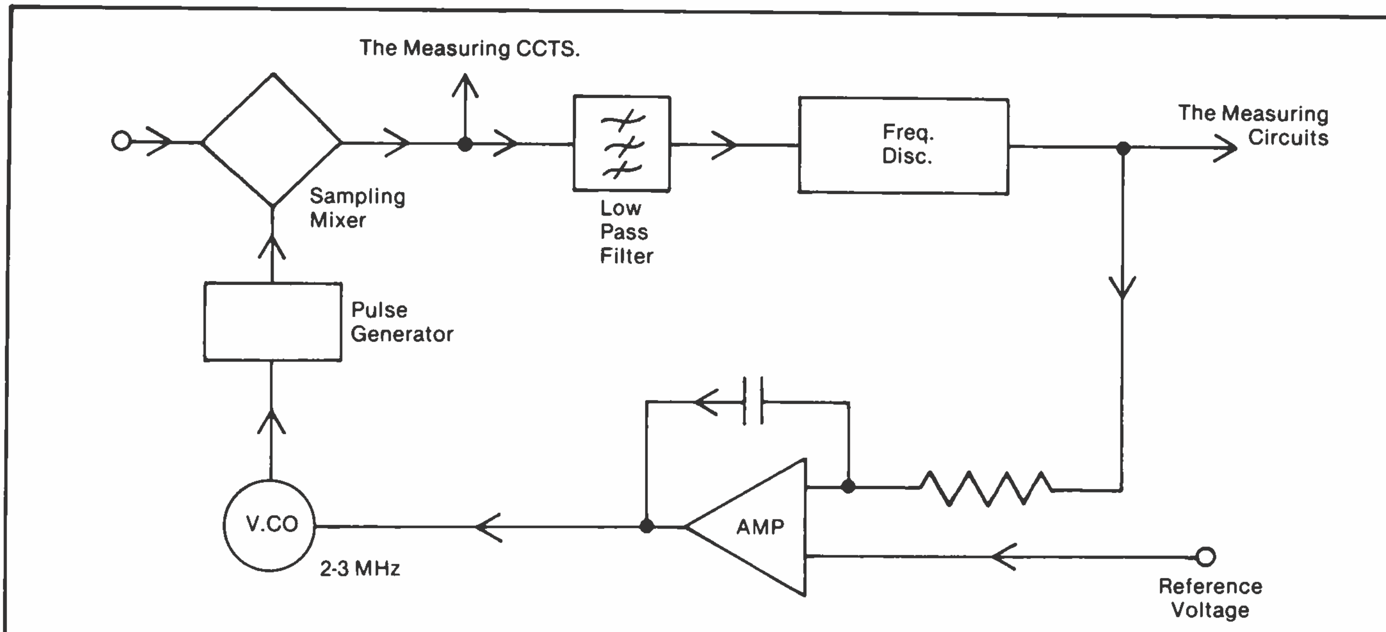

Figure 9.

The frequency discriminator converts this signal to a DC voltage proportional to its frequency. This DC voltage is now compared with a reference voltage which is equivalent to that which would be produced by the frequency discriminator were it being fed by the correct IF frequency. If the IF signal is not at the correct frequency, an error or difference voltage will exist at the input to the integrating amplifier, which will cause its output to rise or fall in sympathy with the degree of the error. The voltage is designed to move the frequency of the VCO in such a direction as to move the IF towards its correct value and hence obtain frequency lock.

It is an advantage of this automatic system that once frequency lock has been obtained the VCO will 'track' any frequency drift of the input signal. At the same time it is essential that the system does not track fast frequency changes of the input signal, or any frequency modulation which it may contain will be cancelled. In a practical system, modulating frequencies as low as say 20Hz may be required to be measured. This means that filtering action of the loop must reject 20Hz and higher, and this in turn makes the system slow to operate.

For a conventional mixer systematically sweeping a 1GHz range, this narrow band loop filter gives rise to impractical lock times of several minutes.

By using sampling techniques, on the other hand, and assuming a sampling frequency of 3MHz, the input signal can never be more than 1.5MHz (half the sampling frequency) away from a harmonic of the local oscillator and, therefore, a suitable lock point.

The characteristic of the sampler to investigate the whole of the frequency band simultaneously provides a further benefit over the conventional mixing technique. This is its ability to recognize the wanted input in the presence of a smaller unwanted interfering signal.

A conventional mixer again systematically searching the band may well 'see' this smaller signal first and lock to it in error. The sampler will convert all signals across the band to lie at frequencies less than half the sampling frequency. It is now a fairly simple matter to detect the highest of these signals and obtain a correct frequency lock. It is the function of the LPF to extract these mixed down signals and reject all others. For this reason its design must be such as to accept half the highest sampling frequency and reject the lowest sampling frequency. For instance, in the example given, the LPF must accept up to 1.5MHz (half of 3MHz) and reject 2MHz (the lowest sampling frequency).

Finally, the simple block shown in Figure 9 is often modified, to give 'lock' speed-up outside the range of the frequency discriminator, and to accommodate other practical considerations when, for example, the VCO reaches the end of its range without detecting a lock situation.

Frequency Measurement

Although many different techniques have been used to measure frequency in sampling frequency meters, this extra facility has so far been denied AMM primarily because of the increase in cost. The introduction of the μP eases this problem and the basic philosophy behind frequency measurement in a sampling system is therefore worthy of some mention in this respect.

The problem arises since a simple sampling mixer has no way of knowing what harmonic is being used to mix with the input signal. All frequency measurement techniques, then, are aimed towards establishing that simple fact.

The value of the harmonic can only be found by making two measurements at different sampling frequencies. This can be accomplished by using either one sampler and changing the sampling frequency or by using two samplers and two sampling frequencies. Since the input frequency could change between measurements, it is the author's opinion that the latter technique is the more favorable and is the one which will be discussed.

The input signal f(in) is sampled by two samplers operating at sampling frequencies of $f_1(s)$ or $f_2(s)$ to produce outputs of $f_1(o)$ and $f_2(o)$ respectively. Thus:

$$f_1(o) = f(in) \quad - Nf_1(s) \tag{1}$$

$$f_2(o) = f(in) \quad - Nf_2(s) \tag{2}$$

It is essential that the value of N above is the same in each equation, and this is accomplished by making $f_1(s)$ and $f_2(s)$ only fractionally different from each other. The actual value of this difference depends upon the input band to be covered and the system used.

From the two equations we can solve the two unknowns N and f(in).

$$N = \frac{f_1(o) \quad - f_2(o)}{f_2(s) \quad - f_1(s)}$$

hence:

$$f(in) = f_1(o) \quad + Nf_1(s)$$

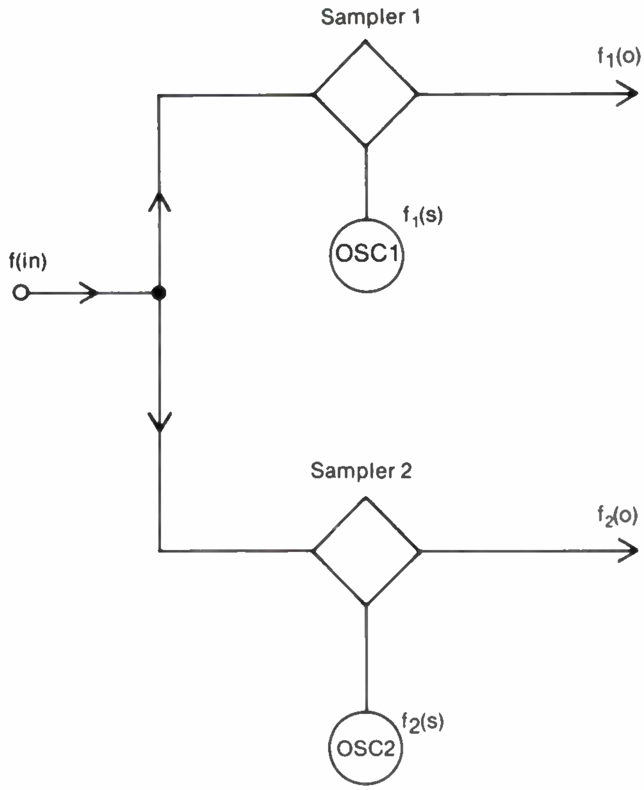

Figure B.

One difficulty which always arises in making frequency measurement is the errors caused by the presence of FM. This is particularly true of high frequency mixed systems where high deviations are likely at high frequency and become a proportionally greater percentage of the low frequency mixed output.

The automatic modulation meter, by increasing the bandwidth of the loop filter, could cancel this FM during a frequency measurement and effectively eliminate the problem. This is a considerable advantage over current systems and, with the inclusion of the μ processor, could well provide other attractive facilities in future instruments.

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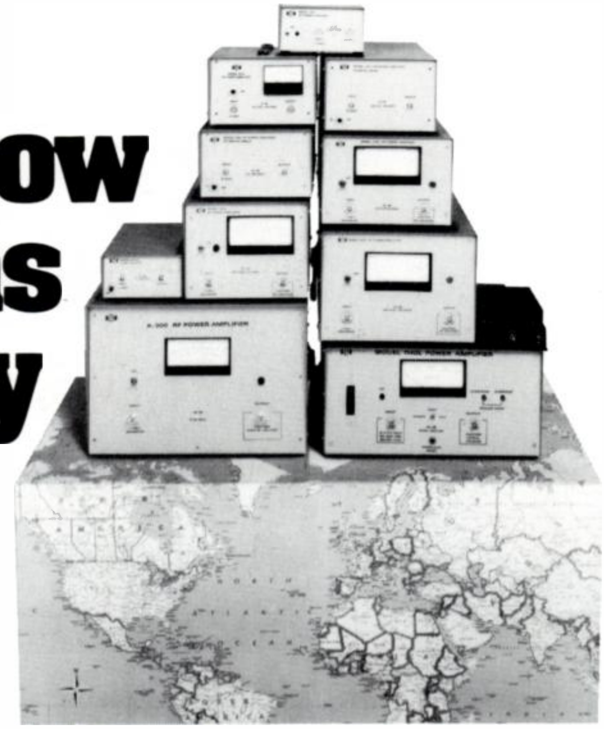

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A revolutionary development in high power solid state amplifiers, the 1140L is designed for high power RF heating, ultrasonics and laboratory applications. Optional matching transformers will deliver full power to any load impedance from 3 ohms to 800 ohms balanced or unbalanced.

150 WATT/240L
- 20 kHz to 10 MHz Coverage
- Up to 150 Watts Output
- 40 Watts Linear Class A Power
- Works into any Load Impedance

Extraordinary performance in a wide range of transducer drive applications. The 240L is a high quality laboratory instrument for ultrasonics, biological research and electro-optic modulation.

100 WATT/3100L
- 250 kHz to 105 MHz
- Up to 180 Watts Pulse
- Driven by any Signal Generator
- Extremely Rugged

Designed to replace bulkier tube amplifiers, the model 3100L provides reliable and maintenance-free operation for NMR, ultrasonics and communications applications.

150 WATT/A150
- 300 kHz to 35 MHz
- Up to 250 Watts Pulse and CW
- No Bandswitching
- Works Into Any Load Impedance

An ultra-linear Class A design, the A150 will "boost" the output of any signal source by a flat 55 dB and provide its full forward power into any load impedance. High quality laboratory unit, for NMR, ultrasonics and biological research.

300 WATT/A300
- 300 kHz to 35 MHz
- Up to 500 Watts Pulse and CW
- 55 dB + 1 dB Gain
- Portable

Highest power in a portable package. Top quality signal transmission in AM, SSB and pulse communication systems. Cannot be damaged by mistuned antenna.

40 WATT/440LA
- 150 kHz to 300 MHz
- 40 Watts Class A Linear
- State-of-the-Art
- Up to 75 Watts CW and Pulse

The widest band solid-state power amplifier available at its 40 watt power level, the ENI 440LA is truly a state-of-the-art instrument. As a drive source for high resolution acousto-optic modulators and deflectors, the model 440LA is invaluable.

10 WATT/510L
- Flat 1.7 to 500 MHz
- 1.3 to 515 MHz Usable Coverage
- 9.5 Watts Linear Output
- Microelectronic Construction

An ultra-linear Class A design, the 510L provides faithful reproduction of the input waveform for AM, FM, SSB, CATV, pulse and other complex modulations. The use of microwave transistors on thin film substrates, microstrip circuitry, and plug-in modules make this unit reliable and easy to service.

3 WATT/603L
- 0.8 to 1000 MHz
- 3 Watts of Linear Power
- Flat 37 dB Gain
- Up to 5 Watts Saturated

3 watts of power 0.8 to 1000 MHz when driven by any laboratory signal generator. Exceptional as a general purpose laboratory instrument and for wideband pulse systems.

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INFO/CARD 37

WRH

Filters

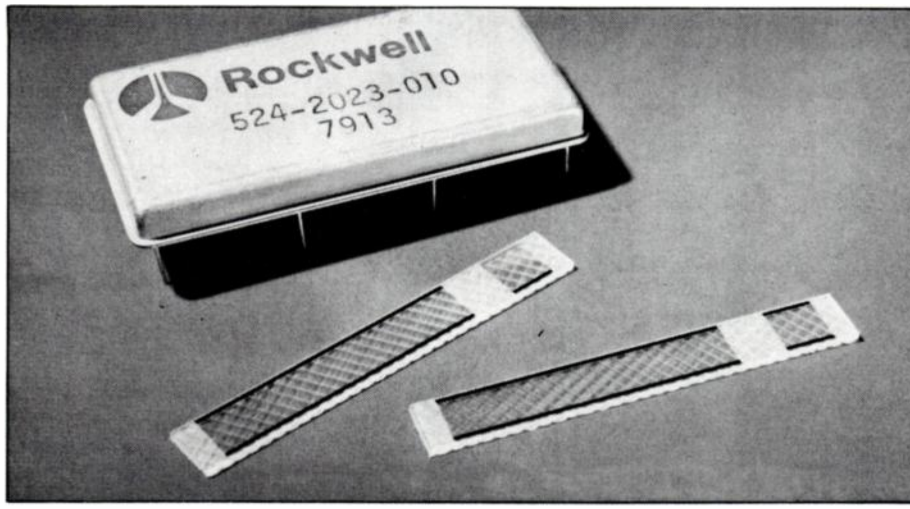
Mechanical Filters and Surface Acoustic Wave Filters are presently available from Rockwell International, Filter Products, Newport Beach, California.

Mechanical Filters are of two types, Low Frequency and Disc-Wire. The Low Frequency Mechanical Filter is available with center frequencies of 4 kHz to 75 kHz. These filters have a 0.1 percent to 15 percent bandwidth/center frequency range and utilize two or three flexure mode resonators composed of stable iron-nickel alloy bars and piezoelectric ceramic transducers. Its small size (1/2 cubic inch) and low cost make the filters ideally suited for omega naviation, selective calling systems, sonar, rapid transit signaling and FSK telegraph applications.

The Collins Disc-Wire Mechanical Filters are available with center frequencies from 60 kHz to 600 kHz and fractional bandwidths from 0.1 percent to six percent. Both symmetrical bandpass and single sideband types are available, and are built with either magnetostrictive or piezoelectric transducers. As many as 12-pole pairs can be realized with this device. These filters find applications in Mobile Radio and High Frequency Communication Systems. In many Disc-Wire Mechanical Filter applications, stringent envelope delay control is required. This can now be accomplished using a Rockwell delay equalizer. Mechanical Filters for Loran-C applications are under development.

Rockwell is presently capable of producing Surface Acoustic Wave Bandpass Filters, Dispersive Delay Lines and Tapped Delay Lines. Rockwell SAWD's are presently being produced on ST quartz and lithium niobate substrates. Bandpass filters with center frequencies from 20 MHz to 500 MHz with fractional bandwidths from 0.2 percent to 15 percent are available. Minimum insertion loss available is 8 dB. Low loss filters, capable of less than 3 dB insertion loss, are presently under development and are planned for production by the end of the year.

Dispersive delay lines with frequencies from 20 MHz to 300 MHz and time-bandwidth products of 15-350 are presently available from Rockwell. These devices find applications in



Radar Expansion/Compression systems, micro-scan receiver systems, spread spectrum systems and high altitude measuring equipment. In addition, tapped delay lines with frequencies from 20 MHz to 500 MHz are also available. These devices are used in coding and correlation schemes and for improving processing gain.

A full line of SAWD's, including low loss filters, convolvers, oscillators and resonators, is planned by mid-1980. Our Newport Beach facilities have full production capabilities, including mask production. INFO/CARD #65.

Dual-Trace 30 MHz Oscilloscope

Almost all circuit designs can be described as a "pyramid of decisions," starting at the top, with one or two of overwhelming importance, and moving from them to a few more that the first ones force on you, and then dealing with the half-dozen or so questions they raise. . . and so on.

The overwhelming constraints on this design were, as you see here, very small size (targeted at about 300 cubic inches, like a small, modern DMM), portability into the field, and a completely sealed (and therefore unventilated) construction. These initial constraints led to the first set of decisions in the pyramid . . .

- First, to minimize internal dissipation by using a high-efficiency, high-frequency, PWM switching-regulator power-supply fed either by battery DC, or by the DC from an external, line-pluggable, transformer-rectifier module. But, because we also wanted

to prevent conducted EMI from entering the instrument, we put the filter for the transformer-rectifier, not in its wall-plug module, but in a shielded compartment at the rear of the scope. That way, it also provides that same broadband EMI attenuation for the battery-cable circuit.

- Second, we set a design goal of 10 watts total dissipation, despite the wide input-voltage range on both battery and AC line supplies. This guaranteed an average temperature rise of less than 5°C. . . and a correspondingly low hot spot temperature rise.

Perhaps the most critical decision was now before us: what cathode-ray tube should we use? It had to be short, it had to perform well at low accelerating voltages (to hold down corona at high altitudes and to minimize internal component spacing and clearances). It had to have a good, sharp, round spot, that stayed in focus over the whole display area; it had to have adequate brightness, and it had to be free of the distortions that seem so much more pronounced on a 3" tube than they are on a 5" tube: astigmatism, pincushion distortion, and graticule parallax.

What did we decide? We decided to take what you might be tempted to call "a giant step backwards." We selected a short, curved-face, monoaccelerator cathode-ray tube. These tubes have much thinner glass walls that are actually stronger than the welded-on flat face construction, and the uniformity of the glass is inherently greater. . . again, because we've avoided the flat face. So, not only does this stubby, strong, curved-face tube give us better vibration and shock resistance, it also gives us the best spot you'll see in any modern scope.

Now, the selection of this CRT leads us to several more decisions:

- To use a 1 kV total accelerating supply. This very low value may surprise you, but we use a much higher beam current (in fact, about 10 times higher than that used in 3 kV accelerating systems) and then we are able to concentrate that higher beam current into a smaller, better-controlled spot. Therefore, as you will all be able to see when you come up to operate this instrument, the effective brightness of the trace is remarkably high, and it stays that way over the entire display area.
- To screen the graticule right on the face of the cathode-ray tube. Thus, we virtually eliminate graticule-parallax errors or distractions (which is an especially important advantage in field service), and we don't need power-wasting illuminating lamps to edge-light the graticule.
- To cushion-mount the CRT at both ends, under slight compression, as an integral part of the high-permeability magnetic shield.

What are the disadvantages of this CRT selection? Primarily the fact that this kind of tube is inherently insensitive. It takes a big signal to deflect it, and a big signal to blank it. So we pay back some of those earlier savings (mostly in cost and power; not much in space) by furnishing higher internal gain and higher output voltage swing in the vertical, horizontal, and blanking circuits. INFO/CARD #66.

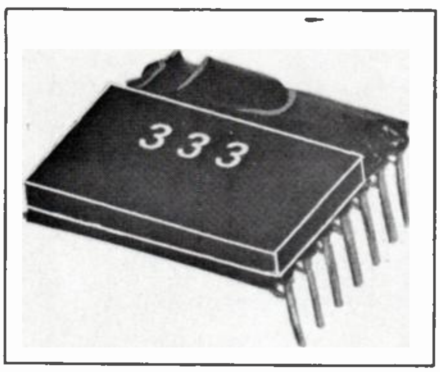
VHF Tunable Notch Filters

The 3468 series of tunable notch filters comprises six separate models to cover 50-300 MHz. Typical notch depth and 3 dB bandwidth is 30 dB and 4 MHz, respectively. The 1 x 1 1/2 x 3" case mounts two self-locking screwdriver controls. Impedance options of 50 or 75 ohms are available and type F, BNC, or SMA connectors are available. Price and delivery is $45.00 and two weeks, respectively. Microwave Filter Company, Inc., 6743 Kinne Street, East Syracuse, N.Y. 13057. Circle INFO/CARD #67.

Time Out Timer

For the first time a miniature, low cost three minute transmitter time out timer is now available from American Microsignal Corporation.

The entire required circuitry is contained in .75" x .75" x .250" high



thick film hybrid module and provides an accurate three minute timer that can be used universally in mobile, base station, and hand-held two-way radios.

The model 333 timer does have some optional features. A small PC carrier board is available to ease add on mounting and provisions for the addition of a potentiometer to make the 333 adjustable in various ranges from one second to several minutes. Also available is a "pin out" for activating any function such as an audible or visible notification of TX time out.

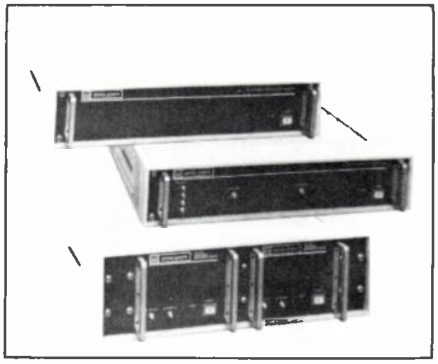
Special OEM prices are available upon request.

For more information call or write American Microsignal Corporation, 8431 Monroe Ave., Stanton, Calif. 90680 (714) 761-1222. INFO/CARD #68.

Active ECM Equipment

Watkins-Johnson Company has introduced its WJ-4700 series of active ECM equipment. The series consists of expandable, modular subsystems designed for integration into an advanced electronic warfare simulation system.

In this system, modulation waveform generators accurately transform computer commands into video wave-



forms which frequency-modulate companion low-power microwave sources. The resulting AM-FM-NOISE radio frequency signals are capable of emulating all known and projected ECM deceptive or noise techniques in the 0.5 to 18.0 GHz frequency range.

A choice of data interfaces is available for computer control of all functions and the generation of complex scenarios. All modules are available in either 19-inch, rack-mounted configurations for laboratory environments or ATR box packages for airborne applications.

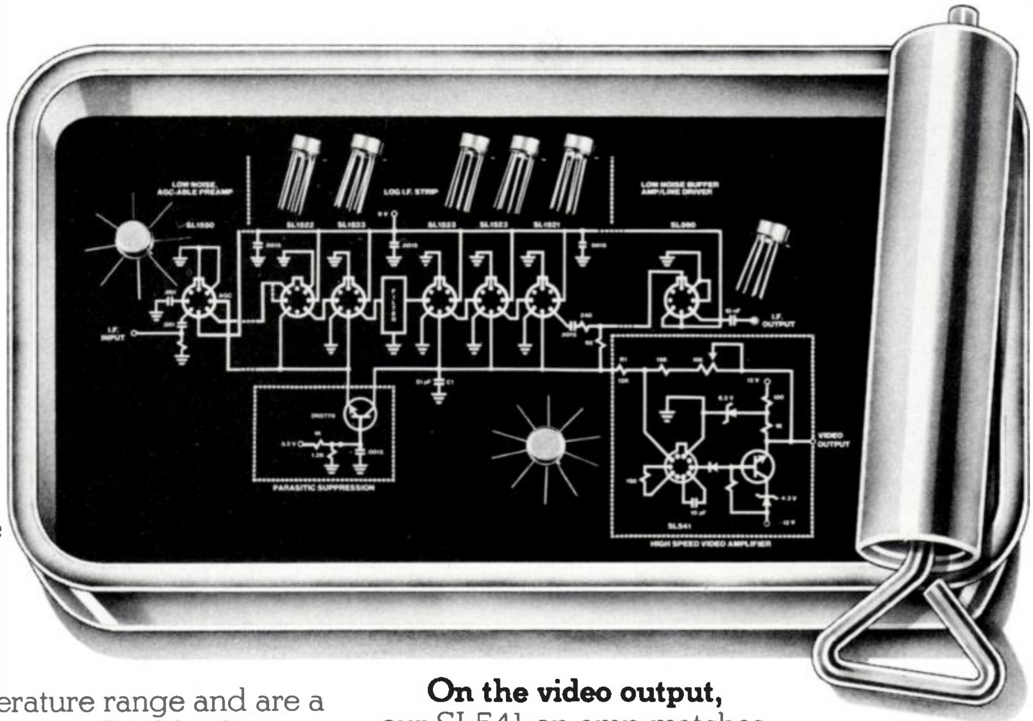
Watkins-Johnson has the capability to supply WJ-4700 series ECM equipment for end uses ranging from simple, single-signal test stations to complete "turnkey" EW simulation installations.

Complete details, including price and delivery, are available from Watkins-Johnson Company, 3333 Hillview Avenue, Palo Alto, Calif. 94304 (415) 493-4141. INFO/CARD #69.

Computer Compatible Lock Box

The new MS100 series Microwave Frequency Stabilizers offer full TTL compatible functional control and status monitoring. Ten standard models cover

I.F. cram course



In a nutshell, Plessey IC's will cut the costs, reduce the size, and increase the reliability of your IF strips.

Into each IC can, we've packed more functional capability than you would believe possible, especially once you've seen the prices.

Our IC's operate over the full MIL-temperature range and are a simpler, less expensive, more flexible alternative to whatever you're using now for any IF strip up to 240 MHz. Whether you're working with radar and ECM, communications, weapons control or navigation and guidance systems.

Let's go through the diagram function by function and we'll show you exactly what we mean.

The log IF strip is based on the Plessey SL1521, the simplest, easiest-to-use and least expensive wideband amplifier you can buy. It has a gain of 12 dB and an upper cut-off frequency of 300 MHz (our less expensive SL521 is available if you're working under 100 MHz). The SL1522 is two 1521's in parallel with a resistive divider for increasing the IF strip's dynamic range, while the SL1523 is two 1521's in series. With these devices, it takes just five cans and a single interstage filter to build a log IF strip at 160±15 MHz with a logging range of 90 dB, ±1 dB accuracy, −90 dBm tangential sensitivity and a video rise time of 20 nsec or less. It's reliable, inexpensive and field repairable, which is more than can be said about the hybrids or discretes you're buying now.

On the video output, our SL541 op amp matches the IF strip to your system, and lets you vary video sensitivity. It has the high slew rate (175 V/μsec), fast settling time (1% in 50 nsec) and high gain stability you need, with on-chip compensation so it's not tricky to use.

For the front end, just slip in the Plessey SL1550 to improve your noise figure, dynamic range and sensitivity. The SL1550 is a low noise, AGC-able preamp with a bandwidth of 320 MHz, 2 dB noise figure and 38 dB gain.

And for the IF output, the Plessey SL560 buffer amp/line driver operates up to 320 MHz with a noise figure less than 2 dB, gain of up to 40 dB, and drives 50 ohm lines with a minimum of external compensation (none in this application).

If all this looks almost too easy, send for complete details today.

When it comes to communications IC's, nobody delivers like Plessey can.

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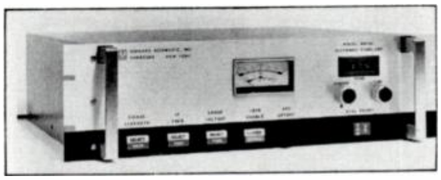
All things to some people.

INFO/CARD 21



1 to 40 GHz with many configuration options offered. Full electronic tuning (includes crystal switching) and advanced oven controller for VCXO improved long-term stability and phase-locked spectrum of microwave signal source. Broad band, optimally dampened, second-order phase lock loop maintains locked source stability to eight parts in 10^9 per hour and six parts in 10^{10} per millisecond. Software support is offered for automatic operation with custom computer interface or standard IEEE 488 GPIB interface is optionally available. Priced from $3200. 45 to 90 days delivery. Niagara Scientific, Inc., 118 Boss Road, Syracuse, N.Y. 13211 (315) 437-0821.

Contact Niagara Scientific Inc., 118 Boss Road, Syracuse, N.Y. 13211 (315) 437-0821. INFO/CARD #70.

GPIB-Programmable Network Analyzer

The introduction of the first GPIB-programmable microwave network analyzer is announced by Wiltron Company. Operating over the 10 MHz to 34 GHz range, the model 560 Scalar Network Analyzer provides swept measurements of transmission loss or gain, return loss (SWR), and absolute power, any two of which may be displayed simultaneously. In addition to its broad frequency range and GPID programmability, the instrument features a 66 dB (+16 dBm to −50 dBm) dynamic range, 40 dB directivity and low cost. The exceptional measurement accuracy is made possible by a new SWR Autotester that has a directivity of 38 dB over the full 10 MHz to 18 GHz range. Measurement accuracy has also been improved by the use of memory, which stores the average of open and short reflections and other system residuals for subtraction from the test data. The resulting normalized data represents the true characteristics of the device under test. Contact: Walt Baxter, Wiltron Company, 825 East Middlefield Road, Mountain View, Calif. 94043 (415) 969-6500 TWX: 910-379-6578. INFO/CARD #77.

Frequency Counter

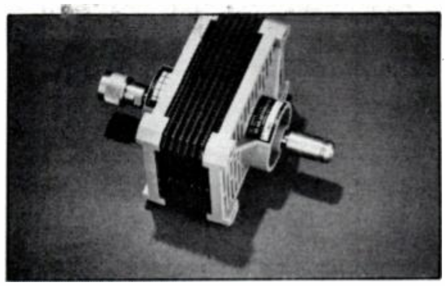
Deluxe 600 MHz frequency counter for AC, DC or portable operation. New model OPTO-8000.1A offers Guaranteed ±0.1 PPM TCXO time base stability, 8 LED digits, selectable input attenuator, 1 sec and .1 sec gate times, power cables and jacks for 9-15 VDC, 115 VAC or 220 VAC 50/60 Hz operation. Housed in a deluxe, heavy duty, black anodized aluminum case with tilt-up bail. Size 3" H x 7 1/4" W x 6 1/2" D. Model #OPTO-8000.1AK (Kit Form) $279.95. Model #OPTO-8000.1A factory wired with 2 year guarantee $329.95. Delivery from stock. Dealer inquiries invited. Optoelectronics, Inc., 5821 N.E. 14th Ave., Ft. Lauderdale, Florida 33334 (305) 771-2050 or 771-2051. INFO/CARD #86.

Attenuator

For broadband coaxial measurements at medium power, Hewlett-Packard now offers a new 30 dB attenuator; the HP 8498A, which covers the DC-18 GHz frequency range.

An important feature of the 8498A is its attenuator pad that is designed to be bilateral, with either end able to accept 25 watt input. The standard connector configuration uses one Type N male and one Type N female so that adapters are not needed for direct connection to high power. Standing wave ratio is 1.3 at 18 GHz.

The 8498A design provides efficient heat dissipation with cooling fins which remain cool to the touch even



during operation of 25 watts. Thus reconnections can be made without waiting for the unit to cool.

Contact Inquiries Manager, Hewlett-Packard Company, 1507 Page Mill Road, Palo Alto, Calif. 94304. Circle INFO/CARD #73.

LCD Multimeter

The model ME-523 is a 3-1/2 digit LCD multimeter that has a HI-LO ohm switch for all ranges, five function modes — DCV, ACV, DCmA, ACmA, and Ohms — automatic polarity indication, and automatic zero adjustment. All modes appear on the LCD display.

Completely portable (weight 12.7 ounces), the battery-operated ME-523 is ideal for use by the laboratory technician or the field serviceman who requires an accurate measurement with a maximum indication of 1999 or −1999. The ME-523 can measure DC voltages from 0.2 to 1000 volts, AC voltages from 0.2 to 600 volts, DC and AC current from 0.2 to 1000 mA, and resistance from 0.2 ohm to 20 megohm. Typical DC accuracies are 0.25 percent.

Contact Soar Electronics (U.S.A.) Corp., 200 13th Avenue, Ronkonkoma, New York 11779 (516) 981-6444 Telex No. 144638. INFO/CARD #74.

Tool-Less Fuse Holder

No tooling, splicing or soldering is required for installation or assembly of the Tool-less Fuse Holder from AMP Incorporated. This new fuse holder handles stranded wire from AWG #24 through #14, and is rated from 5 to 20 amperes, depending on the wire size used. All 1/4" diameter fuses from 5/8" to 1 1/4" long can be accommodated. It is possible to terminate one side of the fuse holder while leaving the other side for hook-up to the hot wire on site.

Clear plastic housings permit inspection of the fuse without disconnecting, while the quick take-up threads on the housing and a detent assure that the interconnection is maintained under shock and vibration.

Contact AMP Incorporated of Harrisburg, Pa. 17105. INFO/CARD #75.

PC Board Test System

A new high speed automatic turnkey system for testing bare PC cards and backplanes has been announced by the Addison Division of Muirhead, Inc.

The new system, called "MatchMaker II" by the manufacturer uses the "Testmate III bed-of-nails" fixture. It can test PC boards up to 21" x 24" with up to 10,200 points. Available with interchangeable test heads, it

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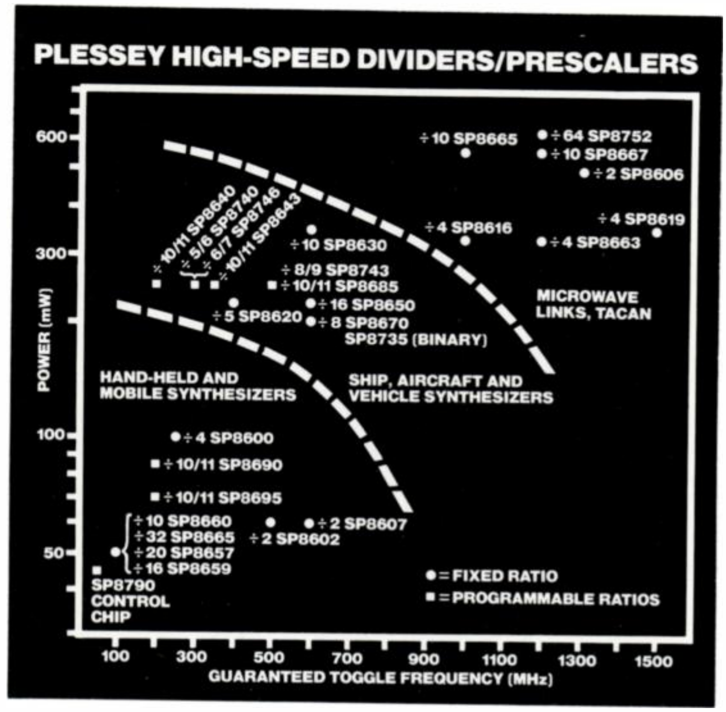

And they're all available now, so contact us for details or a demonstration. We'll show you a winner.

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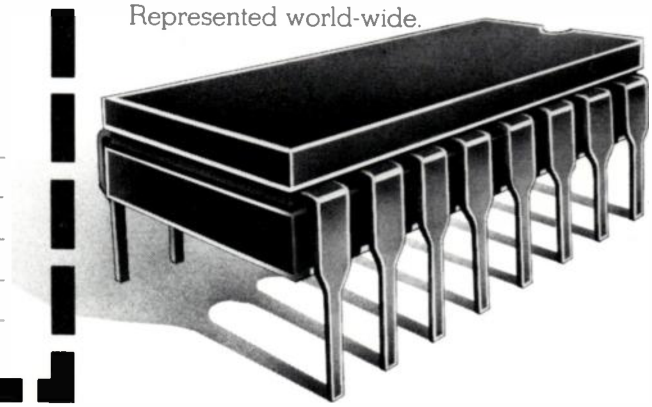
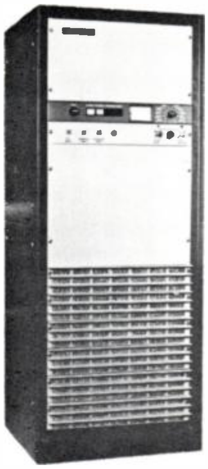


INFO/CARD 22

The 1000L Series Amplifiers . . .



Model 1000L

designed to your needs and our standards

- 1000 watts CW linear
- 4000 watts pulse
- 10 kHz to 220 MHz
- Instantaneous band-width
- Low harmonic distortion
- Adjustable gain
- Unconditionally stable
- Remote control opera-tion
- Fully protected
- Human engineered

Powerful and uncompromising in quality and performance. These versatile high-power amplifiers are ideal for general laboratory use, EMI susceptibility testing, equipment calibration, biological research, NMR spectroscopy, ultrasonics, and many other applications. The series also includes Model 1000LM8 (1 to 220 MHz), Model 1000LM9 (1 to 200 MHz), and Model 1500LA (1 to 150 MHz) with a 1500-watt output. For complete information on our high-power amplifiers, call 215-723-8181 or write:

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160 School House Road
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TWX 510-661-6094

ar AMPLIFIER RESEARCH

INFO/CARD 23

features optional height adjustment and 18 different probe tips for various assemblies.

MatchMaker II tests 5000 points in five seconds on several units simultaneously. It is programmable from a master PC board or a host computer. Any changes in the run list can be entered via the unit's CRT terminal.

Full specifications are available from the manufacturer: Muirhead Addison, 1101 Bristol Road, Mountainside, N.J. 07092. INFO/CARD #76.

Measure 25-Watt to 18 GHz

The usual method for measuring medium power levels up to 25 watts has been to connect a high-power attenuator in front of a 100 mW power sensor. Such a combination created some undesired measuring ambiguities because each element (attenuator and sensor) had its own accuracy specification and the interacting mismatch effect added to that.

HP has combined the attenuator and the power sensor into a single unit. Model 8481B covers the frequency range 10 MHz to 18 GHz; and Model 8482B, 100 kHz to 4.2 GHz. Both models include a 25 watt, 30 dB attenuator permanently attached to a 100 mW power sensor. The senors work directly with the well-knwn HP 435A and 436A Power Meters.

U.S. price of the 8481B/8482B Power Sensors is $900 each. Inquiries Manager, Hewlett-Packard Company, 1507 Page Mill Road, Palo Alto, Calif. 94304. INFO/CARD #72.

Log Amplifiers

Wide dynamic range log amplifiers for military electronic, monopulse, and radar system applications are available from Radar Technology, Inc. of Haverhill, Mass.

Radar Technology's RTL Series Log Amplifiers are sequential detection, IF devices that provide log accur-

acies of ± 1 dB over a dynamic range of 80 dB, and rise times as fast as 30 ns. With operating frequencies from 10 to 160 MHz, they provide a DC coupled video output for handling CW signals or high ground clutters. Contact: Radar Technology, Inc., James J. Noonan, General Manager, 15 Hale Street, Haverhill, Mass. 01830 (617) 372-8504. INFO/CARD #79.

High Frequency Trimmer Capacitors

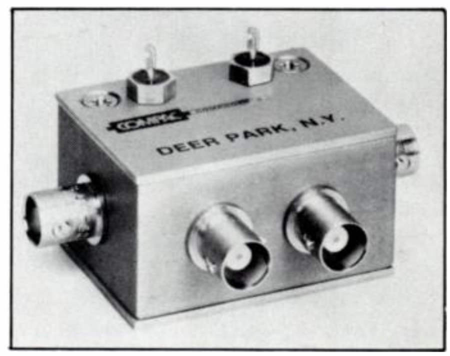
Voltronics Corporation is now in production on its new low cost "E" Line trimmer capacitors. The "E" Line is an internally sealed, high frequency, concentric ring air dielectric trimmer capacitor. It has a non-rotating piston and is available in 9 and 12 pf values. Standard styles are panel mount, horizontal and vertical printed circuit mount, and stripline. In large quantities, it is priced below $1.00!

The "E" Line has ten full linear turns of tuning. The internal "O" Ring seal protects against fluxes, cleaning fluids and adverse environments. It is extremely stable during shock and vibration. The screw head does not move in and out. With Q rating of over 2000 at 100 MHz, the part is usable to over 1.5 GHz. An extended shaft of metal or plastic can be provided.

For more information, contact Richard J. Newman, Voltronics Corp., West Street, East Hanover, New Jersey 07936 (201) 887-1517. INFO/CARD #78.

RF Transfer Switch

A new low cost RF transfer switch for use in RF communications equipment and systems is available from



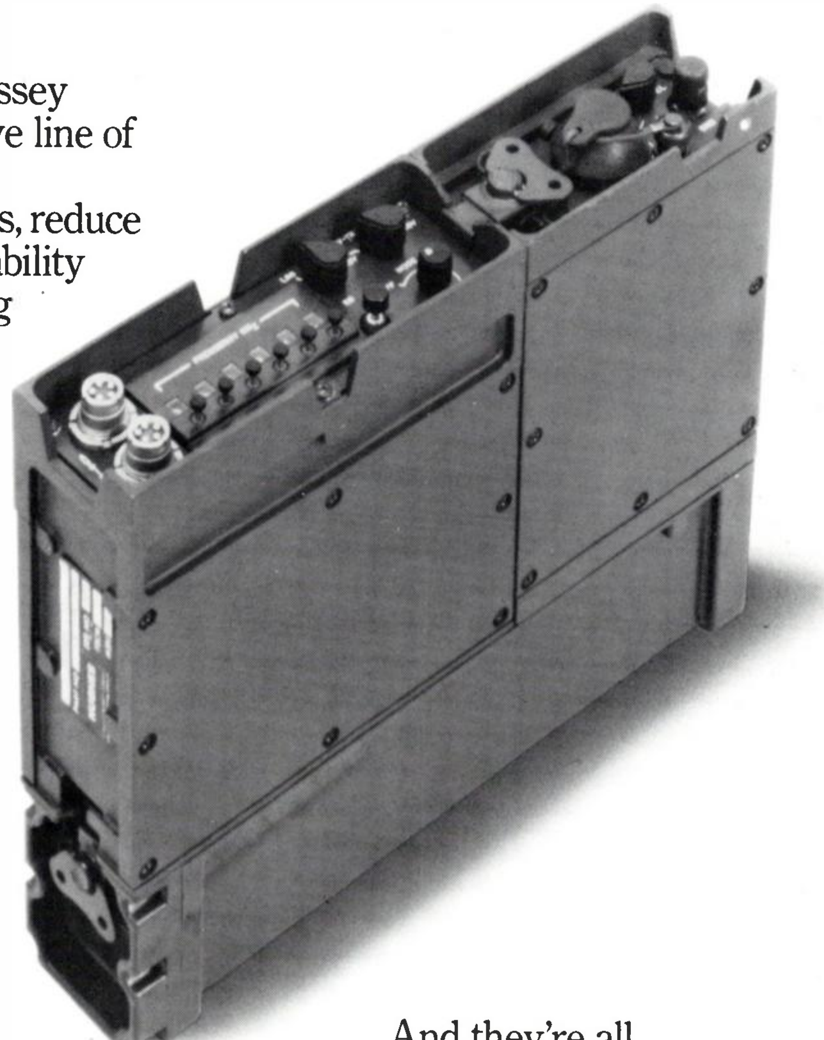
COMPAC, Deer Park, N.Y., manufacturers of RFI shielded enclosures and accessories.

Designated model TSW2800, the new COMPAC transfer switch is a non-latching DPDT type with BNC standard connectors and these specifications: frequency (DC-500 MHz), impedance (50Ω), isolation (Port-to-Port 40 dB typ. min.), coil voltage (24/28 v), dimensions (1.5"W x 2"L x 1.12"H).

COMPAC RF transfer switches are also available in SPDT, 4 PDT, and latching models with other coil voltages, various connectors and extended flanges.

For additional information contact Marketing Dept. COMPAC, 279 Skidmore Road, Deer Park, N.Y. 11729 (516) 667-3933. INFO/CARD #80.

Radio Active



In radio-communications, Plessey offers the most comprehensive line of IC's available.

IC's that will cut the costs, reduce the size and increase the reliability of your designs for everything from commercial CB sets to manpack radios like the Hughes PRC-104 shown.

Typical is our SL6600, a monolithic IC that contains a complete IF amplifier, detector, phase-locked loop and squelch system. Power consumption is a meager 1.5 mA at 6V, S/N ratio is 20 dB, dynamic range is 120 dB, THD is just 2% for 5 kHz peak deviation, and it can be used up to 25 MHz with deviations up to 10 kHz.

Our SL6640 (with audio output) and SL6650 (without audio) are similar, but go a bit further, adding dc volume control to the on-chip preamp, amp, detector and carrier squelch.

In addition to these, we offer a large family of RF and IF amplifiers, most available in full MIL-temp versions, with screening to 883B.

And they're all available now, so contact us for complete details today.

The real action in radio-communications IC's is at Plessey.

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Ad-Vance reduces your shield costs because it already owns tooling for most standard shields. Or, our Magnetic Shielding Specialists will custom fabricate shields to your exact specifications.

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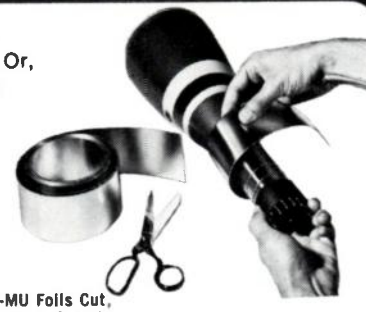

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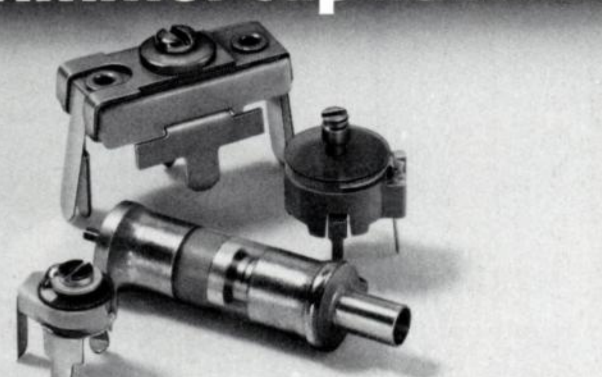
INFO/CARD 25

Sprague-Goodman. The first and last name for trimmer capacitors.



PISTONCAP®/CERAMIC/FILMTRIM™/MICA

At Sprague-Goodman we specialize in trimmer capacitors. They're our only business. So we offer prompt service and off-the-shelf delivery of our full line of catalog parts. From multi-turn tubular Pistoncaps® in glass or quartz, thru ceramic single turn and Filmtrim™ plastic single turn, to our new Mica compression line.

Our comprehensive line of trimmer capacitors deliver reliability at competitive prices, and our staff is always available for custom designing to your needs.

So the next time trimmer capacitors are called for, call us or your distributor and ask for them by name... Sprague-Goodman.

SPRAGUE GOODMAN **Sprague-Goodman Electronics, Inc.**

(An Affiliate of the Sprague Electric Company)

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INFO/CARD 26

D/S Converter

A new best has arrived. The transformation ratio of the Natel Engineering DSC5112 digital/synchro (d/s) converter is so accurate that PPI (plan position indicator) radar display systems driven by it are virtually distortion free. The transformation ratio is ±0.1 percent. Most other converters offer ±7 percent transformation ratios or require a separate transformation-ratio corrector module. With the DSC5112, the eye cannot tell the difference between the symmetry of the display and a perfect circle. This 14-bit converter has an accuracy of ±4 arc-minutes. It has a settling time of 50 μs for a 180° step change on the input.

Contact Natel Engineering Co., Inc., 8954 Mason Ave., Canoga Park, Calif. 91306 (213) 882-9620. INFO/CARD #81.

Directional Coupler

Power handling: 1000 watt av. Octave bandwidths from 100 MHz to 12.4 GHz Coupling: 30 or 40 dB ± 1 dB Directivity: 20 dB min. VSWR: 1.2 max. Connectors: LT (main line), N (secondary). P & A: $399.00 — four weeks. Contact LDV Electro Science Ind. Inc., 2027 Teall Ave., Syracuse, N.Y. 13206 (315) 463-4555. INFO/CARD #83.

Frequency Counter to 40 GHz

40 GHz automatic frequency measurement capability is now a reality with the introduction of EIP Microwave's new 54X series of microprocessor-based microwave counters. Extended frequency capability, combined with high rated performance and power meter option, provides a unique solution to today's and tomorrow's microwave measurement needs.

The Model 548 offers frequency coverage from 10 Hz to 26.5 GHz standard and provides the option to build for tomorrow's extended frequency requirements. This frequency extension is accomplished via the internally installed Option 06 plus accessory remote sensors. Option 06 can be installed in the Model 548 initially, or it can be added later as measurement requirements dictate. The first remote sensor available, Model 591, covers the range from 26.5 to 40 GHz. Additional remote sensors are anticipated to further extend counting capability in higher mm wave ranges (e.g. 90-100 GHz).

For more information, contact EIP Microwave, 3200 Scott Blvd., Santa Clara, Calif. 95051 (408) 244-7975. Circle INFO/CARD #85.

Storage Oscilloscope

A new Option (003) for HP's model 1741A Variable Persistence Storage Oscilloscope provides automatic hardcopy records of single-shot events through trace photography. This automatic trace capture capability is extremely useful for every-day trace photography as well as those applications that require long term monitoring.

The 1741A oscilloscope's capability to wait indefinitely for a signal to occur is even more useful with the addition of this new option. Now the oscilloscope camera system can monitor a circuit mode unattended and capture a randomly occurring signal.

Contact Inquiries Manager, Hewlett-Packard Company, 1507 Page Mill Road, Palo Alto, Calif. 94304. Circle INFO/CARD #71.

SAW Dispersive Delay Line

A series of surface acoustic wave (SAW) dispersive delay line (DDL) devices, offering high-reliability operation over frequencies from 20 MHz to 300 MHz, is now available from Rockwell International.

The SAW-DDL series, is designed for use in radar systems where maximum range and target resolution are critical, and in spread-spectrum communications applications requiring frequency agility and resolution. The devices are capable of operation in MIL-qualified environments.

"These SAW-DDL devices were initially developed for special military applications.

The SAW-DDL devices give system resolution improvement or transmitter power reduction in the range of 15:1 to 350:1. Insertion losses range from 30 dB to 55 dB. Typical sidelobes are 25 to 32 dB.

Typical characteristics of some of the standard SAW-DDL devices now available are:

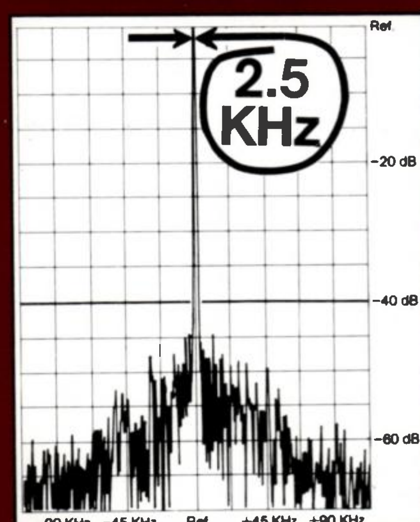
Bandpass Taylor weighing is internal over the bandwidth of "C"-type devices, while the "E"-type units are flat weighted.

The SAW-DDL devices operate from $-45°C$ to $+85°C$. They are designed for mounting on printed circuit boards or with SMA connectors, and typically, measure from about one inch by about one-half inch to six inches by 1 1/2 inches.

In quantities of 100, prices for standard devices range from $400 to $1000 with six to eight weeks for delivery. Rockwell also offers custom SAW-DDL devices for special applications (12 to 15 weeks delivery). Devices qualified for military specifications are also

Did you know . . .

That ANDERSEN'S DI 2.5–1388 IMCON® Dispersive Delay Line can provide your Spectrum Analysis System with this capability:



100% Probability of Intercept
2.5 KHz Resolution
2.5 MHz Instantaneous Bandwidth
1.11 MS Process Time
30 dB Signal Processing Gain

ANDERSEN offers IMCON systems with Time Bandwidth Products to 25,000, and spectral resolution to 160 Hz, for ESM/ELINT applications.

ANDERSEN
Advanced Systems Division

Andersen Laboratories, Inc.
1280 Blue Hills Avenue
Bloomfield, Connecticut 06002
(203) 242-0761

INFO/CARD 27

produced. Contact Jerry Aukland, Advanced Product Mgr., — Filters, Electronic Devices Division, Rockwell International, 4311 Jamboree Rd., Newport Beach, Calif. 92663. INFO/CARD #84.

SAW Filter for T.V. IF

Fujitsu has developed new surface wave filters designed for the use of the IF section of television receivers. These miniature filters, which are fabricated on lithium niobote substrates and packed in TO-8 cans, replace many complex tunable transformers and filters presently used in the television receivers.

These filters have the following features: small size, no adjustment, high reliability and repeatability due to the use of single crystal, adaptability due to a tuner and IC amplifier.

The frequency responses of these filters would be specified according to the requirements of customers.

Contact Fujitsu Limited, Communications and Electronics, 1251 West Redond Beach Blvd., Gardena, Calif. 90247, (213) 538-3397. INFO/CARD #82.

NMR Gaussmeter

A highly accurate NMR Gaussmeter which represents a significant step forward in precision and convenience for electron paramagnetic resonance studies has been introduced by Varian Associates.

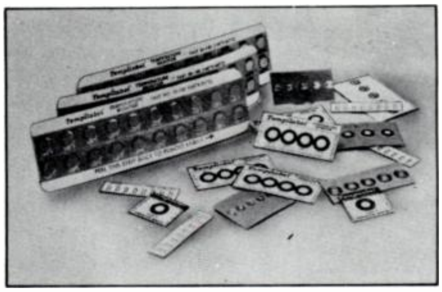
With the new instrument, designated the Varian E-500 NMR Gaussmeter, scientists can measure hyperfine splittings and g-values to within three parts per million. Field measurement techniques in the past have required probes that were bulky and not sufficiently accurate for precise EPR g-value determination.

For further information (literature available), contact: Robert Vaughan, Varian Associates, Box D-421, 611 Hansen Way, Palo Alto, Calif. 94303. INFO/CARD #95.

Tempil Temperature Indicators And Markers

The Tempil Division of Big Three Industries, Inc. manufacturers Tempilabel temperature monitors, Tempilaq temperature indicating liquids, Tempilstik crayons, Tempil Markers and Pyromarkers for the electronics industry.

Tempilabel is an easy to use temperature monitoring system of heat sensitive indicators sealed under transparent heat-resistant windows. Color



change is not reversible and Tempilabel provides a temperature history of the surface being monitored. To serve as a permanent record, Tempilabels can be removed and attached to inspection reports. Accuracy is guaranteed within one percent of temperature rating below 400°F (204°C) and two percent at 400°F and higher. The product is not affected by transient contact with contaminants.

For additional information, contact A. Jeanguenin, 2901 Hamilton Blvd., South Plainfield, N.J. 07080, (201) 757-8300. INFO/CARD #87.

International Rectifier

The IR power MOSFET line of transistors opens the door to the design of advanced products by offering the superior characteristics of Field Effect Transistors at true high power levels. Power MOSFETs simplify circuitry because they are voltage-controlled devices and require only very small instantaneous currents from the signal source. They achieve switching times of less than 100 nano-seconds at high current levels. They have great ruggedness because of the absence of the second breakdown failure mechanism of bipolar transistors. In parallel operations they inherently "current share" rather than "current hog."

Contact Buckley/Boris Associates, Inc., 912 South Barrington, Suite 202, Los Angeles, Calif. 90049 (213) 826-4621. INFO/CARD #93.

Power Meter Calibrator

General Microwave Corporation, announces the immediate availability of its new model 308 Calibrator, a precision instrument designed to simplify

and speed the adjustment of all analog and digital models of General Microwave RF Power Meters in the 476 and 475A series. These instruments measure RF power over a broad frequency range — from 10 MHz to 40 GHz.

The Model 308 utilizes long-life mercury cells in conjunction with a highly stable voltage reference to provide a standard voltage level. A precision divider scales this reference to the 10 discrete values required to calibrate all of the power ranges of the power meter under test.

The model 308 is also provided with a battery-check meter. 0.05 percent accuracy and excellent long term stability are featured. Contact General Microwave Corporation, 155 Marine Street, Farmingdale, N.Y. 11735. Circle INFO/CARD #94.

CAMAC-GPIB Interface

New Model 8901 CAMAC-GPIB Interface announced by LeCroy/California allows CAMAC instruments to operate as standard listeners and talkers on any General-Purpose Interface Bus (IEEE Std. 488).

Program instructions from any GPIB controller to the Model 8901 select an individual instrument module within a CAMAC crate, select any sub-address within that module, and establish the function: read, write, control.

The entire crate of up to 23 individual instrument modules is handled in the same manner as any ordinary single device connected to the IEEE 488 bus. It is possible to interconnect up to 15 CAMAC crates, up to 345 instruments, in this manner.

Details may be obtained by contacting LeCroy Research Systems of California, 1806 Embarcadero Road, Palo Alto, Calif. 94303 (415) 856-1800. INFO/CARD #89.

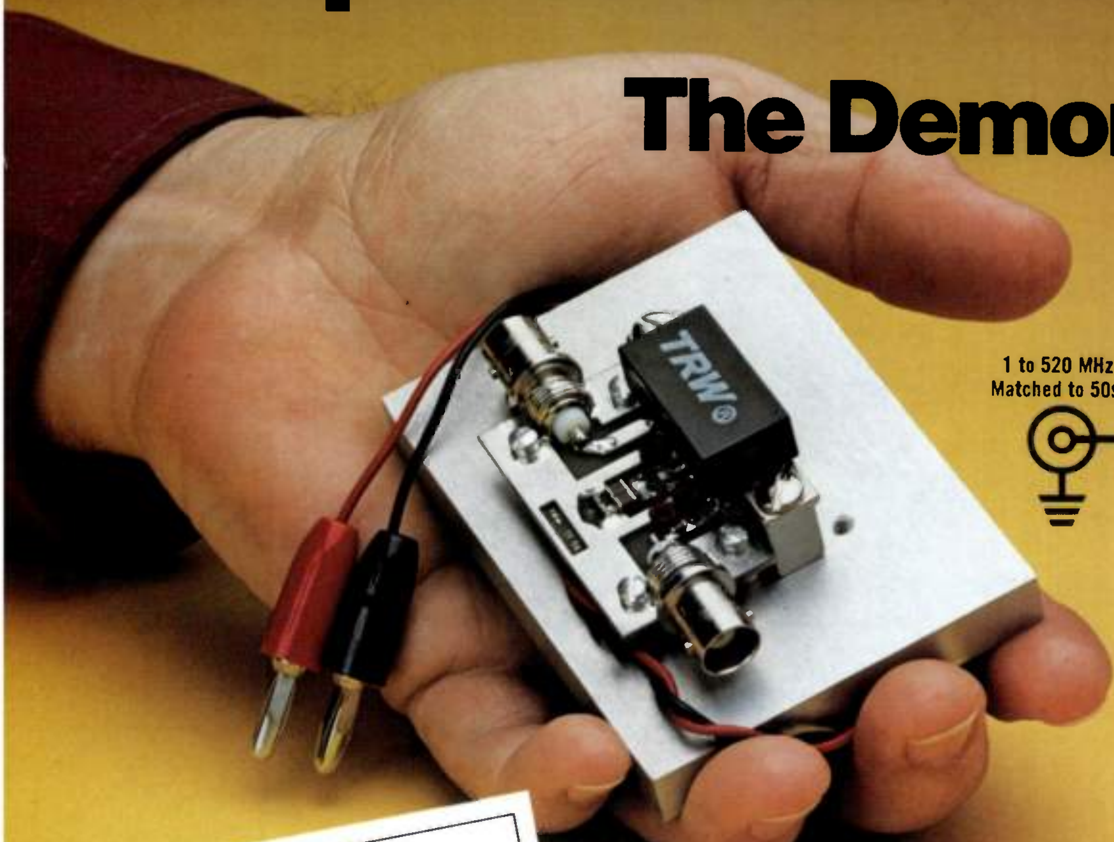
4-Digit LED/LCD Display Decoder-Driver

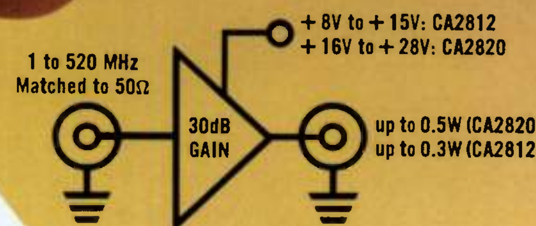
A new CMOS LED/LCD display driver/decoder designed for interface between digital systems and microprocessors has been introduced by Intersil, Inc. The ICM7211 is a non-multiplexed 4-digit BCD-to-LCD display-driver for use in low-power applications, and the companion ICM7212 is intended as a driver/decoder for LED displays.

The ICM7211 device features direct drive to an LCD display, and contains a complete on-board RC oscillator for the LCD backplane frequency. No external components are required. (The ICM7212 LED driver directly interfaces the display without multiplexing, and

Special wide band amplifier offer!

The Demonstrator





Evaluation Test Fixture and Wide Band Amplifier. A $126.25 value, ONLY $39 COMPLETE.*

We want to show you that TRW's wide band hybrid amplifiers are ideal for all sorts of analog and digital applications. *The Demonstrator* will prove it to you. Instantly.

Whatever type of instrument or system you're working on, chances are you'll have to boost an RF signal somewhere—and with minimum distortion. Before you spend hours or days designing and debugging a discrete component amplifier, spend $39 and send for *The Demonstrator*. It's a special evaluation test fixture (worth $100) with a TRW CA2820 or CA2812 RF Linear Wide Band Hybrid Amplifier priced at $26.25, (25-99). Both are yours for only $39.00. Just plug in *The Demonstrator* and you'll see how well a TRW hybrid will perform in your application.

The hybrids feature linear phase response, 50dB reverse isolation and are available in a hermetic package. They're unconditionally stable into all load impedances. You can simplify your design and save PCB space. And our low, low OEM prices will slash costs.

What's more, if our wide band hybrid amplifier isn't demonstrably superior for your application, return *The Demonstrator* for a full refund, no questions asked. Send us your $39 or send for complete data sheets now. Or contact your local TRW Distributor. You can't lose.

*U. S. Price

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TRW RF Semiconductors
An Electronic Components Division of TRW Inc.
14520 Aviation Boulevard, Lawndale, CA 90260

Enclosed is my purchase order or check for $39.00 for The Demonstrator. Send me the model checked: ☐ CA2812 ☐ CA2820

☐ Please send data information on TRW's complete line of thin film RF hybrid amplifiers.

RF

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TRW RF SEMICONDUCTORS
ANOTHER PRODUCT OF A COMPANY CALLED TRW

thus no RFI is generated.) High (8 mA typical) drive current contributes to display brightness. A brightness control line is available for adjustment of light intensity via a potentiometer.

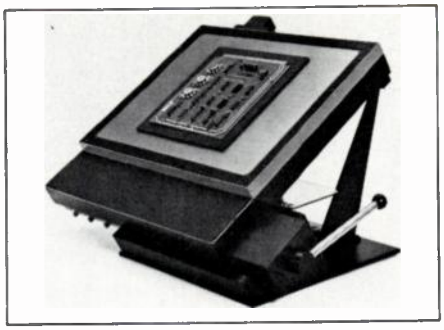
CMOS construction requires only minimal power, typically 10 μA at 5 VDC. The ICM 7211 is a pin-for-pin, function-for-function equivalent to the Siliconix DF411, and additionally, is capable of either Code B or hexadecimal decoding. In either decoding mode, the devices carry a full numeric display function, in addition to a limited alphabetical display (A,B,C,D,E for the ICM7211/12 hex mode, or E,H,L,P, blank for the ICM7211/12 Code B mode). The new chips may be ganged or cascaded to allow for 8, 12 or 16-digit displays.

Contact Intersil, Inc., 10710 North Tantau Ave., Cupertino, Calif. 95014 (408) 996-500 TWX 910-338-0228. Circle INFO/CARD #88.

Subassembly Fixturing System

A vacuum-activated test access interface system has been introduced by the Subassembly Test Systems Division of Fairchild Camera and Instrument Corporation.

Called the Thinline[R] vacuum fixturing system, it provides test access to a



wide variety of printed circuit boards (PCB) or electronic assemblies and can be used with any test system.

The Thinline fixturing system consists of a product access unit (PAU) and a probe receiver.

The product access unit comes in four standard models and can handle board sizes up to 17 x 25 inches.

The probe receiver can be wired directly to any test system as the primary interface, or used as a component of an interface adapter to existing receivers.

Other Thinline products include a cost savings, do-it-yourself fixture kit, universal fixture systems and test contact probes.

The Thinline vacuum fixturing system is available for immediate delivery. Contact Subassembly Test Systems Division, 15 Avis Drive, Latham, N.Y. 12110. Martha Sessums: (415) 962-3615; Mark Thurman: (516) 783-3600. Circle INFO/CARD #90.

4-Port UHF Antenna Multicoupler

The CU-547 four-port UHF antenna multicoupler is now available from TRW RF Filter Products, an Electronic Components Division of TRW Inc. Widely used in airport control towers and mobile communications shelters, the multicoupler links four individual receiver and transmitter outputs to separate TX and RX antennas.

TRW's CU-547 multicoupler is designed to operate with AN/GRT-22 transmitters and GRR-24 receivers supplied by ITT-Ft. Wayne, and with GRC-171 transceivers supplied by Rockwell/Collins-Cedar Rapids.

The highly selective units are being produced under U.S. Air Force contract for the Rivet Switch program, a multi-year effort to update all VHF and UHF ground-to-air communications equipment.

Deliveries of the CU-547 to the Air Force are expected to start in August. It will be available to other users later in the year.

For more information, contact TRW RF Filter Products, Davis & Cope-

200 MHz SYNTHESIZER
DIRECT . . . FROM PTS ONLY

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PERFORMANCE / PRICE

1-200 MHz or .1-160 MHz
QUIET: -70 dB res. phase noise
FAST: 5-20μ sec. switching
RELIABLE: 10,000 h+, dem. MTBF
VERSATILE: optional resolution, controls, interface (BCD or 488 Bus)

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RF801
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FULL VOLTAGE RANGE measures from 300 Microvolts to 100 Volts.

FULL FREQUENCY RANGE within 1.5 dB to 1 Gigahertz. Usable to 3 Gigahertz.

Unique probe design permits low inductance ground connection for repeatable accurate measurements.

Less than 2 picofarads circuit loading in any measurement mode.

Operates from AC line or your service van battery.

Supplied complete with probe, 50 dB adaptor, and 50 ohm terminated BNC adaptor.

NOW EVERY TEST BENCH CAN HAVE A FULL RANGE R.F. VOLTMETER WITH TRADITIONAL HELPER QUALITY AND SERVICE.

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Box 3628, Indialantic, FL 32903
(305) 777-1440 Visa or MC OK

INFO/CARD 29

wood Streets, Camden, N.J. 08103. (609) 365-5500, TWX: 710-891-7087. Circle INFO/CARD #91.

Digital Phase Meter

Wiltron introduces a new Digital Phase Meter which provides accurate measurement of the phase difference between two signals in the 10 Hz to 2 MHz range.

The model 355B has a dynamic range of 66 dB (1mV to 2V and 0.2V to 400V) and an input signal voltage range of 112 dB. Two signals of greatly differing amplitude can be measured within these ranges. Test signals are applied to two identical processing channels. To assure maximum accuracy, an Error Sector indicator alerts the user when the practical limits

of the phase measurement range are reached so the appropriate Display Range can be selected. An optional binary-coded decimal output is available for automatic measurement systems.

The Wiltron model 355B Digital Phase Meter is priced at $1990. For more information, contact: Walt Baxter, Wiltron Co., 825 E. Middlefield Rd., Mtn View, Calif. 94043. (415) 969-6500, TWX: 910-379-6578. INFO/CARD #92.

ICL7112 Laser Trimmed Multiplying DACs

Intersil, Inc. has announced the ICL7112 a monolithic 12 bit, 0.01 percent accurate complementary MOS digital-to-analog converter which is pin-for-pin compatible with the industry-standard 7521/7541. The 12 bit linearity, 12 bit resolution device is the industry's first production IC to combine active laser trimming and absolute matrix positioning to achieve high performance and improved economy. Price of the 12-bit-accuracy version in an 18-pin plastic DIP package is $12.00 in 1,000-unit quantities. Contact: Intersil, Inc., 10710 North Tantau Ave., Cupertino, Calif. 95014 (408) 996-5000 TWX 910-338-0228. INFO/CARD #105.

DIP Connector

These dual inline plug (DIP) connectors afford the designer versatility in packaging layout as a solderless connector using I.C. sockets that will accept .015" max. thick pins or by wave soldering the 6700 directly to the printed circuit board.

The 6700 gives the user the advantage of high density packaging and as interboard bussing jumpers, greatly reduces printed circuit board real estate and the need for costly multilayer circuit boards. In addition the low profile permits high density PCB rack mounting.

The 6700 when mated with Molex's JF 50, .050 inch center flat cable becomes a fast, economical method for reducing PCB and cable assembly costs. Molex Inc., 2222 Wellington Ct., Lisle, Ill. 60532. INFO/CARD #104.

D/A

Raytheon's Semiconductor Division announced the availability of the DAC-08 8-bit high-speed multiplying digital-to-analog converter.

All Raytheon DAC-08's guarantee full 8 bit monotonicity, and nonlinearitis as tight as ± 0.1 percent over the entire operating temperature range. Advanced circuit design has achieved a typical 85ns settling time with very low glitch and power consumption.

Additional features include high output impedance and compliance from −10V to +18V, high-speed, wide power supply range of ±4.5V to ±18V, low power consumption of 33mW at ±5V, and a low price of $2.45 in 100 up quantities for the DAC-08dB dual in-line epoxy-B package. Contact: Raytheon Semiconductor, 350 Ellis Street, Mountain View, Calif. 94040 (415) 968-9211. INFO/CARD #106.

175°C 30 Amp Schottkys

A recently introduced high reliability, 30 amp Schottky power rectifier in the DO-4 case, part of a family of devices designed to be operated at junction temperatures of up to 175°C, is described in a Data Sheet available from International Rectifier Corporation.

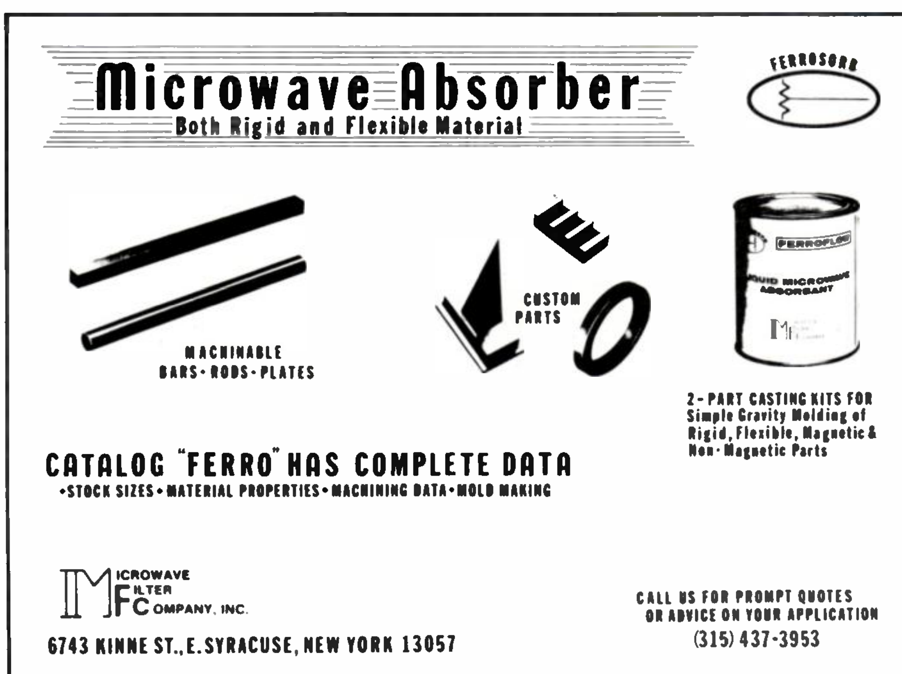
The new device, which provides extremely high power supply reliability, is manufactured using IR's "830" process that results in a very low ratio of reverse leakage current to junction temperature.

The rectifiers are capable of high current operation at high temperatures, and feature the low reverse leakage current of 25 mA at 125°C, and no voltage derating up to 168°C.

For further information and copy of Data Sheet No. PD-2.039, contact International Rectifier, Semiconductor Division, 233 Kansas Street, El Segundo, California 90245; or telephone (213) 322-3331. INFO/CARD #107.

Individually-Calibrated Data Report Now Available For Microwave Attenuators

Now an optional test report can be performed on an HP 8542B computer-operated automatic network analyzer. Several programming changes and higher accuracy procedures have been made to permit this complete test



report to be generated. The test report includes SWR data for both ports and attenuation data at 42 frequencies from 100 MHz to 18 GHz.

Users can program their test system data bank with such step attenuation data to improve accuracy of output test signals. The data is accessed from a look-up table and programmed in as a correction factor at the various frequencies and output levels.

The test report can be ordered by specifying Option 890 on HP 8491-2-3 fixed attenuators ($20-$25) or HP 8484-5-6 and HP 33320-1-2 step attenuators ($110-$175).

Contact Inquiries Manager, Hewlett-Packard Company, 1507 Page Mill Road, Palo Alto, California 94304. INFO/CARD #108.

DMM Selection Guide

A new, full-color six-page brochure describing the complete line of B&K-Precision digital multimeters is now available from Dynascan Corporation.

Featured in the brochure are the model 2830 and model 2810 3-1/2 Digit DMM's, both with autozeroing, and the model 283 3-1/2 Digit Lab DMM with high intensity LED display for maximum readability. All three are accurate to 0.5 percent. Also described is the model 2800 Economy 3-1/2 Digit Portable DMM with autozeroing and 1 percent DC accuracy for cost-effective testing.

All of the products described are available from local distributors. For a free copy of the DMM brochure, write B&K-Precision, 6460 W. Cortland Street, Chicago, Ill. 60635. Telephone: (312) 889-9087. INFO/CARD #109.

Relays

Magnecraft's new updated Low Profile relay brochure does solve compact, close rack mounting circuit board problems. It includes detailed information on Class 62, 63, and 64. Plus specifications for all three classes, and printed circuit board layouts.

For free catalog contact Al Cooper, Magnecraft Electric Company, 5575 North Lynch Avenue, Chicago, Illinois 60630. INFO/CARD #110.

PCB Racks, Enclosures, And Electronic Hardware

A new 118 page Engineering Guide from Birtcher Corp. Industrial Products Division, describes Birtcher's extensive lines of custom and standard PCB racks, enclosures, and electronic hardware.

Included in the Engineering Guide are detailed photos, line drawings, dimensional information and application notes covering: Printed circuits board racks, enclosures, terminals, standoffs, feedthroughs, molded terminals, spacers captive screws, terminal boards, enclosure handles, extractors, plastic and metal PCB guides, heat sinks, component clips, and component clamps. Over 3000 line items are included in the guide.

For free copies write to Ed Karale, Industrial Productions Division, Bircher Corp. 4501 N. Arden Dr., El Monte, Calif. 91731 (213) 575-8144. INFO/CARD #112.

Indicator Lights

A 32-page catalog and technical manual on off-the-shelf indicator lights for all products and purposes is now available from Industrial Devices, Inc. The catalog describes the products that may be obtained directly from the company's nationwide network of industrial distributors.

Three main divisions of the new catalog cover the company's line of LED indicator lights, relampable indicator lights, and non-relampable types.

The catalog section on LEDs contains information on bare LEDs, as well as LEDs in assemblied for panel or printed-circuit board mounting.

For a free copy of the off-the-shelf indicator-light catalog, request form FDG from Industrial Devices, Inc., Edgewater, N.J. 07020 or phone: toll-free (800) 526-0488. INFO/CARD #115.

Connectors

The Sealectro CX-8 catalog lists over 500 various RF connector configurations in 56 pages. The ConheX connector line incorporates the SMB, SMC, and Slide-On interfaces. In addition to the standard catalog numbers, a complete cross-reference is included for QPL to MIL-C-39012 series SMB and SMC units.

The catalog contains all technical specification for both electrical and mechanical data, as well as a useful cable chart for proper selection of connectors.

A copy of the catalog is available upon request from the RF Components Division of Sealectro Corporation, Mamaroneck, N.Y. 10543. INFO/CARD #116.

Thin-Film Resistors

Hybrid Systems Corporation announces the availability of a new resistor products catalog describing its line of thin-film resistors on silicon and glass substrates.

Serving the needs of hybrid manufacturers requiring accurate, precision resistors and resistor networks in extremely small, process compatible format, a wide range of values and circuit configuration are described in the catalog.

Standard resistors, networks and packaged units are described, as well as guidelines for specifying custom networks to ± 0.01 percent accuracy.

The catalog also contains curves illustrating the typical performance of the resistor products.

Hybrid Systems Corporation is a manufacturer of hi-rel microelectronic and modular data conversion products, as well as film resistors, and employs over 200 people in its Bedford, Massachusetts facility.

For further information, contact G.J. Estep, Marketing Manger (617) 275-1570. INFO/CARD #113.

Power Mosfet

A series of high power Mosfet transistors which offer at least twice the power handling capability of Mosfets available from other manufacturers is described in Data Sheet PD-9.300 from International Rectifier Corporation.

The recently introduced devices are capable of operating at kilowatt levels, challenging the predominance of traditional bipolar transistors in power applications.

The IRF300 and IRF301 devices operate at 4 amps and 400 and 350 volts respectively. On-state resistance is 1.5 ohms maximum. On-state resistance is the most significant figure of merit for comparing the power handling ability of Mosfet transistors.

For further information and Data Sheet PD-9.300, contact International Rectifier, Semiconductor Division, 233 Kansas Street, el Segundo, California 90245; or telephone (213) 322-3331. INFO/CARD #114.

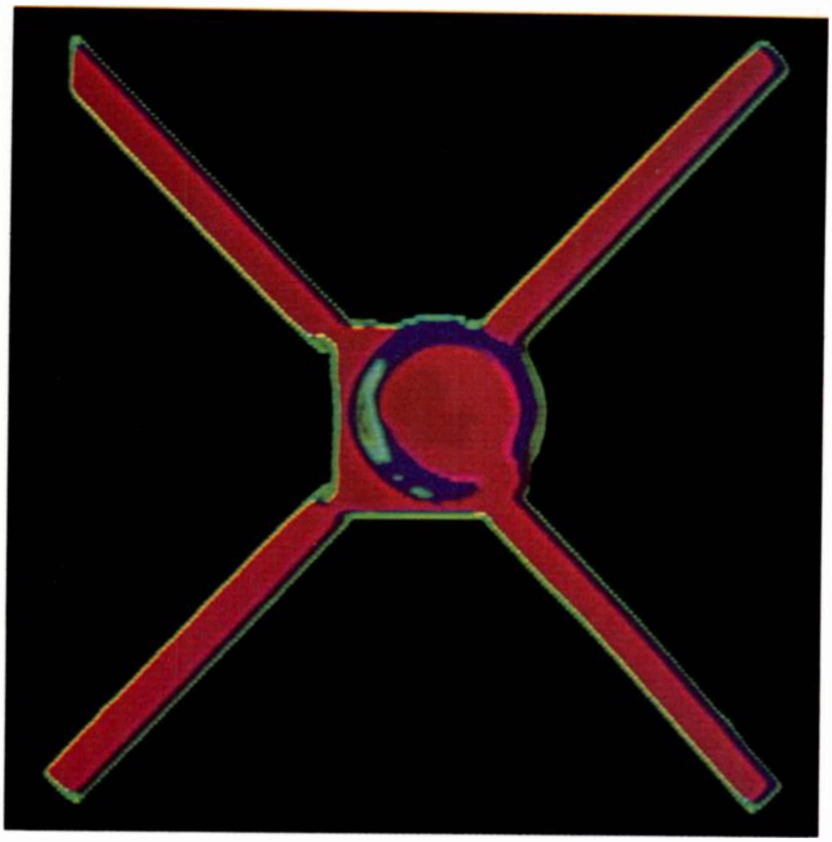
Circular Connectors

ITT Cannon Electric has produced a revised 54-page catalog on standard circular connectors designed to MIL-C-5015.

Included in Catalog MS-21 are MSA, MSB, MSE, MSF, MSR and the ER series. Originally designed for aircraft, these series are widely used in many other fields requiring low cost and high reliability.

The catalog has 51 photos, some eight dozen drawings and a large store of information covering shell sizes, contact arrangements, electrical

Micro-X



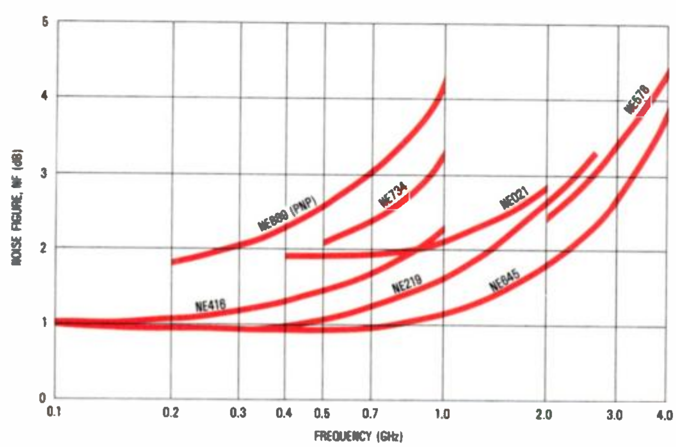
The Best Package Deal Available—In Performance, Reliability and Price

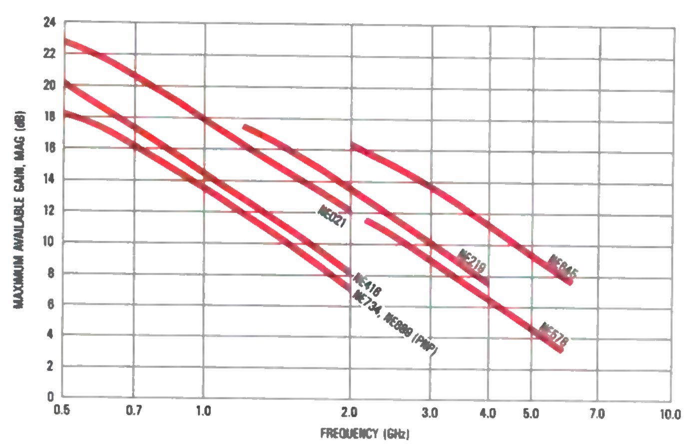
The key to NEC's newly-developed MICRO-X series of hermetically sealed transistors is in manufacturing these high-performance microwave components, with a proprietary ceramic package, using high-speed automated assembly and testing equipment.

The result is a series of state-of-the-art transistors economically priced for large volume OEM's where performance and reliability are primary design considerations.

Ideal for industrial and military applications such as low noise front ends, IF amplifiers and oscillators where plastic transistors cannot be used.

Many devices are priced below $5.00 at 1K. All components available from stock, and Grade C (TXV) screening is available for military applications. Contact your local Cal Eastern representative for a free application note, specification sheet and samples.





NEC microwave semiconductors

California Eastern Laboratories, Inc.

Exclusive sales agent for **Nippon Electric Co., Ltd.** Microwave Semiconductor Products. U.S.A. ☐ Canada ☐ Europe

U.S. Headquarters and Warehouse—California Eastern Laboratories, Inc., 3005 Democracy Way, Santa Clara, CA 95050, (408) 988-3500 • **Eastern Office**—California Eastern Laboratories, Inc., 3 New England Executive Park, Burlington, MA 01803, (617) 272-2300 • **Southwest Office**—California Eastern Laboratories, Inc., 4236 North Brown Ave., Scottsdale, AZ 85251, (602) 945-1381 • **European Headquarters and Warehouse**—California Eastern Laboratories, International, B.V., Havenstraat 8a-Postbus 1258, Zaandam, Nederland, 075-158944 • **Southern California Offices**—California Eastern Laboratories, Inc., 2182 Dupont Drive—Suite #24, Irvine, CA 92715, (714) 752-1665, California Eastern Laboratories, Inc., 2659 Townsgate Road, Suite 101-6, Westlake Village, CA 91361, (213) 991-4436.

INFO/CARD 31

service data, thermocouple contacts, wiring, high potential test voltage and a number of charts and cross-sections.

ITT Cannon Electric, 666 E. Dyer Road, Santa Ana, Calif. 92702. Contact: Richard L. Harmon, (714) 557-4700. INFO/CARD #117.

Magnecraft Catalog

Class 76 miniature P.C. relays 2 and 6 amp, general purpose, high current, printed circuit relays. They are versatile, provide long life and reliable performance. Designed for continuous duty operation, single and double pole versions, UL recognized, dust proof cover, DC operation only.

Contact Marketronics, Inc., P.O. Box 56080, Harwood Heights, Ill. 60656, phone: (312) 282-5503. INFO/CARD #111.

Mixers

A new brochure describing its complete line of Mixer Products is now available from Aertech Industries, Sunnyvale, California.

The 24 page brochure includes information on Aertech Mixers, Mixer Preamps and Frequency Doublers. In addition to specifications and drawings on standard and special mixer products, the brochure presents typical performance curves and data for each product group.

Of special interest are sections on terminology and applications, a discussion of "Critera for Selecting the Right Mixer," and a Mixer Selection Guide.

For a copy of Aertech's Mixer Products brochure contact Aertech Industries, 825 Stewart Drive, Sunnyvale, California 94086. Telephone (408) 732-0880. INFO/CARD #118.

Electrical Contacts

An introduction to its design and manufacturing capabilities is contained in a new brochure published by Deringer Mfg. Company, Mundelein, Ill. The company is the leading U.S. firm specializing in quality precious metal electrical contacts, contact weld taps and assemblies, and related products.

The twelve-page, four-color booklet presents information on the wide variety of contacts and other cold-headed parts made by Deringer from precious and other metals for practically all facets of industry.

For a copy of this capabilities brochure, write Deringer Mfg. Company, 1250 Town Line Road, Mundelein, Ill. 60060. INFO/CARD #119.

RF Signal Processing

Cascadable amplifiers to 2.3 GHz, AGC amplifiers, MINPAC GaAs FET amplifiers, frequency mixers, frequency converters, power dividers, solid state switches, RF PC mounted transformers, articles and tech notes.

Watkins-Johnson Company offers over 1000 superior catalog products. W-J's wide ranging communication electronics experience, combined with an excellent technical staff and extensive in-house production facilities, affords a quick-reaction capability equal to the needs of virtually any special application. In most cases, customer requirements can be met with W-J's catalog items, most of which are available from stock or on early delivery.

For highly unusual applications, W-J will either modify existing products of design and fabricate new units to match the needs. Utilizing in-house capabilities to the fullest, tight deadlines can be met even on quantity production runs. W-J's provision for secure areas allows the company to undertake rigidly classified assignments of wide scope and complexity. INFO/CARD #120.

Cannon PV Miniature Circular

ITT Cannon Electric has printed a new catalog on PV miniature circular connectors with operating temperatures from −55°C to +200°C.

Catalog PV-3 discusses the PV series designed to meet the rugged requirements of MIL-C-26482 series 2/MIL-C-83723 series 1, the specs of which delineate the critical requirements of space-age applications.

Charts, photographs and drawings are utilized to provide specifying and ordering information. Included are accessories and components, assembly instructions and tooling available.

ITT Cannon Electric, 666 E. Dyer Road, Santa Ana, Calif. 92702. Circle INFO/CARD #121.

Pricing Guide

Thor Electronics Corp., has announced that their new "Wholesale Pricing Guide" is available immediately. The 40 page catalog lists over 10,000 types of Electron Tubes, Semiconductors, Integrated Circuits and Computer Equipment.

Among the Electron Tubes listed are Microwave, RF, Photo Multipliers, Magnetrons, Ingitrons, CRT's and Numerical Indicators. Also listed are Broadcast, Aviation and Radar Types.

In addition to the complete spectrum of diodes and transistors, other semiconductors listed are Triacs, Diacs, SCR's LED's, OPTO Couplers and OPTO Isolators.

Represented in the integrated circuits listing are TTL, CMOS, Micro Processor, Memories, RAM, ROM, Uart's, Voltage Regulators, Linear, Digital and Eprom.

The computer equipment listed consists of Computer Terminals, Disc Storage Devices, Printers and Diskettes.

A copy of this catalog may be had by writing to Thor Electronics Corp., 321 Pennsylvania Ave., Linden, N.J. 07036. INFO/CARD #122.

"News from Rohde & Schwarz"

The year-end issue of the technical company magazine "News from Rohde & Schwarz" deals with the following new developments: the Adjacent-channel Power Meter NKS for radio services in the range 20 to 950 MHz, the 2-GHz tuner plug-in for the Vector Analyzer ZPV, the RF Millivoltmeter URV 3, the precise Standard Stereo-decoder MSDC 2, new cassettes for the Audiodat system and new additions to the software for the RF Test Assembly SMPU. The test hint looks at the characteristics of XY recorders while the refresher series on television technology continues with part five "Transmission of chrominance signal with colour subcarrier." Short news articles describe the use of mobile workshops for servicing radio-communications equipment and the first computer-controlled system for transmitter monitoring over the air-waves. Also included are reports on the application of an automatic test assembly in the tracking down of sources of interference, new transmitter-monitoring installations for Iran and two new antennas. Contact Rohde & Schwarz, Pressestelle, Muhldorfstr, 15, Postfach 801469, D-8000 Munchen 80, Telfon (0 89) 41 29 2625, Telex 5 23 703. INFO/CARD #124.

Edgecard Connector

Publication of a 96-page color catalog on edgecard connectors for PCB applications has been announced by ITT Cannon Electric, Santa Ana, California.

Catalog PCB-1 lists a broad range of printed circuit connectors accommodating from 2 to 200 contacts in gold, silver or tin plating for solder, eyelet, or wrap post termination.

This publication includes 33 photographs, more than 100 drawings, a quick selection chart with details on contact arrangements, contact materials and finishes, insulator material, contact resistance, current rating and test

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INFO/CARD 2

voltage. Contact spacing available in these connectors ranges from .098 inches to .200 inches. Commercial, military specifications and PIN types also are available in a variety of mounting styles.

ITT Cannon Electric, 666 E. Dyer Road, Santa Ana, Calif. 92702. Circle INFO/CARD #125.

Keyboard Catalog Describes Standard and Custom Types

If you don't require a full size data input keyboard — the answer to your keyboard needs may be found in this new catalog from Grayhill, Inc., La Grange, Ill. 3 x 4 and 4 x 4 keyboard pads plus pushbutton switch modules that can be stacked in any keyboard array for custom requirements are described in this catalog.

The new catalog includes complete specification information, part numbers, and prices. Request Catalog No. 5 from Tom Menzenberger, Grayhill, Inc., 561 Hillgrove, La Grange, Ill. 60525, or call (312) 354-1040. INFO/CARD #126.

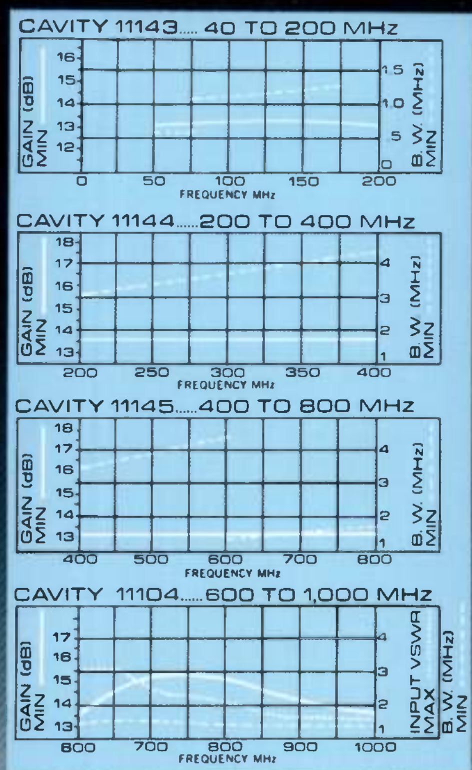
Stripline Package

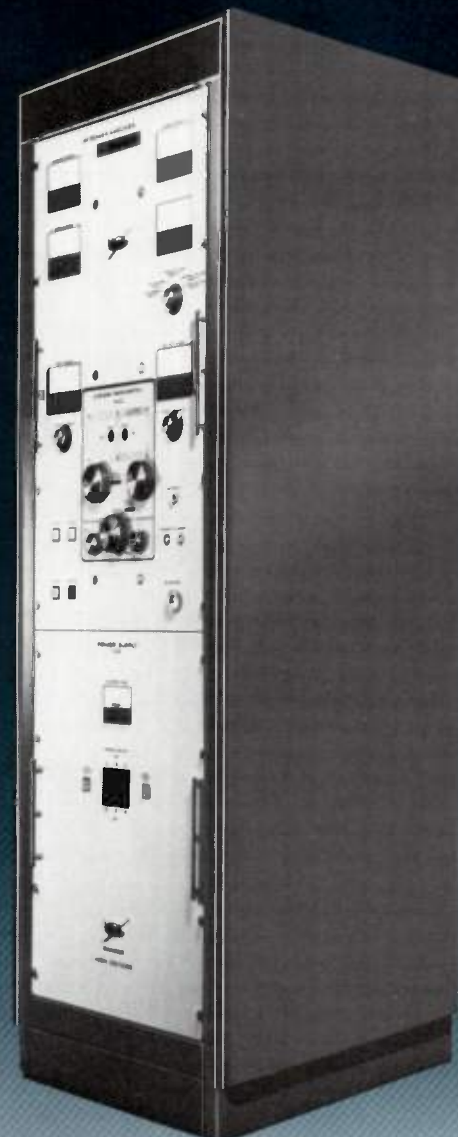
The MICRO-X concept uses a new miniaturized low loss, hermetically sealed stripline package developed by NEC. This development provides for a series of mass-produced transistors with performance and long-term reliability equal of conventional stripline devices. However, the MICRO-X are priced competitively with transistors using less reliable plastic molded packages. Costs are reduced significantly through the use of high-speed, automated manufacturing and testing equipment specifically designed and built by NEC for the MICRO-X series.

Contact California Eastern Laboratories, Inc., P.O. Box 915, One Edwards Court, Burlingame, Calif. 94010. Circle INFO/CARD #127. ☐

Advertiser Index

MCL's PowerPlus 1 KW R.F. Amplifier





The ultimate in RF power amplifier design from MCL. Model 10270 features modular cavity design which allows users to achieve extreme economy and flexibility while retaining high power efficiency and quality construction in a single package.

Providing coverage in ranges from 40 to 1000 MHz through selection of one of our four modular cavities, the 10270 affords maximum utility to the commercial and military user.

Terminations are standard military connectors with a Type "N" input and an "LC" output. Our CW amplifier highlights include a drawer assembly equipped with tilt-out sliderails to facilitate cavity changing and servicing; solid state power supplies for added reliability; regulated filament, grid and screen supplies for added stability and high voltage chassis interlocks for safety.

The amplifier has a primary power requirement of 208/120 Y three-phase, four-wire 60 Hz or 240 VAC three-phase with the option of choosing 208/120 VAC three-phase, four-wire 400 Hz. Special 50 Hz wiring is available upon request.

MCL's model 10270 cabinet and dimensions are 61½" H x 24" W x 26" D. Cabinets weigh 475 lbs. and cavities weigh from 40 to 75 lbs.

2KW Model Available

MCL provides a special 2000 W CW model. This amplifier can be ordered by specifying Model # 10585 which operates in the 400 to 800 MHz frequency range (Cavity # 11145) and may be selected with either 50 or 60 Hz input power.

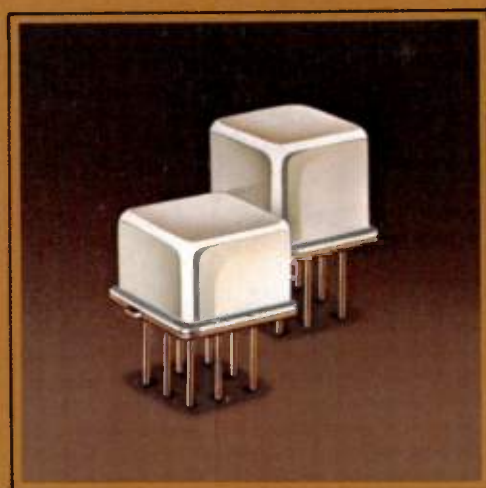
Note: System is shipped complete *with* cabinet as shown unless otherwise specified.

MCL INC
10 North Beach
La Grange, IL 60525
Phone: 312/354-4350

INFO/CARD 34

TO-5 RELAY UPDATE

The Centigrid: You're making it the next industry standard



When we first introduced the Centigrid® we called it The Relay of Tomorrow. But you liked it too well to wait . . . the ultra-low profile; the terminal spacing that permitted direct pc board mounting; the same low coil power and excellent RF switching characteristics as the TO-5. You began putting it into your new designs immediately. And you've never stopped.

Then, early in 1978, we introduced a companion relay: the sensitive Centigrid II, designed for applications requiring ultra-low power dissipation. The can was just a tad taller, but it still took up only .14 sq. in. of board space. And it still offered the same TO-5 proven reliability. You took to it almost as fast as the original Centigrid.

Now that both Centigrid relays are qualified to levels "L" and "M" of MIL-R-39016 (including internal diode suppressed versions) they are fast becoming industry standards. If you'd like complete specification data on either or both, call or write us today.

TELEDYNE RELAYS

12525 Daphne Avenue, Hawthorne, California 90250 • (213) 777-0077

U.K. Sales Office: Heathrow House, Bath Rd. MX, TW5 9QQ • 01-897-2501

European Hqtrs.: Abraham Lincoln Strasse 38-42 • 62 Wiesbaden, W. Germany • 6121-700811

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