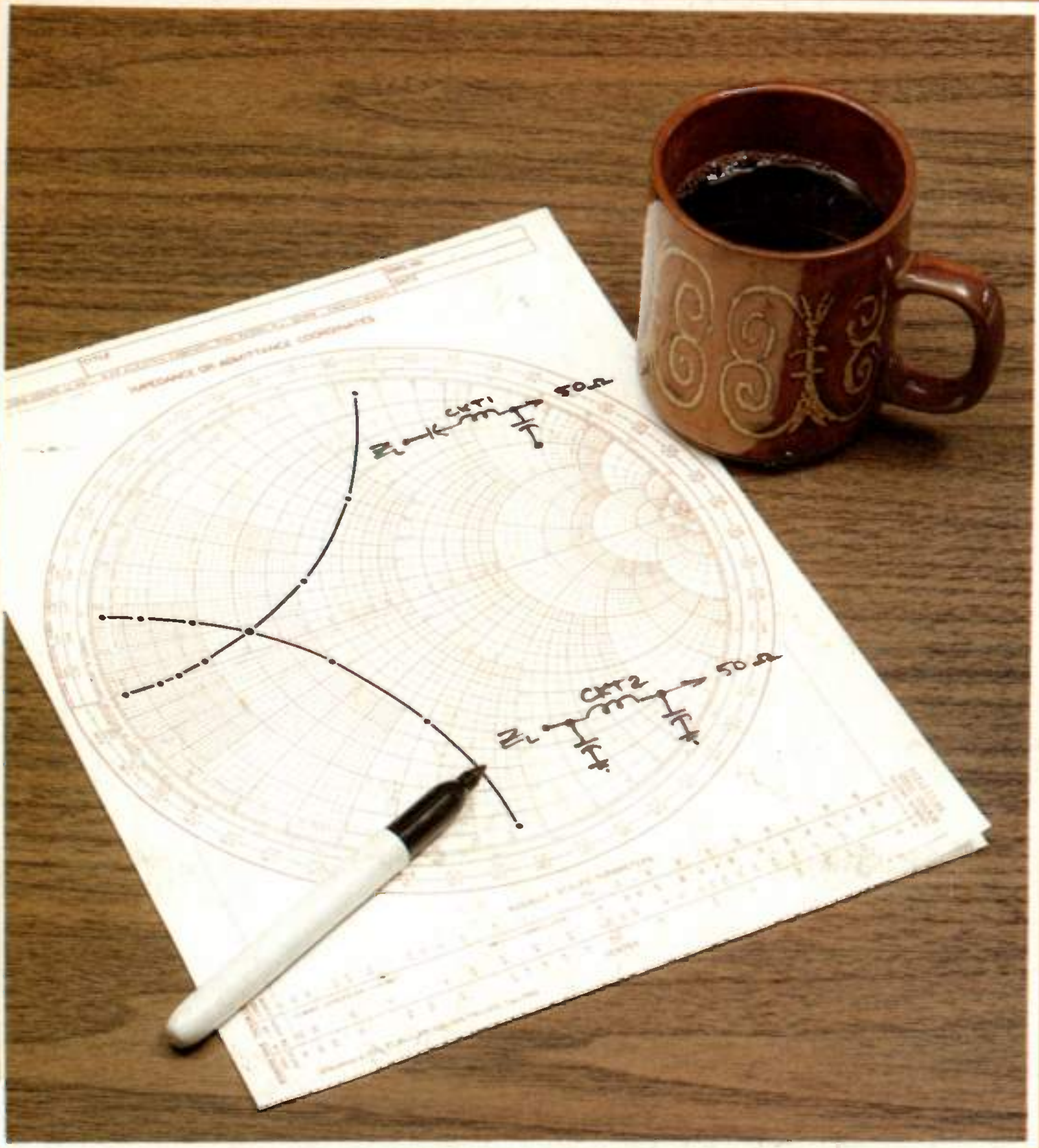
November/December 1978

A Cardiff Publication

rf design



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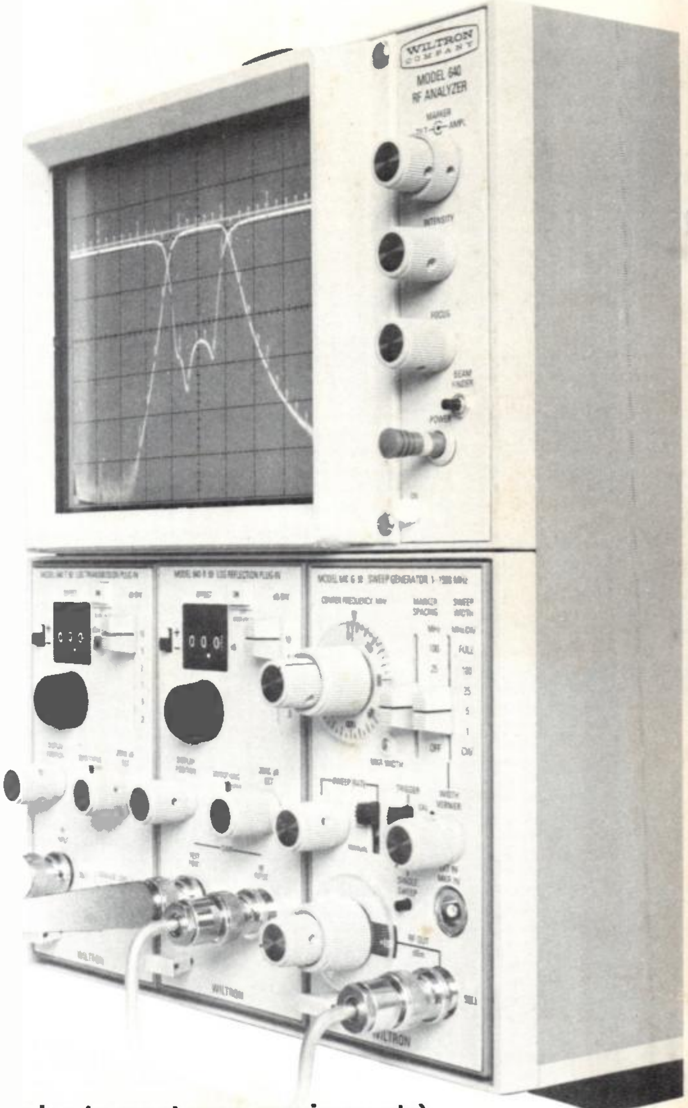

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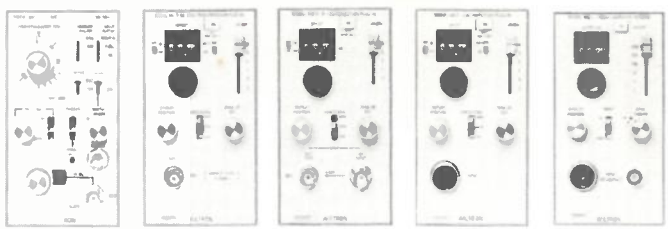

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INFO/CARD 1

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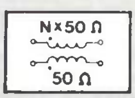
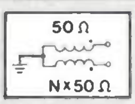


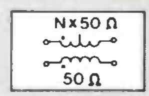
Model						
Metal Case	TMO 1-1	TMO 1.5-1	TMO 2.5-6	TMO 4-6	TMO 9-1	TMO 16-1
Plastic Case	T 1-1	T 1.5-1	T 2.5-6	T 4-6	T 9-1	T 16-1
Freq. Range, MHz	.15-400	.1-300	.01-100	.02-200	.15-200	.3-120
Impedance Ratio	1	1.5	2.5	4	9	16
Max. Insertion Loss	MHz	MHz	MHz	MHz	MHz	MHz
3 dB	.15-400	.1-300	.01-100	.02-200	.15-200	.3-120
2 dB	.35-200	.2-150	.02-50	.05-150	.3-150	.7-80
1 dB	2-50	.5-80	.05-20	1-100	2-40	5-20
Price, Model TMO	$4.95	$6.25	$5.95	$5.95	$5.45	$5.95
(10-49) Model T	$2.95	$3.95	$3.95	$3.95	$3.45	$3.95

UNBALANCED PRIMARY & SECONDARY



Model					
Metal Case	TMO 2-1	TMO 3-1	TMO 4-2	TMO 8-1	TMO 14-1
Plastic Case	T 2-1	T 3-1	T 4-2	T 8-1	T 14-1
Freq. Range, MHz	.015-600	.5-800	.5-600	.15-250	.2-150
Impedance Ratio	2	3	4	8	14
Max. Insertion Loss	MHz	MHz	MHz	MHz	MHz
3 dB	.015-600	.5-800	.2-600	.15-250	.2-150
2 dB	.02-400	2-400	.5-500	.25-200	.5-100
1 dB	.05-200		2-250	2-100	2-50
Price, Model TMO	$5.45	$6.25	$5.45	$5.45	$6.25
(10-49) Model T	$3.45	$4.25	$3.45	$3.45	$4.25

DC ISOLATED PRIMARY & SECONDARY CENTER-TAP SECONDARY



Model							
Metal Case	TMO 1-1T	TMO 2-1T	TMO 2.5-6T	TMO 3-1T	TMO 4-1	TMO5-1T	TMO 13-1T
Plastic Case	T 1-1T	T 2-1T	T 2.5-6T	T 3-1T	T 4-1	T 5-1T	T 13-1T
Freq. Range, MHz	.05-200	.07-200	.01-100	.05-250	2-350	.3-300	.3-120
Impedance Ratio	1	2	2.5	3	4	5	13
Max. Insertion Loss	MHz	MHz	MHz	MHz	MHz	MHz	MHz
3 dB	.05-200	.07-200	.01-100	.05-250	2-350	3-300	.3-120
2 dB	.08-150	.1-100	.02-50	.1-200	35-300	6-200	.7-80
1 dB	2-80	5-50	.05-20	5-70	2-100	5-100	5-20
Maximum Amplitude Unbalance MHz							
.1 dB	5-80	1-50	1-20	1-70	5-100	10-100	5-20
.5 dB	.05-200	.07-200	.01-100	.05-250	2-350	3-300	3-120
Maximum Phase Unbalance Degrees MHz							
1°	5-80	1-50	1-20	1-70	5-100	10-100	5-20
5°	.05-200	.07-200	.01-100	.05-250	2-350	.3-300	.3-120
Price (10-49)							
Model TMO	$5.95	$6.25	$6.25	$5.95	$4.95	$6.25	$6.25
Model T	$3.95	$4.25	$4.25	$3.95	$2.95	$4.25	$4.25

	TMO-series	T-series
Primary Impedance: 50 ohms	.25 cu. inches	.02 cu. inches
Total Input Power: ¼ watt	.07 ounces	.01 ounces

Designers Kit Available

(TK-1) — 2 transformers of each type T1-1, T2-1, T4-1, T9-1, T16-1 **$32.00**

(TMK-2) — 2 transformers of each type TMO1-1, TMO2-1, TMO4-1, TMO9-1, TMO16-1 **$49.50**

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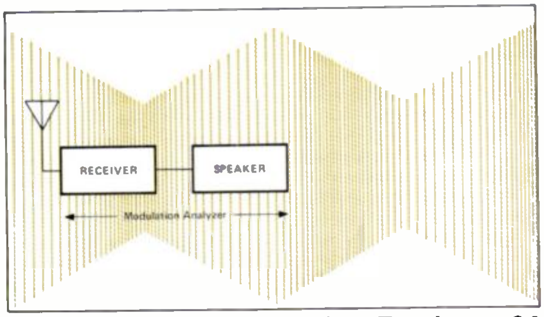
22 Rev G

INFO/CARD 2

rf design

November/December 1978



Transceiver Testing p. 24

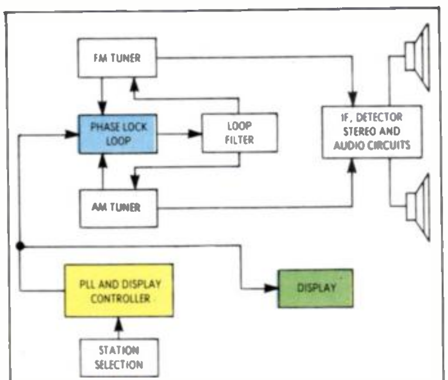
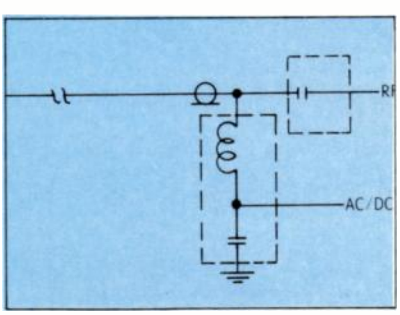


Figure 1. AM-FM Radio Using PLL Tuning.

Digital Tuning p. 31

RF Power p. 40



Co-Ax Power p. 50

For information on new products and literature use Reader Service Card on page 67.

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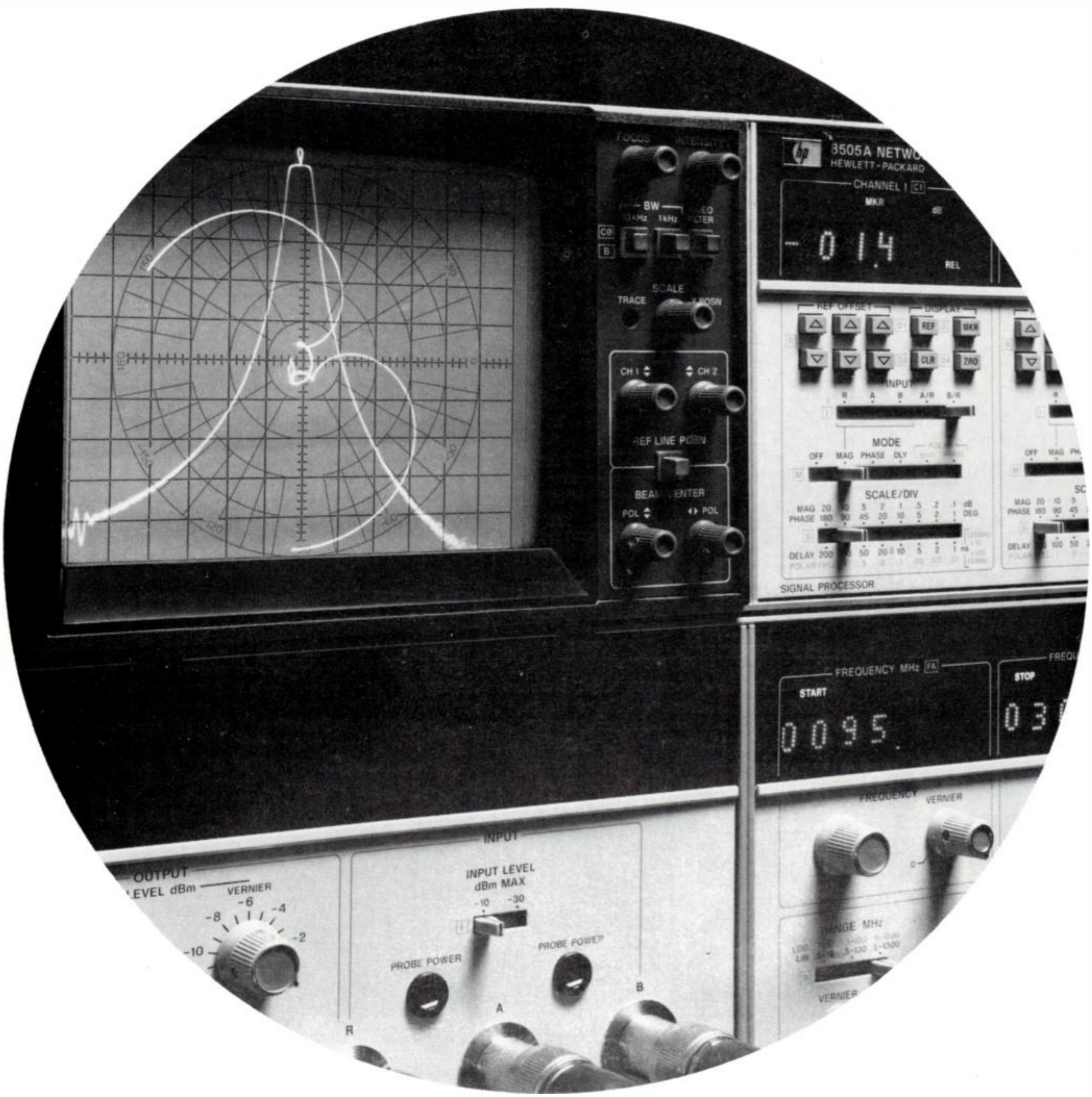
The 1300 MHz Network Analyzer—

Until now performance like this was beyond reach:



■ Over 3 Decades of Swept Frequency Coverage

■ 100 dB Dynamic Range

■ Direct Measurement of Group Delay

HP's 8505A Network Analyzer brings the precision, resolution and range you need for the measurement of phase and magnitude of transmission and reflection, group delay and deviation from linear phase. And any two parameters can be measured and displayed simultaneously.

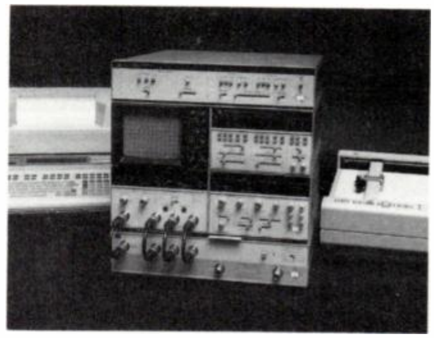
• Test signals come from the 8505A's built-in high performance sweeper with exceptional spectral characteristics and a wide variety of sweep modes (including two independent start/stop sweeps) to accommodate virtually any test requirement.

• The 8505A's 500 kHz to 1.3 GHz frequency range gives you the broad coverage you need to characterize such networks as filters, transistors, antennas, cables, SAW devices and crystals.

• Your measurements are fast and accurate thanks to a swept display with a marker system that provides a high resolution digital readout of the parameter's value at the frequency of any of five variable markers. And group delay measurements are made directly; no calculations required. Or you can observe phase distortions directly in the form of *deviation* from linear phase using the 8505A's revolutionary electronic line stretcher.

• With optional phase-lock capability, the 8505A can be locked to such precision signal sources as the HP 8640 and 8660 Signal Generators. This provides the stability and resolution needed to characterize ultra narrowband devices such as crystal filters.

Get the speed, precision and efficiency of automatic measurements.



Because the analyzer is programmable, you can combine the 8505A containing the optional HP-IB* interface with an HP computing controller (HP Models 9825A and 9830A/B for example) to configure a powerful automatic measurement system. With remarkably simple programming you can make many measurements quickly and with enhanced accuracy, and easily format the data to the form you want. The result is high throughput for cost-effective operation in both production test and design lab applications.

*HP-IB is Hewlett-Packard's implementation of IEEE-488.

Find Out More.

We've only touched on the highlights of the 8505A's performance and capabilities here. For complete data, contact your nearby HP field sales office, or write to us.

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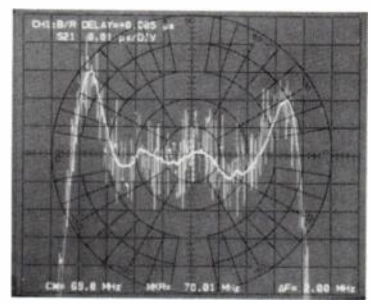
INFO/CARD 4

Add capability with HP's Storage-Normalizer.

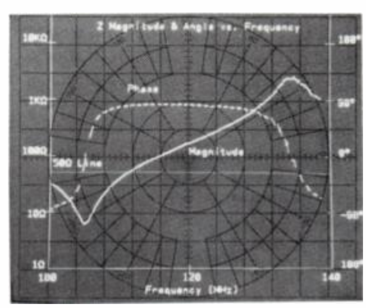
The companion HP 8501A Storage-Normalizer brings these additional features to the 8505A Analyzer:

- *Digital storage* for flicker-free displays.
- *Normalization* to remove errors and make direct comparisons.
- *Magnifier* for up to a tenfold increase in resolution.
- *CRT Labeling* that presents major 8505A settings and marker data.
- *Signal Averaging* that raises signal-to-noise ratio, thereby improving narrowband group delay and low signal level measurements.



Group Delay of 70 MHz bandpass filter with and without averaging. (Vert. scale: 5nsec/div)

When the HP-IB programmable 8501A is combined with the automatic 8505A/computing controller combination, the system offers versatile display capabilities for text and graphics plus high-speed digitizing for fast, yet precise and comprehensive measurements.



Reflection Coefficient data reformatted to impedance magnitude and angle.

r.f. design

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editorial

Gone Are The Days . . .

. . . when the engineer designing RF equipment had to sift through many magazines and many more articles to find a few which could help him do his job better. **r.f. design** will fill that need! This magazine will be edited exclusively for you. In every issue we will try and have a good balance between design, instrumentation and packaging articles. These are the problems faced every day, particularly by the RF engineer.

Please tell us your reactions to our articles and give us your suggestions on where we can get good ones. If you are the kind of person who likes to write, let us know. Or if you have good ideas and *don't* like to write, you can still let us know and we'll help you get them on paper.

Beginning in the next issue we will have a section called "r.f. ideas". In this section we will print thoughts, ideas, shortcuts sent to us by our readers so, again, please write.

We plan to do other new and interesting things pertaining to RF but, as always, a good magazine depends on feedback to be good. We'll be looking for yours.

Pat Wiesner

PS: Pass this copy along to a friend and you can both send in one of the free subscription cards facing Page 8. □

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Programmable Direct Synthesizer: 0.1 to 160 MHz

THE VALUE

Rockland Series 5600 Programmable Frequency Synthesizers employ the *direct* synthesis technique – no slow and noisy phase-locked loops – yet cost less than many PLL designs in this range! Resolution is *constant*: 1 Hz across the entire 0.1 to 160 MHz range. That's a *single* range, too; no range switching, no multipliers. Spectral purity is outstanding: –70 dB phase noise: –35dB harmonics; –70 dB spurious. Stability is exceptionally high: 1×10^{-9}/day, with a very low T.C. (1×10^{-8} from 0°C to 50°C). Or inject your own external reference. Output levelling is exceptionally tight: ±0.5 dB throughout the frequency range.

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The greatest value: Rockland engineering and manufacturing experience. Superb quality. Maximum applications support.

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Model 5600 has manual front-panel controls plus full remote digital programmability.

Model 5610A has blank front panel, no manual controls, but the same full digital programmability. Considerably lower in price than Model 5600. Ideal for OEM Systems.

Model 5620 is a stripped-down chassis version for OEM build-in, and retains all electrical features. Even lower in price than Model 5610A.

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ROCKLAND

UHF Task Force Report Controversy

The available spectrum for land mobile users is becoming scarce. As early as 1981 the 800 MHz private dispatch channels will be assigned in the major urban areas. Yet new license requests are increasing at a rate of 13 percent per year. This means that the number of land mobile users will double about every 5.7 years.

In February, 1978 Raymond M. Wilmotte published the findings of the UHF Task Force Report on Spectrum-Efficient Technology for Voice Communications (commissioned by the FCC). The basic claim of the study was that by using amplitude and frequency companding in conjunction with single side band AM, the allotted land mobile spectrum could be utilized ten times more efficiently than it is with the present FM strategy.

Subsequent to the report, several members of the land mobile community set up an EIA TR-8 Ad Hoc Committee for Spectrum-Efficient Technology to collaborate the findings of the UHF Task Force. In August, 1978 they made their findings public.

There were substantial differences in the findings of the two groups. The disagreement centers upon a subjective judgment of the necessary quality of voice communications. The UHF Task Force based its recommendations on a channel signal to noise ratio of 30dB. The Ad Hoc Committee, on the other hand, claimed that a much higher quality, signal to noise ratio was an operational necessity. If one accepts a signal to noise ratio of 30dB, then amplitude and frequency companding a single side band AM signal has definite advantages over the present FM techniques. Conversely, if a higher S/N ratio is an "operational requirement", then the advantages of FM outweigh those of any AM strategy.

In determining which technology (FM or ACSSB) can best meet the future needs of the land mobile users, three factors were weighed: Signal to noise ratio, spectrum-efficiency (bandwidth of signal), and transmitter power requirements. Basing its recommendations on a signal to noise ratio of 30dB, the Task Force made the following findings: An FM signal can achieve a 30dB S/N at a transmitter output of 20 watts and a bandwidth of 12kHz. The same signal to noise ratio of an AM signal requires an output of over 500 watts, but uses only 8kHz of spectrum. (SSB uses half the AM spectrum at the same power requirement). Even though traditional AM/SSB is more spectrum efficient, the power requirements of this strategy are prohibitive (Figure 1). If, however, amplitude companding is used before the signal is modulated, the Task Force found that the power requirements of the AM transmitter became comparable to those of the FM system. The amplitude companded SSB strategy provided greater spectrum efficiency at the same power. Amplitude companding will also narrow the bandwidth of an FM signal. But, as can be seen from Figure 2, the ACSSB strategy still remains the more

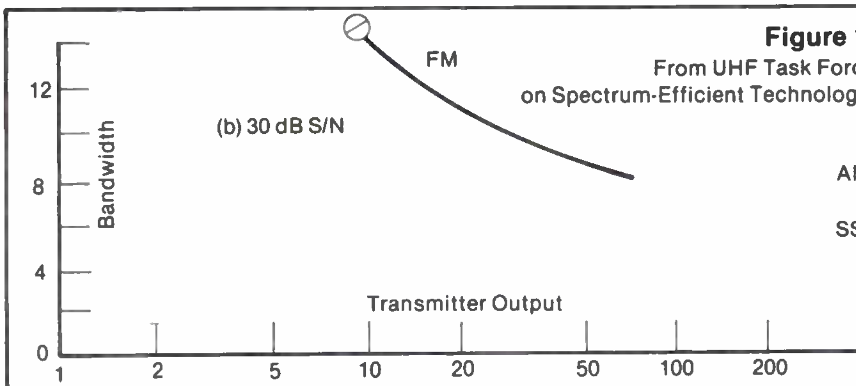

Figure 1.
From UHF Task Force on Spectrum-Efficient Technology.

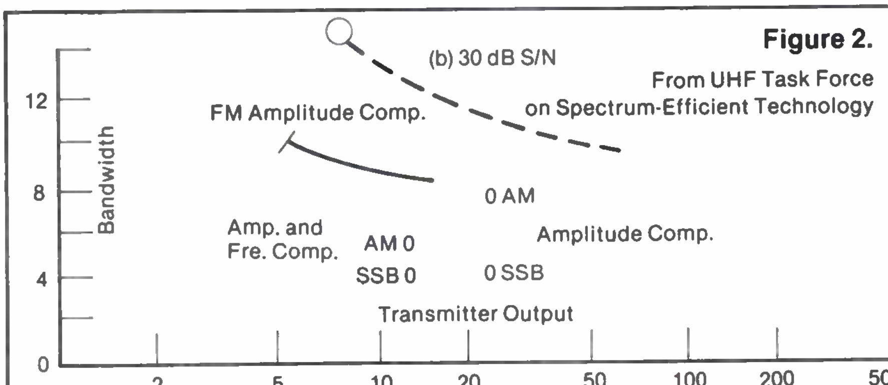

Figure 2.
From UHF Task Force on Spectrum-Efficient Technology

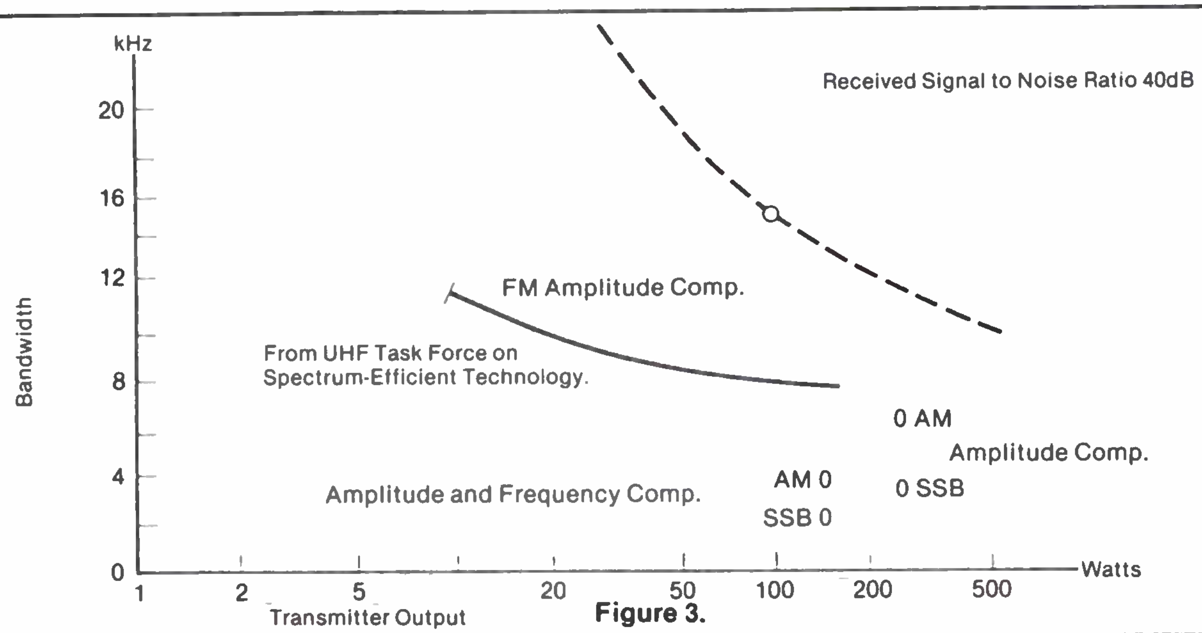

Figure 3.

spectrum-efficient. If in addition to amplitude companding, the audio signal is also frequency companded, then the bandwidth of the SSB/AM strategy is reduced even further.

The Ad Hoc Committee countered that since a greater signal to noise ratio is required for reliable communication, the FM amplitude companded signal, while still less spectrum-efficient, requires substantially less power (Figure 3). Hence, that the present FM strategy is still preferable, on the basis of transmitter power reduction at some cost to spectrum utilization. In addition, the frequency stability required of FM is less stringent than that required for ACSSB/AM.

Again, disagreement erupted over the issue of co-channel and adjacent channel signal compatability. The Ad Hoc Committee claimed that more stringent signal to unwanted signal ratios were required than those used by the UHF Task Force. The assumed acceptable adjacent channel ratios, of course, determines how close in frequency the channels can be spaced. Co-channel interference determines the allowable number of non-interfering conversations that can be held on the same channel in a large geographic region. The Task Force used FM specifications for its work on adjacent channel interference. For co-channel interference, the ratio between wanted and unwanted signals were subjectively found to be the same for FM and ACSSB/AM.

In conclusion, the UHF Task Force found that a substantial improvement in spectrum-efficiency could be obtained by using an ACSSB/AM strategy based on the assumption that a 30dB signal to noise ratio is acceptable. The Ad Hoc Committee claims that more stringent requirements must be placed on the quality of voice communication, implying the preferable strategy should still be FM. Both, however, agree that available spectrum is growing scarce, and more spectrum-efficient utilization would be advantageous to the land mobile community.

Midcon/78 and the RF Design Engineer

Midcon/78 will be held Dec. 12-14, at the Dallas Convention Center. The specific content aimed at the RF design engineer is reflected in the content of the sessions and papers scheduled to be presented.

One session for example, is entitled *RF Communications Equipment — Present and Future.* We have included one of the papers to be presented at the session in the issue of **r.f design,** (*Modern RF Power Design.*) The session will cover modern design concepts and applications for RF communications equipment. Topics include high dynamic range for communications receivers, RF power design, high-power ferromagnetic transformers and VHF FM transmitter/receiver design. Data is aimed at commercial and military equiment designers and management personnel.

A special program of classified technical sessions is scheduled in conjunction with Midcon/78 on Tuesday, Wednesday and Thursday, December 12-14. The sessions will be held in the Dallas Federal Building and transportation will be furnished from the Convention Center via Midcon buses. Topics will include *SAC Force Effectiveness, Future Cruise Missile Technology, $C^3 1$ in NATO, Electronic Warfare, and Satellite Communications.*

Attendance at any classified session requires Final Secret Clearance by the Department of Defense. Additionally, attendance at the two sessions on NATO Wednesday specifies certification of NATO Secret Clearance and is restricted to U.S. citizens. A clearance form package may be obtained by contacting Hal Logsdon at (214) 231-9303, extension 287, prior to November 10.

A session entitled *Future Alternatives for Communications with The Traveling Public* will be comprised of six mobile land-radio panelists. They will present alternative approaches to the communications system technology that will lead to a nation-wide system in the period from 1990-2000. Spread spectrum technology will be presented in one of the session papers.

Another session entitled *Electromagnetic Compatibility Standards for International Marketing* will answer two important questions for consumer and commercial electronic equipment designers. First, what are the present EMC requirements both in the U.S. and abroad, and what impacts will future EMC regulations have? Second, what equipment design measures are necessary to meet present and forecasted EMC regulations?

Adaptive Array Antennas will be a session covering work being done in four different parts of the country. Papers proceed from an overview of present and needed developments to current applications in antijam satellite communications, airborne monopulse radar, over the horizon radar and to selection of algorithms and microprocessor control.

RF and Microprocessors

Microprocessors are playing an increasing role in the world of the RF design engineer. Two sessions will be of particular interest. *Microprocessors Improve Test Instrument Performance* addresses test capabilities not previously available. The session also considers the need for software standardization. *Interfacing Microprocessors to The Outside World* will cover microprocessors with on-chip A/D converters, μP peripherals, buses, and multiprocessing.

Pasquale A. Pistorio, Vice President and Director of Worldwide Marketing for Motorola Semiconductor, will address the Keynote Luncheon at the Hyatt Regency, Monday, December 11, 1978. The exhibition and convention will formally begin Tuesday, December 12. The Motorola executive is expected to discuss the U.S. semiconductor industry's status.

Career Planning

Of general interest to electrical engineers of various backgrounds are three sessions on career development.

Engineering — Feast, Famine, or Career addresses how the career and professional realities that impact on electrical and electronics engineers. have changed since the early seventies. And how an employed professional can more completely control his career. This session will attempt to clarify interrelated corporate requirements, the principles underlying dynamic marketplace components, and how IEEE reacts. Audience participation will be invited.

Engineers — With a Difference will discuss engineers who do not match the "standard" profile. Specifically, this will include women and minority engineering trends, engineers who desire to direct their careers toward upward levels of the corporation, and engineers in industry who are registered.

Why Managers Fail is intended to provide the practitioner with a practical model spelling out the pre-requisites for success in management. The possible causes of managerial failure will be explored and analyzed, and some operational strategies to enhance managerial competency will be recommended.

In overview, Midcon/78 has generated a great deal of enthusiasm. Even after expanding its exhibit space 67 percent, Midcon is sold out. Both East and West Halls of the Dallas Convention Center will be utilized for the displays of electronics ranging from components to systems. More than 15,000 engineers, managers and technicians are expected to attend the three-day Midcon event. And a substantial amount of the program content is directed toward the RF engineer. □

Modern Solid State RF Power Devices

A discussion of devices, design procedures tests and tweaks.

By Walter C. Simciak
Heath Company
Benton Harbor, Michigan 49022

At Wescon in 1960 engineers from PSI, presented a paper on the generation of high power at 1000 MHz using semi-conductors. This thundering power was one watt. It made use of passive varactor multipliers and a 4.5 watt 125 MHz driver which used three RF power transistors.

We have come a ways from that — Ham equipment today makes common use of RF power transistors at all legal levels. HF amplifiers have reached levels of over 1000 watts output. HF transceiver equipment now sees broadband solid state amplifiers that typically provide 100 watts of output from 1.8 to 30 MHz. VHF/UHF applications have reached 250 watts of output power.

HF SSB/CW Power Transistors
(@ 30 MHz and 12.5VDC unless noted)

Power Out	Gain	Device	Manufacturer
50	11.0dB	MRF450A	MOT
	12.0dB	SD1451	SSS
	13.0dB	BLX14 (28v.)	AMP
	14.0dB	PT9783 (28v.)	TRW
	15.0dB	PT9797	TRW
60	11.0dB	MRF455A	MOT
	13.0dB	SD1405	SSS
75	15.0dB	PT9784	TRW
80	12.0dB	MRF454A	MOT
	14.0dB	BLW76 (28v.)	AMP
100	10.0dB	SD1449	SSS
	10.0dB	MRF421	MOT
	10.7dB	S100-12	CTC
	12.8dB	PT9785	TRW
	13.0dB	SD1407 (28v.)	SSS
	14.0dB	PT9780 (28v.)	TRW
130	12.0dB	BLW77 (28v.)	AMP
150	10.0dB	SD1450 (28v.)	SSS
	12.8dB	PT9849	TRW
	13.0dB	MRF428A (28v.)	MOT
200	14.0dB	N755BLY (50v.)	AMP

The new Amperex N755BLY experimental 50 volt device occupies the highest power level of 200 watts. Amperex felt that part of that rating was made possible through the use of a very thin beryllium oxide disk which provides a very low thermal path from the transistor junction to the case (.6°C/W). The Amperex device achieves this higher power using 50 VDC for a supply voltage. Decreasing the voltage typically decreases device power output capability and gain.

At present, the PT9849 device from TRW is the leader in power at 12.5VDC with power of 150 watts. The S100-12 from CTC, SD1449 from SSS and MRF421 from MOT are in the next group at 100 watts output. All of these devices are SSB/CW rated. In other words, they have been characterized for gain and efficiency in a Class B mode and a specified intermodulation distortion typically in the range of −30 to −32 dB.

SSS = Solid State Scientific
CTC = Communications Transistor Corp.
TRW = TRW
AMP = Amperex
MOT = Motorola

Two Meter Devices
(FM Rating at 12.5V 175 MHz)

Power Out	Gain	Device	Manufacturer
150	5.5dB	SD1441	SSS
100	6.0dB	SD1477	SSS
80	6.4dB	MRF245	MOT
	7.6dB	BM80-12	CTC
75	6.2dB	J04075	TRW
70	6.7dB	SD1416	SSS
	5.9dB	J04070	TRW
	6.0dB	CD4070	CTC
60	7.0dB	SD1427	SSS
45	7.0dB	MRF243	MOT
	6.0dB	BLW-60C	AMP
	6.5dB	BM-45-12	CTC
	6.5dB	J04045	TRW
40	6.7dB	SD1415	SSS
	6.7dB	MRF216	MOT
	5.0dB	B40-12	CTC
	4.5dB	PT8874	TRW
	5.7dB	2N6083	MOT, TRW, SSS
	5.5dB	B30-12	CTC
	8.0dB	BM30-12	CTC
25	6.2dB	2N6082	SSS, TRW, MOT
	8.0dB	BLY89A	AMP
	6.0dB	B25-12	CTC
15	6.3dB	2N6081	SSS, TRW, MOT
	8.0dB	BLY88C	AMP
	6.0dB	B15-12	CTC
	7.8dB	PT8873	TRW
	10.0dB	BM15-12	CTC

VHF/UHF Devices

At higher frequencies, the manufacturer's target is for FM (commercial two-way FM) or AM (Avionics) operation — not SSB.The two-way radio market is so much larger than ham radio usage that the attractive 12.5 volt mobile parts are designed and tested at the upper ends of the commercial two-way FM bands (50 MHz, 175 MHz, 470 MHz, etc.).

Comments concerning VHF, UHF devices:

1. If a large OEM (Original equipment manufacturer) designs a particular device type from a manufacturer into a high volume transceiver, other manufacturers will second source. This is especially true now on the older devices such as a 25 watt/6dB gain part. Motorola, Solid State Scientific and CTC all have parts which meet the requirements and may be selected to meet OEM specifications.

2. Many OEMs buy devices using an RF test fixture. A 2N6083 from one manufacturer may not exactly replace a screened 2N6083 from another. Most major manufacturers do run RF, DC and VSWR tests on each device, however, the only way to insure that a replacement device will work is to buy it from the OEM replacement stock. Do not believe replacement guides.

(Continued on page 18.)

Six Meter Devices
(FM Rating at 12.5V at 50 MHz)

Power Out	Gain	Device	Manufacturer
80	10.5dB	A80-12G	CTC
80	10.0dB	A80-12	CTC
75	9.0dB	SD1405	SSS
70	9.0dB	SD1076	SSS
	9.0dB	PT8854	TRW
50	9.0dB	SD1451	SSS
	14 dB	BLY90*	AMP
40	7.5dB	2N5849	MOT
	7.5dB	SD1169	SSS
35	10.0dB	PT8853	TRW
25	10.0dB	A-25-12	CTC
	15 dB	BLY89C*	AMP

*175 MHz devices recommended for 50 MHz

220 MHz Devices
(FM Rating at 12.5V 225 MHz)

Power Out	Gain	Device	Manufacturer
30	6.0dB	SD1272	SSS
25	4.4dB	MRF209	MOT
	4.4dB	CD1803	CTC
13	9.0dB	MRF226	MOT
	9.0dB	SD1143	SSS
10	10 dB	MRF208	MOT
	10 dB	CD1802	CTC
	10 dB	SD1133	SSS

450 MHz Devices
(FM Rating at 12.5V, 470 MHz)

Power Out	Gain	Device	Manufacturer
80	5.0dB	SD1420	SSS
75	4.8dB	CM75-12	CTC
60	4.4dB	MRF648	MOT
	3.8dB	J03060	TRW
55	4.4dB	J03055	TRW
50	6.0dB	SD1460	SSS
45	5.0dB	SD1434	SSS
	5.0dB	J03045	TRW
40	4.8dB	MRF646	MOT
	5.0dB	SD1089	SSS
35	4.6dB	J03035	TRW
30	5.0dB	BLW82	AMP
28	6.0dB	J03028	TRW
25	6.2dB	MRF644	MOT
	6.0dB	SD1088	SSS
20	4.0dB	BLX69A	AMP
15	6.0dB	MRF641	MOT
	7.7dB	J03015	TRW
12	7.5dB	SD1429	SSS
	9.0dB	J03012	TRW
10	6.0dB	2N5946	MOT, SSS, TRW
	6.0dB	BLW81	AMP

On the OEM level, the semi-conductor manufacturers may adjust their device to fit a particular socket via wire band length, process variation, screening, etc. A replacement part does not have this advantage.

3. The gains on the devices may be adjusted mathematically from one frequency to another using the formula:

$$\text{Change in gain} = 20 \log_{10}\left(\frac{Fo}{F1}\right)$$

where Fo is the frequency of specified gain and F1 is the frequency of unknown gain. This is based on the characteristic 6dB/octave roll-off in gain exhibited by RF power devices. Hence a device with 10dB of gain at 175 MHz would have about 11.46dB of gain at 148 MHz.

4. The relative sparse pickings at six meters is mostly due to the low interest in development of new commercial equipment at "low band" FM. Also, many manufacturers will use "high band" two meter parts to minimize stage count.

Device Limitations

Solid State power users still face limitations of RF power devices. Some of them are:

- Thermal Limitation
- VSWR Stresses
- Package Parasitics

Thermal limitations are easy to understand if taken a step at a time. Figure 1 shows a typical RF power device. Each thermal resistance may be thought of as a resistor with a current (heat flow) passing through it. If all the resultant voltages (temperature increases) across each resistor is added up and then added to the fixed voltage (ambient temperature) the maximum voltage (temperature) may be calculated.

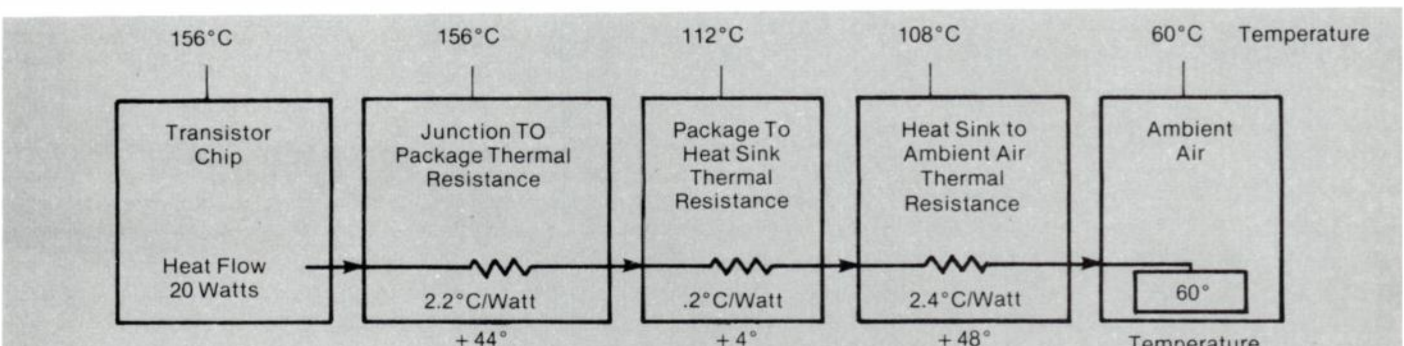

Figure 1. Heat Flow Analysis.

With this in mind, we can begin to understand what must be done to ensure safe operating temperatures for the semiconductors. Changing the junction temperature from 200°C to 175°C doubles the MTBF or life of an RF power device. As users, we have control of two of the three thermal resistances, the package-to-heatsink and heatsink-to-air.

The heat sink should be of proper design — heavy fins to permit heat flow to the entire fin area, and heavy base plate for heat flow to the fins. An extruded heat sink is better than a casting unless the casting is very good. What occurs in a poor casting is that air becomes trapped in the metal core causing the metal to be porous. This does not permit good heat flow.

The case to heat sink interface requires an extremely "flat" surface for the transistor to mount against. The use of a good thermal paste such as GE Insul grease or Dow Corning 340 fills in any remaining voids. The type of package in to which the transistor is mounted also determines the case to heat sink thermal resistance. A few resistances are:

1/4" Stud	1.0° C/W
3/8" Stud	.5° C/W
1/2" Stud	.4° C/W
3/8" Flange	.2 C/W
1/2" Flange	.1° C/W

VSWR stress capacity may be designed into a transistor, however, it is a trade off with gain. Emitter ballasting and base cell spreading enhance this ruggedness with the predictable loss of gain. Larger die increase ruggedness, however, this could again reduce gain by 2dB for each doubling in current factor. Most of the devices intended for commercial two-way service have already been "traded-off" and are tested at various high output VSWRs. This means the device will not destruct in the manufacturer's test fixture under elevated voltage and high VSWR on the output. However, it is up to the designer, to design circuit and thermal stability into the transceiver.

Package parasitics represent a real limitation to RF power devices. The input lead on a 3/8" stud may only have 1.3 nHy. However, that small amount at 148 MHz represents +j1.2 ohms series inductive reactance. Typical transistor input impedances are only a few ohms. This could make devices exhibit extremely narrow bandwidths and/or lower gains (due to circuit losses). Figure 2 shows some typical package inductances.

(Continued on page 19.)

(Limitations Continued)

	TO-39	TO-60	1/4" Stud	3/8" Stud	1/2" Stud	JØ
Input Lead	3	3	1.1	1.3	1.4	1.0
Common Lead	3	3	.35	.4	.7	.2
Output Lead	3	3	1.2	1.4	1.5	1.5

Figure 2. Parasitic Lead Inductance (NHy)

Fairly recent developments in packaging VHF/UHF RF power devices have been:

1. Isolated emitter TO-39 (MOT, SSS, TRW)
2. XO-72 Stripline package (MOT, CTC, SSS)
3. "Balance Transistor" (CTC)
4. TO-220 Package at RF (MOT, SSS)

The isolated TO-39 has the transistor chip mounted on a small piece of beryllium oxide which is in turn mounted onto the thick metal bottom of the TO-39 transistor can. Since beryllium oxide has a very high thermal conductivity, the heat readily transfers from the transistor die to the metal plate. The transistor die is then wire bonded with the emitter being connected to the transistor shell or can. Since most RF circuits are common emitter and that emitter goes to ground, the can may now be soldered to the ground foil of the PC board making the PC board the heat sink. These small TO-39 devices are characterized at powers of four watts out and are very cost competitive.

The XO-72 stripline package is a small effective holder for high gain UHF and L-Band devices. Up to 13dB of gain at 470 MHz and a 1/2 watt output.

The balance transistor from CTC is a special package that places two transistors into a single package. Experimental as yet, it offers wideband push-pull advantages that previous packages do not.

The TO-220 package is the familar plastic audio power output package. It is a spin off from the CB industry who required inexpensive 30 MHz devices. The semi-conductor people picked up on this and are now also offering 50 MHz and 88 MHz parts (88 MHz is known as "Mid band" and is common in Europe). Some devices have been also characterized at 175 MHz. The main advantage is low cost.

Special Devices

There are several developments that should also be covered:

- Power Modules
- VMOS Power Devices
- Microwave Devices

Power modules are complete power amplifier strips providing up to 30 watts of output power and gains of over 20dB. Except for a few U.S. OEM's, the majority of the usage is in Europe, where the size advantage of these hybrids outweigh the cost disadvantage. Several common types are show below:

Frequency	Power Output	Gain
66-88 MHz	20.0	20dB
135-180 MHz	20.0	20dB
150-160	30.0	21.8dB
400-512	7.5	17.8dB
400-512	12.0	19 dB
400-470	15.0	18.8dB

These types are manufactured by TRW, Motorola and Amperex. All that is required is low pass filtering as the harmonic content is only −30dB.

VMOS is a new (to the USA) mos process which has received a great deal of attention in RF applications of late. Devices are offered from CTC and Siliconix. The devices suffer from two problems at present:

- High voltage (24 to 40 volts)
- High cost

The first characteristic keeps the device out of the commercial two-way mobile usage which takes care of the second item.

The devices look very good for SSB usage. They are very linear devices and inherently thermally stable. The design guidelines for amateur radio equipment at present call for operation on 12.5 volts per mobile and emergency applications which eliminate their consideration from many designs. Devices are show below:

Device	Power Out	VDC	Gain	Freq.	Mfr.
VMP4	13W (saturated)	24V	11dB	175MHz	Siliconix
BF25-35	25W	35V	10dB	175MHz	CTC
BF50-35	50W	35V	10dB	175MHz	CTC
BF100-35	100W	35V	10dB	175MHz	CTC

Figure 3.

In the microwave area, most manufacturers agree that the new 900 MHz high power devices would not be effective at the 1296 MHz ham bands. This is a disappointment at CTC is due to have their 60 Watt 6dB gain part for the 800-960 MHz commercial band shortly. There are a group of L-Band devices characterized for pulse operation in the 1.1 to 1.4 GHz area. These devices must be de-rated to 25 percent for operation on CW. Typical in this area is:

Device	Power	Gain	Manufacturer
LM-25-28	25 W	7dB	CTC
LM150PX	150 W Pulse	5.4dB	CTC
1214-120P	120 W Pulse	8dB	CTC

(Continued on page 20.)

Typical Design Procedure

A typical procedure for a modern solid state design would be:

1. Determine losses following power output device including filtering, T-R switching and miscellaneous losses.
2. Determine device power output requirements based on loses and desired output power.
3. Determine driver requirements.
4. Select devices.
5. Determine other requirements such as VSWR stability, over voltage requirements, linearity, input VSWR, bandwidth and any special requirements.
6. Design circuit and design and correlate transistor test fixtures.

Filter is especially important with the advent of the new FCC rules. Figure 4 is a quick reference as to those requirements. A Class C amplifier typically has a 2nd harmonic at only −30dB (dependent on output network) while a Class B amplifier is more of the order of −40dB. The addition of filtering is mandatory at VHF to meet FCC compliance.

Below 30 MHz
With carrier output power of 5 Watts or less — 30dB
With carrier output power greater than 5 Watts — 40dB

Above 30 MHz but below 235 MHz
With carrier output power of 200 milliwatts or less — 40dB
With carrier output power greater than 200 milliwatts follow the formula:

Attenuation = 46 + $\log_{10}$ (Power) until 60 dB is reached (25 watts) 60 dB is the maximum requirement

(By comparison commercial two-way FM is required to do 43 + 10 $\log_{10}$ (Power))

Above 235 MHz
Spurious shall be reduced to best engineering practices.

Figure 4. FCC Harmonic and Spurious Limits.

VSWR Test Box

VSWR stability is the ability of the amplifier not to become regenerative under an all phase VSWR load test. If the amplifier goes unstable, many carrier unrelated spurious signals appear causing a great deal of interference to other services and greatly stress the output device.

A simple method of evaluating this condition at VHF/UHF frequencies is using a test box as shown in Figure 5. This type of box stresses an amplifier circuit "around" the Smith chart i.e. a short circuit, shunt capacitance, open circuit, shunt inductance, and back to a short circuit. Actual VSWR may be adjusted by placing some loss such as a length of coaxial cable between the test box and amplifier. (Any amplifier can be made to look good if the right length of cable is selected for open or short circuiting.)

Once a VSWR problem is found, what can be done? *Circuit design.* At VHF, network design, shutdown circuits, thermal considerations, prossibly feedback. At VHF, network design, low frequency feedback and low frequency bypassing.

As an example of changing networks at VHF, examine Figure 6. These two networks provide the *(Continued on page 22.)*

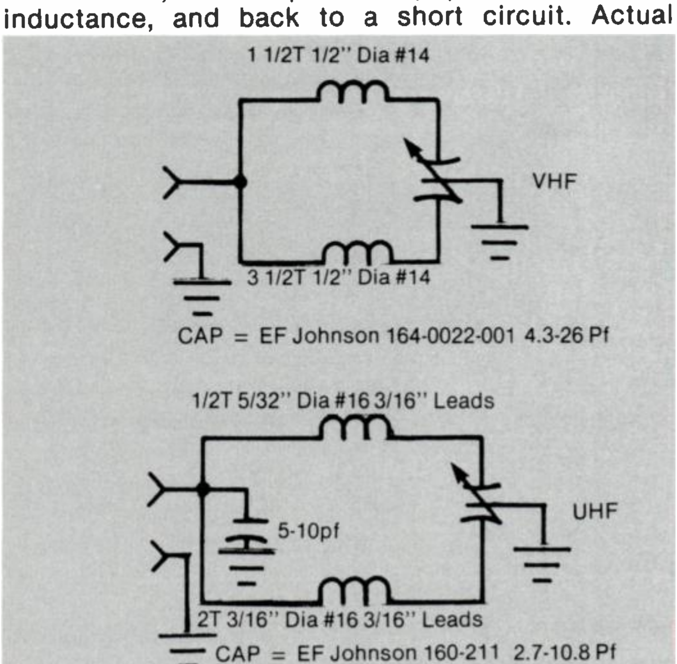

Figure 5. VSWR Test Box Circuitry.

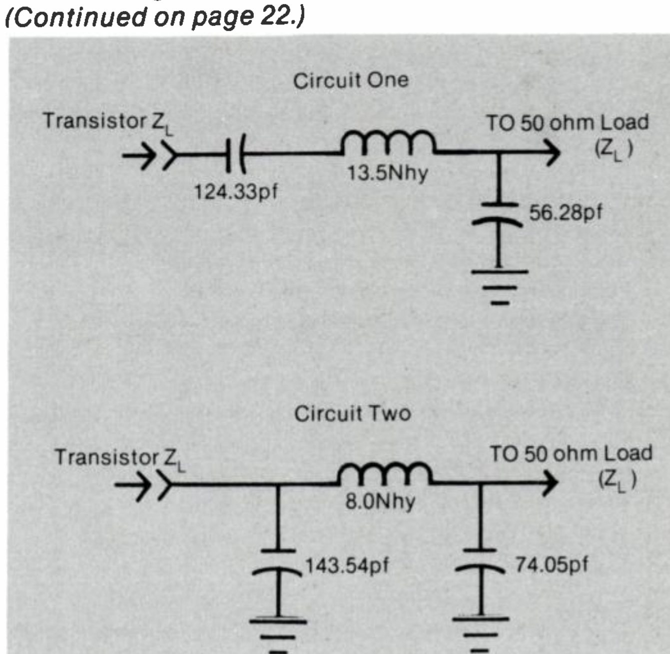

Figure 6. Output Networks Same Q.

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(VSWR Test Box Continued)

same output load, and same Q, at the transistor. With a resistive load of 0 to 5K on the output of the network in place of the 50 ohm design center, the networks perform totally different as shown in Figure 7. The transistor sees entirely different areas of the Smith chart.

Examining the same circuits with reactive loads in Figure 8, again a difference may be seen. Circuit one pivots 230° while circuit two pivots 193°. Certainly, this is only one area of the overall circuit, but analyzing both input and output networks with respect to various high VSWR loads and low frequency resonances aid in improving the output VSWR stability.

Bypassing at low frequencies is extremely important. Since the low frequency gain of an RF device is extremely high, care must be taken to eliminate any tuned circuits or feedback paths at these frequencies. Watch driver stages for oscialla-tion as they can see as much VSWR as the output device.

Over voltage is an area which also must be carefully watched. An 18 Volt BV_{CEO} 80 Watt RF power transistor may not last with 20 volts from an unregulated supply at a high line voltage or a 24 volt boost battery jumpered across your 12 volt automobile battery for starting purposes.

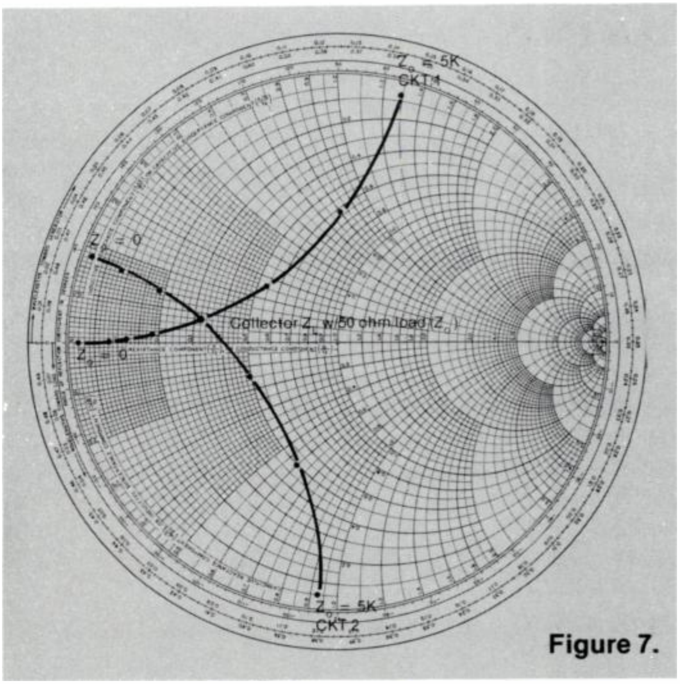

Figure 7.

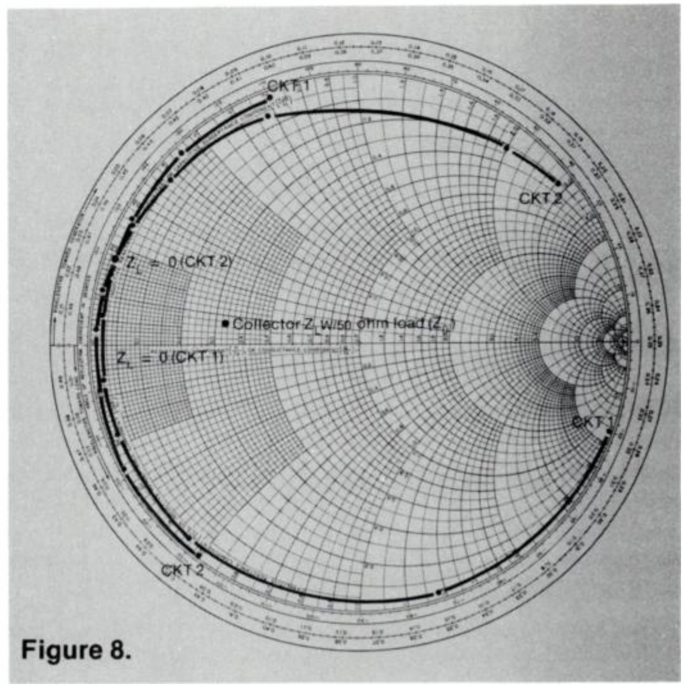

Figure 8.

Linearity

Semi-conductor houses typically look for 30 to 32dB of third order — Inter-Modulation distortion (IMD) (a measurement of linearity) on a linear HF part. VHF and UHF devices are usually made for FM Class C operation. As a result, a great many of the VHF "solid state linears" on the market have IMD's of only 9 to 15dB. This is likewise true of many transceivers. This is due to both the transistors and the "highest power available" specification to which many OEMs design. Motorola explains that while the linear devices and the Class C devices use the same type of transistor structure, to accomplish linearity, larger dies are used and these are fabricated with slightly lower collection resistivity. This is a gain trade-off again. Unless a large commercial need appears, it would seem doubtful that any truly linear devices would be forthcoming for VHF.

Input VSWR is an especially key area for add-on amplifiers. Some transceivers now in the field will not stand more than a 1.6:1 VSWR without going into regeneration as previously explained. Many add-on amplifiers have input VSWRs of 2:1. The results are predictable.

Broadband goes along with input VSWR just as much as overal gain. Having a broadband width gain-wise is of no use if your exciter goes regenerative. Proper use of minimum Q impedance transformation networks, broadband transformers, feedback techniques and new transistor packaging has made reasonable bandwidths attainable for both input VSWR and power output.

Once all the above areas have been explored, circuit design may begin.

Special attention to components at both HF and VHF/UHF is a must. Adequate heatsinks, low loss feritte core material, high Q capacitors and inductors head the list. Special attention should be paid *not* to use capacitors above the self-resonant frequency, unless you want an inductor. For PC material, the G-10 has been used for designs up to 470 MHz. □

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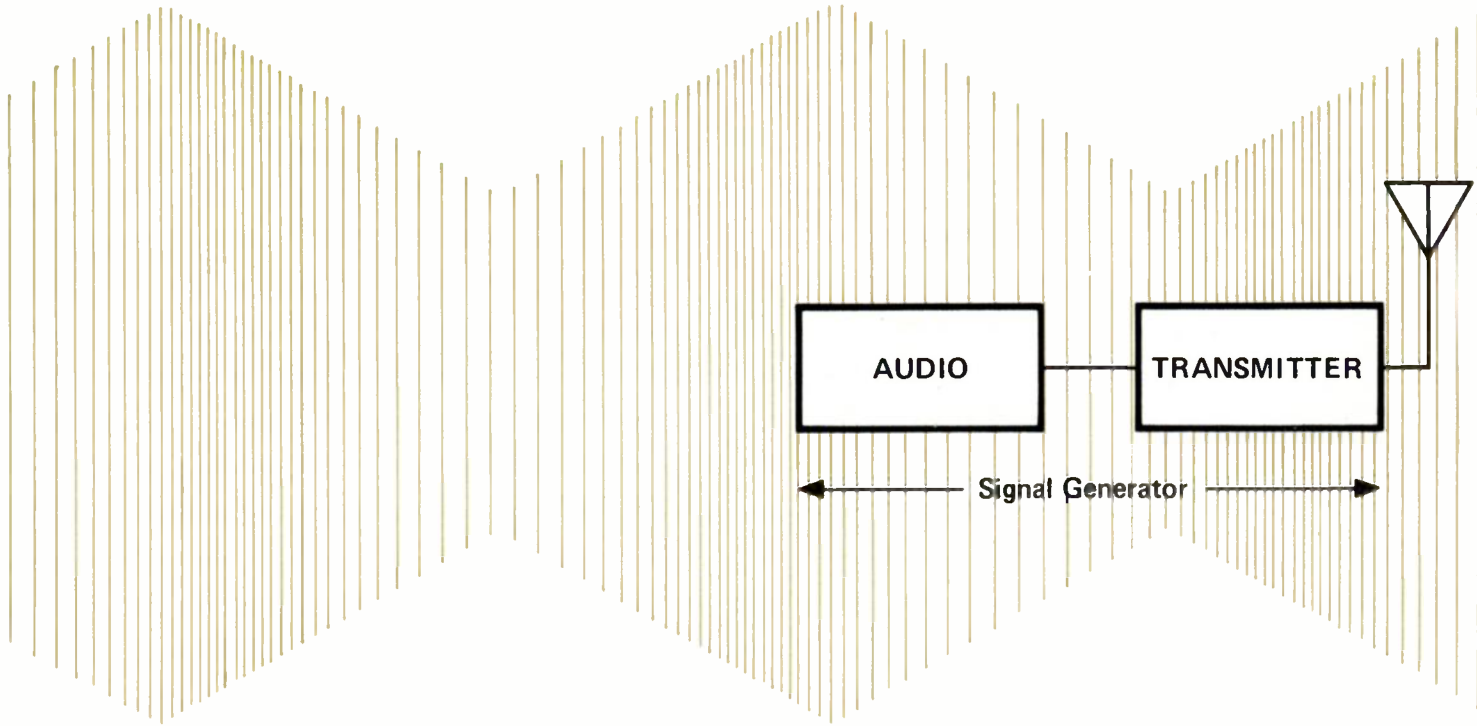


Figure 1. Signal Generator and Modulation Analyzers are

Transceiver Testing: Suddenly Thi

By John L. Minck
Applications Engineer
Hewlett-Packard

Transceiver testing techniques have been developing over time to the point where they are now fairly efficient yet meet the various regulatory and technical requirements of the industry. Signal genertors serve as calibrated transmitters to design and test the receiver section. But the transmitter test portion has been filled by a benchful of frequency counters, power meters, modulation meters, spectrum analyzers, distortion analyzers, scopes, voltmeters, and more.

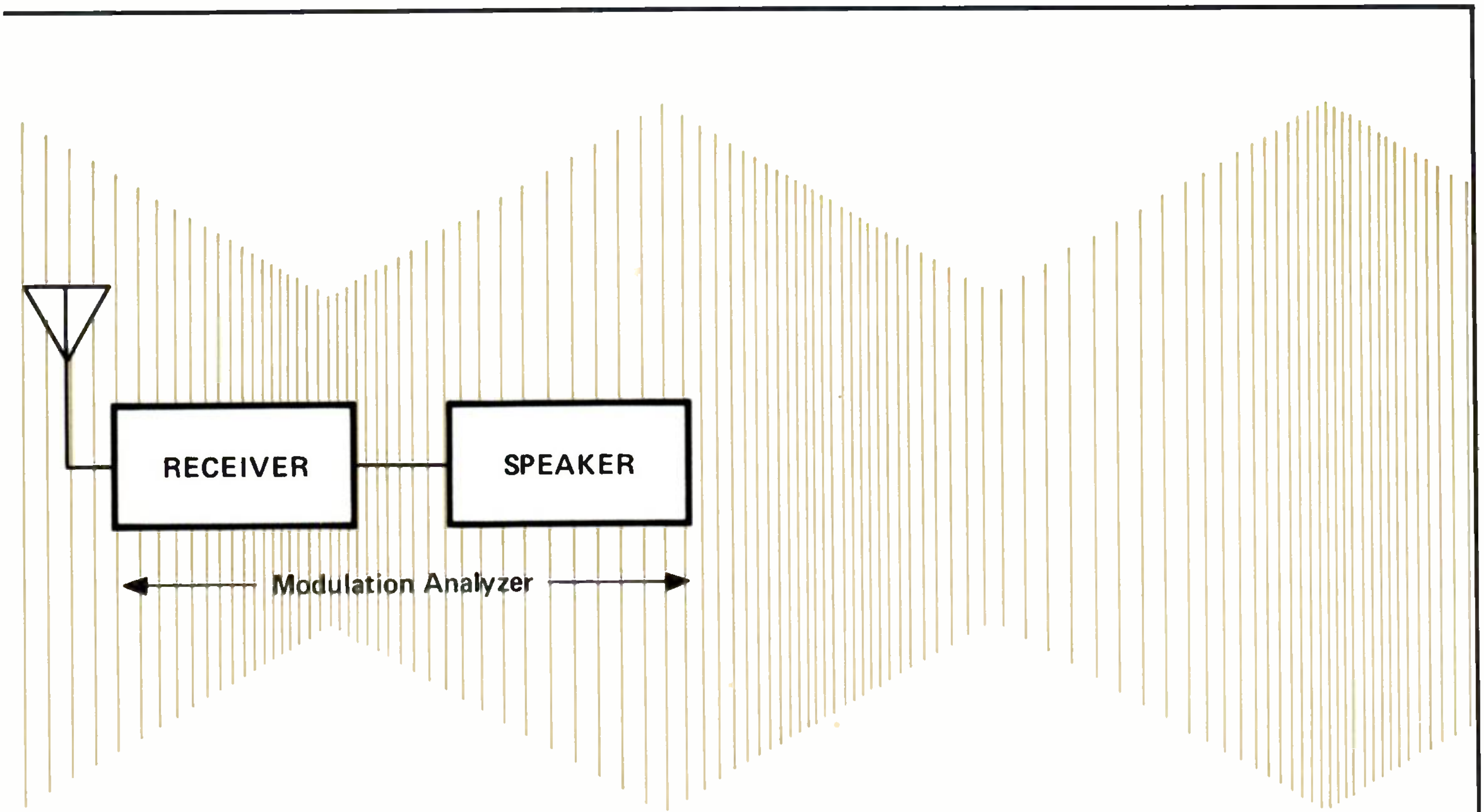
Transmitter testing really requires a different mix of capabilities than that offered by the general purpose test bench. RF frequency and power measurements can usually tolerate somewhat lower accuracies than the typical general purpose frequency counter and power meter. Yet modulation measurements should be more accurate than ever with navigation aids such as ILS guide slope and localizer being totally dependent on AM modulation accuracy.

New Modulaton Analyzer Improves Speed and Accuracy

A new instrument concept bids to improve speed and accuracy of many transmitter characteristic measurements and at the same time challenge older procedures and the traditional benchful of equipment.

The typical communication system consists of a transmitter and receiver (see Figure 1). In the testing phases, a signal generator serves as a precision, calibrated **transmitter** and thereby permits the user to reproduce exact signal conditions for receiver test and alignment. The transmitter tests likewise require a precision, calibrated **receiver** which accurately measures frequency, power and modulation characteristics for testing and optimizing performance. In addition, there are regulatory overtones because transmitters must meet FCC requirements. In effect, the benchful of equipment was really serving as the precision calibrated receiver.

The HP 8901A Modulation analyzer is a calibrated super-heterodyne receiver, just like a spectrum analyzer, but its detection system recovers the entire modulation spectrum. The modulation is recovered with very high fidelity so that highly precise measurements, such as distortion or SINAD, can be made on the modulation signal. Further, the AM, FM ø detector circuits are specifically designed for high rejection of other modulation forms so that



laboratory duals of operating transmitters and receivers.

ngs Are Easier and More Accurate

extremely low incidental and low residuals of AM can be measured in the presence of simultaneous large amounts of FM, and vice versa.

Analysis of Multiple AM and FM

There are many applications of multiple AM and FM. Making quantitative measurements on simultaneous AM and FM is one of the more difficult jobs — but one ideally suited for modulation analyzers. Such a simultaneous modulation capability is shown in the spectrum analyzer display of Figure 2(a). The signal is 46.5 percent amplitude modulated with a 5 kHz triangular wave and 4.5 kHz peak frequency modulated with a 5 kHz sine wave.

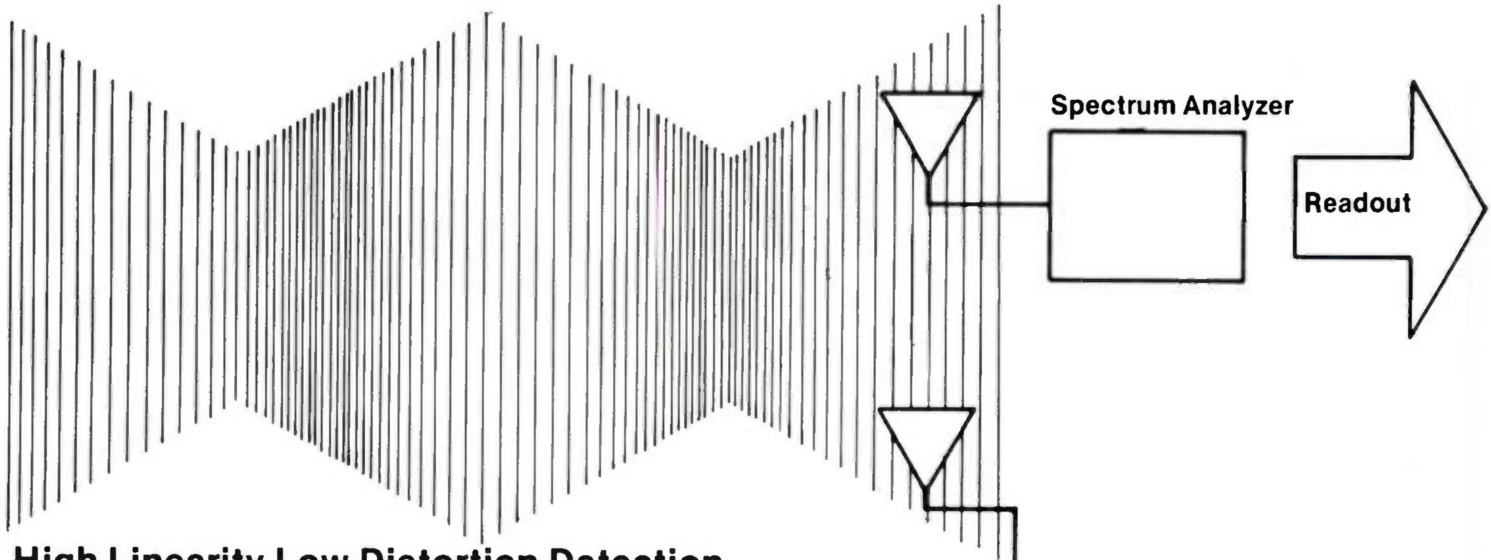
The modulation analyzer directly displays each contributing modulating characteristic and in addition can furnish each detected signal itself at an output port. Figure 2(b) shows the LED display readouts for the signal displayed on a modulation analyzer. Figure 2(c) and 2(d) are detected wave forms.

Measuring incidental or residual modulation is easy with modulation analyzers. For example, small amounts of phase modulation are often induced by circuits and components used to produce amplitude modulation. Separate detection circuits easily display incidental ØM in the presence of even 90 percent AM.

Entire Modulaton Envelope Is Processed

Several other transmitter measurements are best suited for modulation analyzers. Frequency measurements on a modulated RF waveform usually require the entire modulation envelope to be processed so that the signal sidebands get frequency averaged in. This is especially important for signals with complex modulations such as voice, or combined modulations which cannot be visually averaged on a spectrum analyzer display. Of course frequency counters also count the average frequency.

RF peak envelope power measurement similarly requires linear processing of the entire modulation envelope to sense total peak envelope power. With the modulation analyzer, power can be sensed either at an input point where multiple signals may be present, or the detectors in the IF circuits can be used to make a frequency selective power measurement in the presence of larger interfering signals.



High Linearity Low Distortion Detection

Finally, the modulation analyzer processes and detects the full modulation envelope with high linearity and low distortion, so that an audio distortion analyzer can follow to measure modulation distortion of S/N ratios. Further, modulation analyzers provide a method to measure true instantaneous peak modulation transients as required in modulation limiting tests. The measuring power of the modulation analyzer is summarized in Figure 3.

Microprocessor Control

The microprocessor makes the modulation analyzer essentially automatic. In the tuning section, for example, the unit searches for the largest input signal, then autoranges all the detection ciruitry to display the selected signal charactertistics.

The approximate frequency of a signal can be keyed in, when it is weaker than competing signals. The modulation analyzer then locks to the signal closest to the keyed in signals. A third tuning mode can be used to track the frequency of a signal which is changing continuously.

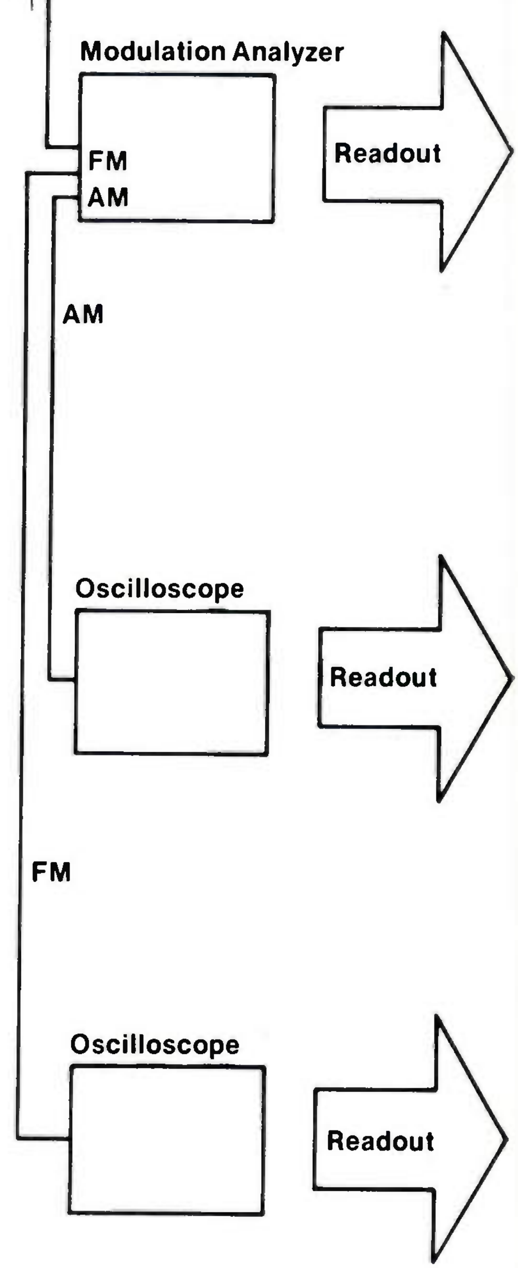
The entire modulation envelope is sensed to determine the signal characteristics. Modulation charactertistics are all single push-button operations. AM can be measured to a depth of 100 percent with an accuracy of ±1 percent. AM rates from 20 Hz to 100 kHz, depending on the R.F. frequency, can be measured. FM peak deviation can be measured with ±1 percent accuracy. And finally, the modulation analyzer is HP-IB programmable.

Internal Calibrator and Modulation Standards

There are a number of RF and VHF applications which depend crucially on accurate modulation measurements. Prominent among these is the air navigation application. Landing System Glide Slope and Localizer System is directly dependent on measurements of percent amplitude modulation.

Spectrum crowding is driving the Federal Communications Commission to split channel spacing on mobile FM to 25 kHz (12.5 kHz in Europe).

One of the unique features of the 8901A, and a necessary adjunct for obtaining the very highest accuracy, is an optional internal calibrator consisting of a 10 MHz carrier that is amplitude modulated at a 10 kHz rate with 33.33 percent nominal depth. The FM calibrator provides the 10 MHz carrier with a peak deviation of approximately 33 kHz at the 10 kHz rate. The exact value of both modulations is automatically internally sensed and computed to a precise degree each time the calibrate button is pushed.



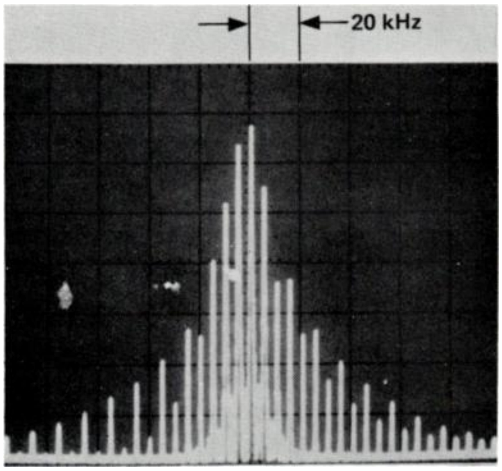


Figure 2 (a) Spectrum Analyzer display of simultaneous AM (46%) and FM (4.5 kHz Peak) modulation.

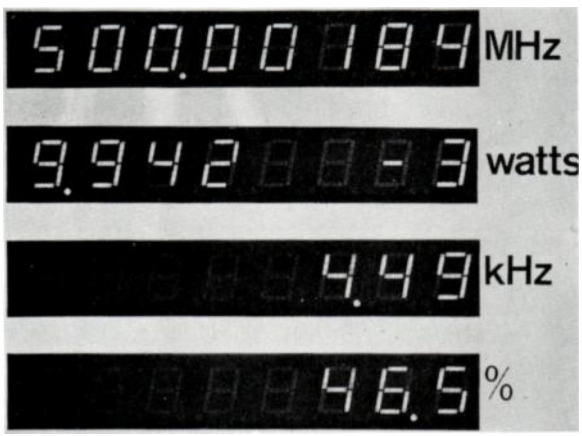


Figure 2 (b) Modulation Analyzer display showing digital displays of RF signal parameters.

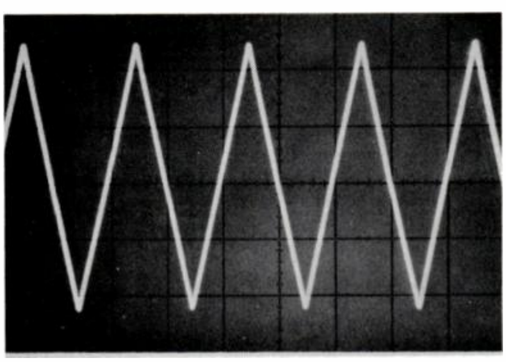


Figure 2 (c) Recovered 5 kHz AM input signal viewed on scope.

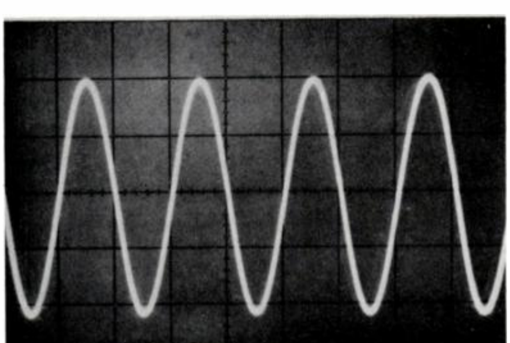


Figure 2 (d) Recovered 5 kHz FM input signal viewed on scope.

Figure 3. Capabilities Of A Modulation Analyzer

1. Highly accurate, quantitative measurement of AM/FM/ØM.
2. Measurement of simultaneous AM/FM/ØM.
3. Incidental AM/FM/ØM.
4. Measurement of ± modulation.
5. Linear recovery and output of AM/FM/ØM waveforms.
6. RF frequency/frequency error ratio of simple signals or those with complex modulation envelopes.
7. Selective counting of low level RF signals even in the presence of high level ones.
8. Modulation frequency response with or without low pass, high pass, or de-emphasis filters.
9. PEP. of all signals + harmonics.
10. Peak envelope power of 2 RF tones (for SSB power).
11. Selective power measurement of one modulated signal out of many.
12. Power of harmonics of modulated signal.
13. Transient (with peak hold) AM/FM/ØM modulation measurements.
14. Residual AM/FM/ØM with built-in audio shaping.
15. Video replication of spurious-causing problems, i.e., fan vibration microphonics, or line induced modulation.
16. Spurious measurements; non-real time with harmonic mixed and image responses that must be processed out.
17. Ratio displays of frequency, power, or modulation expressed as a percent or dB relative to a previous reading or a keyed-in number.
18. Measures and displays frequency of modulated signal in the RF amplifier.
19. Indicates with limit light when a measured value exceeds a pre-set limit.

Residual modulation measurement to simulate actual operational radios are considerably enhanced in the 8901A by including built-in, selectable low pass and high pass filters for matching the bandwidth requirements of varius applications (mobile FM, tactical military, etc.). Also, four de-emphasis networks can be selected for measurements on FM communications transmitters.

AM Calibrator

A block diagram of the AM calibrator is shown in Figure 4. A limited 10 MHz RF signal is applied to two identical modulators (A & B), isolated by identical buffer amplifiers. Modulator B is then switched on and off by a shaped square wave drive signal. After further isolation with identical buffers the summed signals appear at the CALIBRATOR OUTPUT jack. If both signal paths are identical, then the output RF voltage from the calibrator periodically varies from one RF voltage level to twice that level. Such a signal represents 33.33 percent.

It would appear that for the calibrator to work accurately the two paths would have to be absolutely identical. However, the 8901A doesn't rely heavily on this because its microprocessor makes additional measurements to specifically characterize each path and correct for minor differences.

Accuracy is enhanced by measuring residual AM of the unmodulated carrier and adding an appropriate portion of it to the calibration value.

Other possible sources of error are a result of the two path signals not adding directly. Non-linear distortion, differential phase shift between channels, mutual loading of the two output buffers, feedthrough of the OFF modulator, and drift have all been thoroughly considered in the design and their effects measured and sufficiently minimized.

Traceability to national standards is indirect because the National Bureau of Standards does not presently offer a calibration service in RF modulation.

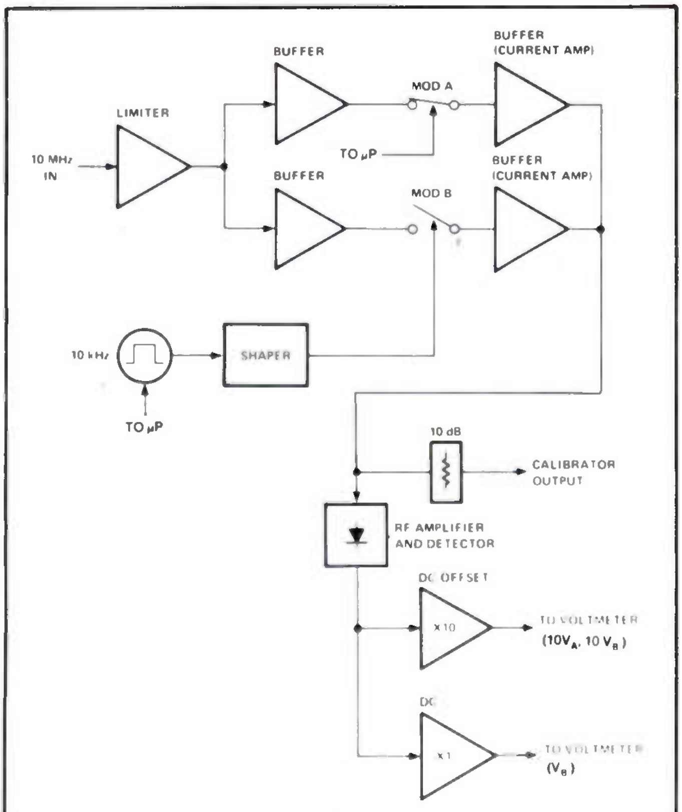


Figure 4. AM Calibrator

FM Calibrator

Operation of the FM calibrator is similar to the AM calibrator in many aspects. Figure 5 shows the block diagram with a 10 MHz voltage-controlled oscillator (VCO) used for both the AM source and the FM source. The shaped modulating waveform provides peak FM of approximately 33 kHz.

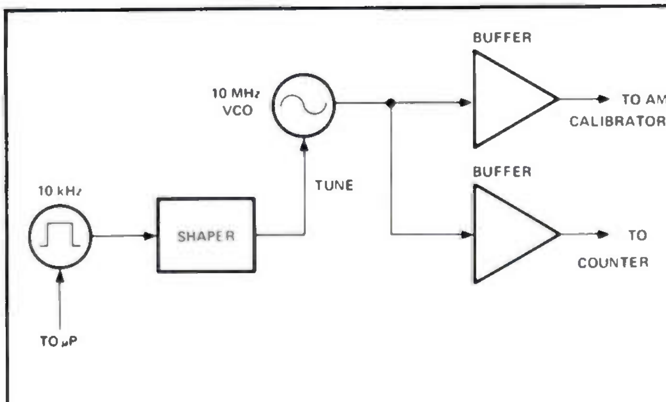


Figure 5. Block Diagram of the FM Calibrator

When the calibrator button is first pressed, the VCO input is switched to the high fequency peak f_H, and the frequency accurately measured with the 8901A internal counter. Then, with the VCO switched to the lower frequency f_L, the counter measures the result and computes peak deviation FM as $\frac{f_H - f_L}{2}$ • 33 kHz. Nominal peak deviation is chosen for the calculation because it is a good compromise between deviation used for commercial FM and mobile FM applications.

The design strategy of both AM and FM calibrating sequence is the same. As the calibrator turns on, the instrument runs through a measuring sequence which first determines the precise value of either AM or FM as described above. The modulation analyzer then measures the residual FM of the signal at f_H. From these two measurements the 8901A can very accurately determine the value of peak deviation that should be measured.

If the front panel CALIBRATOR output jack is cabled to the modulation analyzer input, the instrument makes a measurement of the calibrator signal and uses the computed modulation value to indicate the instrument's calibration factor in percent. Note that the calibrator sequence recalculates the modulation each time the CALIBRATION system is turned ON. For highest accuracy, it is good practice to recalibrate periodically.

The calibrator is specified at 0.1 percent AM depth accuracy and 0.1 percent FM peak deviation accuracy. Coupled with this high accuracy capability in the calibrator are powerful special ratio functions and key functions in the modulation analyzer itself.

So transceiver design and testing has entered a period of improved convenience, accuracy and speed. In these complex days, any advantage should be seized. □

Say you've been doing some IF testing in the kHz range, and now you need to switch to the RF MHz range. With the high performance Model 3002, you just change the lever/indicator switches on the front panel. With anyone else's signal generator you reach for a different model—and drop a few thousand more dollars.

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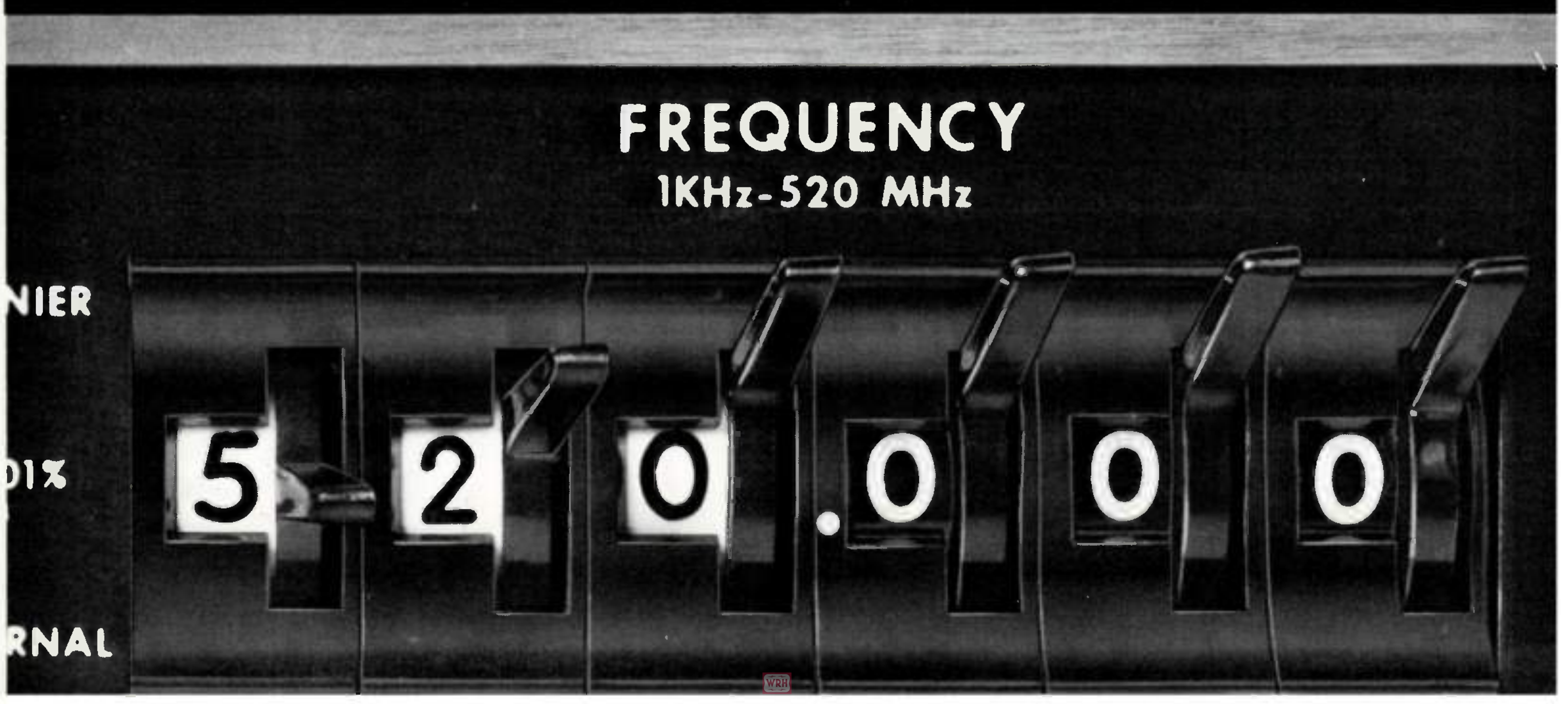

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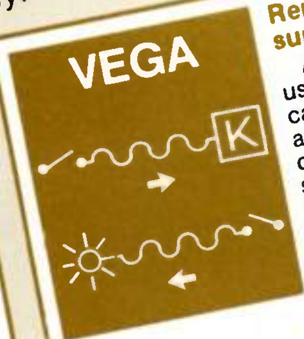

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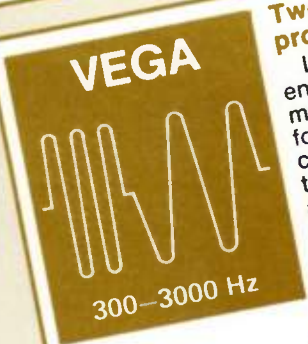
Available in 19" rack panel using standard Vega plug in cards or custom packages and assemblies as required. Encoders and decoders using single tone, two tone sequential D.T.M.F., multiple tone simultaneous, FSK and other formats are available as required.



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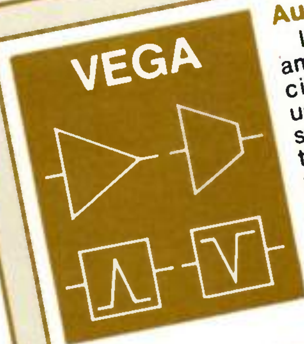

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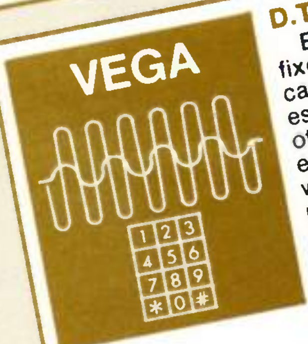
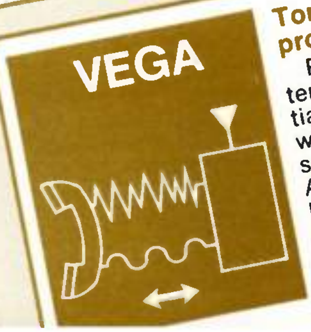


D.T.M.F. products

Encoders and decoders for fixed station and mobile applications. Multiple digit addresses, group call, transpond and other options available. Decoders feature advanced designs which are optimized for mobile radio environments with maximum voice and noise falsing, signal drop out (double digit falsing) protection designed in.



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INFO/CARD 10

An AM-FM Digital Tuning System

By Thomas B. Mills
National Semiconductor

Digital tuning system approaches to AM-FM broadcast receivers are becoming increasingly popular as manufacturers are finding lower component costs and increased features give their products greater appeal. Operational features of a digital tuned receiver include:

- Precise tuning of station frequency
- Display of exact receive frequency
- Keyboard entry of station frequency
- Storage of multiple stations in memory
- Pushbutton up/down scan through the band
- Pushbutton search (stop on next station)
- Power on to last station
- Provision for time of day clock
- Static drive of LED for noise-free operation
- Able to address CB synthesizer

While some of the above features have appeared in radios in the past, they have been limited to very "high end" models and have accomplished these functions using expensive analog or combinations of analog and digital techniques. Recent developments in flexible, general purpose controller ICs, coupled with new high speed phase locked loop ICs, allows the receiver designer to realize some or all of the above features with a minimum of circuits and at a cost attractive enough to consider their use in a broad section of product lines.

The tuning system described here is built around three ICs specifically designed for AM-FM receiver tuning, using phase locked loop techniques. Designed primarily for automobile radio application and featuring 12 volt operation with low standby current, the needs of high quality tuners have not been neglected.

System Description

A block diagram of a phase locked loop (PLL) tuned receiver is shown in Figure 1. Varactor tuners perform the usual RF, local oscillator, and mixer functions, while the PLL generates the tuning voltage in accordance with station selection information generated by the controller IC. The controller IC also generates data for the display driver. Station selection information, whether it be direct frequency entry, scan or search, or memory recall, is inputted to the controller via momentary switches. All data communications between the controller, the PLL and the display driver is in serial format using three wires to reduce pin count and printed circuit board space. This also allows for economical remote locations of any of these parts as styling might dictate.

Explanation

The three IC's that the AM-FM timing system is designed around have been color coded throughout the article.

The Digitally Tuned Radio Controller DTR Controller MM57170.

The Phase Lock Loop Synthesizer PPL Synthesizer DS8907 (ECL/I^2L).

The Display Driven MM 5450.

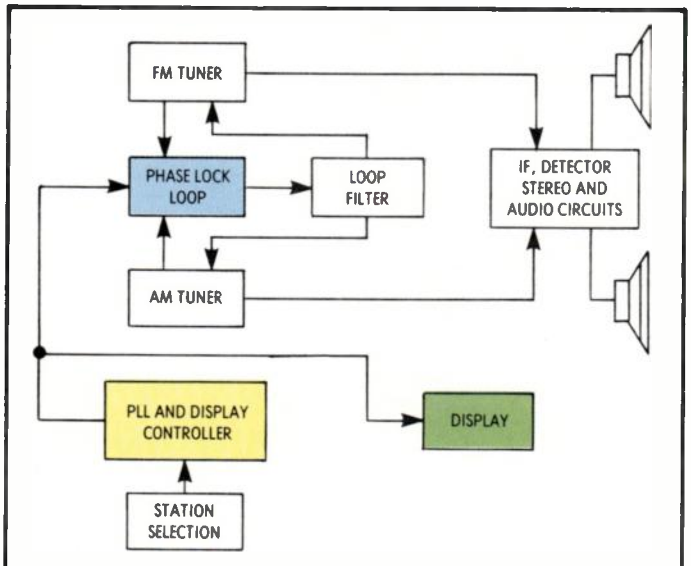

Figure 1. AM-FM Radio Using PLL Tuning.

A review of how a PLL synthesizer tunes an FM station is shown in Figure 2a. In this example, it is desired to receive a station with a carrier frequency of 101.3 MHz. For a receiver utilizing an IF of 10.7 MHz, the local oscillator is tuned to 112.0 MHz by the PLL. THe 112.0 MHz signal from the local oscillator is divided by 4480 in a programmable counter to produce 25 kHz which in turn is fed to one input of a phase detector. A 4 MHz crystal oscillator which serves as the frequency reference for the PLL is divided by 160 to also produce the 25 kHz reference to the other input of the phase detector. The phase error between the two 25 kHz signals produces an error signal which is filtered in the loop filter and is used to control the frequency of the 112.0 MHz local oscillator. In this manner, the local oscillator is forced to be an exact multiple of the 25 kHz reference frequency. Station selection is accomplished by changing the divide-by-N number in the programmable divider: if the divider were set to divide by 4481, the local oscillator would be forced to run 25 kHz higher in frequency of 112.025 MHz. Figure 2b illustrates the scheme used to tune an AM station.

Serial data from the controller IC provides the number that the PLL divides by. In previous designs, this has been done by "parallel loading" the number, in binary, to the PLL. In the above example, a thirteen-bit number is required and would therefore require thirteen wires from the controller to the PLL as illustrated in Figure 3. By using the serial data technique, Figure 4, only three wires are needed.

Similarly, conventional four-digit multiplexed displays require seven segment lines and four digit lines. The serial data approach requires only three lines to supply display data, and in fact can be the same three lines used to input the PLL IC.

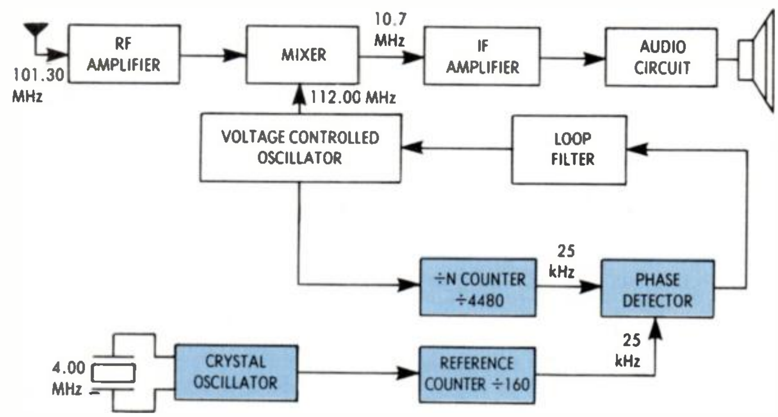

Figure 2a. FM PLL Synthesizer Example.

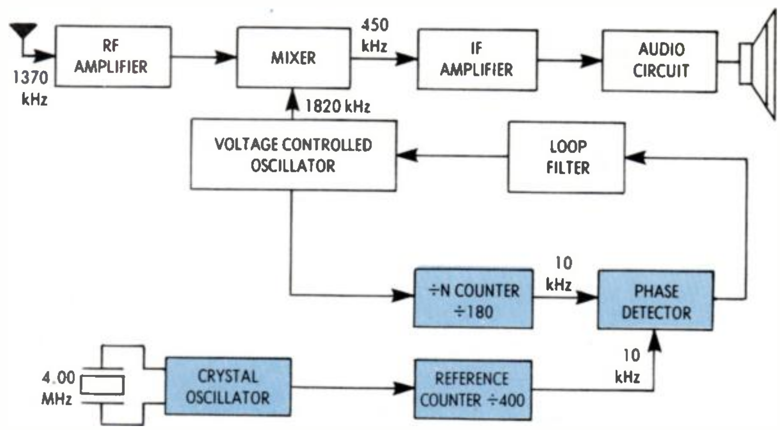

Figure 2b. AM PLL Synthesizer Example.

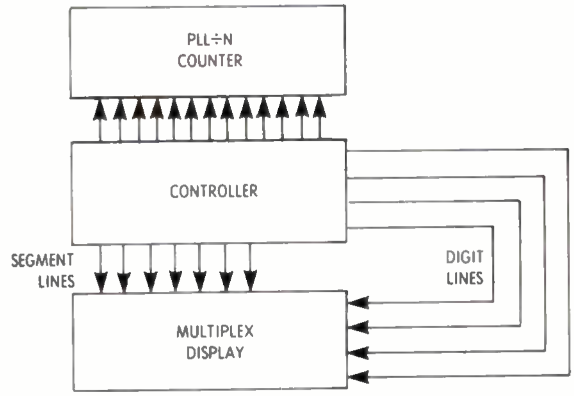

Figure 3. Conventional Parallel Data Entry.

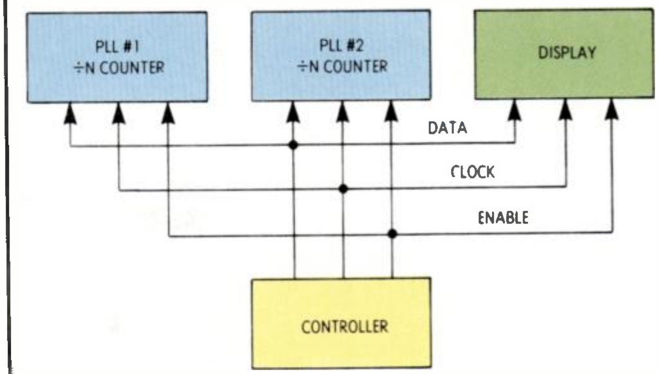

Figure 4. Serial Data Entry.

The ECL-I^2L Synthesizer

The DS8907 PLL Synthesizer is specifically designed for use in AM-FM receiver applications. The simplified block diagram of Figure 5 illustrates the functions of the circuit. Constructed with ECL-I^2L bipolar technology, it contains the reference oscillator, phase comparator and charged pump, dual modulus programmable divider, and 18-bit shift register/latch for serial data entry.

A Colpitts type crystal oscillator operating at 4 MHz is used for the frequency reference. A frequency of 4 MHz was chosen because of lower crystal costs and the availability of crystals in the small HC-18 holder. A chain of dividers is used to generate various frequencies used in the complete tuning system. A 500 kHz signal is available to clock the controller chip. 25 Hz and 10 kHz signals are used as reference frequencies for FM and AM. Finally, a 50 Hz signal is available to act as the real time clock reference for the controller.

The PLL consists of a 13-bit dual modulus I^2L divider, an ECL phase comparator, an ECL (p/p + 1) prescaler, and a high speed charge pump. The I^2L divider is clocked by the AM input via and ECL ÷ 7/8 prescaler, or through a ÷ 63/64 prescaler from the FM input. The AM input will operate at frequencies up to 15 MHz, while the FM input capability exceeds 120 MHz. The choice of reference frequencies provides for 10 kHz resolution on the AM band and 25 kHz on the FM band. Input amplifiers on the IC allow the dividers to be driven directly through a small capacitor from the local oscillators.

The DS8907 is designed to operate from two supply voltages: 10 volts for the charge pump to allow a full 10 volt swing to drive 8 volt varactor tuners directly without an amplifier, and 5 volts for the high speed programmable divider. The reference divider is also operated from the 10 volt supply. The power requirements from the 10 volt supply are less than 2mA, which may be left "on" in the radio "off" condition in automobile applications so the 50 Hz clock signal is always available for timekeeping.

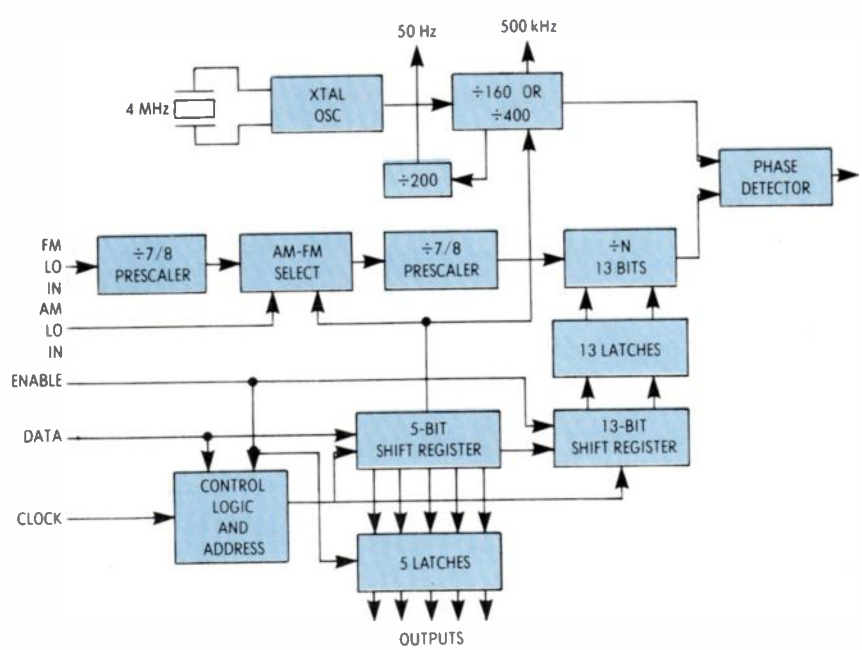

Figure 5. ECL-I^2L PLL.

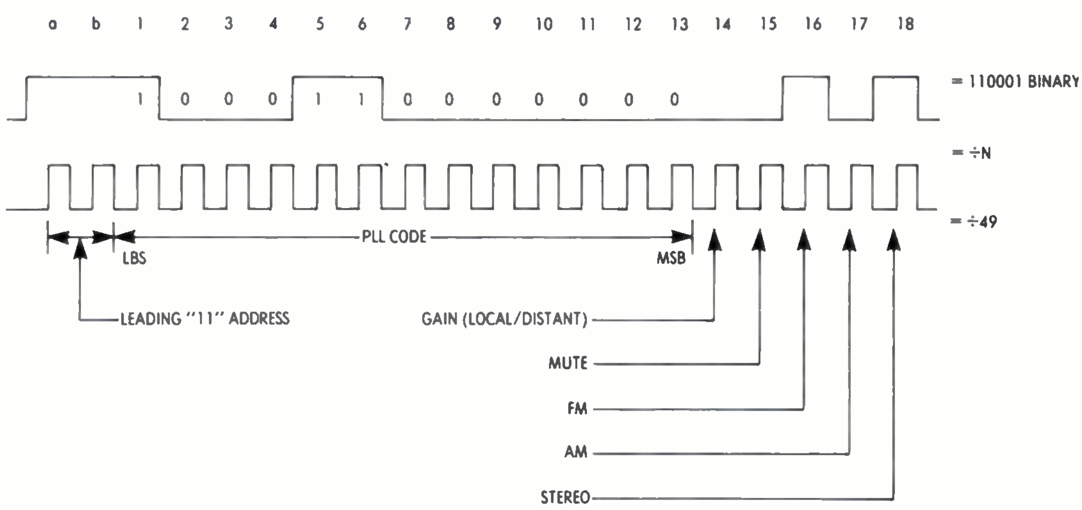

Figure 6. AM-FM Synthesizer Code Format.

Data entry to the DS8907 is shown in Figure 6. Data is clocked in on the positive edge of the clock; the first two bits are an address code that is recognized by the IC. The next thirteen bits are the divide-by-N code, least significant bit first. The last five bits are outputted from the chip as received and may be used for such functions as local-distance gain setting in the search mode, mute during station change, AM-FM bandswitching (this bit is also used in the IC to switch reference frequencies), and stereo-only during search.

Typical performance parameters of the DS8907 are shown in Figures 7 and 8.

Figure 8. Phase Lock Loop Performance

Phase Detector Gain K_D	$\frac{V_{CC}}{4\pi}$ V/rad or 0.8 V/rad
Phase Detector Switching Speed	30ns
Loop Bandwidth	300 Hz
Reference Frequency Sidebands	>60dB
S/N Ratio AM: 30% mod	>45dB
FM: 22.5% deviation	>50dB
Switching Speed (one channel)	<1.5ms

The Serial Data LED Driver

Most presently available LED displays and their associated drivers use multiplexing techniques to reduce pin count and number of interconnections between the processor, the LED driver, and the display itself. This technique works quite well for calculators, but causes interference problems when used with receivers. Attempts to reduce interference increase cost and complexity and often do not completely solve all of the problems. This is especially true in table radios and tuners where the antenna is located near the display and the requirements of good signal-to-noise must be met.

The MM5450 was designed to specifically overcome these problems. Serial data entry is used to reduce interconnection to the controller, and once loaded, drive to the LED display is static. A 36-bit shift register receives the incoming data and, when the last bit is received, the first bit loads the 34 display bits into latches. On the next half-clock cycle, the shift register is cleared and ready to receive new data. An enable pin prevents data from entering the circuit from the common data bus when the IC is not selected. This technique allows for not only static display, but also freedom from flickering when data is changed since the display does not change except when data is latched such as after a station change.

Like the DS8907 PLL circuit, data to the MM5450 is clocked on the positive edge of the clock, and is enabled (will receive data) when the enable pin is low.

Figure 7. Synthesizer Performance

Power Supply	5V @ 100mA
	10V @ 2mA
Input Impedance FM	500Ω, 7pF
AM	1000Ω, 7pF
Toggle Level FM	$35mV_{RMS}$
AM	
Charge Pump Output Current	± 0.1mA
General Purpose Outputs, I_{SINK} = 1mA	1V max

Figure 9. Serial Data LED Driver Performance Characteristics

Power Supply Voltage	4.5-12V
Power Supply Current	4-5mA
Brightness Input Current	0-0.75mA
Output Sink Current	
I_{IN} = 0.75mA	15-20mA
I_{IN} = 50μA	0.7-1.4mA

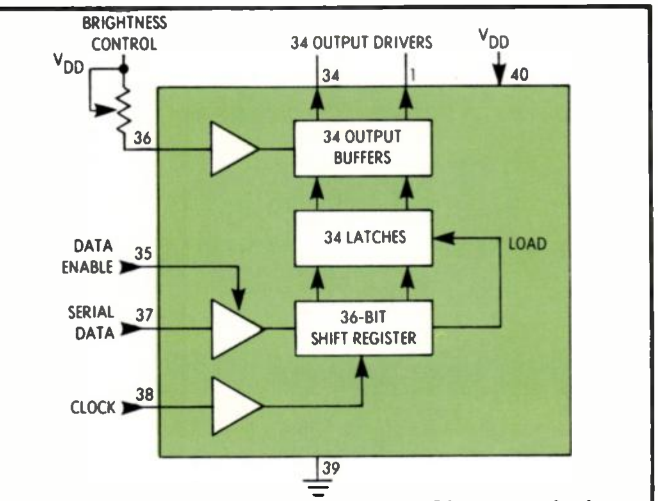

Figure 10. MM5450 Performance Characteristics.

Figure 12. Digitally Tuned Radio Controller		
Memory Channels		5 AM, 5 FM
Keyboard		6x4 matrix
Station Selection		Slew up/down search up/down
Display		4 digit
Power Up		last station
Hardwired Options		diode selection of AM and FM IF frequencies
Clock		all standard clock features
Bands	AM	530-1610 kHz
	FM	88.1-107.9 MHz
Resolution	AM	10 kHz
	FM	25 kHz
Local Oscillator	AM	450 kHz high side
	FM	10.7 MHz high side
Search Speed		20 increments per second

Brightness control has also been incorporated into the MM5450. Figure 11 shows an equivalent circuit of the output driver. Using the current source output characteristics of the N-channel MOSFETs, and matching characteristics in the IC, a "current mirror" circuit similar to that used in linear IC's allows for a single variable resistor to set the 34 output currents. By varying the current into pin 36 between 0 and 0.75mA, the output current to each segment may be varied 0 to 15mA. In order to reduce dissipation, the voltage at the segment output pins should be kept at 1 volt by providing a low impedance supply at the anodes of the display.

The Digitally Tuned Radio Controller

The heart of any synthesized (PLL tuned) radio lies in the controller device. It is this part that generates channel codes and data for the display, accepts the "on channel" signal from the radio, and can provide a time of day clock if desired. In the last few years, microprocessor technology has been responsible for a new family of controller circuits which are really small computers on a chip. Advances in design and processing technology have reduced the cost of these circuits to where they can be used in even the lowest cost consumer products.

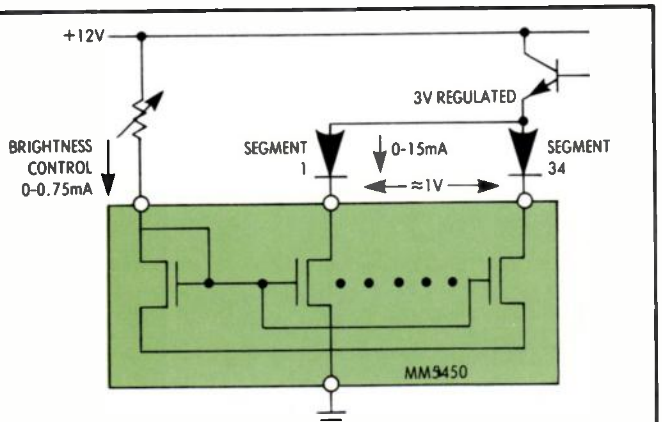

Figure 11. MM5450 LED Driver Output Circuit.

The MM57170 Digitally Tuned Radio controller series of ICs are designed to provide the most common features required of a PLL tuned radio. It is an N-channel silicon gate MOS/LSI device containing timing, logic, keyboard interface, I/O, RAM and control ROM functions for implementation of the controller function. The MM57170 operates from a supply voltage between 4.5 and 9 volts, and this application operates from 5 volts for easy interface to the PLL and display driver. Drawing less than 8mA of current, it is designed to be left on in automobile and table radio applications to maintain the station memories and last channel memory as well as time of day.

Figure 12 outlines the features of the MM57170 in a radio application; it should be mentioned that these features represent a particular application: the control ROM may be reprogrammed to suit features and operational routines unique to customer specifications. As described for operation with a 6x4

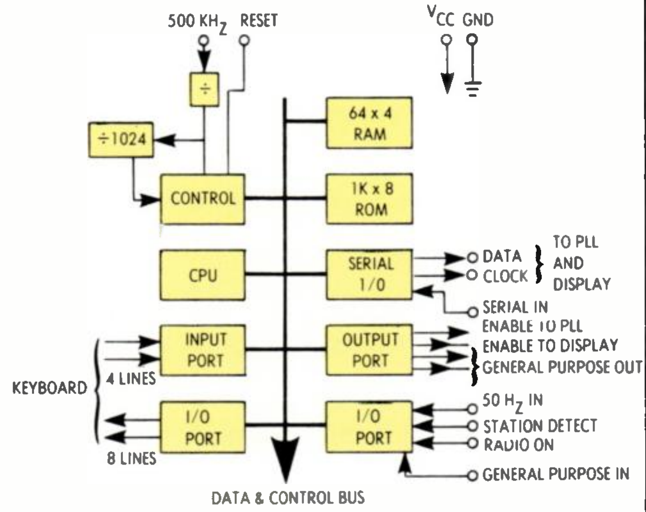

Figure 13. MM57170-Series
Digitally Tuned Radio Controller

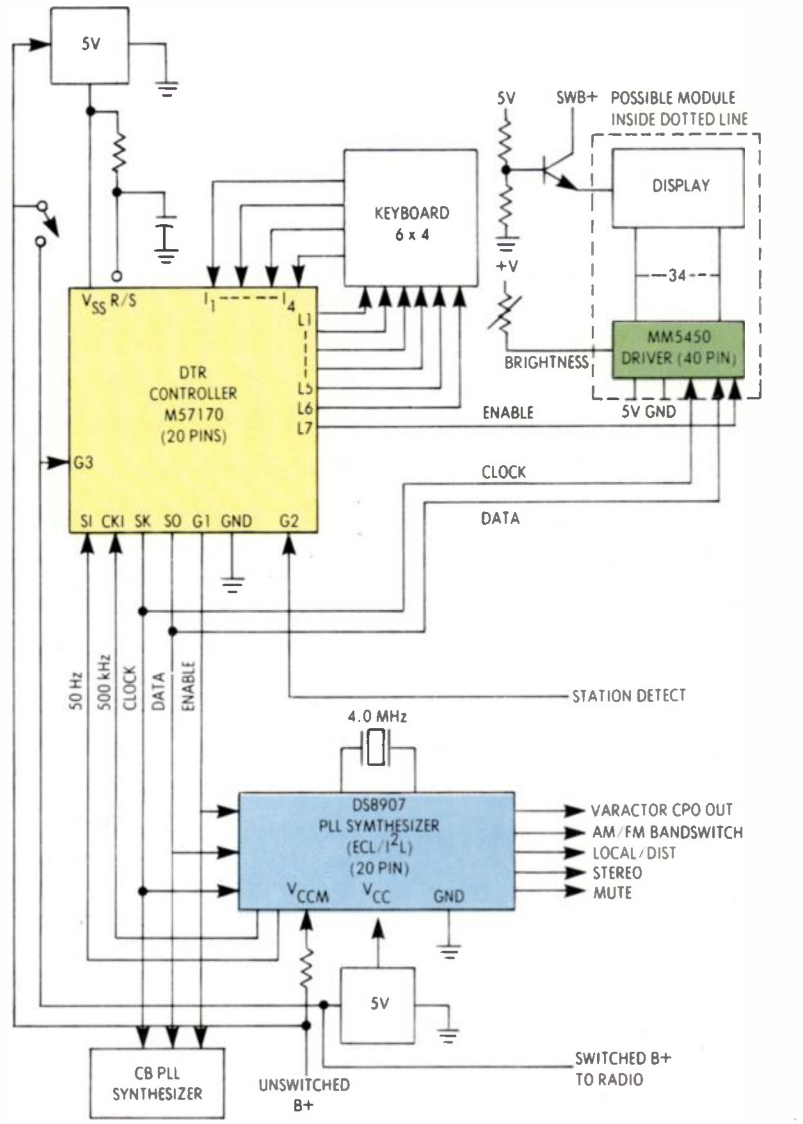

Figure 14. Digitally Tuned Radio Controller System Direct Drive LED.

keyboard (24 keys), the MM57170 is packaged in the small 20-pin package for greater space saving over large 24- or 28-pin packages. The basic structure and input/output capabilities of the circuit are shown in Figure 13.

Diode straps are used in the keyboard to select FM/IF frequencies during manufacturing. Since the resolution of the PLL is 25 kHz at the channel frequency, and the code for a particular receive frequency is generated mathematically in the controller, a constant in the formula used may easily be modified to accommodate different IF filter frequencies in 25 kHz increments, allowing the manufacturer to accommodate a wide distribution of ceramic filters.

Using an expanded keyboard, the controller will address not only the display and the AM-FM synthesizer, but a citizens' band synthesizer on the same data bus. Thus, control of AM-FM-CB combination radios becomes simplified and is accomplished at reduced cost and savings in space over present designs that separate these functions.

The Complete Tuning System

How all the parts of the Digitally Tuned Radio fit together is shown in Figure 14. Simplicity of interconnection is clearly evident and illustrates the advantages of serial data transfer techniques. Two regulators are shown to supply both standby and operating power to both the PLL and the controller. During radio off, a total of less than 10mA is drawn, which could be reduced to 2mA if the clock option were not used and it were desired only to maintain station memory. Although a keyboard is shown for data entry, it is anticipated customer styling requirements will dictate the type of switches used. Momentary contact pushbuttons and rotary type switches can result in a front panel layout resmbling many radios in production today.

The system of Figure 14 brings to the designer of tomorrow's radios the features he needs along with the flexiblity to design a complete product line around a minimum number of components at a competitive cost. □

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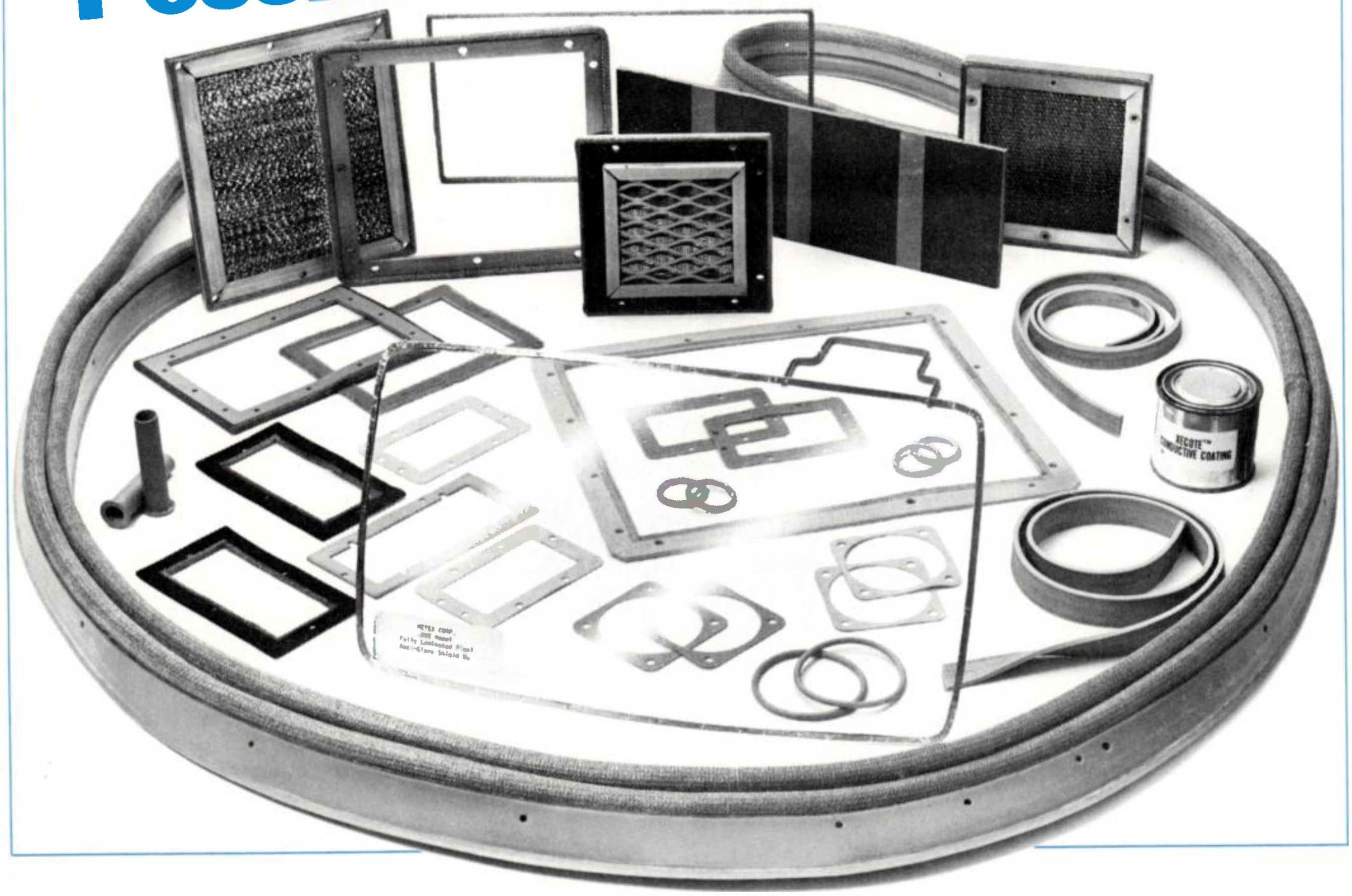

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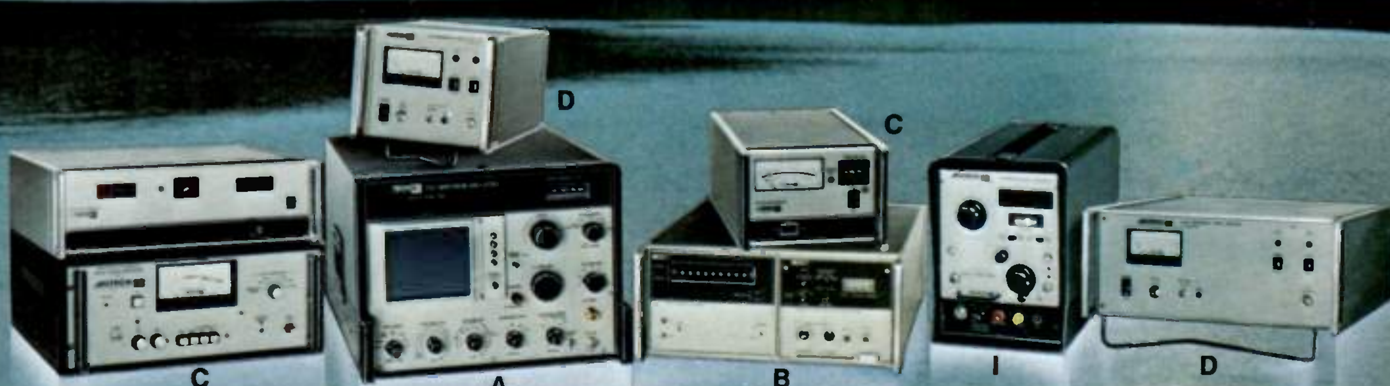

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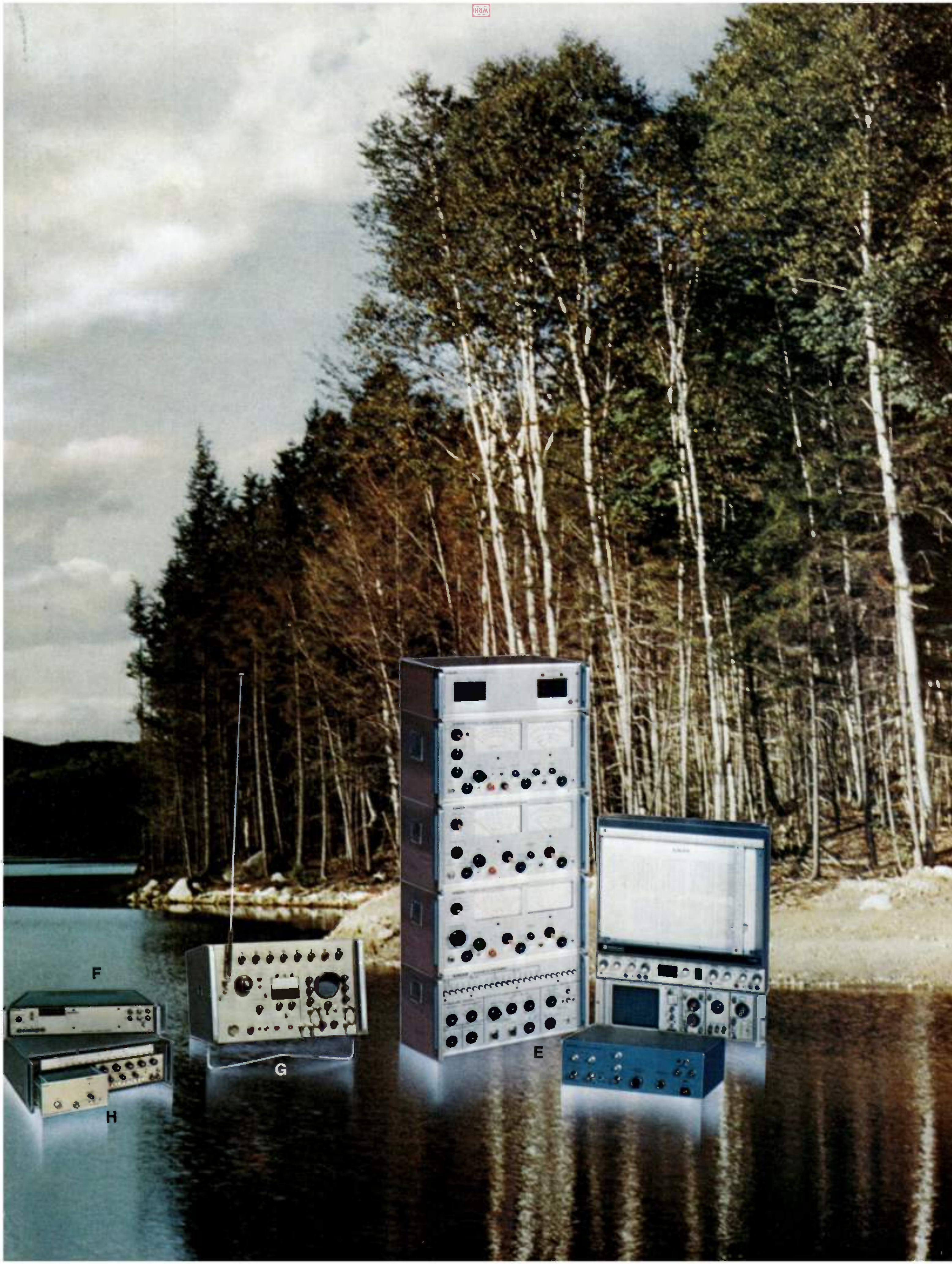
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When Will Your RF Power Transistor Really Fail?

It's hotter than previously thought, leading to faster high temperature metal derating, and reduced MTBF.

By Bob Johnsen
Motorola Semiconductor Group

The purpose of this article is to clarify and correct some long-standing industry-wide assumptions which have been commonly maintained about thermal resistance and high temperature derating of RF power transistors. The temperature-dependent thermal properties of silicon and beryllium oxide have been measured and documented by many laboratories during the last twenty years. Only in rare cases has this information been disseminated by semi conductor device manufacturers to the users.

Most manufacturer's data sheets include a single number for the thermal resistance of a particular device ($R_{\theta JC}$) and use this number to calculate a linear derating constant out to some specified maximum junction temperature. How often have you calculated junction temperature from a data sheet, as $T_J = T_A + (R_{\theta JC}) P_A$ (where T_A = ambient temperature, P_A = dissipated power)? Unfortunately, the thermal resistance of silicon increases by 80 percent from 25° C. to 200° C. The thermal resistance of BeO changes by 30 percent, if the case temperature goes from 25° C. to 100° C. Hence, the device thermal resistance is temperature-dependent. The modeling of this dependence, leads to higher calculated junction temperatures, and shorter mean time before failure estimates. It may be later than you think for your RF power transistor.

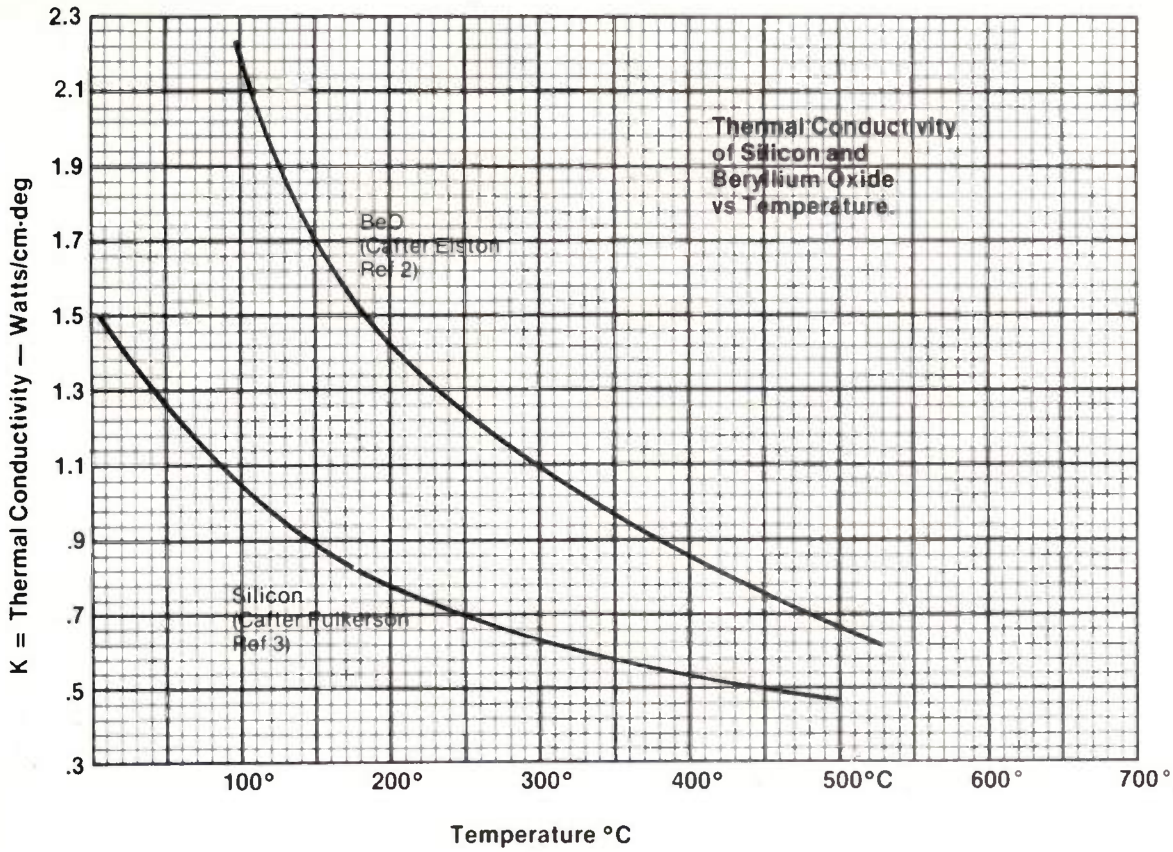

Figure 1.

The reciprocal, of the material thermal resistivity of Si and BeO vs. degrees is plotted. The obvious temperature-dependance of material resistivity leads to an amplified temperature-dependance of device thermal resistivity. (Figure 4).

Temperature-Dependent Thermal Properties of Silicon and Beryllia

The temperature-dependent thermal conductivities of silicon and beryllium oxide are seen in Figure 1. The temperature ranges are somewhat wider than are necessary for typical transistor operation, but are shown to emphasize the wide variation in thermal conductivities. Fulkerson[3] et al tabulate the values for thermal conductivity and resistivity of silicon from 100°K to 1350°K (see Table I), and they find that the thermal resistivity of silicon as a function of temperature can be estimated by a linear approximation over the temperature range shown.

$$r = 1/k = -0.1171 + (2.954 \times 10^{-3})\, T(°K) \quad (1)$$
(400-660°K)

$$r = 1/k = -0.9609 + (4.229 \times 10^{-3})\, T(°K) \quad (2)$$
(600 – 1050°K)

A similarly least-square fit to Fulkerson's data over the range 200 to 700°K, within 1 percent, is given by:

$$r = 1/k = -0.2286 + (3.1683 \times 10^{-3})\, T(°K) \quad (3)$$
(200 – 700°K)

Similarly for beryllia, one can fit the data of Elston et

TABLE I

Smoothed data for thermal conductivity and resistivity of Si

T (°K)	k (W cm^{-1} deg^{-1})	W = 1/k (cm deg W^{-1})
	Smoothed ORNL Values	
100	7.52	0.133
150	3.88	0.258
200	2.44	0.410
250	1.78	0.563
300	1.40	0.716
350	1.15	0.870
400	0.939	1.065
450	0.825	1.212
500	0.736	1.359
550	0.663	1.508
600	0.604	1.656
650	0.555	1.803
700	0.500	1.999
750	0.452	2.210
800	0.413	2.420
850	0.380	2.634
900	0.351	2.845
950	0.327	3.055
1000	0.306	3.268
1050	0.287	3.479
1100	0.273	3.65_7
1150	0.261	3.82_9
1200	0.251	3.97_7
1250	0.245	4.08_1
1300	0.241	4.14_9
1350	0.239	4.18_9

al over the range of 200 to 800°K, with equation (4).

$$r = 1/k = (1.943 \times 10^{-5})(T\,(^\circ K))^{1.7} \quad (200 - 800^\circ K) \tag{4}$$

where k is the thermal conductivity in units of watts/cm°K.

Note: $R_{\theta JC}$ is a symbol which characterizes the thermal resistivity of an entire device and is dependent on the device geometry as well as the operating conditions. Where as r is the bulk thermal resistivity of the material, and is dependent on the absolute temperature alone.

Geometric Factors And The Thermal Resistance Calculation

The thermal resistance of most silicon transistors is controlled by the bulk properties of silicon and beryllium oxide, geometry of the heat generating (base) areas, and the temperature of the heat sink (case). The interfaces generally are well behaved and contribute little to the overall total thermal resistance if the device, die and package elements are assembled and handled properly.

Die temperature calculations are performed in two steps. The first uses the method of Linsted and Surtey[4] to calculate the temperature distribution of a die by using a double Fourier series solution to LaPlace's equation. ($\nabla^2 T = 0$ LaPlace's equation for steady-state heat flow). Figure 2 shows the device geometry and some of the boundary conditions. Equation (5) will calculate the temperature rise at any (x,y,z) point in the die, where A,B,C,D,F are die and heat-generating area boundaries. Q is the heat

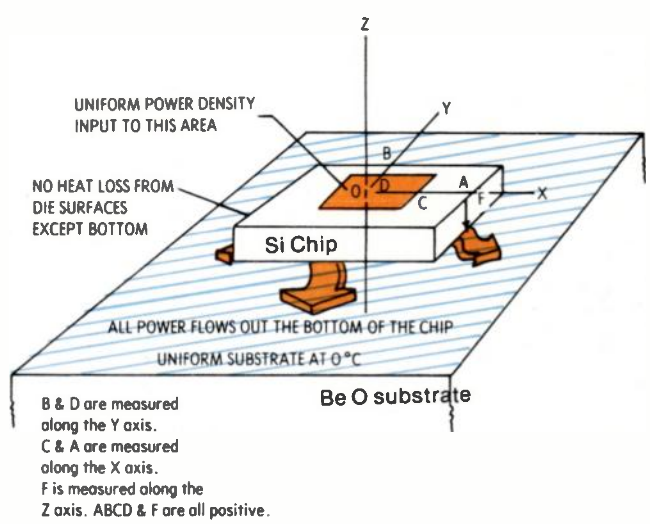

Figure 2. Model for Heat Flow.

input in watts, and k is the thermal conductivity of the material in watts/cm°K.

The Fourier series solutions are amenable to computer calculation and converge adequately within ten to twenty terms. Figures 3 and A show the treatment of multiple base cell transistors. Lines of symmetry between adjacent base cells are considered to be adiabatic die boundaries as assumed by Linsted. The power dissipated is assumed to be equally shared among the several base cells. The result of this calculation is the temperature rise of the silicon chip, assuming a constant thermal resistance for bulk silicon. The same model is used to calculate the temperature rise for the beryllia piece,

$$\begin{aligned} T = {} & -\frac{Q}{K}\left(\frac{CD}{AB}\right)(z - F) \\ & + \sum_{m=1}^{\infty}\left(-\frac{Q}{K}\right)\left(\frac{2BC}{m^2\pi^2 A}\right)e^{m\pi z/B}\left(\frac{1 - \exp\left[2m\pi(F - z)/B\right]}{1 + \exp\left(2m\pi F/B\right)}\right)\left[\sin\left(\frac{m\pi D}{B}\right)\cos\left(\frac{m\pi y}{B}\right)\right] \\ & + \sum_{n=1}^{\infty}\left(-\frac{Q}{K}\right)\left(\frac{2AD}{n^2\pi^2 B}\right)e^{n\pi z/A}\left(\frac{1 - \exp\left[2n\pi(F - z)/A\right]}{1 + \exp\left(2n\pi F/A\right)}\right)\left[\sin\left(\frac{n\pi C}{A}\right)\cos\left(\frac{n\pi x}{A}\right)\right] \\ & + \sum_{m=1}^{\infty}\sum_{n=1}^{\infty}\left(-\frac{Q}{K}\right)\left(\frac{4}{\pi^2 mn\gamma}\right)\left(\frac{1 - \exp\left[2\gamma(F - z)\right]}{1 + \exp\left(2\gamma F\right)}\right) \\ & \cdot e^{\gamma z}\sin\left(\frac{n\pi C}{A}\right)\sin\left(\frac{m\pi D}{B}\right)\cos\left(\frac{n\pi x}{A}\right)\cos\left(\frac{m\pi y}{B}\right) \end{aligned} \tag{5}$$

where

$$\gamma^2 = \pi^2\left[\left(\frac{n}{A}\right)^2 + \left(\frac{m}{B}\right)^2\right]$$

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using the silicon die area as the power dissipating area for the beryllia, again assuming the thermal resistance of the beryllia as a constant. The thermal resistances of the silicon die and the beryllia substrate are in series, so adding the above numbers gives a value for the thermal resistance of the device at a particular temperature and a power level low enough to avoid the effects of the temperature variations of the respective thermal resistances.

The second step in the thermal resistance calculation takes into account the temperature-dependent thermal resistivity. The calculated thermal resistance of the beryllia piece (from the previous section) is mathematically divided into fifty layers, each with 1/50 of the total BeO thermal resistance. (The first layer at the bottom is assumed to have its temperature at the heat-sink ambient with its thermal resistance value corrected to the proper temperature using the equations for the temperature-dependent resistivity). The power flux through the first layer then leads to its temperature rise, and this new temperature determines the thermal resistivity value for the second layer. Its temperature rise is calculated, and so on, until the result for the top surface of the fiftieth layer gives the temperature rise above the ambient for the beryllia piece. The same method is used for the silicon die, using the beryllia top surface temperature as the starting point, and correcting the thermal resistance of each of fifty layers based upon the temperature of the layer directly beneath it, until the top surface of the silicon die result gives the calculated die temperature for that particular case of ambient temperature and power dissipation. The results of these calculations indicate that the overall thermal resistance of a given device is not a constant number, but is a function of the dissipated power and the ambient (case) temperature. Another result is that the junction temperature of a device dissipating power will rise more than 1°C for a 1°C rise in ambient temperature, because of the increase in thermal resistance. Figure 4 shows the calculated device thermal resistance and junction temperature for the 150 W HF/SSB device as a function of ambient temperature and power dissipation.

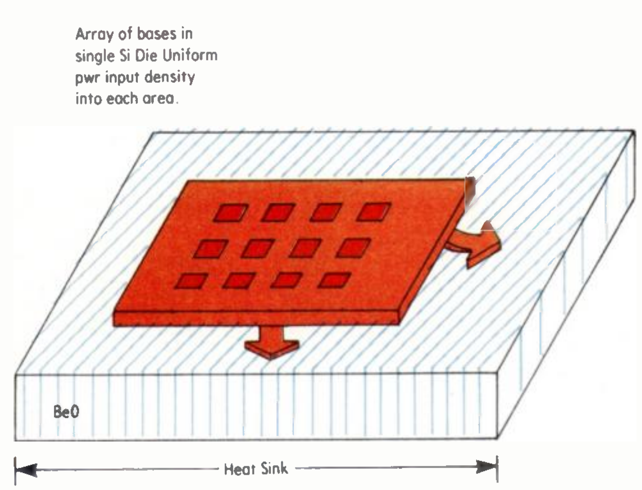

Figure A.

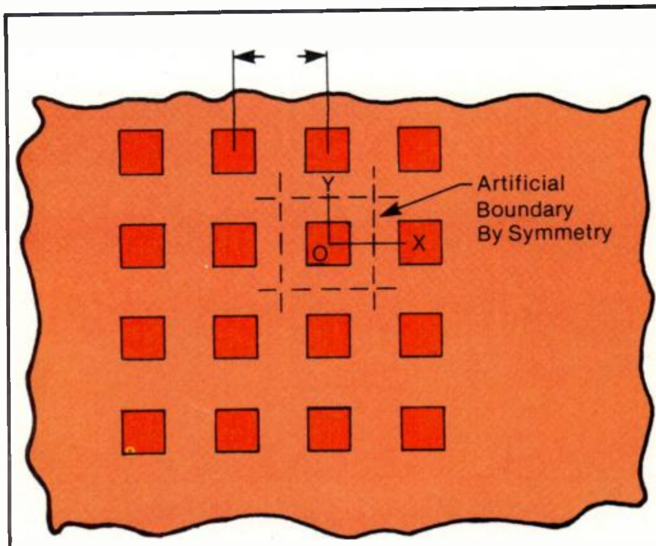

Figure 3. Array of Base Areas in a Silicon Die

Experimental Verification Of Calculated Die Temperature

Actual temperature measurements are made with infrared microscope, Barnes Eng. Co. Model RM2A. This instrument uses an indium antimonide diode photodetector at liquid nitrogen temperatures to measure the infrared radiance emitted from a 1.5 mil spot on the surface being examined. The IR radiance versus temperature curve is calibrated by measuring the radiance at various known temperatures monitored by a calibrated thermocouple while the device is heated by external means. An experimental calibration is necessary because the radiance output of the device at a given temperature is a function of the average emissivity in the area seen by the microscope, and this average emissivity is a function of the geometry and processing history of the device in question. The effective emissivity depends upon the relative amounts of metal and silicon and the infrared transparency of the varying thicknesses of SiO_2 glass in the field of view. The calibration data of radiance versus temperature can be least-squares curve fit to an equation of the form $T = (A)(R)^b$, where A and b are the fitted constants, and R the measured radiance.

The device is then powered up in its circuit, and the radiance data collected point-by-point around the surface of the silicon die. A computer program inputs the array of radiance data, calculates the actual temperature from the calibration equation, and prints a map of the temperature profile, as well as some statistical information about the temperature distribution.

Figure 5 is a plot showing the correlation of measured to calculated temperature for the 150-watt die, under various conditions of flange temperature (30° to 150°C), supply voltage, drive power, and output

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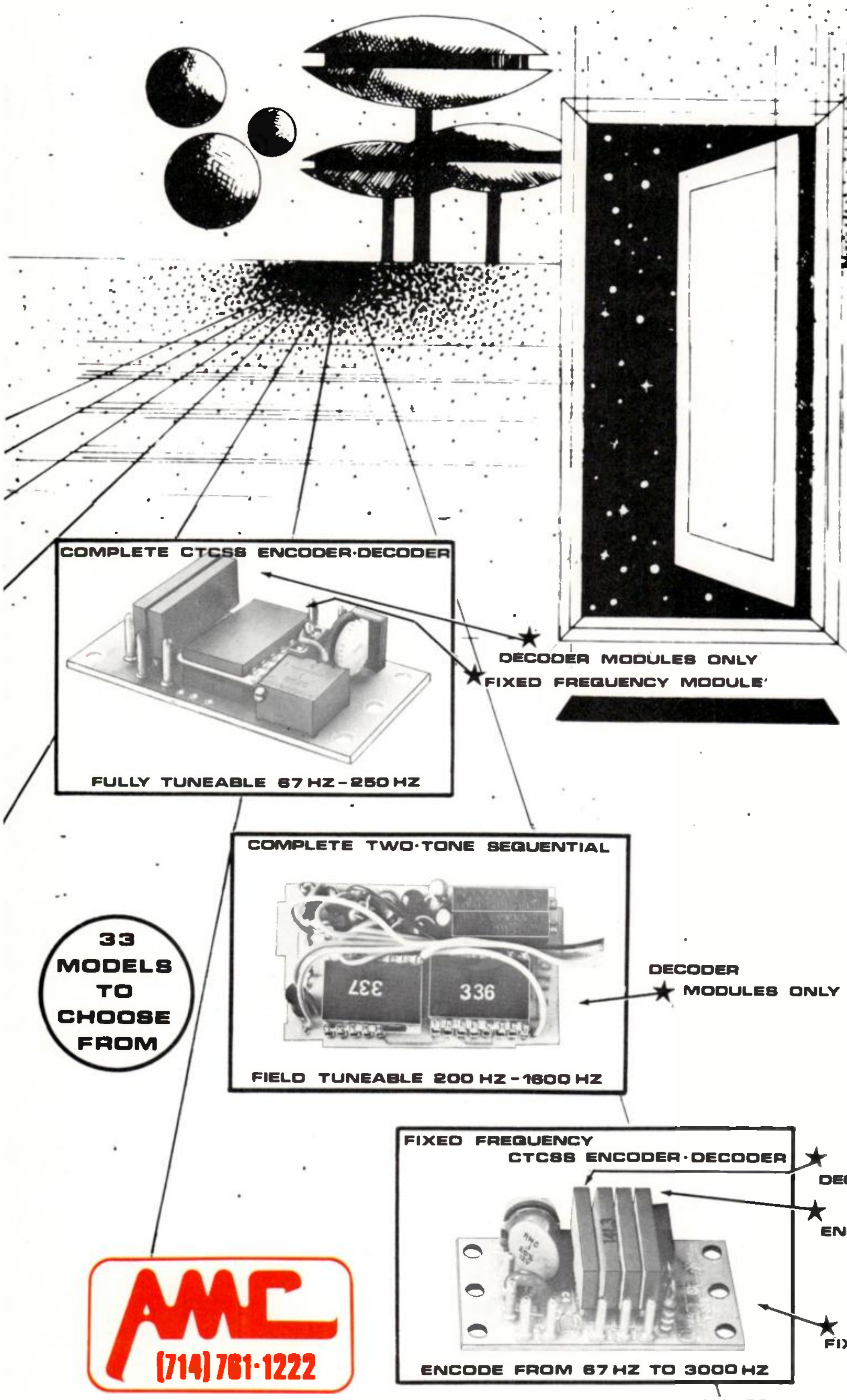

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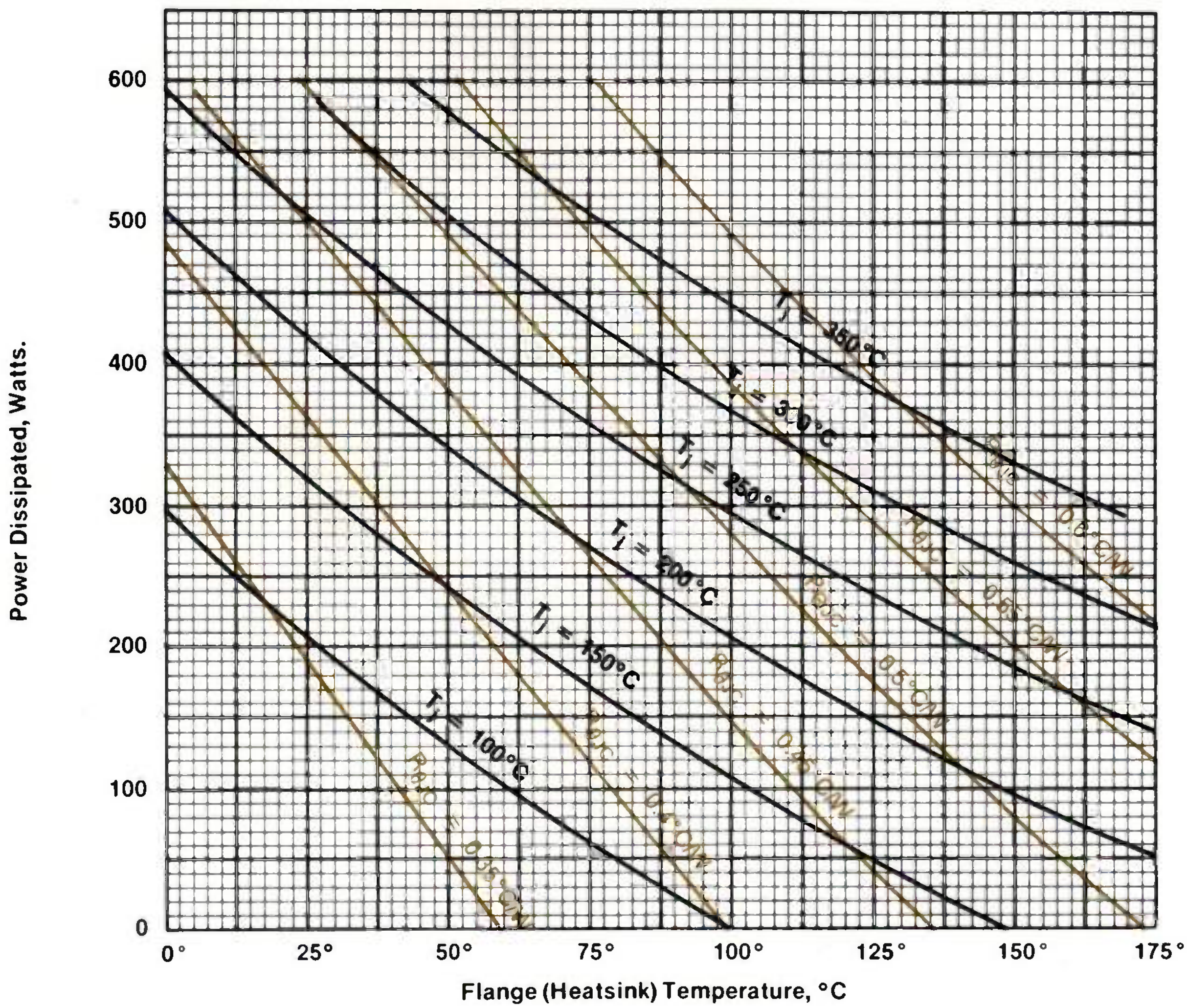


Geometry —— MRF 421 Transistor

BeO Thickness — 40 mil

Black line — Junction Temperature T_j

Ocher line — Thermal Resistance $R_{\theta JC}$

Figure 4. Power Dissipated vs. Flange (Heatsink) Temperature

Note that the device thermal resistivity $R_{\theta JC}$ is a function of both ambient temperature (horizontal axis) and dissipated power (vertical axis). At an ambient temp of 65°C and dissipated power of 300 watts $R_{\theta JC}$ = .45°C/Watts at 100°C and 300 watts $R_{\theta JC}$ = .51°C/W. Note also, that if the correct $R_{\theta JC}$ is known the junction temperature can be accurately determined from $T_J = T_A + R_{\theta JC} P_D$. From the previous example T_J = 65°C + (.45°C/Watts) 300 watts = 200°C. and T_J = 100° + (.51) (300) = 253°C which can be read directly from the graph also.

load magnitude and phase angles from 50 Ω to over 30:1 VSWR. The calculated temperatures seem to be somewhat higher than measured at the higher power levels. The calculated temperatures are based on the calculated power dissipation, disregarding RF losses in the actual loads and circuits.

Metal Migration And Mean Time to Failure

The calculated/observed temperature agreements are seen to be close enough so that the calculated temperature can be used as the basis for reliability calculations of Mean Time Before Failure (MTBF) for metal migration based upon Black's[5] work.

$$MTBF = \frac{(\text{cross section})^3}{I^2 \cdot f(T^\circ)} \qquad (6)$$

Equation (6) is the equation used for calculating metal migration lifetime, where the cross section refers to the conducting stripe dimensions in cm^2, and I is the current in the stripe in amps.f(T°) is an

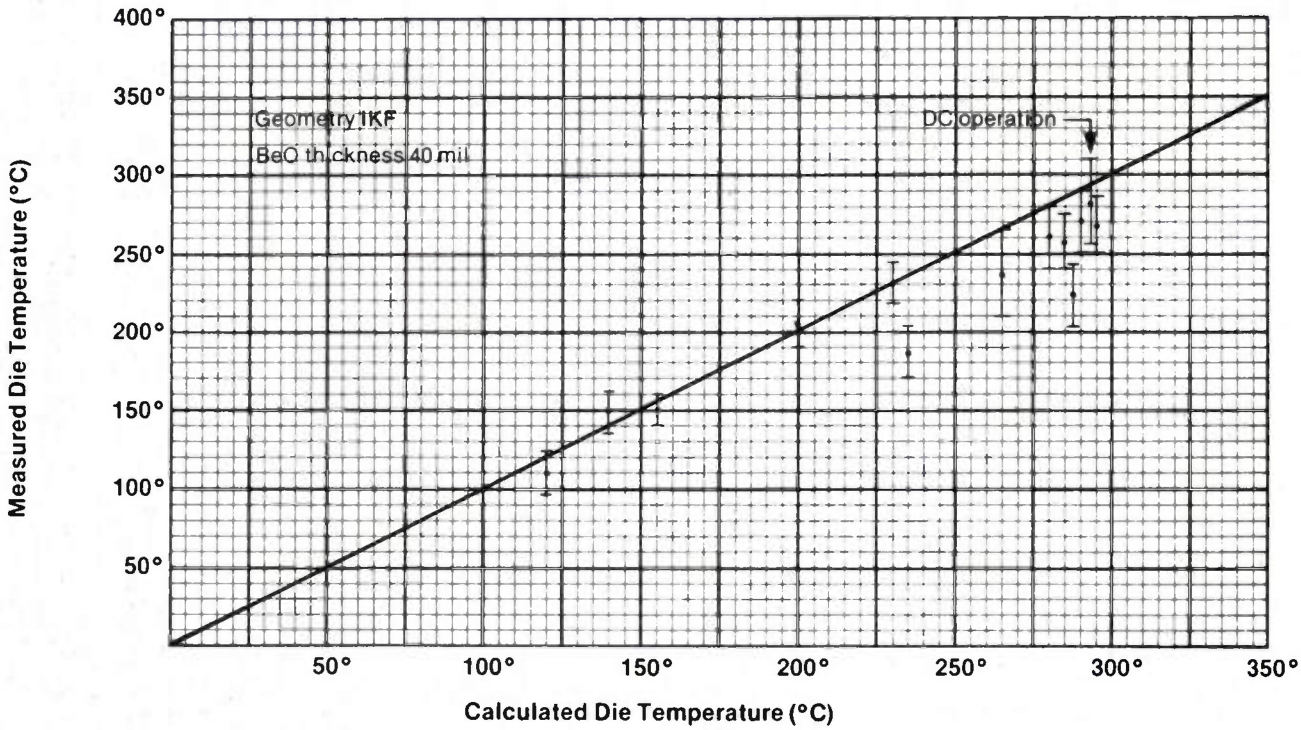


Figure 5.

A comparison between measured and calculated die temperatures shows excellent agreement. Calculated temperatures disregard RF losses in actual loads and circuits.

Arrhenius function of the stripe material, having the form:

$$f(T^\circ) = B \exp(-\varnothing/KT) \qquad (7)$$

The material dependent parameters B and Ø are shown in Table II. K is Boltzman's constant, and T is in degrees Kelvin. Figure 6 presents the results of the calculations of device temperature and MTBF as a function of power and ambient temperature.

The temperature lines are valid for any combination of supply voltage, efficiency and drive power, by reading the power axis as power dissipated. The MTBF lines, because of the current dependence, have been constructed based upon the assumptions of 12.5-volt supply and 50 percent efficiency, so that the power axis should be interpreted as output power. It is possible to use the MTBF set of lines at other conditions by entering the graphs by reading the axis as power dissipated, and finding the MTBF,

TABLE II

Material	B	Ø
Large Crystal Glassed Al. (Ref. 6)	8.5×10^{-10}	1.2
Al. – 2% Cu. Alloy (Ref. 7)	7.9×10^{-17}	0.6

then scaling the MTBF by the ratio squared of the η = 50 percent current to the actual current.

$$MTBF = MTBF\,(\text{from graph}) X \left(\frac{I @ \eta = 50\%}{I\ actual}\right)^2 \qquad (8)$$

To Scale Metal Migration MTBF From 12.5 To Other Operating Voltages

Keeping $P_D + \eta$ constant, then the current for 28 V operation compared with that for 12.5 V operation is given by:

$$I_{12.5} \times 12.5 = I_{28} \times 28$$

$$\frac{I_{12.5}}{I_{28}} = \frac{28}{12.5}$$

From Black's[5] equation:

$$MTBF \alpha \frac{1}{I^2}$$

For like geometries, the ratio of the MTBF at 28 V to the MTBF at 12.5 V is:

$$MTBF_{28} = MTBF_{12.5} X \left(\frac{28}{12.5}\right)^2$$

$$MTBF_{28} = MTBR_{12.5} X\ 5.02$$

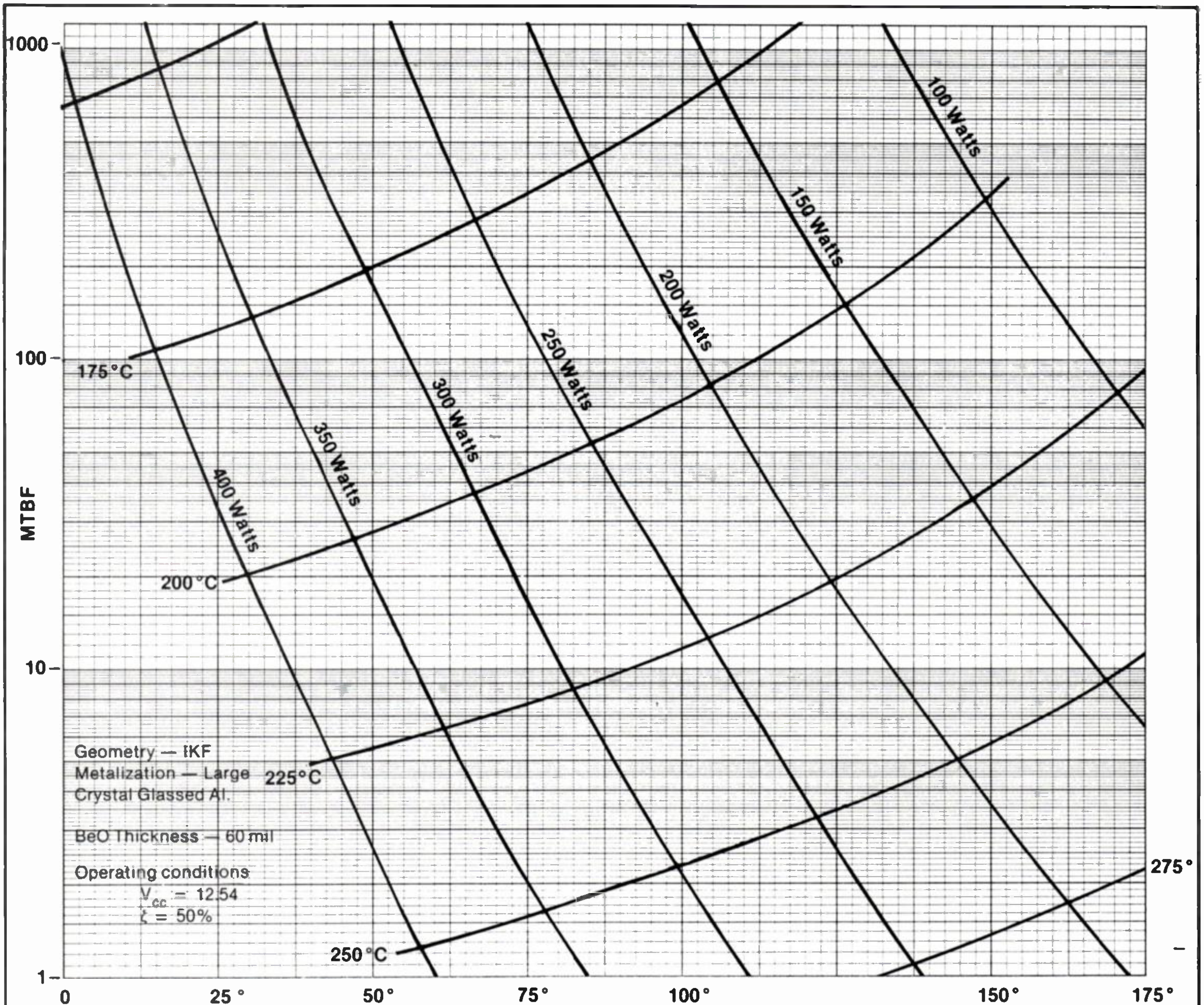


Figure 6. Metal Migration MTBF VS Ambient Case Temperature (°C).

Similarly, for 50 V operation: $MTBF_{50} = MTBF_{12.5} X16$.

Conclusion

We have discussed the elements of thermal resistance and metal migration lifetime with particular attention paid to their variation with temperature as functions of power dissipation and ambient temperature.

Graphical presentations of the results are included which should be useful to the device user interested in better reliability in his application.

References

1. G.A. Slack, Journal of Applied Physics, 35, 3462, 1964.
2. J. Elston, J. DeGoer, and Z. Mihailovic, J. Nucl., Mater., 11, 333, 334, 1964.
3. Fulkerson, Moore, Williams, Graves, and McElroy, Phys. Rev., 167, 768-780.
4. Linsted and Surtey, IEEE Transactions on Electron Devices, ED 40, 1972.
5. Black, Proc IEEE, 57, 1587, 1969.
6. Hall, ECOM, DAAB07-70C 0164, October 1971. □

Contact Motorola for application note AN790. Reader Service No. 140.

Acknowledgements

The author expresses grateful acknowledgement to Alan Wagstaffe for continued interest, encouragement, and critical review of early manuscripts; and to Henry Pfizenmayer for the program details on Linsted's equation.

Co-Ax Provides D.C. Power For Receiver

The technique used for many years to combine power and signal on the same conductor is worth revisiting. It falls into the broad category of frequency division multiplexing. This is easier to do than to say.

Often a designer is faced with the problem of supplying power to a remote electronic package such as an antenna preamp, receiver, or repeater amplifier. For reasonably low power levels, it may not be necessary to run a separate line. If the electronic device is connected by a good quality coaxial cable, the power may be supplied via the center conductor of the coax. Certain precaution and design constraints must be observed to keep the power and the signals separated. The term "power" in this context means the ac or dc energy needed to bias the electronic devices to an active state.

Devices usually requiring remote power include UHF and microwave converters which are mounted at or near the antenna in order to keep the carrier to noise ratios low. Antenna preamplifiers are often used in the lower bands for the same reason so that the sophisticated and expensive receivers can be kept in a control room. Remote television receive sites and fringe area reception often use wideband preamps at the antenna. Repeater amplifiers which are connected by coax such as CATV systems and private data terminal systems also require some type of remote powering.

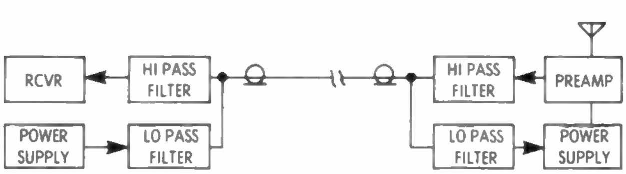


Figure 1. System Block Diagram.

The power applied to the coax may be d.c. or a.c., and the a.c. may be 50 Hz, 60 Hz, or 400 Hz.

The complexity of the filters will depend on the frequency and bandwidth of the desired signals. For example, when using 60 Hz power and VHF signals, the high pass filter is a simple capacitor, and the low pass filter consists of an inductor and a capacitor.

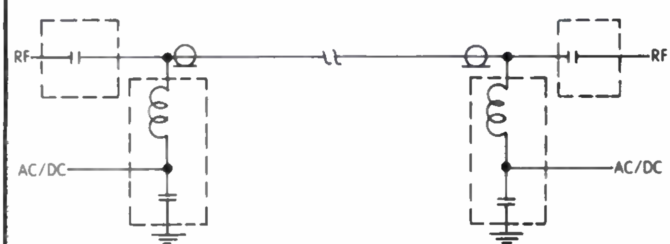


Figure 2. Schematic of The Separation Filters.

For 50Ω and 75Ω coaxial systems, the low pass filter, i.e. the inductor, should present at least a 10 x Zo impedance to the system, and the bypass capacitor should have a very small impedance at r.f. and very large impedance at a.c. For example in a 50Ω system with 60 Hz power and 460 MHz, the inductor would be:

$$X_L = 10Zo = 500\Omega$$

$$L = \frac{X_L}{2\pi f} = \frac{500}{2\pi(460\times10^6)} = 170nH$$

In a 75Ω broadband system with a frequency as low as 5 MHz, the minimum required inductance is:

$$L = \frac{10\times75}{2\pi(5\times10^6)} = 23.9\,\mu H$$

For broadband systems, low Q chokes with iron or ferrite cores should be used.

The bypass capacitors usually range from 0.001 μF to .01 μF. Large values may be required for very low frequencies. Disc ceramic and low inductance feed through types are preferred at high frequencies.

The high pass coupling capacitor is often part of the r.f. matching network. However, if a coupling capacitor must be provided, calculate the value which yields an r.f. impedance of less than three ohms but has a very high impedance at the power frequency. For example, at 5 MHz calculate —

$$C = \frac{1}{2\pi f X_c}$$

$$C = \frac{1}{2\pi\,(5x10^6)\ (3)} = 0.01\mu F$$

At 60 Hz, a 0.01 uF capacitor has —

$$Xc = \frac{1}{2\pi(60)\,(10^{-8})} = 265\ K\Omega$$

In a 75Ω system, the 60 Hz power would be attenuated about −73 dB.

At 890 MHz, a 3Ω coupling capacitor is —

$$C = \frac{1}{2\pi(890x10^6)\ (3)} = 59.6pF.$$

Precautions

The amount of power that can be supplied in this manner depends on a number of factors. The CATV industry is limited to 60 volts r.m.s. and self-current-limiting. For a given energy level, lower voltages mean better safety but higher currents. High currents mean larger IR drops. Direct current allows simple power supplies at the receiver but accelerates galvanic corrosion. Alternating current does not contribute to galvanic corrosion but usually requires a transformer at the receiver. AC currents can also cause hum modulation by partially saturating iron and ferrite chokes and by voltage modulating poor quality or defective capacitors.

Use coaxial cable with heavy copper braid or solid aluminum outer sheaths in order to keep the loop resistance low. Proper mating connectors, as always, should be used to avoid intermittent connections.

Fuses or other types of short circuit protection may be used as required.

At low power levels, all of the above problems can be overcome. This technique has been used for many years and is well proven. □

Basic RF AMP Design

The first in a series of six articles that begins with the fundamentals of RF Power Amplifiers and takes the designer through VHF, UHF and Smith Chart practical design techniques.

By Thomas P. Litty Chief Engineer
Casady Engineering, Inc.

"What a Transistor Really Looks Like at VHF and UHF"

At VHF and UHF a transistor no longer looks exactly like a transistor, figure 1 depicts the equivalent circuit.

Once we understand what the transistor looks like it is possible to design a circuit that will give optimum performance.

As we have seen from the equivalent circuit of figure 1, the transistor at VHF & UHF cannot be viewed simply as a current amplifier since there are too many reactive components to make life that simple. The solution therefore must be to impedance match the RF power (RF current if you wish) in and out of the transistor. To do this with the minimum of effort, we may simplify our equivalent circuit to the extend shown in figure 2.

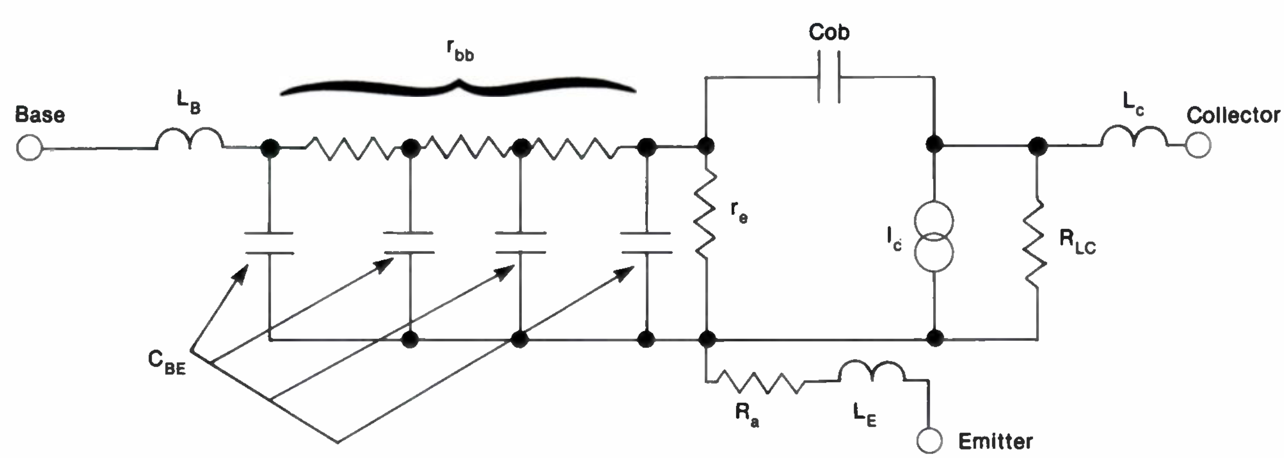
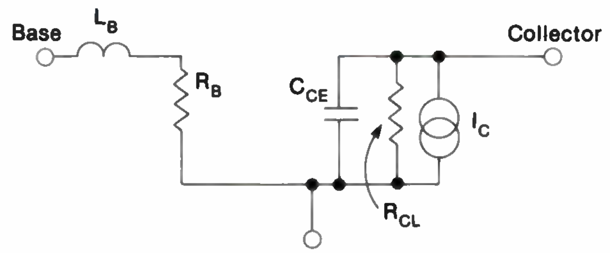


Figure 1.

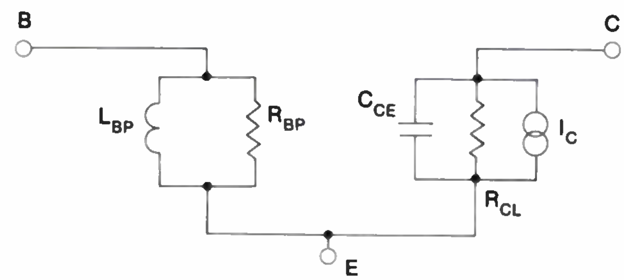


L_B = Base Lead Induct

R_B = Base Lead R

R_{CL} = Collector Load R Inside Transistor

Figure 2.



L_{BP}, R_{BP} = Base Parallel Equivalent of Series L_B and R_B

New Equivalent Circuit.

Figure 3.

Base Matching

To match the base of the transistor to 50 ohms, it is often advisable to resonate out the base inductance L_B at the operating frequency or its 2nd harmonic. For simplicity we will resonate it at the operating frequency as follows:

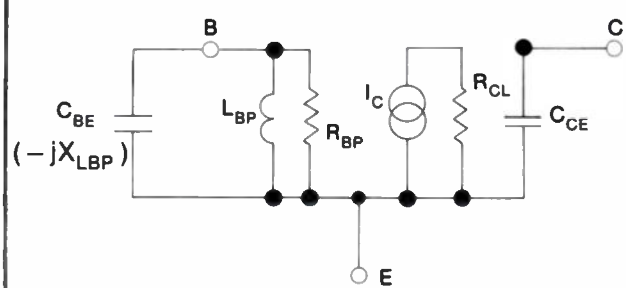
1] Obtain the parallel equivalent circuit for L_B and R_B as follows:

$$Q = \frac{X_{LB}}{R_B}$$

$$R_{BP} = (1 + Q^2)\, R_B$$

$$X_{LBP} = \frac{(1 + Q^2)\ (jX_{LB})}{Q^2}$$

2] By selecting a capacitor with a resistance of $-jX_{LBP}$ we can resonate out the base inductance. See figure 4.



Calculation of C_{BE} to resonate out L_{BP}

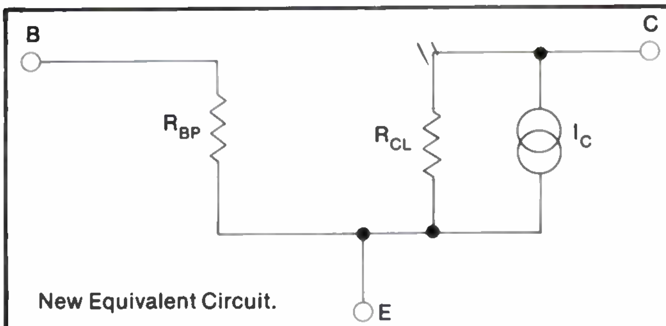
Figure 4.

About The Author

Tom Litty holds a B.S.E.E. from Loyola University of Los Angeles. He has been deeply involved in RF design since 1967. He has held a Amateur radio license for 24 years. At present he is Director of Engineering for Casady Engineering Associates in Torrance California (manufacturers of RF security systems). Among his contributions are the JO (balanced base or controlled Q) transistor which he patented while employed at TRW Semiconductors. Litty founded TPL Communications and was chief engineer until 1977. His hobbies include Antique Car Restortion, Amateur Radio, and Jogging.

Tom Litty believes that designing with RF power transistors is no longer black magic. Most design work with these transistors can be approached with simple mathmatical models resulting in a maximumized design with very little cut and try effort. In this and future articles, theoretical and practical design examples will be discussed utilizing simple mathmatics and the Smith Chart as design vehicles. This article is intended as a primer for those new to RF power amplifier design, and as a refresher for those who consider themselves old timers.

With C_B now in place our circuit looks as follows:



New Equivalent Circuit.

Figure 5.

3] We now may match the input impedance to 50 ohms by using this simple impedance matching network.

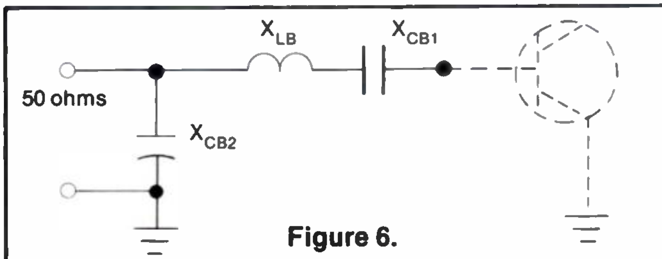


Figure 6.

X_{CB1} is simply a Q multiplying capacitor which also allows adjustment to the circuit should any be necessary.

The values of the components can be computed as follows:

$$Q = \sqrt{\left(\frac{50}{R_{BP}}\right) - 1}$$ [Use this number for solving equations below]

$$X'_{LB} = Q(50)$$

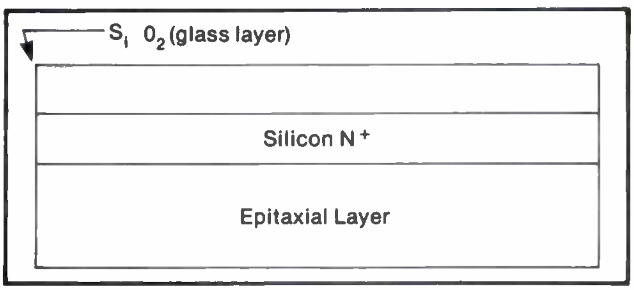
$$\boxed{X_{LB} = 1.5(X'_{LB})}$$

$$\boxed{X_{CB1} = .5(X'_{LB})}$$

$$\boxed{X_{CB2} = X_{LBP} = \frac{(Q(50))\ (1 + Q^2)}{Q^2}}$$

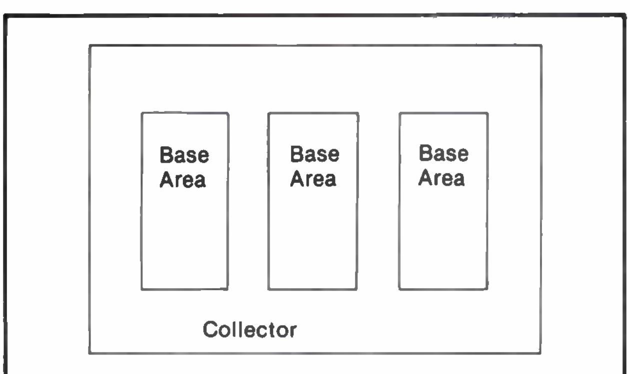
What is an RF Power Transistor?

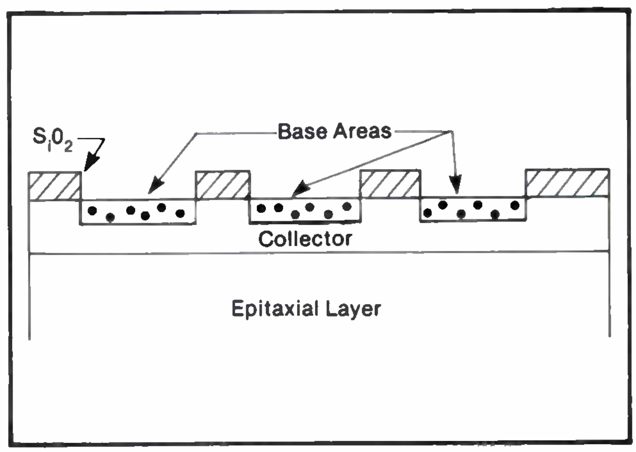
Almost all RF power transistors today are Silicon wafers doped to form a high conductivity layer, known as an epitaxial layer, on one side and a Si O_2 glass layer on the opposite.



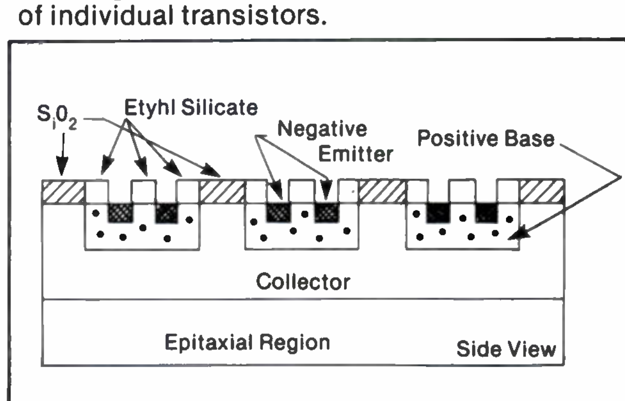
Using a photographic process the Si O_2 layer is imprinted with a base mask. This mask is actually a photograph of the base region of the transistor.

This base area is then etched out of the Si O_2, using hydroflouric acid. A Boron gas is then passed over the open areas, dopping the open area positive (since this is a NPN transistor).





A single silicon wafer contains up to thousands of individual transistors.



Collector Matching

To match the collector output to 50 ohms we proceed as follows.

1] Determine collector load impedance as per this formula

$$R_{CL} = \frac{V_{cc}^2}{2Po} \qquad V_{CC} = \text{supply voltage}$$

2] By using the following simple circuit, (see figure 7), we may match the collector load impedance, R_{EL} to 50 ohms. This assumes you are developing enough power to make R_{EL} less than 50 ohms i.e. appx. 14W @ 12 volts. If this is not the case, other simple variations of this circuit can be used, for example, "reverse it".

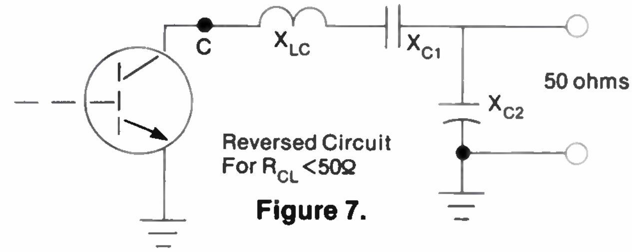


Figure 7.

Calculations for X_{LC}, X_{C1}, and X_{C2}.

$$R_{CL} = \frac{V_{cc}^2}{2P_o}$$

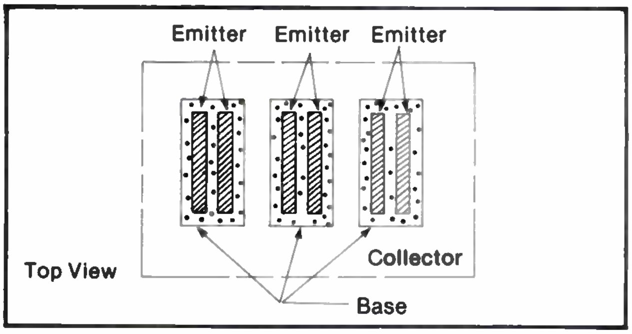
$$Q = \sqrt{\frac{50}{R_{CL}} - 1}$$

$$X'_{LC} = Q\, R_{CL}$$

$$\boxed{X_{LC} = 1.4\,(X'_{LC})}$$

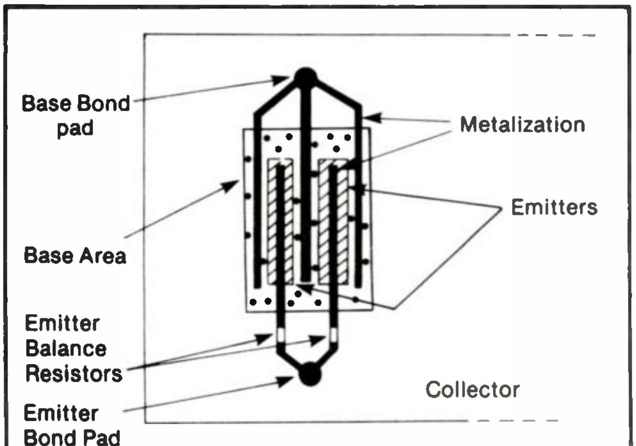
$$\boxed{X_{C1} = .4\,(X'_{LC})}$$

$$\boxed{X_{C2} = \frac{(1 + Q^2)\quad(X'_{LC})}{Q^2}}$$



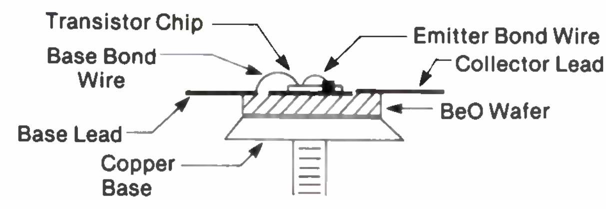
The holes cut for the base area diffusion are then filled up by Ethyl Silicate, a substance similar to Si O_2, and new holes cut for the emitter regions by the same process as that used for the base.

The emitters are then diffused through these holes using a gas containing phosphor.

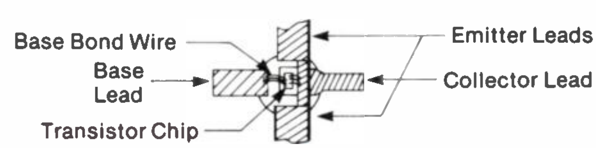


It is at this time that the emitter balancing resistors, among the more common are nichrome and aluminum, are deposited. All emitter and all bare areas are connected.

When the waffer is diced, connections to the outside world are made using fine gold wires.



Side View



Transistor Top View

Collector contact is made through the bottom of the transistor chip which mounts to a metalized Berrillium Oxide waffer.

DC Voltage

The only step left is to provide DC voltage for the amplifier. This is done through a DC isolation choke of approximately five (5) times the collector load impedance. Some base to ground DC connection should also be provided to eliminate high standby leakage currents and to prevent the RF input power from biasing the transistor off (loss of power gain will result).

The collector choke should be heavily by-passed, on the DC side, to eliminate oscillations and RF feed through into the rest of the system.

See figure 8.

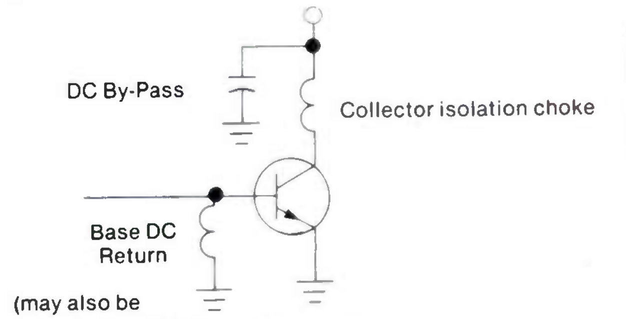


Figure 8.

Design Example

Assuming the following values, which may be obtained from a RF transistor data sheet, we proceed as follows:

R_B =	1 ohm
L_B =	j 4 ohm
C_{CE} =	35 pf (neglect)
Power Output =	14.4 Watts
Operating Voltage:	12 Volts

1] $$X_{CB3} = -jX_{LBP} = \frac{(1+Q^2)(X_{LB})}{Q^2}$$

$$Q_1 = \frac{X_{LB}}{R_B} = \frac{2}{1} = 2$$

$$\boxed{X_{CB3} = -j\frac{(5)\ (2)}{(4)} = -j2.5 \text{ ohms}}$$

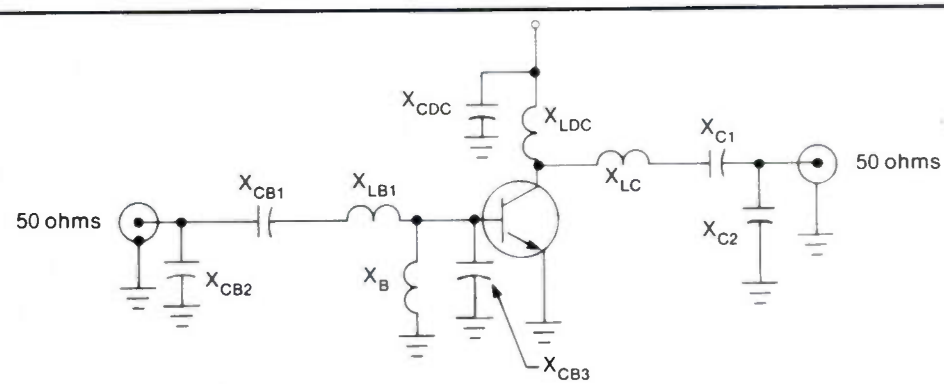


Figure 9.

2] $$Q_2 = \sqrt{\frac{50}{R_{BP}} - 1}\ ,\quad R_{BP} = (1 + Q_1^2)\ R_B$$

$$R_{BP} = (5)\ 1 = 5 \text{ ohms}$$

$$Q_2 = \sqrt{10-1} = 3$$

$$X_{LB1} = 1.5\,[X_{LB}] = 1.5\,[Q_2(5)]$$

$$\boxed{X_{LB1} = +j\,22.5 \text{ ohms}}$$

3] $$\boxed{X_{CB1} = -j\,[Q_2(5)]\,.5 = -j\,7.5 \text{ ohms}}$$

4] $$X_{CB2} = \frac{(Q_2)\ (5)\ \ (1+Q_2^2)}{Q_2^2} = \frac{(15)\ \ (1+9)}{9}$$

$$\boxed{= -j16.7 \text{ ohms}}$$

5] $$\boxed{X_{LDC} = 5\,(R_{CL}) = 5\ \frac{(144\ \ )}{(28.8\ \ )} = j\,25 \text{ ohms}}$$

6] $$Q_3 = \sqrt{\frac{50}{R_{CL}} - 1} = 3$$

$X'_{LC} = Q_3R_{CL} = 3(5) = 15$

$\boxed{X_{LC} = 1.4(15) = j21 \text{ ohms}}$

7] $\boxed{X_{C1} = -j \left[.4 \ (X'_{LC})\right] = -j6 \text{ ohms}}$

8] $X_{C2} = -j \left[\dfrac{(1 + Q_3^2) \ (X'_{LC})}{Q_3^2}\right]$

$X_{C2} = \dfrac{-j(10) \ (15)}{(9)}$

$\boxed{X_{C2} = -j\,16.7 \text{ ohms}}$

9] $\boxed{X_{CDC} = \dfrac{R_{CL}}{10} = -j.5 \text{ ohms}}$

10] $\boxed{X_B = (-j10) \ (R_{BP}) = -j\,50 \text{ ohms}}$

Practical VHF & UHF Amplifiers

All of the design work just described is not the simplest way to build a transistor amplifier. I feel this way because all those calculations have to be made, and I personally hate paper work. However, quite a bit of cut-n-try goes into each successful transistor design, regardless of the calculations preceding it. Therefore we are going to describe several simple designs that will make any VHF or UHF transistor play quite well and explain how you can optimize them for the best performance.

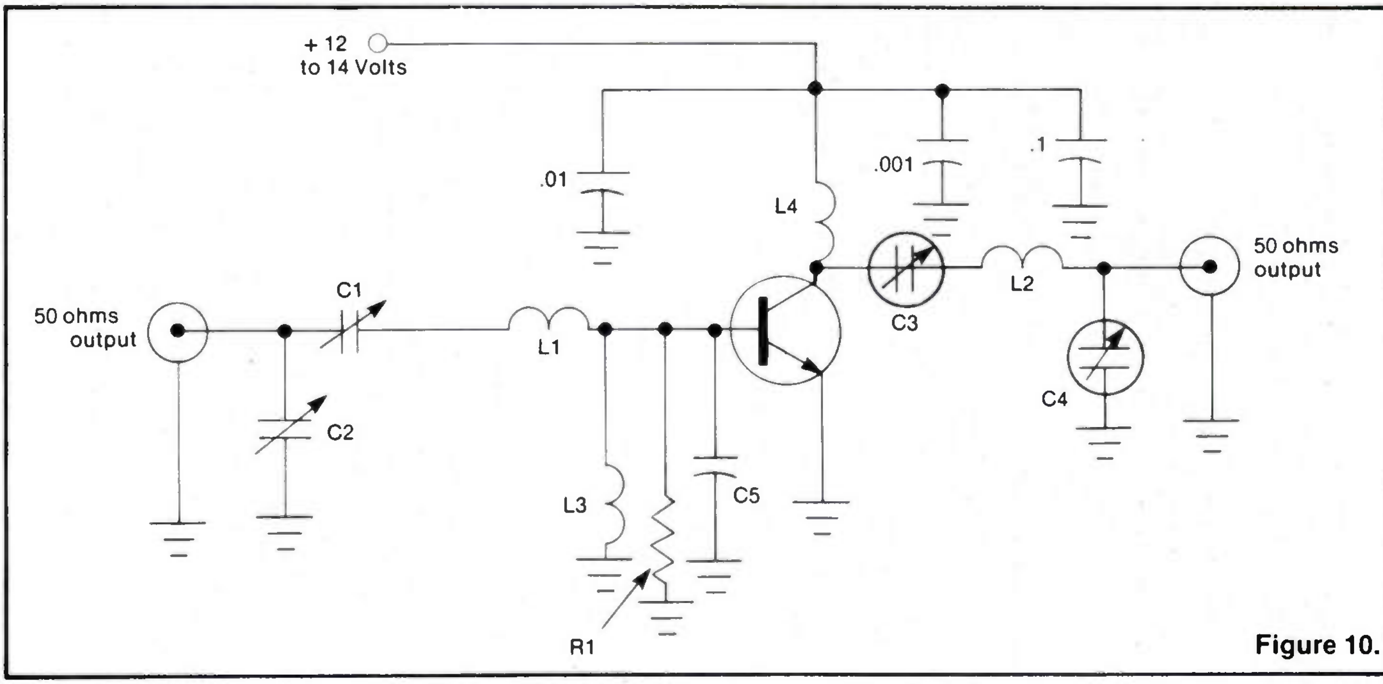


Figure 10.

This amplifier will wofk with any VHF transistor whose power output is between 3 and 40 watts.

Some of the more common transistors that can be used and their respective power gains are as follows:

Power Output	Power Gain	(Typ)	Type
3 - 5 Watts	10dB	TRW	2N5589
		TRW	PT5589
		Amperex	2N6080
		SSS	2N6080
		Motorola	2N6080
		CTC	B-3-12
7 - 12 Watts	6 - 8 dB	TRW	2N5590
		Amperex	2N6081
		SSS	2N6081
		Motorola	2N6081
		CTC	B-12-12
10 - 18 Watts	8 - 10 dB	Amperex	2N6081
		SSS	2N6081
		Motorola	2N6081
		TRW	PT5649
		CTC	B-12-12
20 - 30 Watts	5 - 8 dB	Amperex	2N6801
		SSS	2N6081
		Motorola	2N6081
		TRW	2N5591
		Amperex	2N6081
		SSS	2N6081
		Motorola	2N6081
30 - 40 Watts	4 - 7 dB	Amperex	2N6081
		SSS	2N6081
		Motorola	2N6081
		TRW	2N5706
		CTC	B-40-12

Referring now to figure 10, these transistors will work quite well with the suggested values and if you follow the tweaking (cut-n-try) suggestions. Later articles will suggest even better production circuits.

C1	ARCO 404
C2	ARCO 404
C3	ARCO 404
C4	ARCO 404
C5	100 - 150 pf
L1	3T# 16 1/4" I.D.
L2	3T# 16 1/4" I.D.
L3	3.3 μH RF choke (appx.)
L4	5T# 18 1/4" I.D.
R1	10 - 500 ohms

To tune this amplifier apply voltage and tune C1 and C2 for minimum reflected power, then adjust C3 and C4 for maximum power output. To tweak this amplifier simply adjust L1 and L2 until C1 and C3 are almost completely meshed for maximum power output and minimum reflected power. Adjust R1 until the output power drops about 5 - 10 percent and you are ready to go.

A simple explanation of why we tweak in this way, now follows:

a] C1 and C3 are made as large as possible to bring the loaded Q down thus increasing the bandwidth and stability of the amplifier.

b] R1 acts as a stabilizing element swamping and terminating the input circuit so that mis-adjustment will not cause oscillations.

Important Construction Techniques

The following are some very important suggestions that can make or break you as an amplifier builder. If you follow these suggestions in building the latter described amplifier you should have little difficulty in making it work.

1.] Keep the leads as short as possible on all DC by-pass capacitors.

2.] Keep the leads as short as possible on C5 and place it as close to the transistor base lead as possible.

3.] Keep as much ground return area as possible, preferably by using double sided board.

4.] Keep the emitter leads on the transistor as short as possible.

5.] Follow my suggested circuit layout for maximum success. See figure 11.

6.] Thin copper foil should be used to connect the top ground plane to the bottom ground plane around the emitters, DC by-pass and RF input and output.

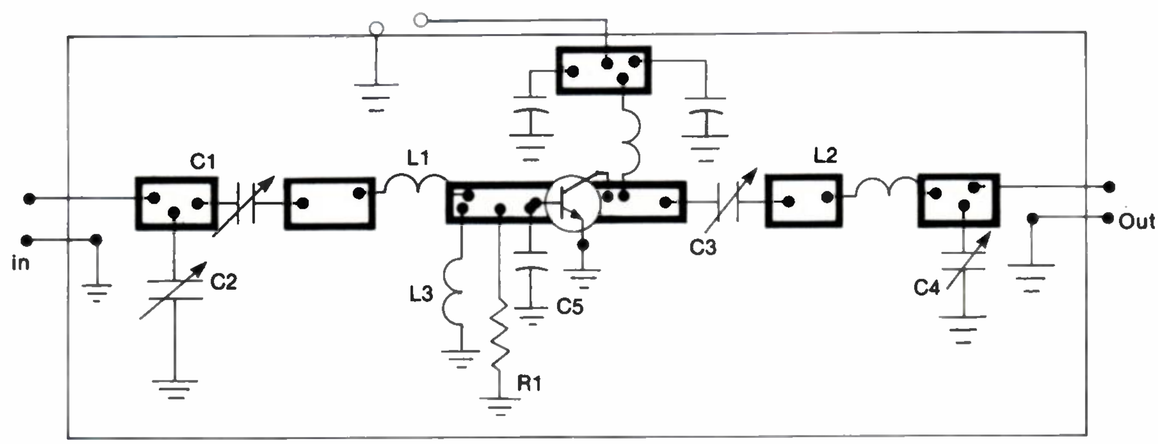


Figure 11.

How to Get More Power And More Power Gain

The next step is to combine these amplifiers to provide more power gain and/or more power handling capability. Figure 12 is a suggestion of how to cascade and parallel these simple amplifiers to provide 80 watts of RF power output from 30 to 10 watts power input. A handy widget, known as the Wilkenson Combiner, is used to split and combine power. This device utilizes the simple quarter wave transmission line formula for its operation.

Good heat sinking should be provided and the power transistors not stressed mechanically in any way, since they are brittle and once broke, are useless.

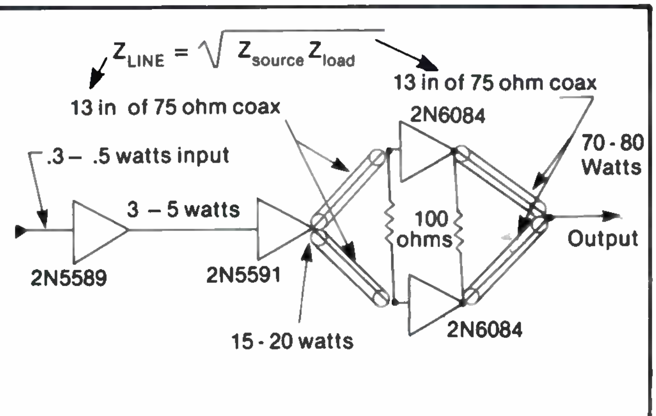


Figure 12.

The Quietest Signal Generator in the World!

INTRODUCING
THE **7100**

Programmable
Microprocessor
Based Signal
Generator...
300 KHz — 1.3 GHz;
Phase Noise: 136 dB/Hz
Noise Floor: —145 dB/Hz

COMSTRON/ADRET's Model 7100 covers 300 KHz to 650 MHz (300 KHz to 1.3 GHz with optional doubler) with 1 Hz resolution and is a microprocessor based synthesized signal generator featuring full programmability of frequency, modulation and level, as well as better than —136 dB/Hz phase noise 20 KHz from the carrier and a noise floor of greater than 150 dBc.

The various AM, FM and PM modulations, as well as simultaneous AM/FM and AM/PM combinations, are achieved either internally or externally with DC coupling capability in external mode.

The output level, displayed by graduated meter and LED indicators, is adjustable between +20 dBm and —140 dBm/50 ohms.

All frequency, level and modulation functions are displayed through LED indicators, while management of all controls is microprocessor directed.

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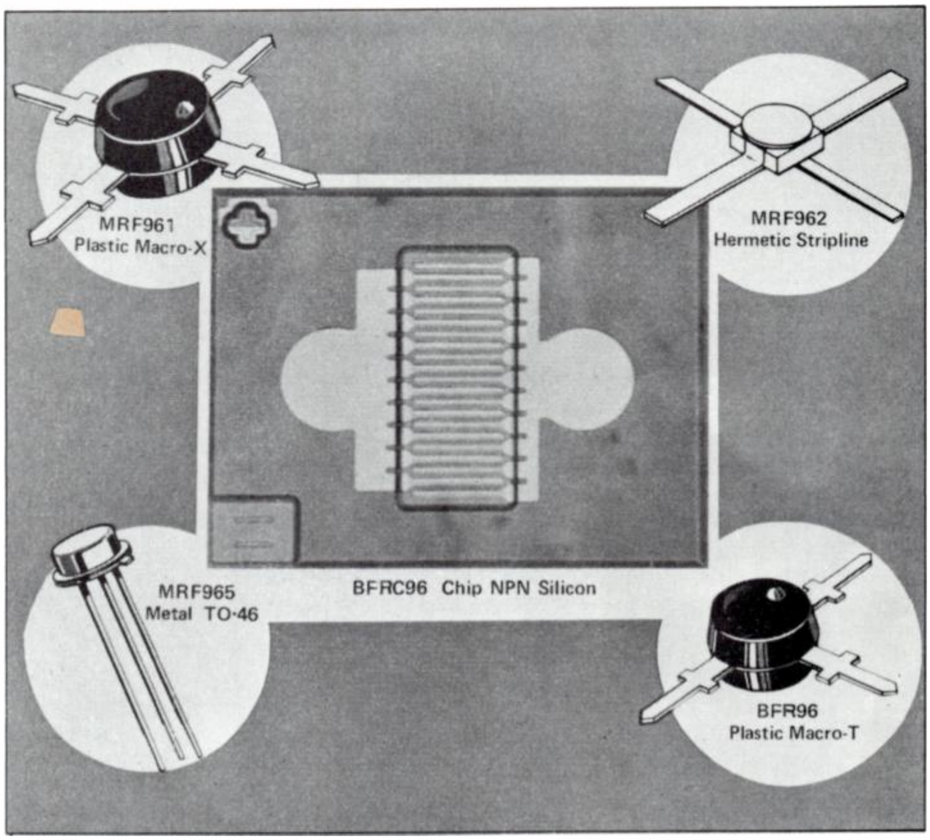
INFO/CARD 17

RF Transistor Wears Four Hats

Motorola has introduced a new series of RF transistors that combines state-of-the-art performance, a variety of packaging options, and a major breakthrough in pricing for the UHF market. Intended for low-to-medium power amplification, the new transistor series features high gain (up to 15 dB (max) at 0.5 GHz) and a very low noise figure (2 dB (typ) at 0.5 GHz and 10 mA). Prices range from a low of $1.40 (in chip form) to a high of only $7.50 (hundred-up) for high reliability applications. This reduces the state-of-the-art performance category to the commodity pricing level.

The transistor series encompasses 5 device types — a basic chip and four package options — with optimized specifications and pricing for a wide variety of applications.



The Unencapsulated Chip — BFRC96

Available in unencapsulated form for hybrid applications, the basic chips achieve high-performance characteristics from fine-line geometry, ion-implanted arsenic emitters and gold top metalization.

Gold top metalization prevents metal migration due to the high-current densities in the fine metal lines required for high frequency operation. Ion implantation facilitates precise control of dopant densities and gradients. The use of arsenic dopant results in a higher f_T and corresponding improvement in noise figure compared with the more conventional processing.

The high current, low noise figure and high f_T performance of the BFR96 series of transistors makes them eminently suitable for broadband VHF/UHF linear amplifier and oscillator applications.

Plastic Packages for High-Volume Applications — BFR96/MFR961

Low-cost package options offer the basic chip in two types of plastic packages — the 3-leaded MACRO-T package (BFR96), and the 4-leaded MACRO-X package (MFR961). These are particularly well suited for MATV/CATV applications.

The MACRO-T package has become an industry standard and adapts the BFR96 to existing board layouts and designs. The 4-leaded MACRO-X package offers 2.5 dB higher gain, due to lower parasitics resulting from opposed-emitter lead construction, at no increase in price.

The Metal/Ceramic Package — MRF962

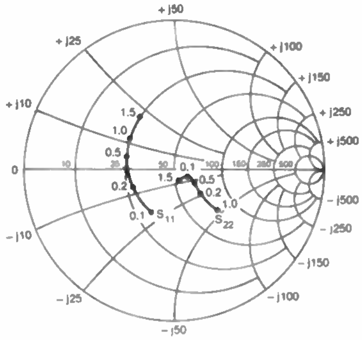
The metal/ceramic, hermetic stripline MRF962 package is intended for use in equipment which is subject to particularly hostile environmental conditions and when high reliability is required. This low parasitic package enables the MRF962 to be specified for operation up to 2GHz and gives typically a 6.0 dB higher power gain compared to the same die in a MACRO-T package at 500 MHz. The metal/ceramic package allows higher power dissipation than the plastic case.

The TO—46 Metal Package — MRF965

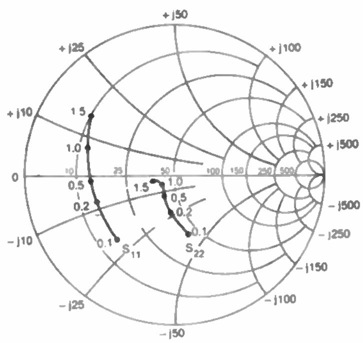
The higher dissipation rating and hermiticity of the MRF965, in its TO-46 package, allows its use in high gain VHF/UHF Class C amplifier applications up to 400 milliwatts output power. This is in addition to the Class A linear applications discussed for the other package options.

More information on the BFR96 series may be obtained by writing to Motorola Semiconductors, P.O. Box 20912, Phoenix, Ariz. 85036. Circle Reader Service No. 75.

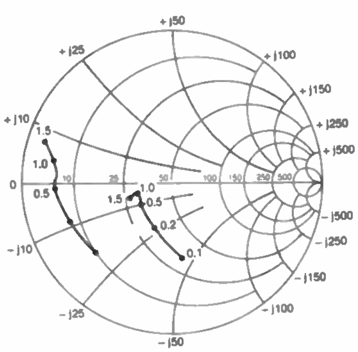
BFR96
INPUT/OUTPUT REFLECTION
COEFFICIENTS versus FREQUENCY
(V_{CE} = 10 V, I_C = 50 mA)



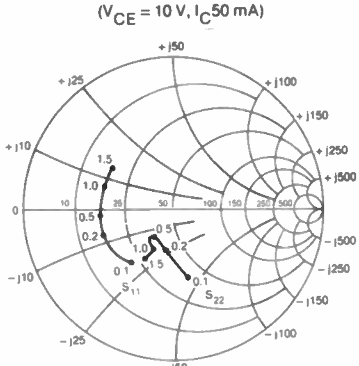
MRF961
INPUT/OUTPUT REFLECTION
COEFFICIENTS versus FREQUENCY
(V_{CE} = 10 V, I_C = 50 mA)



MRF965
INPUT/OUTPUT REFLECTION
COEFFICIENTS versus FREQUENCY
(V_{CE} = 10 V, I_C = 50 mA)



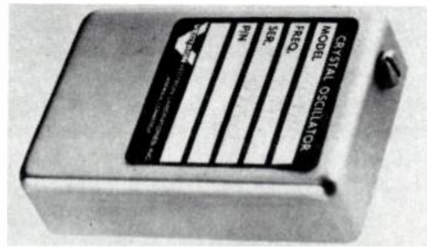
MRF962
INPUT/OUTPUT REFLECTION
OEFFICIENTS versus FREQUENCY
(V_{CE} = 10 V, I_C50 mA)



Linear VCXO to 400 MHz

VCXO model CO-275VH provides linearity of ±1 percent at any specified center frequency up to 400 MHz with +7 dBm output level. Modulation voltage of ±5V, at a rate of DC-10 kHz, produces ±0.1 percent deviation with wider or narrower deviation available.

Type CO-275VAH provides frequency stability of ±.01 percent over 0-5°C while type CO-275VBH includes temperature compensation to



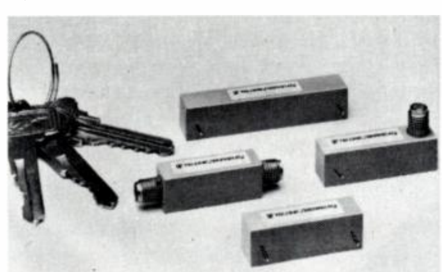
provide ±.001 percent stability. An oven controlled model is also available for those applications requiring higher stability. The unit measures 2"x3"x3/4" (51x76x19 mm) and is designed for printed circuit board mounting; chassis mount configuration with RF output connector is also available.

Contact Vectron Laboratories, Inc., 166 Glover Ave., Norwalk, Conn. 06850, Telephone: 203-853-4433, TWX 710-468-3796. Circle Reader Service No. 111.

Micro-Miniature Filter Series

The model TIB filter series complies with all applicable military specifications and replaces filters that are twice as large. The new filters are offered with two to eight sections, measure an average 3/8 in. x 3/8 in. x 1-1/2 in., and weigh less than 1 ounce.

These filters are low ripple Chebyschev design, employing a unique



method to produce resonators which yield state-of-the-art miniaturization.

The TIB series covers the frequency range from 150 MHz to 3.7 GHz. The band widths can range from 2 percent to 70 percent, and insertion loss can vary from 0.5 to 6 dB. Impedance is 50 ohms, with VWSR's less than 1.51.

Prototype quantities are priced from $250 to $400 depending on the specifications of the individual filter. Delivery is six to twelve weeks.

Contact Telonic/Berkeley, 2700 DuPont Drive, Irvine, Calif. 92715. Telephone 714-833-3300, or toll free outside California: 800/854-3813. Circle Reader Service No. 112.

Bus-Compatible Interfaces

The model 1488A-12 bus-compatible interface is designed for incorporating the Rockland series 5100 frequency synthesizers into automatic, computerized, or microprocessor-controlled systems employing the IEEE 488/1975 General Purpose Instrumentation Bus (GPIB).

The interface plugs into both the synthesizer and the host system via

standard cables and is fully compatible with both, meeting all constraints specified for the IEEE 488/1975, and providing everything needed for full control of all programmable parameters. It may be field-installed at any time, with new or existing host synthesizers.

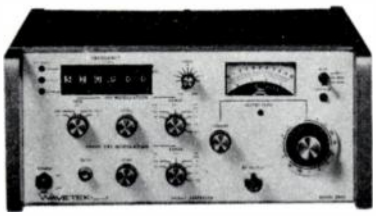
Significantly faster than most program sources, the Model 1488-12 accommodates up to one million 8-bit data transfers per second (1M Byte/sec) and provides full buffering of all data.

The model 1488-12 is compatible with any program source with the standard IEEE 488/1975 format and signal level.

For further information, consult Mr. David Kohn, Rockland Systems Corporation, 230 W. Nyack Road, W. Nyack, N.Y., 10994. Telephone (914) 623-6666. Circle Reader Service No. 77.

Signal Generator 1 to 520 MHz

Model 3003, 1 to 520 MHz signal generator, features 0.001 percent accuracy and 0.2 parts per million per hour stability as standard instrument specifications. The unit also offers a choice of two user-selectable, preset modulation frequencies between 100 Hz and 10 kHz in addition to the standard, internal modulation frequencies of 400 Hz and 1 kHz. FM deviation and percent AM modulation can be read from the front panel meter, and the unit has simultaneous



AM-AM, FM-FM, and AM-FM modulation capability.

GPIB control of frequency is possible when the model 3003 is used with the model 3911 GPIB converter. Optional level control via the GPIB is possible with the option 01A and model 3911. Other options include a high stability reference for improved stability and accuracy and a low level leakage option for testing extremely sensitive receivers.

Price of the model 3003 is $3,230. For further information please contact Mario Vian, Wavetek Indiana, Inc., 66 N. First Avenue, Beech Grove, Ind. 46107, (317) 783-3221. Circle Reader Service No. 78.

Phase Modulator

Electrac, Inc. announces the availability of a new VHF wideband phase modulator, model 4163A. The system employs a phase-lock loop system which automatically locks to an ex-

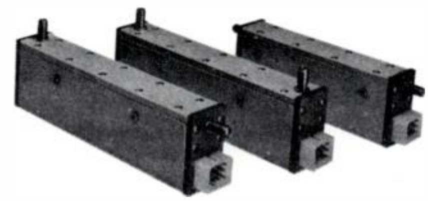
ternally supplied reference carrier frequency. It provides a clean output up to +12dBm at a frequency exactly twice its carrier frequency. The model 4163A performs phase modulation up to 1.5 radians with 2 percent linearity and with a modulation bandwidth of dc to 5 MHz.

The model 4163A is designed to meet NASA and military ground equipment specifications, and is ruggedly packaged in a 1.1 x 3 x 7 inch aluminum casting. Power requirements are ±15Vdc @50mA; +5Vac @65mA and 105-125Vac, 60Hz. For details, write or phone Electrac, Inc., 1614 Orangethorpe Way, Anaheim, Calif. 92801, (714) 879-6021. Circle Reader Service No. 80.

Programmable Attenuators

A line of digitally programmable, miniature attenuators has been introduced by Telonic Berkeley.

Frequency range of the 8360 series is dc to 4 GHz. Impedance is 50 ohms, the average power rating is 3 watts, and the peak power rating is 1 kW. The model 8360 has a 0 to 11 dB attenuation range with 1 dB steps. Three



other standard models offer 0 to 70 dB and 0 to 130 dB in 10 dB steps.

Contact Telonic/Berkeley, 2700 DuPont Drive, Irvine, Calif. 92715. Telephone 714/833-3300, or toll free outside California: 800/854-3813. Circle Reader Service No. 113.

Micro-Miniature Filters

Telonic/Berkeley also announces the new Micro-miniature bandpass filters used in aerospace, military and similar applications where size and weight are critical factors. The new filters are offered with two to eight sections, measure an average 3/8 in. x 3/8 in. x 1-1/2 in., and weigh less than 1 ounce.

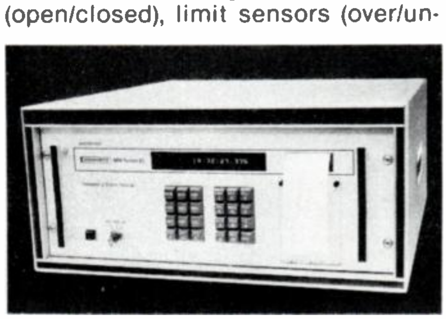
These filters are low ripple Chebyschev design, employing a unique method to produce resonators which yield state-of-the-art miniaturization. The new TIB series covers the frequency range from 150 MHz to 3.7 GHz. Depending on customer specifications, the band widths can range from 2 percent to 70 percent, and insertion loss can vary from 0.5 to 6 dB. Impedance is 50 ohms, with VWSR's less than 1.51.

Prototype quantities are priced from $250 to $400 depending on the specifications of the individual filter.

Contact Telonic/Berkeley, 2700 DuPont Drive, Irvine, Calif. 92715. Telephone 714/833-3300, or toll free outside California: 800/854-3813. Circle Reader Service No. 114.

Sequence-of-Events Recorders

A sequence-of-events recorder monitors the status of many different two-state inputs — e.g., relay contacts (open/closed), limit sensors (over/un-



der), or analog threshold detectors.

Comprehensive, continual, diagnostic self-testing, to ensure highest reliability...plug-in EMI/RFI filters for very noisy channels (eliminating the need for expensive and bulky "filter cabinets" used in older SER designs) ...field expandability (by simple cable-plug-in of additional input chassis) from 32 to 1024 channels, in steps of 8...redundant input opto-isolators ...EAROM alpha-description memories, for non-volatile yet reprogrammable, storage that is not power-line dependent, or vulnerable to common circuit failure...operation direct from 125V DC station battery, English-language keyboarding for program-entry and control functions...an RS-232 (modem) interface for remote communications...a small, light, low-cost 32-input master processor chassis.

For additional information call or write Mr. David Kreiss, Dranetz Engineering Laboratories, 2385 S. Clinton Ave., South Plainfield, N.J. 07080; (201) 755-7080. Circle Reader Service No. 81.

Millivoltmeter

Racal-Dana has made available their model 9301A, a sampling, true rms, RF millivoltmeter with high accuracy. It operates over a frequency range of 10kHz to 1.5GHz and is usable as an indicator to 2GHz. Employing a dual sampling process followed by RMS conversion to give a True RMS reading

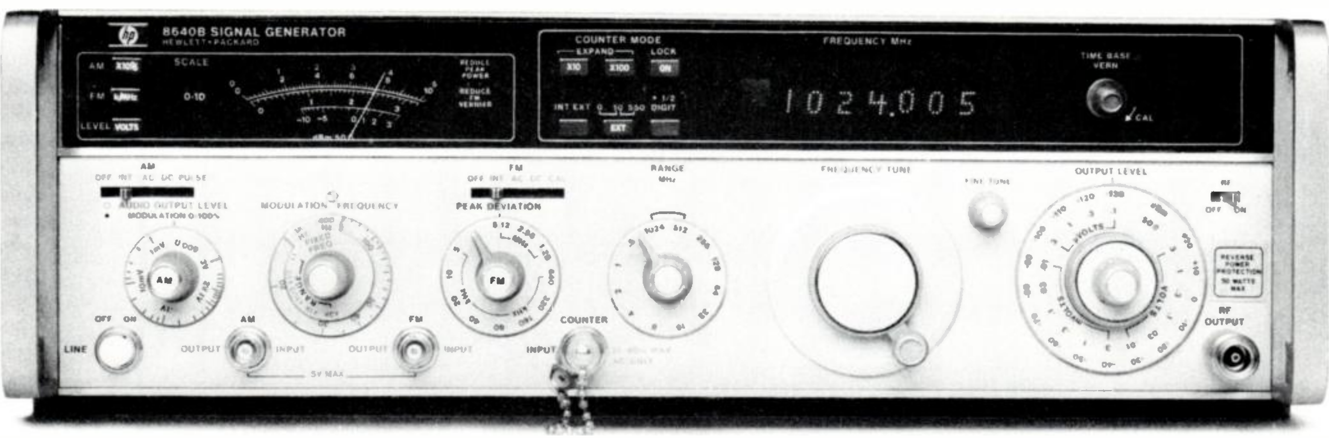
at all frequencies over the complete voltage measuring range from 100mV to 300V.

The true rms characteristics ensure accurate readings even with distorted sinusoidal signals, which makes it ideally suited for wide-band noise measurement.

The low residual noise of the 9301A ensures that low level measurements are practicable with this instrument. The sampling system employed in the Racal-Dana model 9301A provides a frequency response which is independent of voltage range and virtually unaffected by temperature changes from 0° to 55°C. Furthermore, the "sample and hold" facility permits the measurements to be held for a period of up to three minutes.

Contact Racal-Dana Instruments Inc., 18912 Von Karman Ave., Irvine, Calif. 92715. Circle Reader Service No. 115.

For high performance receiver testing, you need high performance signals.



HP 8640B w/Opt. 001, 002, 003 – 0.5 to 1024 MHz.

When HP introduced the 8640B, its product concept brought together the superior characteristics needed for high performance receiver testing:

- Spectral purity; <130 dB/Hz, 20 kHz offset
- Wide dynamic range; +19 to -145 dBm
- Phase lock stability/external count capability

Since then we've continued to add to the original capabilities:

- Opt. 001 – Variable modulation
- Opt. 002 – Extended frequency, 0.5 to 1024 MHz
- Opt. 003 – Reverse power protection to 50 watts
- Opt. 004 – Avionics version for NAV/COM tests
- 8640M – Ruggedized/military version

Now with the 8640B you get ½ digit phase-lock resolution (500 Hz, 100 to 1000 MHz), improved modulation and power settability. You can also use the new Model 11710A Down Converter to extend output frequency down to 5 kHz and test standard IF amplifiers at 262 kHz and 455 kHz. 8640B Signal Generator $6,750*, 11710A Down Converter $930.* *Domestic U.S. prices only.

So for your high performance receiver testing, you'll still choose the performance leader in RF signal generators. For more information, call your nearby HP field sales office, or write.

04608C

HEWLETT hp PACKARD

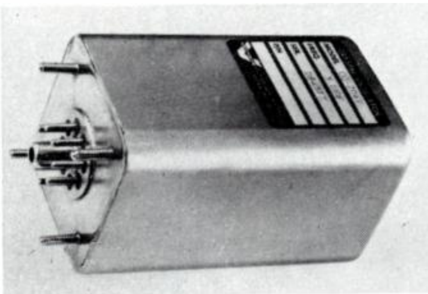
Sales and service from 172 offices in 65 countries.
1507 Page Mill Road Palo Alto California 94304

For assistance call: Washington (301) 948-6370, Chicago (312) 677-0400 Atlanta (404) 434-4000, Los Angeles (213) 877-1282

INFO/CARD 18

Ultra Stable Crystal

An ultra stable crystal oscillator provides long-term stability (aging rate) of $1X10^{-10}$ per day and $3X10^{-8}$ per year. Short-term stability is better than $1X10^{-11}$ per second stability



over 0 –50°C is better than ± $5X10^{-9}$ with a –55°C to +71°C temperature range optional. The noise characteristic of –140 dB/Hz, 1 kHz from the signal, makes the CO-206V especially suitable as a reference for synthesizers and in applications requiring multiplication to microwave frequencies. Standard output is 1 vrms into 50 ohms at 5 MHz, although other frequencies and logic output are available. Voltage frequency control (VCXO capability) is included to permit remote fine frequency adjustment or locking onto an external reference.

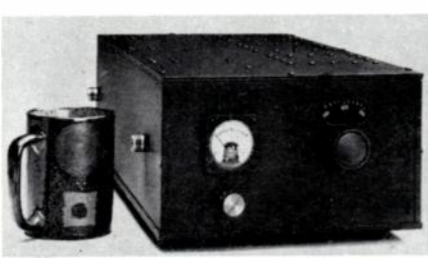
Vectron Laboratories, Inc., 166 Glover Avenue, Norwalk, Conn. 06850. Circle Reader Service No. 75.

Tunable Band-Pass Filter 225 to 400 MHz

Telonic/Berkeley is introducing an extremely narrow-band, tunable bandpass filter which covers the UHF military communications band from 225 MHz to 400 MHz.

The new filter is ideally suited for application where multiple transmitters are in use, to eliminate cochannel interference.

The Telonic/Berkeley Model TTF312-0.2-3EE is an iris-coupled, 0.01 dB Chebyschev design, with a band width



nominally 0.2 percent of the tuned center frequency. The design's optimum "Q" provides a maximum insertion loss of 3 dB. This filter utilizes a vernier dial, calibrated in frequency for direct readout. The front panel display includes a meter for a relative power monitor which samples output of the filter and shows the operator when the filter is optimally tuned. For complete specifications and prices contact the Marketing Department, Telonic/Berkeley, 2700 DuPont Drive, Irvine, Calif. 92715. Telephone: 714/833-3300 or toll free 800/854-3812 outside of California. Circle Reader Service No. 76.

Universal Counter 100 psec Resolution

Priced competitively with frequency and period only counters, this new model 5314A universal counter from Hewlett-Packard has features not generally found on counters costing twice as much. It measures frequency to 100 MHz, period to 400 nanoseconds with 100 picosecond resolution, and time interval. Pulse width, time between events, and logic timing can be measured easily to a resolution of 100 nanoseconds. Measurements of ratio, ratio averaging and totalize (from 10 Hz to 10 MHz) are also included in its capabilities.

With a seven-digit easy-to-read amber display, trigger levels for both channels, slope controls for both channels, the 5314A is ideal for applications including production line testing, and service and calibration of both analog and digital instruments. It also has many applications in telecommunications, frequency monitoring, education and training, and research and development.

U.S. price of the Hewlett-Packard model 5314A is $375. Contact Inquiries Manager, Hewlett-Packard Company, 1507 Page Mill Road, Palo Alto, California 94304. Circle Reader Service No. 116.

Frequency Counter-On-a-Chip

The 9910 series is based upon an LSI chip which is virtually a "counter-on-a-chip". The series feature RFI shielding for protection in "noisy" environments.

The model 9913 is a 10Hz to 200MHz frequency counter with a sensitivity of 10mV, and designed primarily as a bench instrument. To meet the requirements of field applications, Racal-Dana has two instruments to offer, models 9915, 10Hz to 20MHz frequency counter and model 9919, 10Hz to 1.1GHz frequency counter. Both models offer a sensitivity of 10mV and battery operation of up to 15 hours when used in the economizer mode. The 9917 is a direct-gated, 560MHz unit, and includes an LF multiplier enabling direct frequency measure-

ments down to 10Hz with a .01Hz resolution.

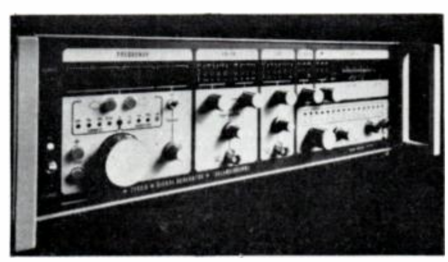
The 9910 series comes with a standard reference oscillator which offers a stability of one part in 10^6/month, or if you require greater stability, the 04A high stability oscillator will give three parts in 10^9/day, and 04B, five parts in 10^{10}/day. U.S. list prices: 9913 — $395, 9915 — $650, 9917 — $895, 9919 — $1095, 9921 — $1995.

Contact Racal-Dana Instruments Inc. 18912 Von Karman Ave., Irvine, Calif. 92715. Circle Reader Service No. 117.

Signal Generator

Comstron/Adret has introduced a programmable, low-cost unit with noise performance 10 dB better than most cavity generators.

Their new model 7100 covers 300 kHz to 650 MHz (300 kHz to 1.3 GHz with optional doubler) with 1 Hz resolution. A microprocessor provides band switching, continuously tunable frequency, and full programmability of frequency, modulation and level. The 7100 is fully programmable via an IEEE 488 bus — the microproces-



sor handles scaling and protocol. Frequency switching speed is 100 mS.

Spectral purity includes a total noise spec of better than –136dB/Hz at 20 kHz from the carrier as well as an ultimate noise floor of better than –150dBc.

The 7100 provides for AM, FM, PM, VOR, FSK/PSK and pulse modulation.

Phase modulation can be set from 0 radians to 5 radians and has an external modulation signal bandwidth of 100kHz. A VOR modulation input provides the low distortion modulation necessary for avionics applications.

The frequency stability of the 7100's internal time base is 5 x 10^{-9} per hour.

For more information, please contact Ron Juels, Comstron/Adret, 200 East Sunrise Highway, Freeport, New York 11520 (516) 546-9700. Circle Reader Service No. 84.

Modulation Meter

Racal-Dana is offering two new modulation meters that offer frequency coverage to 2GHz. They feature automatic tuning and amplitude leveling. Identified as the Racal-Dana models 9008 and 9009, both are new to the U.S. market. Both instruments provide fully automatic measurement of AM and FM signals in approximately one second. Automatic tuning and amplitude leveling guarantees measurement accuracy. Models 9008 and 9009 both permit measurements on equipment operating at frequencies in the MF, VHF and UHF bands.

The Model 9008 is remotely programmable and offers full frequency

coverage from 1.5MHz to 2GHz, while the model 9009 provides frequency coverage from 10MHz to 1.5GHz.

Each of the new modulation meters furnishes eight FM ranges with 100kHz peak deviation and six AM ranges to 100 percent modulation depth. Both units are portable and operate from either AC or an optional rechargeable battery power pack. Single unit price for the model 9008 is $1495, and single unit price for the model 9009 is $1295. (U.S. list.) For more information contact Mr. Norbert Laengrich, Racal-Dana Instruments Inc., 18912 Von Karman Avenue, Irvine, Calif. 92715. 714/833-1234. Circle Reader Service No. 82.

Oven Oscillator

A specially designed 05 high stability oscillator for the PM6620 series of Philips timer/counters has been introduced by Philips Test and Measuring Instruments which increases stability to less than 5 x 10^{-10} per 24 hours and 5 x 10^{-9} for the temperature range of 0 degrees C to 50 degrees C.

This new oscillator, the PM9691, ensures maximum accuracy in Philips counter/timers, and lowers the time interval average down to 1 ns, and makes possible high time resolution on fast phenomena such as propagation delays, pulse durations and transition times."

The Philips PM6620 series now offers a choice of 5 timebase oscillator options, frequency ranges at 80, 520 and 1000 MHz, trigger hold-off, to avoid false triggering on spurious signals and independent trigger selection for channels A and B of AC/DC coupling.

Contact Irving L. Straus Associates, Inc., Corporate Communications, 655 Third Ave., New York, N.Y. 10017, (212) 661-3030. Circle Reader Service No. 118.

Frequency Counter

Continental's Mini-Max will give you precise, continuous guaranteed readings from a low range of 100 Hz to a high range of 50 MHz. Mini-Max utilizes a crystal-controlled time base that has a 3ppm accuracy assuring the user of a quality, high performing direct reading instrument that updates

itself every 1/6 second. The time base circuitry has a built-in voltage regulating system that will compensate for battery voltage changes.

Mini-Max has a built-in-high sensitivity preamplifier that allows readouts from signals as low as 30 mV with input diode protection up to 100V peaks. Mini-Max is easy to operate by simply connecting it to a power source (battery or battery eliminator) using the standard clip lead cable or mini-antenna (both supplied) you're ready to checkout AM, CB, business radio, RF generators, video sync circuits, and any other application within the 100 Hz to 50 MHz range.

Mini-Max's lightweight (8 oz.) and

Mini-size make it a completely portable unit ready to go Mini-Max is priced at only $89.95.

Contact: Continental Specialties Corporation, 70 Fulton Ter., P.O. Box 1942, New Haven, Conn. 06509. 203-624-3103. Circle Reader Service No. 119.

Frequency Counter

Philips has also introduced a communications-type universal counter with a multi-stage pin diode attenuated AGC high frequency input channel which optimizes triggering on RF signals up to 1.3 GHz, and on LF signals up to 80 MHz.

Conservatively rated at 10 mV sensitivity the frequency counter offers a maximum degree of overload protection and noise immunity.

In addition to frequency measurements, the PM 6616 performs period, period-average, multiple ratio and count

measurements. The period-average mode offers superior resolution for the user. The maximum RF input voltage on input B of the new Philips frequency counter is 12Vrms, with the vertical standing wave ratio always less than 2. Sensitivity is 10 mVrms at (150 MHz — 1000 MHz) 6 dB down at 80 MHz and 1300 MHz. Input A sensitivity is 10mVrms (20 Hz - 80 MHz) 6dB down at 10 Hz.

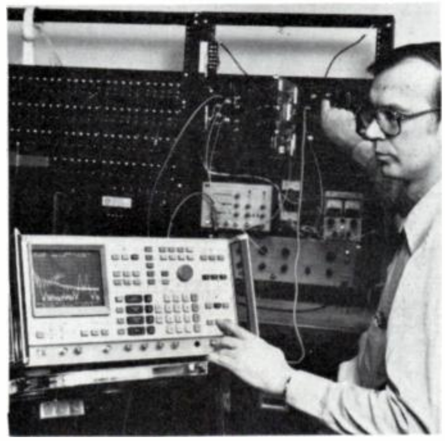
The PM 6616 unit equipped with 01 (PM 9677) time base oscillator is priced at $1,395 in the United States. Philips Test & Measuring Instruments, 85 McKee Drive, Mahwah, New Jersey. 07430. (201) 529-3800. Circle Reader Service No. 86.

Spectrum Analyzer

A resolution of 3 Hz at 40 MHz with up to 0.5 dB absolute amplitude accuracy is one of the major contributions of this new Hewlett-Packard model 3585A spectrum analyzer.

Frequency range of the 3585A is from 20 Hz to 40.1 MHz over a measurement range from −137 dBm to +30 dBm. The internal microprocessor controls, calculates, manipulates data and simplifies operation.

Center frequency and span settings have 0.1 Hz resolution and 1 x 10^{-7} per month stability over its entire operating range. This frequency precision and stability makes it possible to use



the narrowest resolution bandwidth, 3 Hz, for close-in analysis even at 40 MHz.

Not only are all 3585A functions remotely-programmable via HP-IB, the instrument also can be commanded to feed its measurements out via the bus, for interpretation and further interaction by a computing controller. Among the applications for the 3585A are automatic production-line testing of linear and non-linear electronic devices.

The HP 3585A spectrum analyzer is priced in the U.S. at $17,500. Contact Inquiries Manager, Hewlett-Packard Company, 1507 Page Mill Road, Palo Alto, California 94304. Circle Reader Service No. 122.

Signal Generator

Racal-Dana Instruments has introduced its model 9081, a 5 to 520MHz AM/FM phase modulated RF synthesized signal generator. Designed to test HF/VHF/UHF communication receivers, the 9081 is tuned with a single spinwheel. The output frequency has an accuracy and stability locked to an internal frequency standard of three parts in 10^9 per day.

The channelized mode has 10 ranges that allow channel spacing to be set from 5 to 60kHz.

The 9081 has full modulation facilities and offers high accuracy of AM, FM and phase modulation, directly calibrated for both internal and external modulation on the front panel meter. List price is $4495.

Contact Racal-Dana Instruments Inc., 18912 Von Karman Ave., Irvine, Calif. 92715. Circle Reader Service No. 120.

Frequency Counter

Continental Specialties has developed the Max-100 which gives you continuous readings from 20Hz to a guaranteed 100MHz, with full 8-digit accuracy. Precise readings, derived from a crystal-controlled timebase with 3ppm accuracy, are updated every second. The result is an easy-to-use, direct-reading instrument that is ideal for a wide variety of uses in audio, digital and RF applications. Max has a built-in high-sensitivity preamplifier, permitting readings with as little as 30mV. Yet the input is diode-protected up to 200V peaks.

Max can be used with standard clip-lead cable (supplied), Mini-Whip antenna, or low-loss, in-line tap with UHF connectors. For AM or FM; CB, ham, business radio and R/C trans-

mitter or receiver alignment. Monitoring audio and RF generators. Checking computer clocks and other digital circuits. Repairing ultrasonic equipment. As well as depth sounders, fish spotters, ultrasonic remote controls

Contact Continental Specialties Corp., 70 Fulton Ter., P.O. Box 1942, New Haven, Conn. 06509, (203) 624-3103, TWX 710-465-1227. Circle Reader Service No. 121.

8-Digit Counter

The model 5800 is designed to be used as both a bench and a portable instrument ideally suited for communications applications in the areas of avionics, marine, telecommunications, mobile, etc.

The frequency counter, has a basic sensitivity of 10mV. Two input channels are available, a 1M ohm input impedance channel from 10Hz to

250MHz, and a 50 ohm input channel from 5MHz to 520MHz. The counter is a portable measuring system, operating 4 hours between charges. Three front panel selectable gate times provide a maximum resolution of 0.1Hz. Fastest gate time is 0.1 sec. (10Hz resolution) on the low frequency high input impedance channel and 0.2 sec.

(10Hz resolution) on the prescaled high frequency 50 ohm input channel. Signal levels as high as 250V may be applied to the 1M ohm input. The low impedance input will take signals as high as 5V.

Price for unit is $429.00. Contact Robert M. Scheinfein, Vice President of Sales, Data Precision Corporation, Audubon Road, Wakefield, Mass. 01880. (617) 246-1600. Circle Reader Service No. 88.

Galium Arsenide FET Transistor

A galium arsenide FET transmitter delivering five watts minimum power output is available from Raytheon Company.

The BCM-5005 incorporates in a single package a QCM-5002 RF power amplifier; crystal-controlled, phase-locked source; TTL-compatible transmitter enable switch and DPSK phase shifter; and crystal, oscillator and RF power monitor outputs.

Bandwidth of the unit is a 300 kHz channel, with frequency selection by plug-in crystals. Frequency stability is ± 10 kHz, while noise is − 44 dBm/MHz. The basic QCM-5002 amplifier will operate over bandwidths in excess of 10 percent.

Weighing 10 lbs. and measuring 13.12" x 6.0", the BCM-5005 is suitable for use in ground-transportable equipment. Delivery of the unit can be made three to four months after receipt of order.

For additional details, contact Raytheon Company, Special Microwave Devices Operation, 130 Second Avenue, Waltham, Mass. 02154. Russell B. Mason 617-899-8400 X4749. Circle Reader Service No. 127.

Programmable Generators

Interstate Electronics Corporation has extended their Series 800 into a family of ultra-high-speed programmable pulse and function generators which operate on the IEEE 488, with each GPIB handshake averaging 1.25 microseconds.

Selling at $2,295, the lowest-price member of the new family is the 14-MHz model 820. This function generator offers sine, squarewave, ramp, triangle, and dc functions, trigger/gate,

offset, 30V p-p, the IEEE 488 bus, and ASCII, all as standard capabilities.

The model 845, a 14-MHz pulse/function generator priced at $2,995, provides true pulse and crystal referenced clock frequencies together with programmability of pulse delay, width, offset, amplitude, and mode.

The 20-MHz model 860, At $3,995, retains ultra high speed while using an auxiliary microprocessor to provide store, recall, and "learn" modes which are retained even in a power-off condition.

Contact: Dave Lawson, Le Ance & Company, Inc., 4120 Birch Street, #101, Newport Beach, Calif. 92660. (714) 752-1911. Circle Reader Service No. 125.

Marine Radiotelephone

The first fully synthesized VHF-FM marine radiotelephone to automatically search all 104 US and ITU marine VHF channels, pausing momentarily on every active channel to give the operator time to note the traffic, is now being marketed by Intech.

Called the Mariner 90 by Intech, the new VHF-FM radiotelephone also has the capacity to scan up to 16 preselected channels. Or if desired, the Mariner 90 can also be directed to priority-watch one designated channel. In the last instance the operator can work one channel and the radio will automatically cut-in the designated priority-watch channel whenever traffic occurs on that channel. This ability to locate active working channels is especially valuable to vessels entering new harbors or cruising in unfamiliar waters.

Contact Intech Incorporated, 282 Brokaw Road, Santa Clara, Calif. 95050. Phone is 408-244-0500. TWX 910-338-0254. Circle Reader Service No. 128.

Nylon LED Mounts

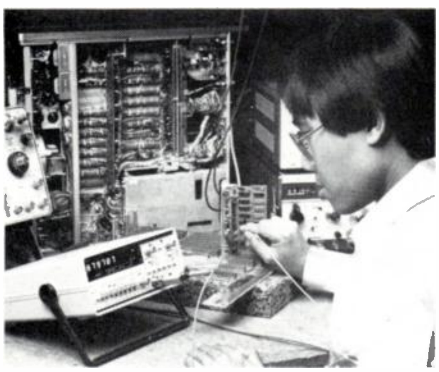
With the wide variety of so many different LED applications, accurately controlled mounting in production is often a major problem. Bivar has introduced a line of tubular spacers to elevate LED's to heights of from .080" through .380", in .005" increments. A total of 61 standards are available from stock.

Made from nylon per MIL-M-20693A, composition A, type 1, and U.L. rated 94V-2 material, these new mounts space LED's, maintaining bases consistently parallel to mounting surfaces to prevent paralax. The rigidity of the mounts keeps LED's from being bent or tilted during handling or final assembly. Product uniformity, production ease and substantial savings by the elimination of scrap and rejections can be accomplished by the use of these inexpensive production aids. Available immediately from stock, the 905 series mounts are priced typically at $12.00/K in 10 K lots.

Contact Bivar Inc., Edward Muldoon, President, 1617 E. Edinger Ave., Santa Ana, Calif. 92705. Circle Reader Service No. 129.

100 MHz Universal Counter

H-P has announced a 'counter on a chip' and an off-the-shelf microprocessor, this universal counter-timer sells for only $800 (U.S.). The counter measures frequency to 100 MHz, and time intervals to 100 nanosecond resolution. In addition, it has



a full range of period, frequency ratio, time interval averaging and totalizing capability. It uses the reciprocal taking technique for high resolution and accuracy at low frequencies.

With trigger levels for both channels, slope controls for both channels and a variable sensitivity control, the 5315A is ideal production line testing, service and calibration of both analog and digital instruments.

Time interval hold-off delay permits ignoring unwanted multiple spurious start and stop commands.

U.S. price of the Hewlett-Packard model 5315A Universal Counter is $800. Contact Inquiries Manager, Hewlett-Packard Company, 1507 Page Mill Road, Palo Alto, Calif. 94304. Circle Reader Service No. 83.

Linear Amplifier

The model 603L is extremely wideband solid state class A linear amplifier capable of delivering more than 3 watts of power over the frequency range of 0.8 to 1000MHz.

The gain of 40 dB ± 1.5 dB makes this unit completely compatible for boosting the output signal of any signal or sweep generator. The high peak

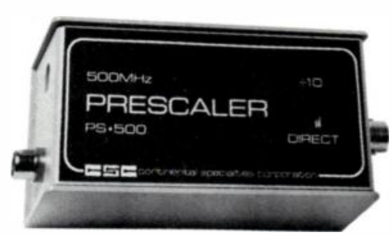
power capability of over 5 watts output can drive into any load impedance including an open or short circuit without damage or oscillation. Harmonic distortion is at least 20 dB down below the fundamental at rated power output. The input and output impedance is 50 ohms.

The linear output is a faithful reproduction of the input waveform for AM, FM, SSB, CATV, VHF/UHF-TV pulse and other complex modulations.

The applications include; VHF/UHF-TV signal distribution, RFI/EMI susceptibility testing, a booster for wideband sweepers, NMR/ENDOR, laser modulator driver, and transistor and antenna testing. Electronic Navigation Industries Inc. 3000 Winton Road South, Rochester, N.Y. 14623. Circle Reader Service No. 89.

Prescaler

CSC's new PS-500 prescaler is a UHF decade divider that can extend the range of any 50 MHz frequency counter into the UHF band. Featuring the latest ECL III integrated circuit, the PS-500 provides all the little circuit extras that are needed to assure clear, crisp, spurious free signals to your frequency counter. A unique switch selection enables you to use your frequency counter in its own range or by simply switching to the



÷ 10 mode extends your counter to over the 500 MHz range. The PS-500 can be powered by any source, 12V automobile cigarette lighter, 110 or 220VAC charger/eliminators or any 7.2-10V DC power supply. The PS-500 extended range will let you check, Marine Radio, Sonar, Business Radio, UHF/TV, Marine Radar, Aviation, AM Mobile Radio, Navigation Equipment and much more.

Contact Continental Specialties Corporation, 70 Fulton Ter., P.O. Box 1942, New Haven, Conn. 06509, 203-624-3103, TWX 710-465-1227. Circle Reader Service No. 87.

literature

Analog Dialogue

Current issue contains application notes and new product descriptions on a wide range of precision components for data acquisition. Featured is a 12-bit integrated circuit data acquisition system, a multiple-output voltage reference, IC converter circuit design tips, and a noise measurement test set. New product descriptions include a low-cost temperature meter, Motorola 6800 microcomputer-compatible analog I/O boards, improved DAC80's and a new monolithic divider.

Analog Dialogue is published quarterly by Analog Devices. Route 1 Industrial Park, P.O. Box 280 Norwood, Mass. 02062. Circle Reader Service No. 96.

Catalog Data Conversion

A recently published, 144-page catalog by Datel Systems describes in detail a broad line of high performance data conversion modules and accessory circuits. The product areas include many new state-of-the-art devices from A/D's, D/A's, analog multiplexers, sample-holds, fast op amps, instrumentation amplifiers, V/F converters to data acquisition systems. The catalog also has a section devoted to the principles of data acquisition and conversion. Available models are first listed in selection tables at the beginning of each section for convenient comparison of specifications and prices. Datel, 1020 Turnpike St., Canton, Mass. 02021 (617) 828-8000. Circle Reader Service No. 97.

RF Filter Capability Brochure

In a new RF Filter catalog, Bird Electronic Corporation displays nearly 200 coaxial filters, filter/couplers and filter/coupler/switches. The filter tables in this 20-page catalog list salient performance data and mechanical specifications of low pass, high pass and band pass models with cut-off frequencies from 1 MHz to 2.7 GHz.

Filter-couplers listed combine harmonic rejection with RF power level sampling in one compact package. Some include a solid-state switch which controls transmit/receive signal paths. Extensive application notes guide the reader to cost and time savings in quickly identifying essential specifications.

A new eight-page brochure titled

RF Power Sensor Brochure which lists more than a hundred typical RF Power Sensor models is also available from Bird Electronic Corporation. Developed for OEM requirements these Thruline bi-directional couplers provide rectified samples of the RF signal proportional to forward and reflected power levels. Bird RF power sensors protect and monitor transmitters and also provide signal samples for video/scope displays, percent modulation measuremens, frequency checks, and other signal analysis functions. Sensors can be designed to provide either a sample of raw RF or a detected signal, or both.

In the new Power Sensor brochure PS-8, RF and dc output signal characteristics, connector variations, physical form and frequency ranges listed afford an overview of parametes adaptable to individual OEM design requirements. An inquiry form facilitates feasibility, price and delivery estimates. From Bird Electronic Corporation, 30303 Aurora Road, Cleveland (Solon), Ohio 44139. Circle Reader Service No. 98.

Become A Consulting Engineer

Six reports (230 pages) on how to start a successful consulting business have been written by Dr. Steven Tomczak, president of S. Tomczak & Assoc. The report titles are: How To Get Prospects; How to Turn Prospects into Clients; Making the Decision Sole Proprietorship, Partnership, Corporation; Negotiations and Fee Determination; Tax Savings for Consultants; Twenty Start-Up Projects to Do in Your Spare Time. $29.95 for six reports. Credit card orders toll free; National 1-800-854-0561, California 1-800-432-7252. S.Tomczak and Assoc. 119 Via Zurich, Newport Beach, California 92663. Circle Reader Service No. 99.

Automating Swept RF Measurements

New mil-spec requirements for cables include swept measurements of VSWR, insertion loss, and return loss. In the future, these requirements may well extend to commercial supplier as well. Performing swept tests and interpreting the results manually is common procedure in the test lab, but the time element makes manual procedures impractical for production testing.

An automated test setup employing a Tektronix Digital Processing Oscilloscope, graphics terminal and hardcopy unit is described in this note. Practical considerations in making RF swept measurements are considered in detail, allowing the reader to evaluate different approaches to automating these measurements.

Readers may obtain a free copy of application note 45K2.5 from: Tektronix, Inc., P.O. Box 500, Beaverton, OR 97077, or by calling the nearest Tektronix field office. Circle Reader Service No. 100.

Ceramic Capacitor Catalog

A catalog describing KD Components' line of ceramic capacitors is now available from the company's California office. The catalog contains complete specifications on high voltage, multilayer ceramic capacitors and low corona high voltage capacitors, as well as other ceramic capacitors designed to withstand temperatures of 200°C and above.

Typical applications for the high voltage multilayer ceramic capacitors, which are designed for circuits requiring long life and reliability, including multiplier circuits, high voltage power supplies and RF packages. The low corona capacitors are built for applications that call for a quality capacitor free of corona. For more information contact: Mike Day, KD Components, Inc., 3016 S. Orange Ave., Santa Ana, Calif. 92707 (714) 545-7108. Circle Reader Service No. 90.

Inductor Motor Catalog

Printed in full color, a new 20-page catalog of FHP and integral HP induction motors from 1/12 HP to 15 HP has just been announced by Howard Industries. Howard's full line of 48-56 Frame FHP and 180-210 Frame Integral HP induction motors are presented with cutaways, performance/rating charts, torque curves and dimension drawings. Catalog contains all the data necessary to select the exact motor for your needs, including induction motor parts sets.

Write today for your copy: Howard Industries, 700 Grand Avenue, Brinkley, Arkansas 72021. Phone: (501) 734-3300. Circle Reader Service No. 91.

Connectors Catalog

Featured in this four-page brochure are twenty-six series of connectors used in military, aeronautical, computer, telecommunications, industrial, systems and instrumentation applications. Souriau, Inc. manufactures "D" subminiature, printed circuit, circular, microminiature, rack and panel, rectangular, underwater, hermetic, aerospace and modular type connectors. Souriau connectors are QPL'd and

EMI Filters.

Simplify selection and speed up delivery.

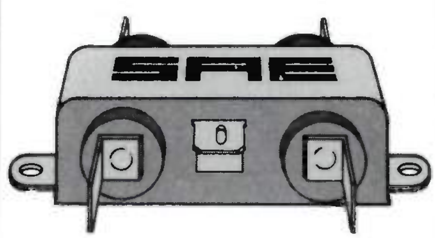
Competitive prices and faster than competitive delivery.
More than 18 distributors nationally stock SAE's line of electromagnetic interference filters for off-the-shelf delivery at low prices. SAE's standard line covers many application requirements with eight varieties of filters, including custom designs for special applications. All feature 100% high-voltage testing of dielectric and meet UL or CSA requirements.

Application support when you need it.
SAE applications experts are as close as your phone to help you select a standard filter to meet your mechanical and electrical requirements. And they'll be glad to help you with special requirements to bring you up to date on newly designed SAE filters, too.

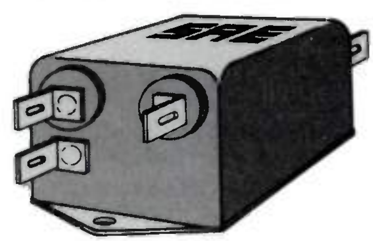
Get the SAE catalog for your file.
For a copy of our catalog with application information, electrical specifications, and mechanical details of standard products, write SAE, Stanford Applied Engineering, 340 Martin Avenue, Santa Clara, CA 95050, (408) 243-9200.

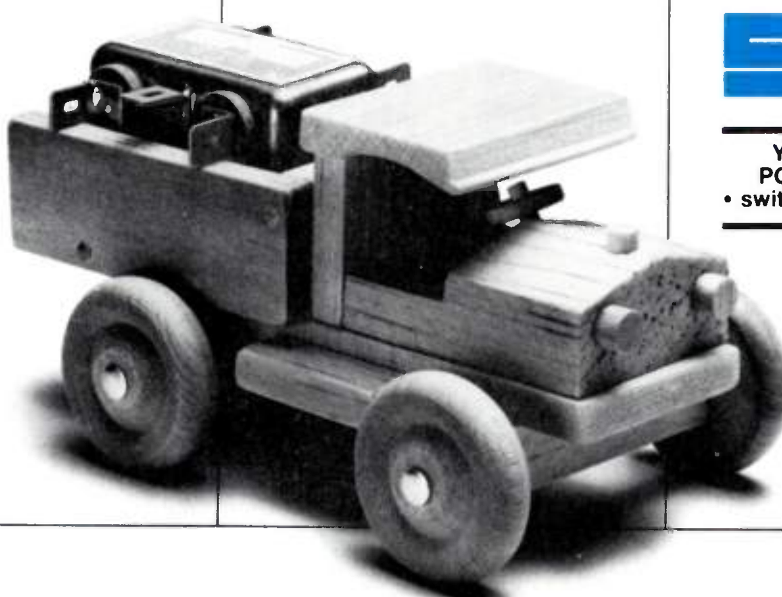
Connector filters. Available in I.E.C. or 3-prong, twist-lock connector versions for suppressing line-to-line or line-to-ground interference.

General application filters. The economical solution to most line-to-line and line-to-ground interference problems.



High performance filters. For high attenuation with low impedance loads, such as motors and switching power supplies, in severe EMI environments.





SAE

Your quality source for PC connectors • sockets • switches • flat cable systems.

INFO/CARD 20

MIL spec approved to MIL-C-24308.

Souriau's short form catalog is available free upon request to: Souriau, Inc., 7740 Lemona Avenue, Van Nuys, California, 91405, (213) 787-5341. Circle Reader Service No. 92.

Oscilloscopes

A comprehensive new book on oscilloscopes, which bridges the gap between the oscilloscope operators manual and application of the instrument to practical measuring problems, has been written by Rein van Erk of the Philips Scientific and Industrial Equipment Divsion, and will be released by McGraw-Hill. Entitled *Oscilloscopes: Functional Operation and Measuring Examples*, the new book is written from a user's perspective, and offers coverage of oscilloscope applications, including valuable information on operations, probes, special purpose versions and measuring pitfalls.

The book's table of contents lists: 1) Basic operation of the oscilloscope; 2) Additional features and their functions; 3) Special oscilloscopes and variants; 4) Oscilloscope probes; 5) Measuring pitfall; 6) Measuring examples; 7) Specifying an oscilloscope. Appendixes: A) Glossary of Terms in Oscilloscopy; B) Tables of Notations, Symbols, and Units. Philips Test & Measuring Instruments, Inc., 85 McKee Drive, Mahwah, New Jersey 07430. Circle Reader Service No. 95.

LED Catalog

Industrial Electronic Engineers, Inc., (IEE), presents a catalog on IEE-Hercules LED Digital Displays. Featured in the catalog are Digital, Alphanumeric and Integrated Logic LED displays, ranging in size from .27" up to 1.02" high. There is also a section on Display Mounting Hardware (Bezels and Sockets) and Clock Displays and Modules. Detailed dimensional drawings and technical data accompany the more than 133 different model LEDs and accessories available.

The fully-detailed IEE-Hercules Catalog No. HE-1 is available free upon request to: IEE, 7740 Lemona Ave., Van Nuys, California 91405 (213) 787-0311, ext. 268. Circle Reader Service No. 93.

Relay Specification Catalog

A new Solid State Relay Selection guide from Grayhill, Inc., La Grange, Illinois contains engineering information which the company states is necessary reading for the first time specifier and the previous user of solid state relays. The engineering information section describes critical specification criteria, including temperature, current, load and environmental effects on the operation of a solid state relay. Design requirements of clamping networks, snubber networks, and zero voltage turn-on circuits in solid state relays are discussed. Criteria for choosing optically isolated, transformer isolated, or hybrid relays are clearly shown.

The relays described in this catalog include the Grayhill miniature 2.4 amp and 4 amp printed circuit mount and plug-in verions, and 6, 10, and 15 amp relays in standard packages. These relays are completely specified, including the critical parameters of the output and the input circuit. All variable parameters are graphically illustrated.

In addition to complete specification information, part numbers and prices are included. Request Catalog No. 7 from Andy Wendt, Grayhill, Inc., 561 Hillgrove, La Grange, Illinois 60525, or call (312) 354-1040. Circle Reader Service No. 106.

Clean Circuit Designers Kit

The Clean Circuit System Designers Kit addresses itself to EMI control techniques for switching power supplies. The information presented offers a comprehensive analysis of EMI problems and how to solve them utilizing either capacitors or filters. It also provides a full understanding of EMI standards and safety requirements, explains where the problems are and offers economical solutions.

The kit is divided into five sections. (1) Clean circuits seminar (2) Applications Notes. (3) Library of articles. (4) Product to Literature. (5) Applications Assistance.

The CDE Clean Circuit Systems Designers Kit No. 3 is available for $35 by writing to Mr. W. Carlson, Director/Marketing Communications, Cornell-Dubilier Electronics, 150 Avenue L. Newark, New Jersey 07101, or call (201) 589-7500. Circle Reader Service No. 94.

Catalog Test Instruments

An enlarged group of high performance, high quality test and measuring instruments is featured in a new short form color catalog released by Leader Instruments Corp. of Plainview, N.Y.

The 12-page booklet describes eight oscilloscope models with bandwidths from 4 to 30 MHz; eight professional audio system instruments including two audio system analyzers; four multimeters including digital and analog versions; 80 and 250 MHz Frequency counters; three color bar generators including an NTSC Model; an FM Multiplex generator, LCR Bridge and other general purpose instruments and accessories. Contact: Mr. Patrick Redko, National Sales Manager, Leader Instruments Corp., 151 Dupont Street, Plainview, N.Y. 11803. (516) 822-9300. Circle Reader Service No. 101.

RF Products Catalog

A new, comprehensive catalog (No. 100) covering their complete line of MIC microwave & IF/RF products is available from RHG Electronics Laboratory, Inc., Deer Park, N.Y.

The 104-page catalog contains three sections of detailed technical data on IF amplifiers, MIC mixers, mixer preamps, microwave relay links, and is the largest and most comprehensive in RHG's 17-year history.

Technical information is also included on the relationship of log amps to other components, linearity measurement, phase and gain matching, and mixer specifications.

Copies of Catalog 100 are available from Marketing Dept., RHG ELectronics Laboratory, Inc., 161 East Industry Court, Deer Park, L.I., N.Y. Tel: 516-242-1100. Circle Reader Service No. 103.

Magnetic Shielding Techniques

Ad-Vance Magnetics' expanded two-color 48-page magnetic shielding catalog/manual is divided into a 20-page product facilities section, and a 28-page engineering section.

The comprehensive compilatior of reference data on magnetic shielding techniques includes: Two Engineering Reports on Shielding Effectiveness; Eighteen Typical Solutions to Shielding Problems; Standard Inspection Procedure For Foil; Two Technical Article Reprints; Calculation Assists in Shield Design; Why You May Need More Than Figures to Design Magnetic Shields; Three Graphs (Shielding Efficiency, DC hysteresis loops, etc.); Various Basic Tables; In-House Helmholtz Testing of Finished Shields.

Expanded catalog No. 76A is available without cost from Mr. Richard D. Vance, president, Ad-Vance Magnetics, Inc., 226 E. Seventh Street, Rochester, Ind. 46975. Circle Service No. 105.

Catalog Attenuator Line

A 16-page catalog from Telonic/Berkeley showcases the firm's extensive line of attenuators. The line contains complete series of rotary step, fixed value coaxial, programmable and custom units.

The new catalog itemizes the attenuators in six different series: subminiature and miniature rotary step; tandem mounted rotary step; bench type rotary step; fixed value coaxial; programmable; and special and custom designed attenuators.

A highlight of the catalog is the presentation of the first four models of Telonic's new line of coaxial step, digitally programmable attenuators. These units utilize the firm's thick film (distributed field) chip concept with the "edge line" conductor theory to provide a highly accurate, low cost attenuator for the OEM automatic instrument and systems market.

Contact the Marketing Department, Telonic/Berkeley, 2700 DuPont Dr., Irvine, Calif. 92715. Telephone: 714/833-3300 or toll free: 800/854-3813 outside of California. Circle Reader Service No. 102.

RFI Shielded Cases

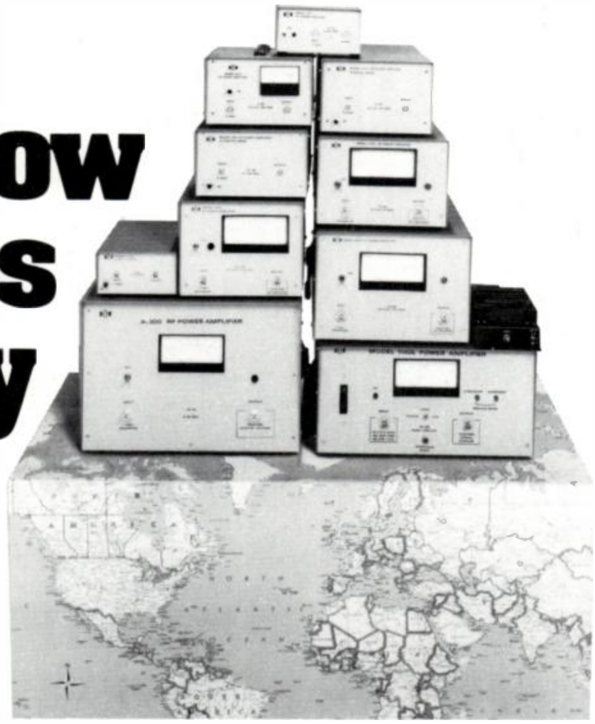
A new eight-page catalog describing their line of low cost RFI shielded cases and accessories is available from Compac, Deer Park, N.Y., case designers and manufacturers.

The well-illustrated catalog contains photos and drawings describing a variety of blank cases, standard size cases and a custom series. It also describes the Compac RFT series which offers greater shielding effectiveness through closer spacing of 0-80 screws tapped directly into the sidewalls.

Compac cases are effective from 60 to 100dB at 100MHz. Various configurations are noted in the numerous outline drawings. The easy-to-read, illustrated catalog is available from Marketing Dept., Compac, 279-I Skidmore Road, Deer Park, New York. 11729 — Tel: 516-667-3933. Circle Reader Service No. 104.

Advertiser Index

Tomorrow ideas Today



400 WATT/1040L
- 10 kHz to 500 kHz
- Up to 700 Watts Output
- Useful Power up to 1 MHz
- Built-in True Average Power Meter

Primarily designed as a transducer drive source, and for use in high power ultrasonic laboratory applications. Any load impedance may be connected to the output without fear of damage or oscillation.

1.4 KILOWATT/1140L
- 9 kHz to 250 kHz
- All Solid State
- Weighs less than 45 lbs.
- Works from 115 Volt Outlet

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.

ENI

World's Leader in Power Amplifiers

If you would like to receive the new catalog of our full line of amplifiers and multicouplers, write:

ENI, 3000 Winton Rd. So., Rochester, New York 14623. Call 716-473-6900. TELEX 97-8283 ENI ROC.

INFO/CARD 25

TO-5 RELAY UPDATE

Still the world's smallest RF relay ...and the stingiest

When we first told you about the inherently low inter-contact capacitance and low contact circuit losses of our TO-5 relays, you agreed that they were ideal for RF switching. And you began designing them in immediately. They provided high isolation and low insertion loss up through UHF (typical performance 45 db isolation and 0.1 db insertion loss at 100 MHz).

Then you discovered another benefit – particularly for hand-held transceivers where battery drain is critical. The TO-5 is very stingy on coil power; the sensitive versions draw only 210mW at rated voltage.

So if you're looking for a subminiature RF switch, don't settle for anything less than TO-5 technology. It's available in commercial/industrial as well as MIL qualified types. Write or call us today for full technical information.

TELEDYNE RELAYS

3155 W. El Segundo Blvd., Hawthorne, Calif. 90250 • (213) 973-4545

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