November/December 1980

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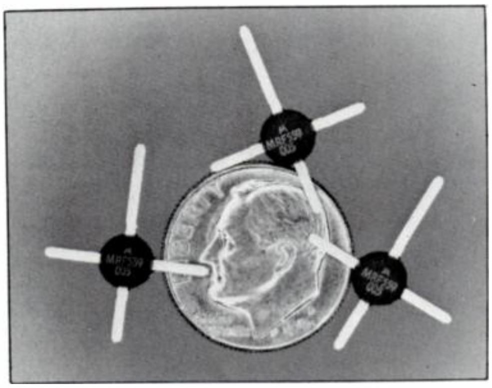
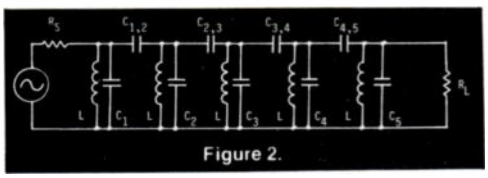


RF Plastic Power



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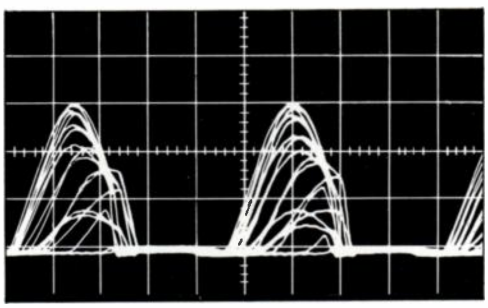

Parasitic Oscillation

Solar-Electric Power

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INFO/CARD 3

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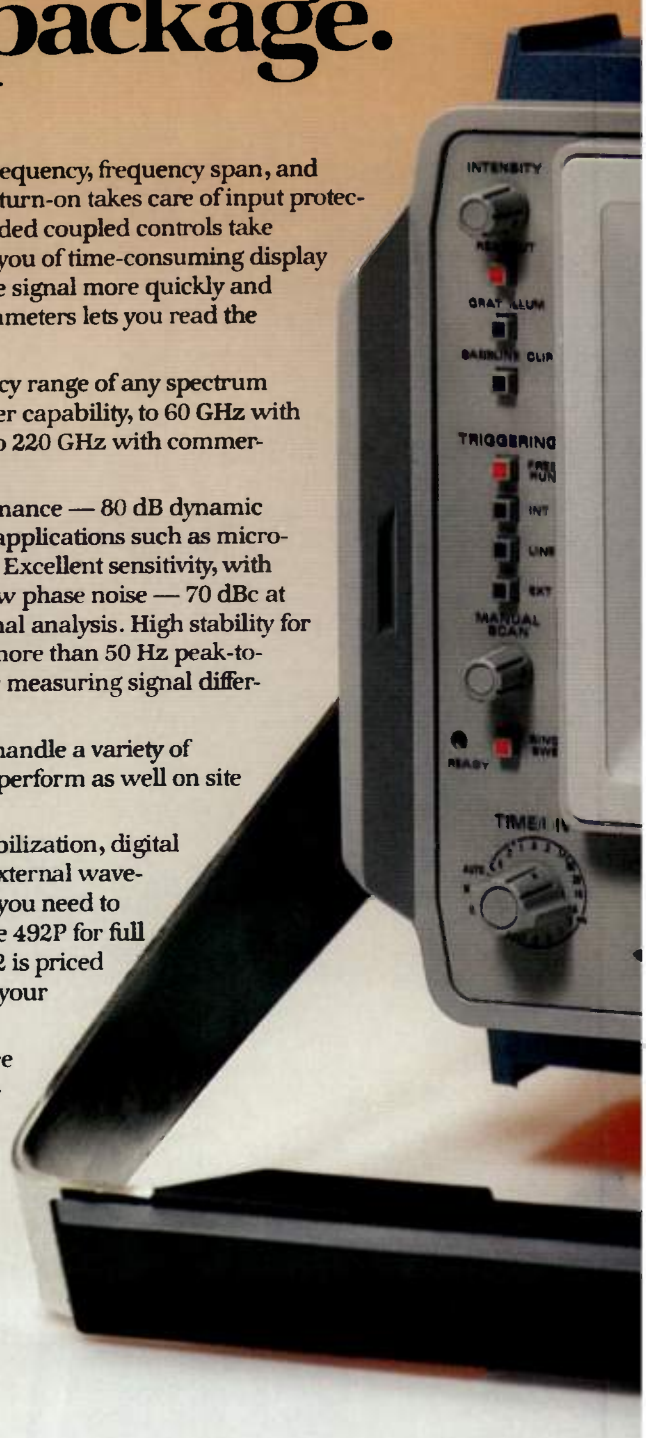

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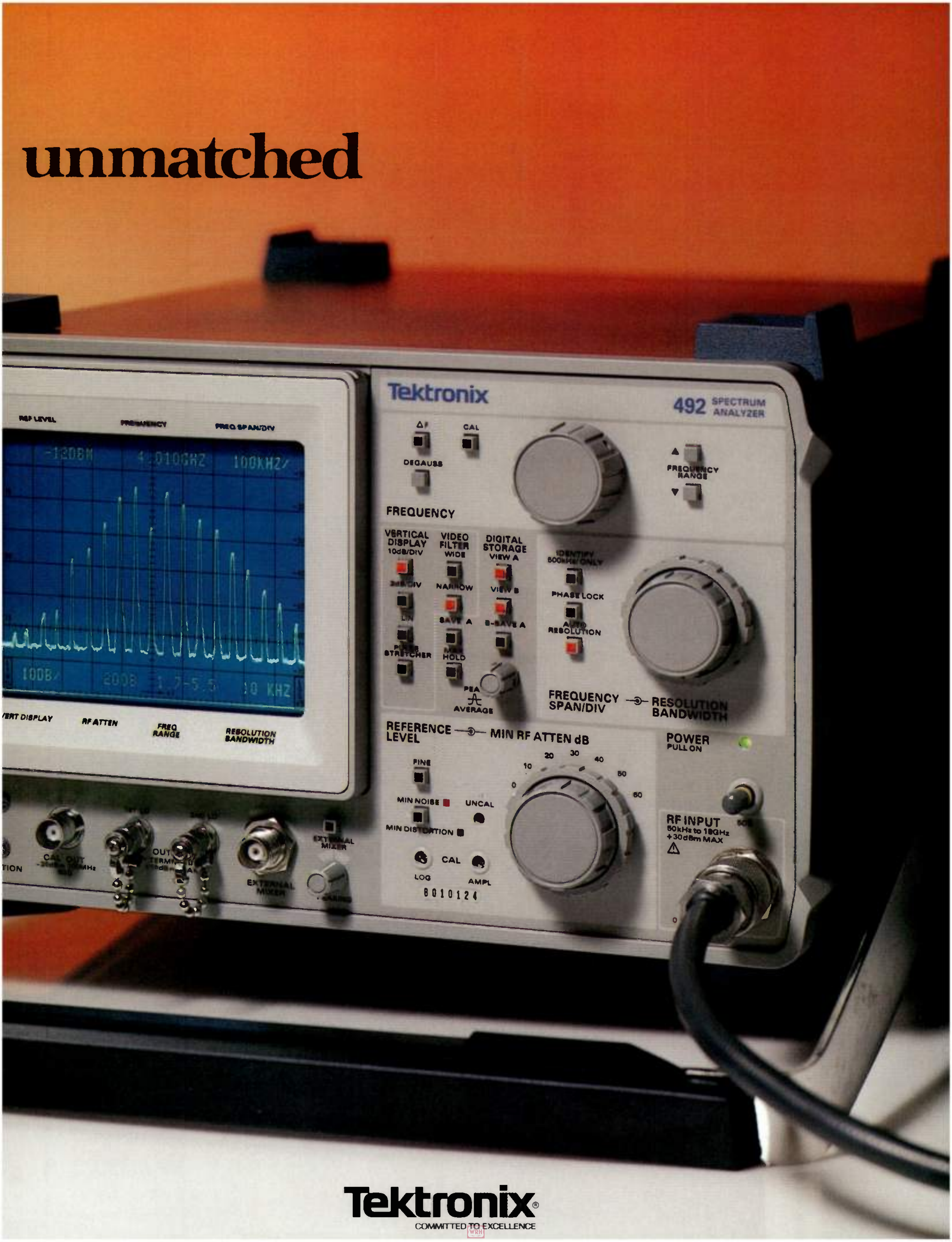
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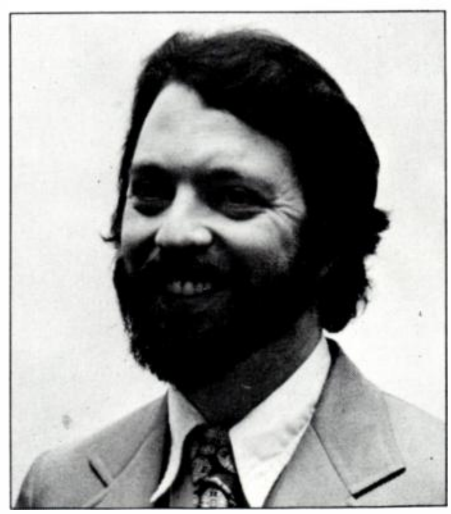
Start of a New Year

In more ways than one a new year's beginning. *r.f. design* is happy to be around for the start of another year. This November-December 1980 issue marks the beginning of our third year.

Here are some of the areas of interest that I'd like to pursue in 1981.

- Filter Design
- Receiver Design
- Amplifier (or Preamplifier) Design
- RF Semiconductor State-of-the-Art
- EMI-RFI
- RF Switching
- Low Phase Noise Oscillators
- Modulation Techniques
- Detectors, Detection
- Signature Analysis (Analyzers)
- Good RF Construction Techniques
- Antennas, Phased Arrays
- Data Transmission
- Various Methods of Cooling
- Transients: What it is, what it affects
- Stripline, Microstrip Techniques
- Smith Chart Solution to RF Problems
- Reliability/Maintainability
- Toroidal Transformers — Design and Application
- How Power Supply Specs Affect Your Design
- Unwanted Oscillations: Defined, Observed, Cured
- Instrumentation Categories: Spec A, Sig Gen, Analyzers, Bridges, etc.
- RF Components — Specifications vs. Circuit Tolerances

I am open to suggestions — what interests you? What areas do you need to know more about? What instrumentation, future, new or old needs detailing — in specifications/applications/availability? Let me help you by rounding up the information, asking the experts the right questions and printing it on these pages.



Speaking of newness — check out the 7 pages of new literature and new products. It's a small roundup of items that have recently appeared on the market to improve your designs or help measure their performance. Examples include: chip inductors, capacitors, resistors and hybrid filters; delay lines, resonators and MOSFET transformers to mention a few components. Instrumentation needs can be met by noise standards, log-amplifier meters, voltage-tuned filter assemblies and frequency extenders.

For the second time in a row many advertisers are trying to reach out to you in the form of direct (mail) inquiry cards. I'd like *your* point-of-view. Does it interest and help you to reach the needed manufacturers? If you have not yet tried — give it a go and see the results.

r.f. design has plans and they're all positive. There are new sections being considered, new features and services that can be provided. We're flexible, interested and unbound. Stick with us and possibly you'll be pleasantly surprised to see the direction we're taking. We at *r.f.* love the area, are excited about the future and are willing to try.

Rich Rosen

Rich Rosen

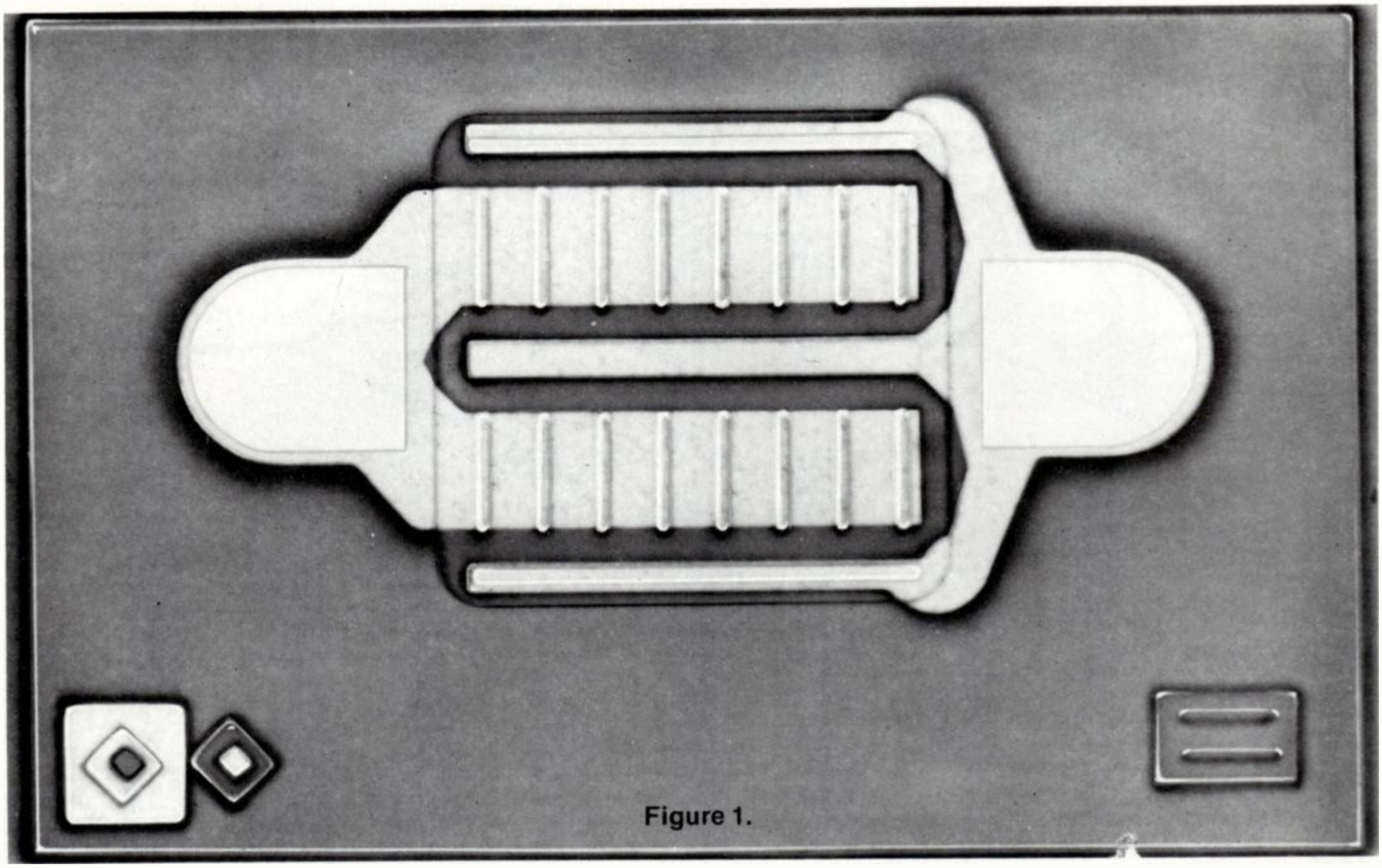


Figure 1.

Rich Potyka
Dan Bennett
Motorola Semiconductor Group
Phoenix, AZ

RF Plastic Power

A new standard for the industry?

Since the mid 1960's literally hundreds of various types of low power RF transistors have been introduced. It seemed that for every new radio, amplifier or instrument design a new "special" device just had to be created. In spite of this a handful of devices have emerged as standards in the one watt or less RF output category. The 2N4427, 2N3866, and 2N5109 are examples of the most popular ones. They are all metal can TO-39 types with many diverse applications. Types available include commercial Hi-Rel and JAN. In adding to this "standard" family, a number of design and applications factors had to be taken into account. After several years of work, the MRF559A emerged — a new standard for the Eighties.

Design Factors

The heart of any active device is the die or chip itself. Currently popular devices are from either the early RCA "overlay" design family or the simple interdigital designs of 1964-1966. Figures 1 and 2 show the 2N3866/2N5109 and the 2N4427. While adequate for many applications they lack a key element for safe repeatable linear operation — effective emitter ballasting. Without this, non-uniform current distribution causes hot spots on the emitter periphery. This localized heating in turn results in non-linear operation and reduced lifetime.

The MRF559 uses a combination of radially placed overlay structures to evenly distribute the RF over the shortest path. Figure 3 shows the MRF559 in detail. The hub of the device is the base or input feed area. The spokes are each a small spine emitter overlay transistor. Base current is fed to the emitter through a diffused P+ region which surrounds the emitter spine. The emitter is contacted, much like the 2N3866, by a wide strip of metallization. Unlike older aluminum devices this metal is a sandwich of nichrome, titanium, tungsten, and gold. This scheme provides a metallization lifetime up to ten times longer than aluminum. In addition no corrosion can form where the connecting gold wires are bonded i.e., there is no "purple plague."

Beyond the emitter fingers are individual nichrome resistors which provide for almost ideal ballasting and heat distribution. The emitter feed metallization was carefully designed, with two bonding areas, for short, equal feed paths to the active area.

To verify the design a thermal analysis was performed on a computer-optimized model using a Barnes RM2A infrared microscope. The instrument, modified with digital

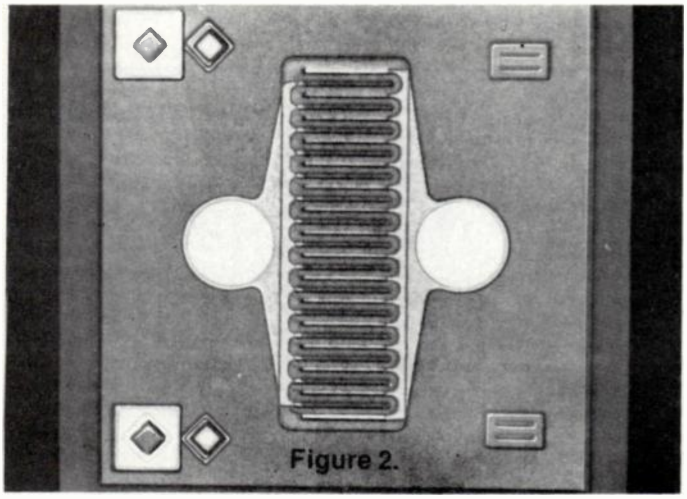


Figure 2.

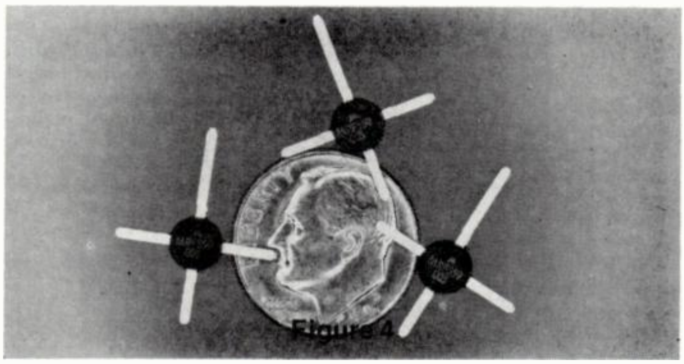


Figure 4

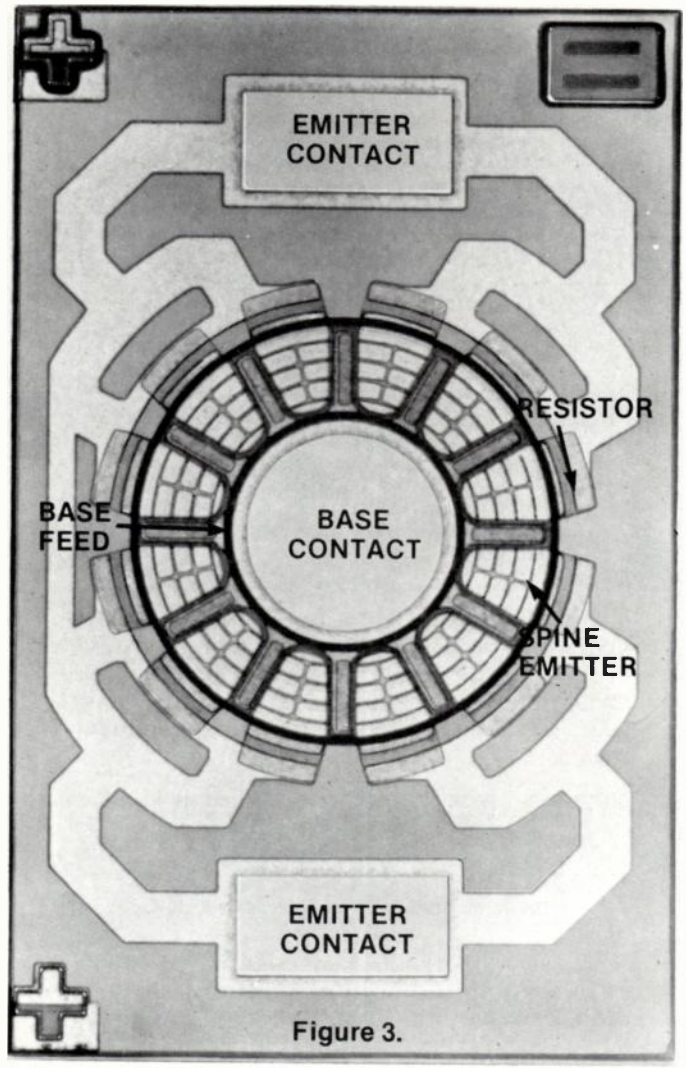


Figure 3.

read-out, confirmed 30 to 50 percent improvement in die temperature for a given dissipation and mounting (package).

Several starting material, matrix lots were processed and evaluated to determine the optimum for general purpose operation. The part could be built with relatively low material resistivity without reducing ruggedness. Improved linearity and saturated power result from this new ballasted-material-combination.

Packaging and cost were next attacked. Both labor and the cost of precious metals have increased dramatically in the last five years. A new device for universal use should make the most of automated assembly, test, and relatively low cost materials. Instead of the TO-39, a copper lead frame MACRO-X™ package (see Figure 4) was selected. Only a nominal 0.2 inch diameter by 0.1 inch thick, plastic encapsulated configuration offers a size advantage over the conventional metal can. In addition Stripline Opposed Emitter configuration improves RF performance. The thick 10 mil copper leads are silver-plated. They solder very well and easily conduct heat out of the package. To identify orientation the collector lead is cut longer than the emitter and base leads. Date coding is printed on the bottom — the part number on the top. This tiny power pill fits into many odd places. Without the hot collector can other components can be placed closer to it and stray radiation is significantly reduced. Assembly is performed in continuous strips of 36 units reducing set-up and handling cost. As we move on into the 1980's more advanced automatic equipment will continue to reduce costs making the MRF559 even more attractive with respect to metal types.

Figure 1. 2N3866/2N5109 Die-basic over-lay metal structure Circa 1963. **Figure 2.** 2N4427 Die. Note the inter-digitated base/emitter fingers and the absence of emitter resistor ballasting. **Figure 3.** MRF559. The radial geometry and metal feed structure help improve linearity and lifetime. **Figure 4.** Small size and dual emitters make the MRF559 ideal for high density applications.

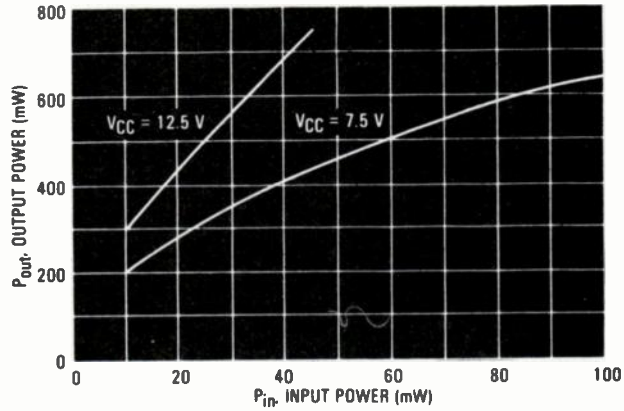
Characterization

No part can be characterized for every possible application but the MRF559 takes a good shot at it. Aside from the usual *maximum* ratings and mechanical details the data sheet is divided into four major sections — *DC, UHF RF, 800 MHz RF,* and *"S" parameters.*

The DC parameters are complete with leakage, I_{CES}, and C_{ob} specifications. In addition, a typical f_τ (3 GHz) is indicated.

It was felt that one of the first and largest potential uses of the MRF559 was in the land-mobile market (utilized in mobile and hand-held transceivers). Consequently the two

FIGURE 5 — OUTPUT POWER versus INPUT POWER
f = 512 MHz



specialized RF sections deal with UHF (512 MHz) and 800 MHz operation. (See Figures 5, 6, 7, 8). Included are data at 7.5 and 12.5V_{CC} plus Class C impedance figures. Note that Z_{ol} is the conjugate of the optimum load line under the specified operating conditions. This number should be treated mathematically like Z_{in}. It is the impedance to be matched to or it can be considered the output impedance at f_{τ} of the device.

Unlike older metal can devices the MRF559 with its advanced die and low emitter inductance performs well beyond 1 GHz. Full 870 MHz data also includes its 7.5V operating performance. For more general applications S-Parameter information is included. Noise figure, C_{ob} versus voltage and f_{τ} curves complete the section.

Applications: Where Can I Use It?

There seem to be three natural areas of immediate use for this device: *Instrumentation, land-mobile,* and *MATV/CATV.*

Instrumentation applications generally require continuous operation and very stable parameters. The MRF559 appears well suited for this since its ballasting offers lower temperature operation. With a relatively low V_{CC} of 10V, the f_{τ} holds over 2.5 GHz out to 120ma I_c. This makes the MRF559 good for line drivers, buffers, power VCO's, etc. With the isolated emitter leads and G_u max of > 10 dB at 1 GHz it is relatively easy to use simple external feedback for very wide band operation.

Similar to instrumentation the CATV/MATV users are concerned with lifetime and stability. The noise figure of

FIGURE 6 — OUTPUT POWER versus FREQUENCY
V_{CC} = 7.5 V

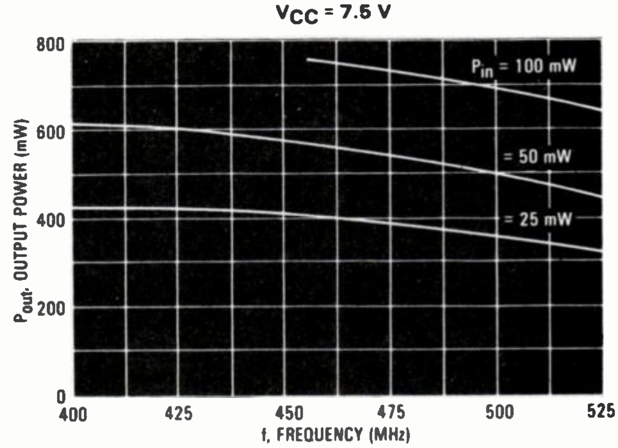
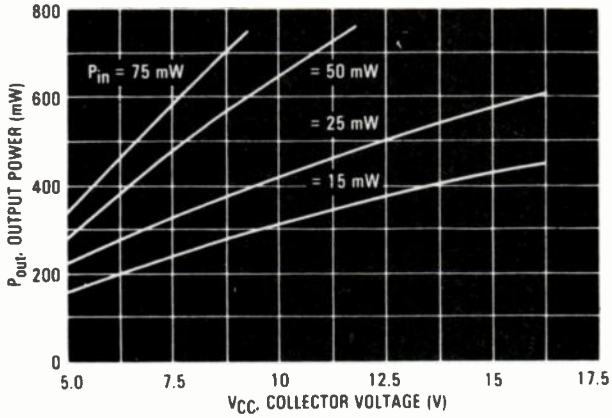


FIGURE 7 — OUTPUT POWER versus COLLECTOR VOLTAGE
f = 512 MHz

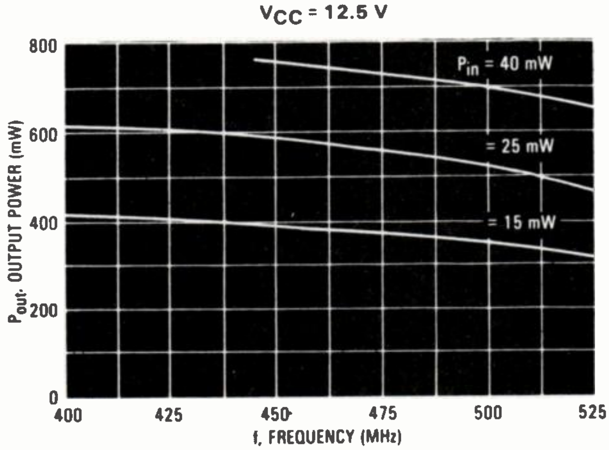


the MRF559 is only a little over 4 dB at 500 MHz clear out to 100ma I_C. It is thus ideal to up-grade old extender amplifier designs or MATV drops on out to 53 channel operation. Its small size will allow the designer to more easily construct push-pull circuits since the base and collector leads can be arranged to be roughly 0.2-0.3 inches apart without breaking up the ground integrity. By extracting the heat through the collector lead simpler, lower cost designs can be created without the need for complex mechanical hardware.

The two-way radio field will no doubt offer a wide range of opportunities for the MRF559. Light weight low cost hand-held transceiver design is a true RF art. The transmitter has minimal heat sinking, shielding, and space. The power amplifier usually operates into other than fifty ohms. The tiny rugged MRF559 makes an excellent doubler, tripler, driver or low power P.A. Its size and isolated case permit high-packing density without cross coupling problems. The high f_T of this part, relative to the mobile bands, makes it a high efficiency multiplier at supply voltages down to 5 volts. Its high dynamic range permits operation at high (>50 percent) efficiency over at least a 10 dB span. All of this means utilization of a single device in three to four sockets minimizing documentation, part count and cost. Eliminating the need for clip-on or press-fit heat sinks (and the dual emitter configuration) gives the designer a greater freedom in layout.

In this cost conscious world it's good to know that the key design component in 1980 will remain cost effective over the next decade. The marine and amateur markets are most subject to foreign competition and the MRF559 will help today's radio designer hold off this pressure.

FIGURE 8 — OUTPUT POWER versus FREQUENCY
V_{CC} = 12.5 V



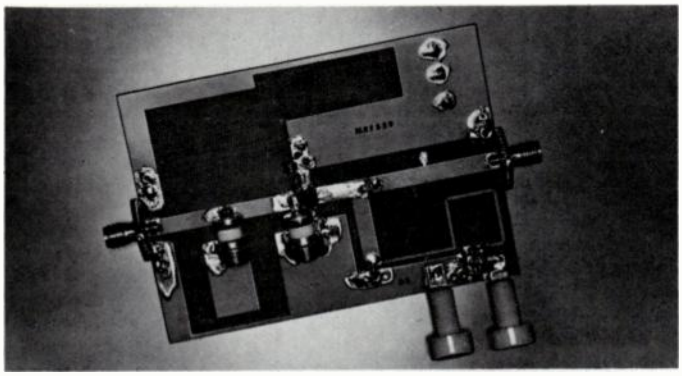


Figure 9. Completed amplifier.

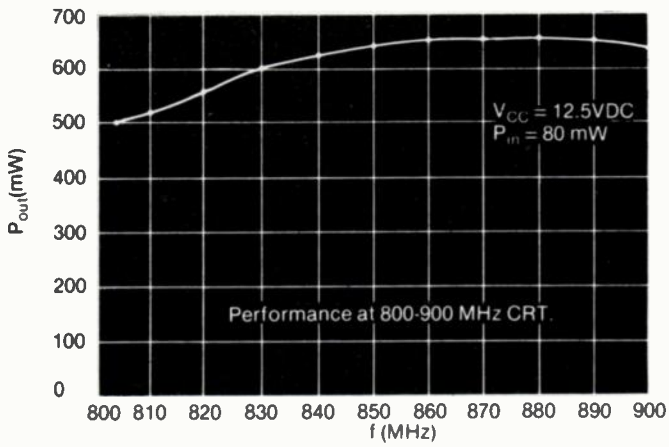


Figure 10. Power output versus frequency.

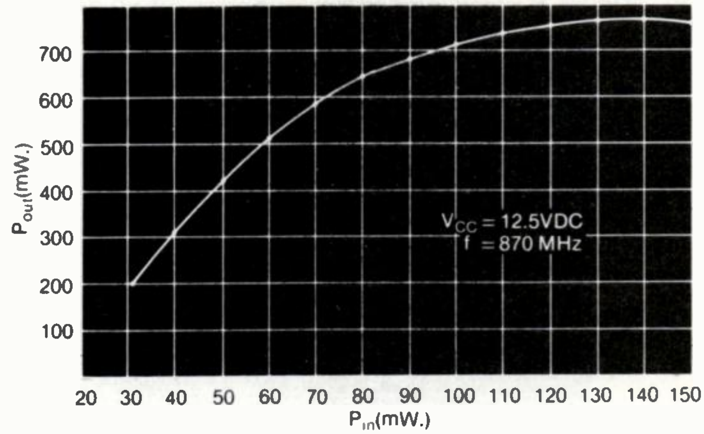


Figure 11. Power Output versus Input Power.

Design

How easy is it to build a basic 800 MHz amplifier? The following is a good example of an 800 MHz driver amplifier.

A class C configured amplifier is designed around the MRF559 to provide maximum gain and optimum input VSWR. The MRF559 presents a capacitive input and an inductive output reactance. Matching is done at these conjugates, namely; $Z_{in} = 4.1 + j5.9\Omega$ and $Z_{out} = 18 - j39.5\Omega$. These impedance points were derived at a drive level of 75mW, a $V_{CC} = 12.5$ VDC and operating at the uppermost band edge of 870 MHz. Input matching was derived from the above operating point plotted on a Smith Chart. Here the need for medium broadband performance in the

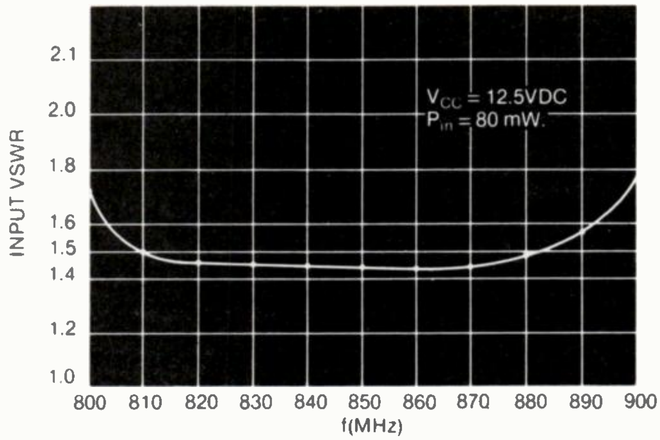


Figure 12. Input VSWR versus frequency.

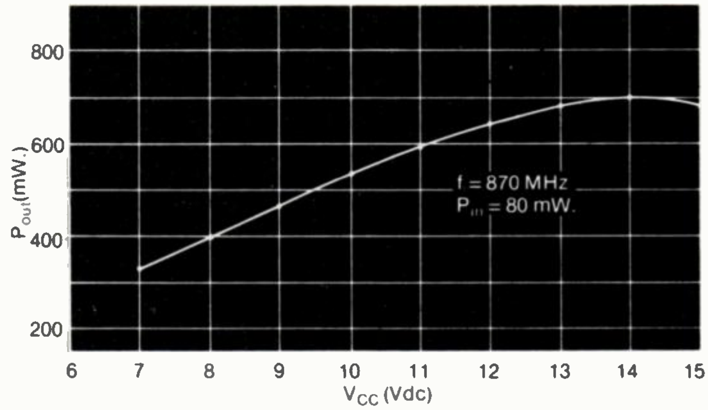


Figure 13. Output power versus supply voltage.

806 to 870 MHz region dictates the synthesis of a low Q input matching network.

The first matching element at the device input consists a shunt capacitance which revolves the 4.1 + j5.9Ω point on a 50Ω normalized Smith Chart to the resistive point of 14.5Ω. A transmission line was employed to rotate clockwise to intersect the unity susceptance circle where more shunt capacitance was employed to bring the input of the network to 50 ± j0Ω.

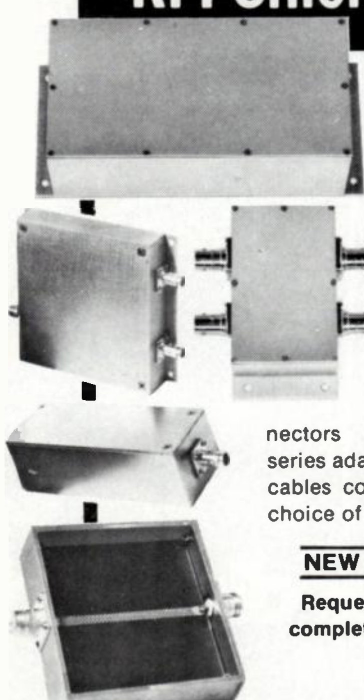
A simple *output* matching transmission line rotates the point 18 − j39.5Ω to 12.65 − j21.75Ω on the Smith Chart. The last microstrip element, a shunt inductor, rotates the latter to 50 + j0Ω.

The completed amplifier depicted in Figure 9 was printed on .0625" Teflon glass material.

Performance of the design is characterized in Figures 10 thru Figure 13 after sweeping and tuning for optimum band response and minimum input VSWR.

Conclusion

The MRF559 is intended to be a new cost-effective, high performance, general purpose RF transistor replacing the 2N4427 types. By using new die, metallization, and packaging techniques gain, efficiency, linearity and bandwidth figures are achieved at lower costs than the metal can devices of the '60's. The plastic MACRO-X package also provides improved emitter grounding and ease of assembly not possible with other package styles. □



Among the good things that come in small packages are Wavetek's new Ultramin™ RF and microwave filters. They'll reduce weight and save valuable board space when you're designing circuits for anything that flies, swims, or walks.

For example, our T5 Series covers the 25 to 500 MHz range, yet weighs less than 0.046 ounces and is only 0.36 inches in diameter. The T8 Series is only a little larger and covers the 10 to 1,000 MHz range. R and S Series filters cover the full 10 to 3,000 MHz range.

TYPICAL PERFORMANCE	
BANDPASS FILTER	HIGHPASS FILTER
f_o = 21.4 MHz	500 MHz
TO-8 Package	TO-8 Package
3dB BW = 2.1 MHz	3dB f_{co} = 450 MHz (and ≈1500 MHz)
40dB BW = 5.5 MHz	f_{stop} = 400 MHz
Number of sections = 5	Number of sections = 5
I.L. = 4.1dB	I.L. = 0.6dB at 500 MHz
40dB/3dB shape factor = 2.6:1	3dB/40dB shape factor = 1.13:1

Rugged, low-mass Ultramin™ filters can be specified to meet stringent requirements for temperature, humidity, shock, and vibration, including MIL-E-5400, MIL-STD-202, MIL-E-8189, and MIL-F-18327.

They're available in bandpass, lowpass, highpass, and bandstop designs. 0.01 dB Tchebychev response is standard; other responses are available on request.

Write or call for our complete Ultramin™ Series catalog. It's the prescription you've been waiting for.

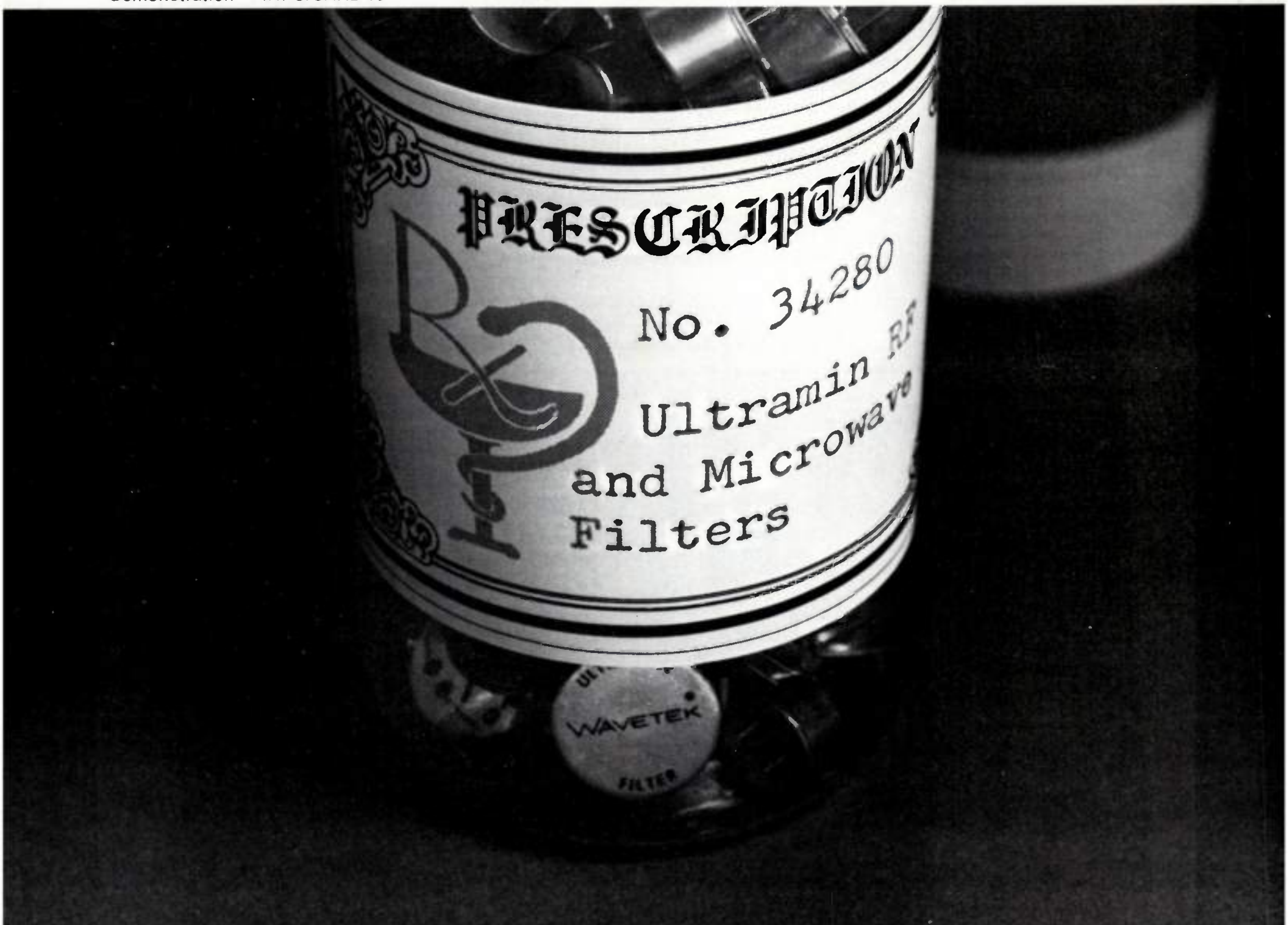
Wavetek Indiana, P.O. Box 190, 66 N. First Ave., Beech Grove, IN 46107. Toll free 800-428-4424; in Indiana (317) 783-3221.

WAVETEK®

Jerry Schick

Demonstration — INFO/CARD 10

LITERATURE — INFO/CARD 11



Use as directed for weight loss.

Finally a way to make noise figure measurements–10 MHz to 18 GHz–that are accurate and repeatable.

HP's new 346B Noise Source can cut your uncertainty in half.

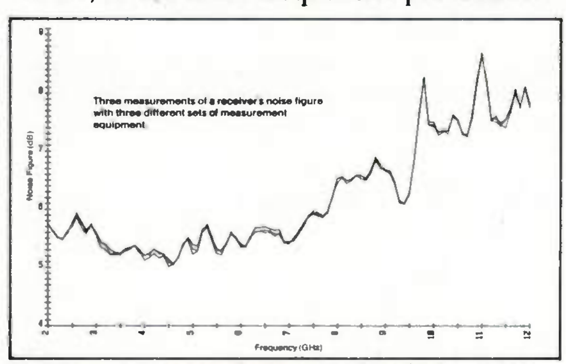
In conventional noise figure measurements, you now get better accuracy because ENR (excess noise ratio) has an RSS uncertainty of ±0.1 dB from 10 MHz to 8 GHz, ±0.19 dB at 18 GHz, and is plotted on the nameplate at 20 frequencies. Low SWR of <1.15 from 30 MHz to 5 GHz and <1.25 to 18 GHz further reduces uncertainty.

When used with conventional meters, the 346's built-in current regulator makes the noise output insensitive to 28 ± 1V drive variations. HP 340B/342A meters use the 11711A adapter. Prices: 346B, $1200*; 11711A, $125*

For more information call your nearby HP sales office or write Hewlett-Packard Co., 1507 Page Mill Road, Palo Alto, CA 94304.

Or configure a repeatable, error-correcting automatic system.

Using an off-the-shelf power meter, local oscillator, and a few instruments and accessories, you can automatically measure both gain and noise figure, while correcting for second stage noise, ENR variations, and ambient temperature effects; as fast as 100 frequencies per minute.



The X-Y chart shows excellent repeatability with 3 separate plots of receiver noise figure using 3 different power meters, sensors, and noise sources. Peak excursions are <± 0.1 dB from 2 to 12 GHz.

DESIGNED FOR HP-IB SYSTEMS

*Domestic U.S. prices only.

04002

HEWLETT PACKARD

INFO/CARD 12

Narrowband Butterworth or Chebyshev Filter Design Using the TI-59 Calculator

A TI-59 program is provided whereby a Butterworth or a Chebyshev Filter of any ripple (orders 2 through 9) can be designed quickly and without error.

Lee R. Watkins, Martin Marietta, Waterton, Colo.

There are many times while designing electronic circuits that a filter is required. In this article the standard low pass to narrowband bandpass transformations are used. This transformation is only approximate but for bandwidths of about 10 percent or less it provides excellent correlation with the full bandpass transformation. The reason the full bandpass transformation is not used is that it generates component values that are not realizable for narrow bandwidths.

In the full bandpass case the circuit configuration is one of shunt L's and C's connected by a series L,C network. The narrowband case has the configuration of Figure 2. The program, transformation formulas and examples are given.

Both the Butterworth and Chebyshev Filter Designs begin by solving for the low pass element values which have been normalized to give 3 dB of attenuation at $\omega_c = 1$ radian (e.g. C in farads, L in henrys and R in ohms).

The Butterworth element values are given by:

$$g_K = 2\sin\frac{((2k-1)\pi)}{2N},\ K = 1, 2, \ldots N \qquad (1)$$

g_K = Element value
N = Order of Filter

These element values are already normalized to the 3 dB point.

The element values for the Chebyshev filter are more difficult to obtain even though the equations are closed form. The equations are:

$$g_K = \frac{4a_{K-1}a_K}{b_{K-1}g_{K-1}},\ K = 2, 3, \ldots N \qquad (2)$$

g_K = Element value (normalized to the ripple bandwidth) which will be modified later. See Figure 1 for a definition of ripple bandwidth.

$$a_K = \sin\frac{(2K-1)\pi}{2N},\ K = 1, 2, \ldots N \qquad (3)$$

N = Order of Filter

$$b_K = \gamma^2 + \sin^2\left(\frac{K\pi}{N}\right),\ K = 1, 2, \ldots N \qquad (4)$$

$$\gamma = \sinh\frac{\beta}{2N} \qquad (5)$$

$$\beta = \ln(\coth[\frac{Am}{17.37}]) \qquad (6)$$

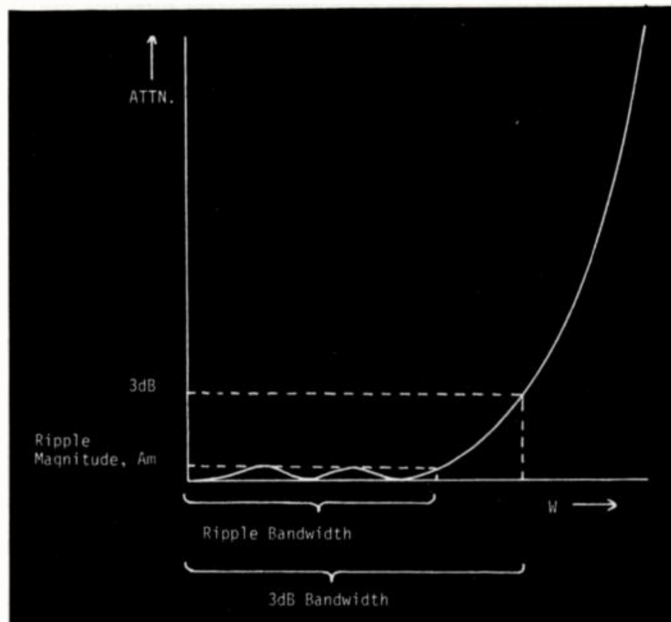


Figure 1.

$$Am = \text{Ripple Magnitude in dB} \qquad (7)$$

$$g_1 = \frac{2a_1}{\gamma} \qquad (8)$$

$$R_{source} = \tanh^2\left(\frac{\beta}{4}\right),\ \text{for } N \text{ even} \qquad (9a)$$

$$R_{source} = R_{load},\ \text{for } N \text{ Odd} \qquad (9b)$$

After solving each of the low pass element values (normalized to the ripple bandwidth) we must renormalize, since most filter designs work with the 3 dB bandwidth, by modifying the values by the factor:

$$\omega_{3dB} = \cosh\left|\frac{1}{N}\cosh^{-1}\frac{1}{\varepsilon}\right| \qquad (10)$$

$$\varepsilon = \sqrt{10^{0.1Am} - 1} \qquad (11)$$

At this point the narrowband transformation equations are applied to transform the low pass filter configuration to the narrowband bandpass filter configuration. The equations apply to both the Butterworth and Chebyshev filters.

The transformation process makes the source impedance equal to the load impedance whereas in other types of transformations this may not be the case.

The coupling coefficients for the transformation are given by:

$$K_{ij} = \frac{1}{\sqrt{g_i g_j}} \tag{12}$$

The value of the parallel inductance is given by:

$$L = \frac{1}{\omega_o^2 C_N'}, \text{ Henrys} \tag{13}$$

Where ω_o = Center frequency in Radians

$$\omega_o \textit{ is defined as } \omega_o = \sqrt{\omega_1 \omega_2} \tag{14}$$

Where ω_1 and ω_2 are the upper and lower 3 dB frequencies

$$C_N' = \frac{g_1}{BW^2_{3\,dB}\, \pi R_L} \quad \textit{farads} \tag{15}$$

R_L = Renormalized load resistance in ohms
The coupling C's are given by:

$$C_{ij} = \frac{K_{ij}\, BW_{3\,dB}\, C_N'}{f_o} \tag{16}$$

f_o = Center Frequency in Hertz
Lastly, the Resonant C's are given by:

$$\begin{aligned} C_1 &= C_N' - C_{1,2} \\ C_2 &= C_N' - C_{1,2} - C_{2,3} \\ &\;\;\vdots \\ C_{N-1} &= C_N' - C_{N-2,\,N-1} - C_{N-1,\,N} \\ C_N &= C_N' - C_{N-1,\,N} \end{aligned} \tag{17}$$

Example #1

Design a Butterworth filter of order 5 centered at 30×10^6 Hz with a 3 dB bandwidth of 1.5×10^6 Hz and a load resistance of 1000 ohms.

Procedure:
1 — Repartition the calculator by pressing.
4
2nd OP
17
CLR
2 — Read side 1 and 2 of card #1.
3 — Read side 1 and 2 of card #2 (or key in the program).
4 — Press B (for Butterworth filter).
5 — Enter order (2-9), Press 2nd A.
6 — Enter center frequency in Hz. Press 2nd B.
7 — Enter 3 dB bandwidth in Hz. Hz. Press 2nd C.
8 — Enter 0 (ripple magnitude). Press 2nd D.
9 — Enter the value of the load resistance in ohms. Press 2nd E. The printout is shown at right.

```
BUTTERWORTH TYPE
         5.      =ORD
         3.  07   =FO
       1.5  06   =BW
         0.  00  =RFL
         1.  03   =RL
         1.  03   =RS

 429.19685-09 =IND
 62.296671-12 =CAP

 3.2787721-12 =CAP

 429.19685-09 =IND
 60.474024-12 =CAP

 1.8226464-12 =CAP

 429.19685-09 =IND
  61.93015-12 =CAP

 1.8226464-12 =CAP

 429.19685-09 =IND
 60.474024-12 =CAP

 3.2787721-12 =CAP

 429.19685-09 =IND
 62.296671-12 =CAP
```

The values are given starting from the filter input. Note the filter is symmetrical.

The schematic is:

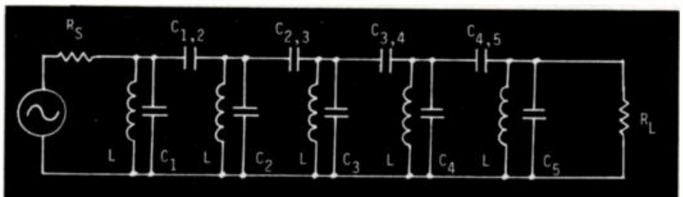


Figure 2.

Example #2

Design a Chebyshev filter of order 6, centered at 30×10^6 Hz with a 3 dB bandwidth of 1.5×10^6 Hz, a load resistance of 1000 ohms, and a ripple magnitude of 0.3 dB.

Procedure:
1 — Repartition the calculator by pressing
4
2nd OP
17
CLR
2 — Read side 1 and 2 of card #1.
3 — Read side 1 and 2 of card #2.
4 — Press C (for Chebyshev).
5 — Enter order (2-9). Press 2nd A.
6 — Enter center frequency in Hz. Press 2nd B.
7 — Enter 3 dB bandwidth in Hz. Press 2nd C.
8 — Enter ripple magnitude in dB. Press 2nd D.
9 — Enter the value of the load resistance in ohms. Press 2nd E. The printout is shown at right.

```
CHEBYSHEV    TYPE
         6.      =ORD
         3.  07   =FO
       1.5  06   =BW
         3. -01  =RPL
         1.  03   =RL
         1.  03   =RS

 283.90966-09 =IND
 95.800231-12 =CAP

 3.3326167-12 =CAP

 283.90966-09 =IND
 93.152554-12 =CAP

 2.6476772-12 =CAP

 283.90966-09 =IND
 93.914478-12 =CAP

 2.5706927-12 =CAP

 283.90966-09 =IND
 93.914478-12 =CAP

 2.6476772-12 =CAP

 283.90966-09 =IND
 93.152554-12 =CAP

 3.3326167-12 =CAP

 283.90966-09 =IND
 95.800231-12 =CAP
```

The schematic is:

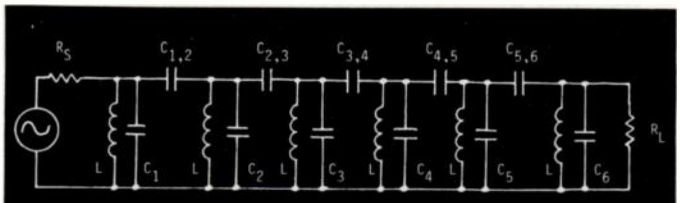


Figure 3.

In order to help select the proper filter for the specific application the curves of Figures 4 through 9 are provided to show relative stopband attenuation. For a more thorough treatment of filters and their denormalization refer to the references. The program listing is also given.

Note: In the program that follows, the DSZ function is used. Normally the DSZ function is only defined for locations 0-9, however it can be used for other locations. For example if we wish to use location 15, we do the following:

Press 2nd DSZ
E

E is pressed because E has a location code of 15 which is the code used in the program.

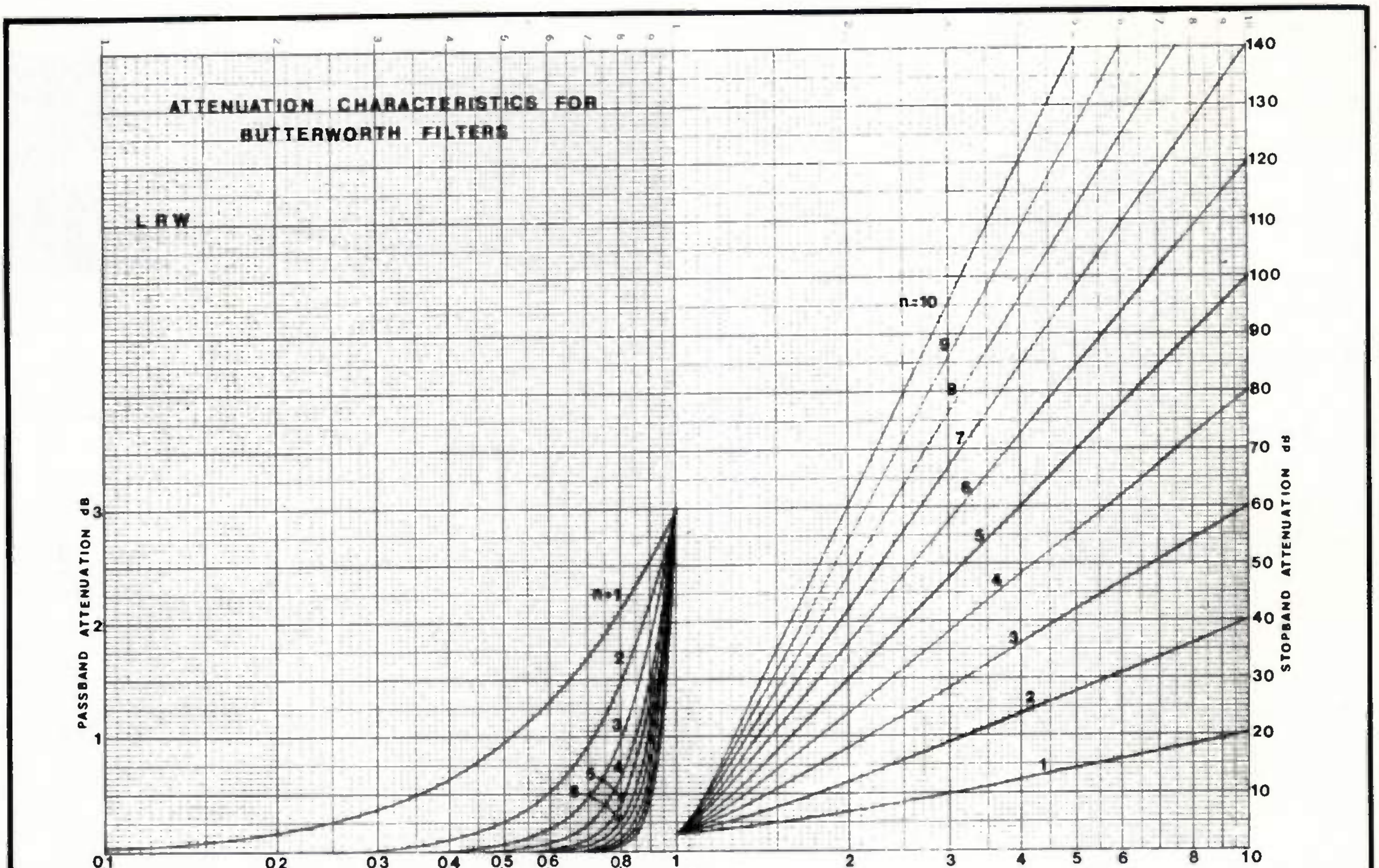

ATTENUATION CHARACTERISTICS FOR BUTTERWORTH FILTERS
LRW
PASSBAND ATTENUATION dB
STOPBAND ATTENUATION dB
n=10
n=1
0.1 0.2 0.3 0.4 0.5 0.6 0.8 1 2 3 4 5 6 8 10
10 20 30 40 50 60 70 80 90 100 110 120 130 140

FIGURE 4

HP's budget-minded Microwave Spectrum Analyzer

The 8559A delivers precision and convenience for a wide range of applications.

HP's 8559A Spectrum Analyzer plug-in with the HP 182T display is easy-to-use, economical, and portable. The combination weighs less than 40 pounds and its rugged design makes it excellent for field use.

Most measurements can be made using only 3 controls. You simply tune to the signal, set frequency span (resolution and sweep time are automatically optimized), and then set the reference level and read signal amplitude.

The 8559A/182T is a high-performance instrument at a truly affordable price, $10,875. For more information on this budget-minded instrument call your nearby HP sales office, or write Hewlett-Packard, 1507 Page Mill Rd., Palo Alto, CA 94304.

Domestic U.S. price only.

53102

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INFO/CARD 14

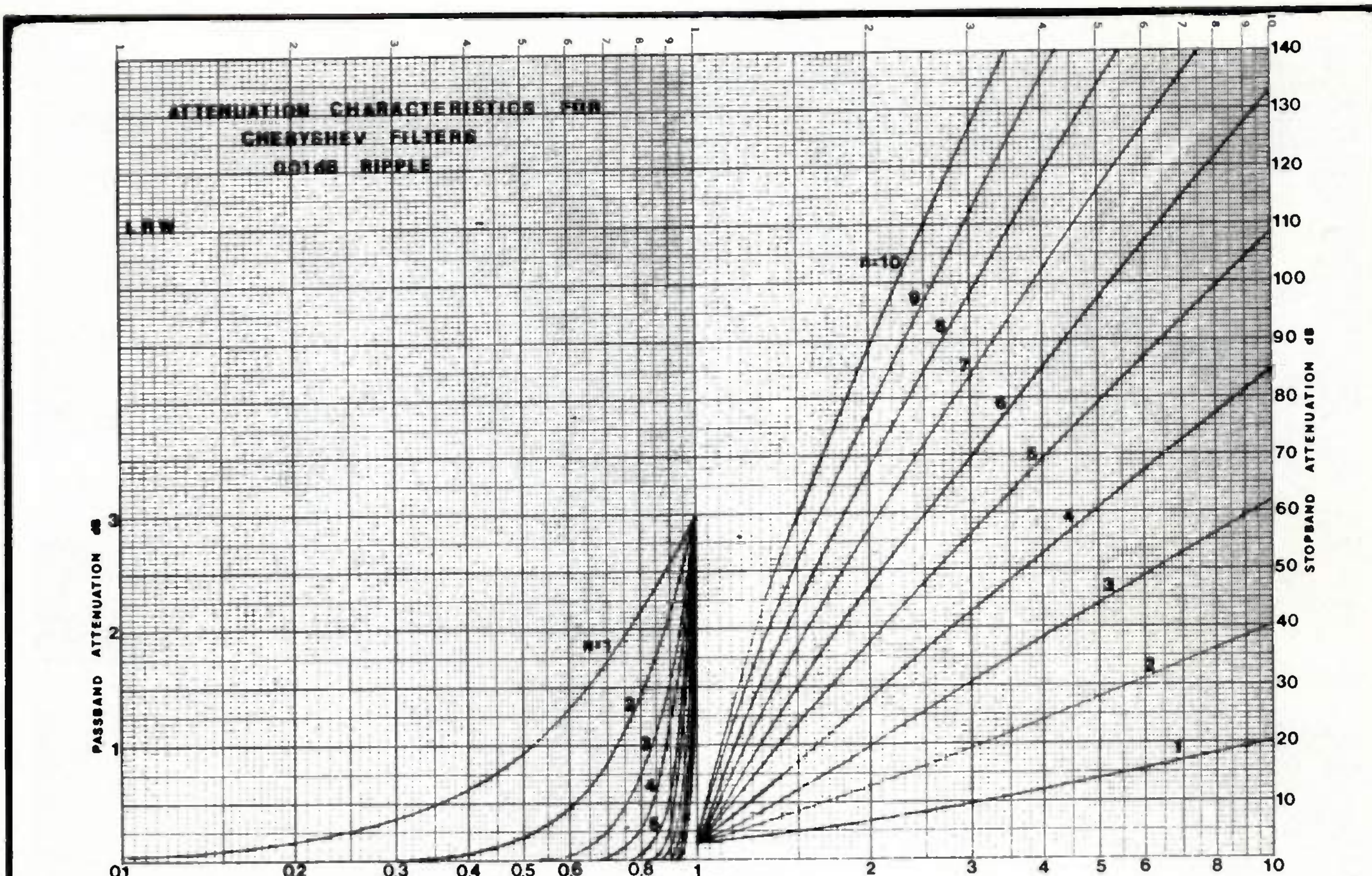

FIGURE 5

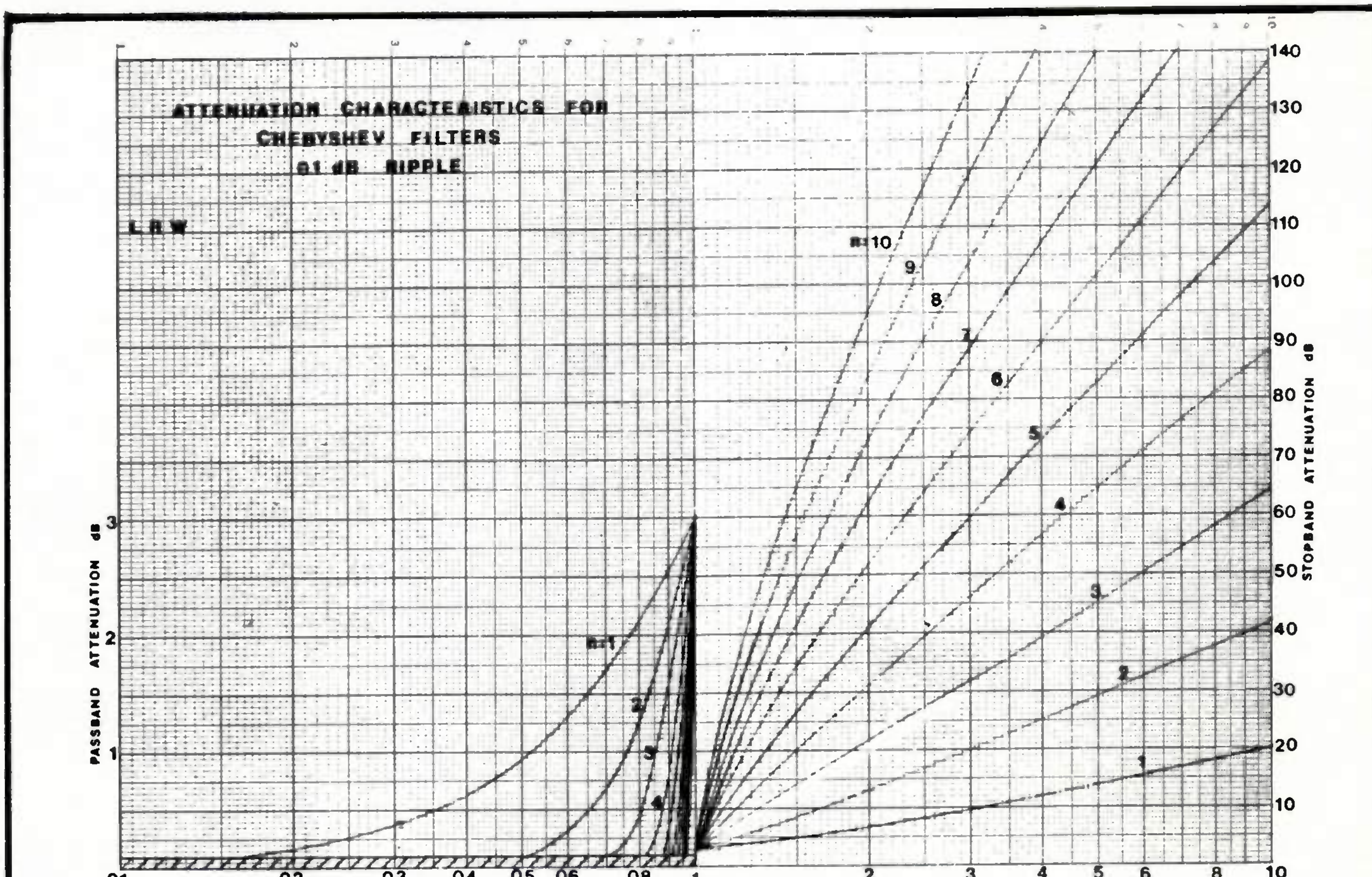

FIGURE 6

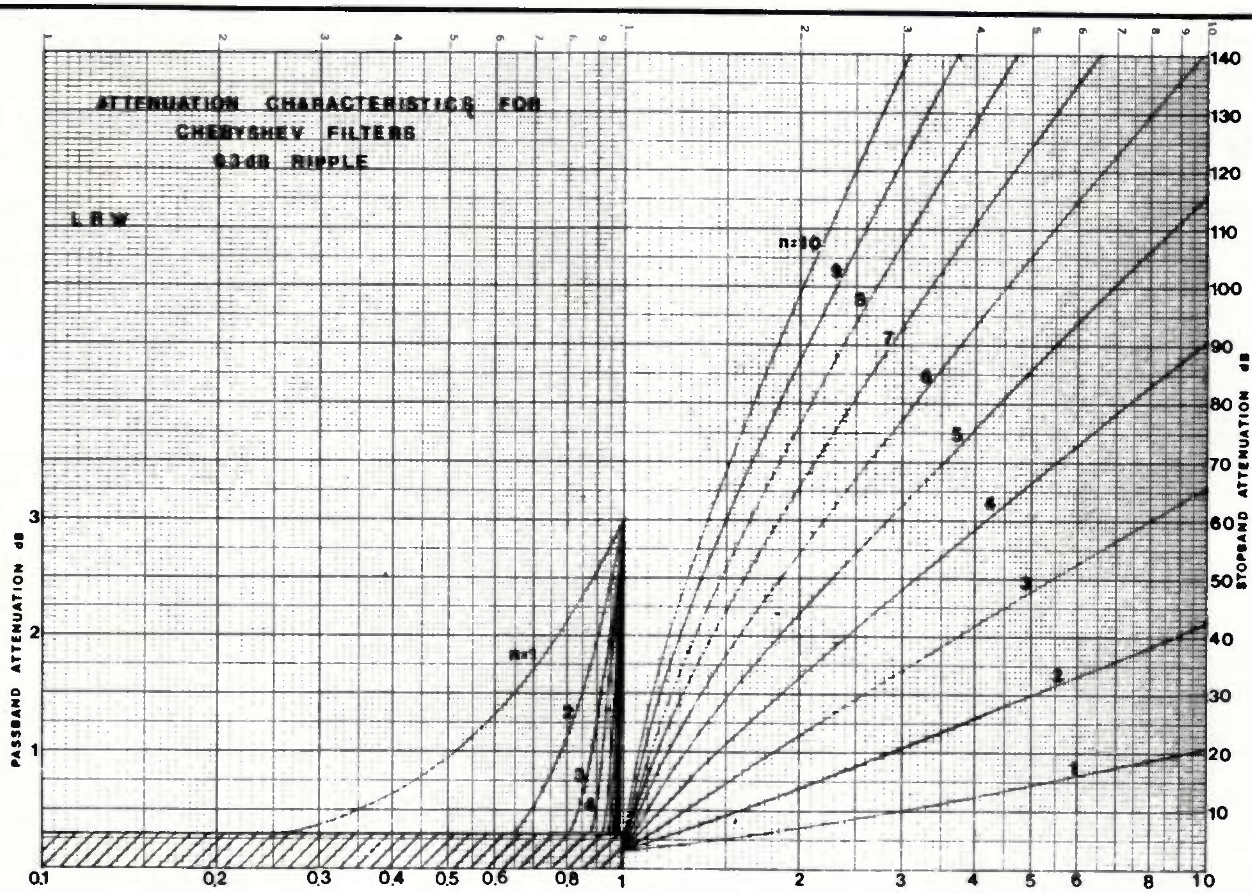

FIGURE 7

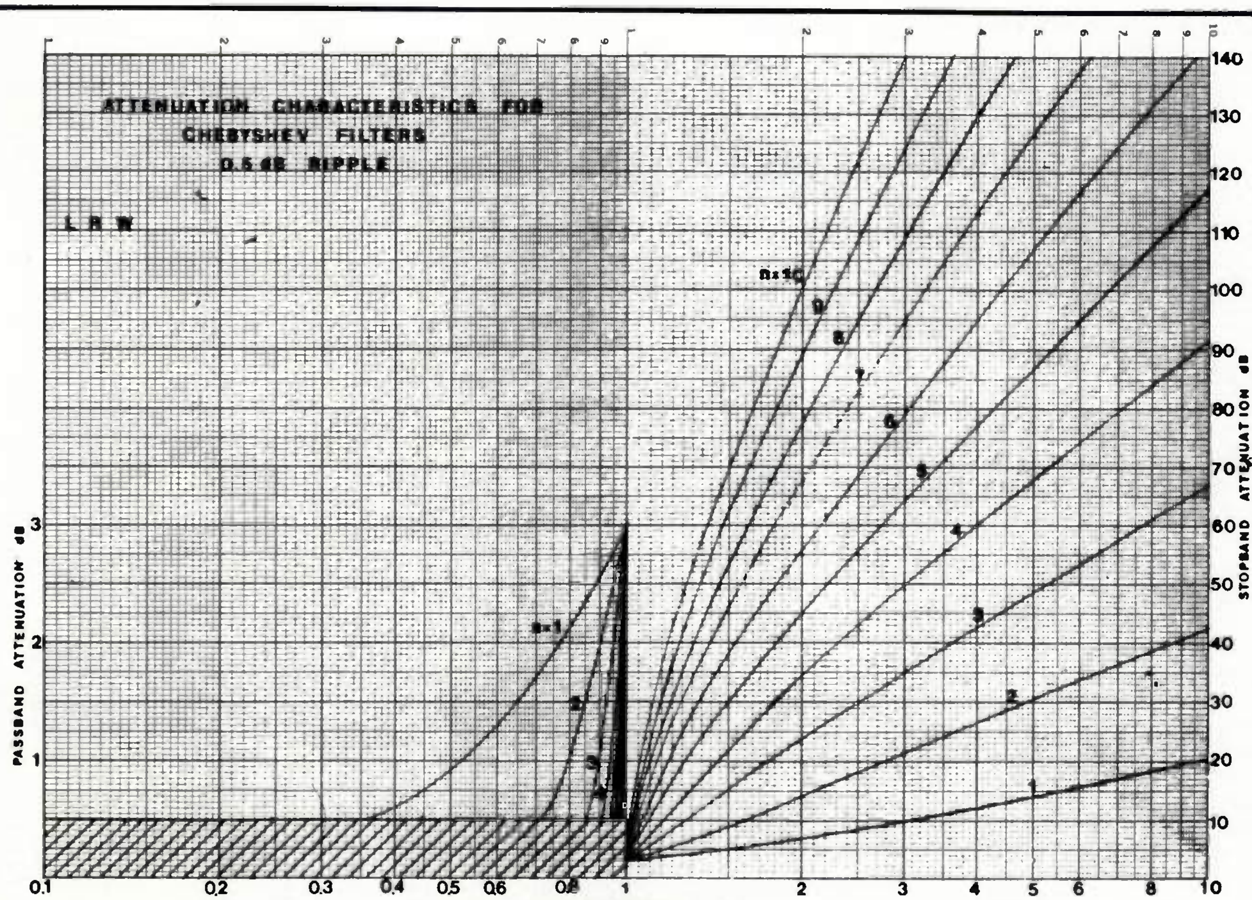

FIGURE 8

Fluke introduces two new advanc synthesized signal generators you

With 20 years experience in RF instrumentation, we're driving down the cost of high performance.

The 6070A and 6071A are designed to fill a critical gap in today's signal generator market: the price/performance gap that separates $10,000 synthesizers with limited capabilities from the more sophisticated, state-of-the-art units costing $25,000 and up. As such, they represent a new generation of RF synthesizers from Fluke that deliver the industry's most-wanted features at a very affordable price.

Innovative design achieves signal purity and broad frequency coverage.

Fluke engineers developed a number of unique and cost-effective synthesis techniques for the 6070A and 6071A that deliver a high degree of spectral purity without sacrificing broadband range.

The frequency range of the 6070A is 200 kHz to 520 MHz and the 6071A extends the range to 1040 MHz. Yet both instruments have spurious output levels of 90 to 100 dB below carrier, performance equalling or exceeding the best cavity-tuned generators on the market today. Microprocessor control – which Fluke introduced to signal generator design in 1975 with the 6010A – allows precision resolution and settability you can't find from any other manufacturer.

Fluke's new approach to synthesis in the 6070A and 6071A combines several unique elements: a refined single loop de-

***Internal modulation** is fully programmable from 20 Hz to 200 kHz with 3 digits resolution. The generators can also function simultaneously as signal generators and independent audio oscillators – two instruments in one.*

***Pinpoint frequency tuning** provided by optically coupled, magnetically detented spin knob. Combines digital precision with the speed and convenience of analog control.*

***Built-in, easy-to-program IEEE-488** interface ties the signal generator capability of the instruments to the power of automated system control. Talk/listen capability provides "learn" and "teach" modes.*

***Output level adjustable** in 0.1 dB steps from + 19 dBm (13 dBm above 520 MHz) to -140 dBm – displayed in dBm or volts and in relative or absolute units.*

IEEE-488

ed technology can specify with confidence.

sign that both improves reliability and lowers maintenance costs; a Surface Acoustic Wave (SAW) device to achieve low noise performance; and a delay line discriminator in a phase-locked loop that improves spectral purity and increases the modulation flexibility of the instruments.

A major emphasis on packaging design minimizes RF leakage and insures spectral purity. Fluke's own thick film hybrids improve RF performance and keep the parts count low. And a high efficiency power supply helps reduce weight, volume and heat rise.

Versatile modulation brings you two instruments for the price of one.

AM, FM and ØM are internally selectable. Modulation frequencies from 20 Hz to 200 kHz can be selected. Modulation can be applied separately or simultaneously for frequency, amplitude or phase, and the internal signal can also be used as an independent signal source, separate from the RF output, giving the user two instruments — a signal generator and an audio oscillator — in one high performance package.

A high deviation mode of up to 1 MHz or 100 radians is provided for frequency of phase modulation. External dc coupling for AM and FM is also available.

More microprocessor benefits.

The advanced 16-bit microprocessor control of the 6070A and 6071A makes these signal generators easy to operate and a pleasure to use.

Complex functions are executed rapidly from simple, direct keyboard commands.

A remarkably fluid-feeling spin knob gives even greater precision and control by allowing you to tune around any frequency, amplitude or modulation parameter, or spin quickly to another setting: rapid-tuning convenience with digital precision.

A built-in memory for storage of front panel set-ups is provided to save time and reduce operator errors. And the 6070A and 6071A also include a relative units function that allows you to define a zero point for subsequent programming, useful in both the frequency and amplitude domains.

Both instruments are IEEE-488 programmable for complete system use. Plus self-diagnostics, error code displays, digital sweep and other special functions combine to simplify testing in any RF design application. A full line of options and accessories is available to expand the capabilities of the 6070A and 6071A.

For more information on these new signal generators, call toll free **800-426-0361,** use the coupon below or contact your nearest Fluke sales office.

***Digital frequency sweep** for sophisticated testing of narrowband crystal filters, wideband amplifiers and other devices: manual, single and auto modes are standard.*

***Noise performance** exceeds the cavity-tuned generators: SSB phase noise −138 dBc/Hz at 20 kHz offset from the carrier at 500 MHz broadband noise floor −150 dBc/Hz.*

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☐ Send information on other IEEE products.
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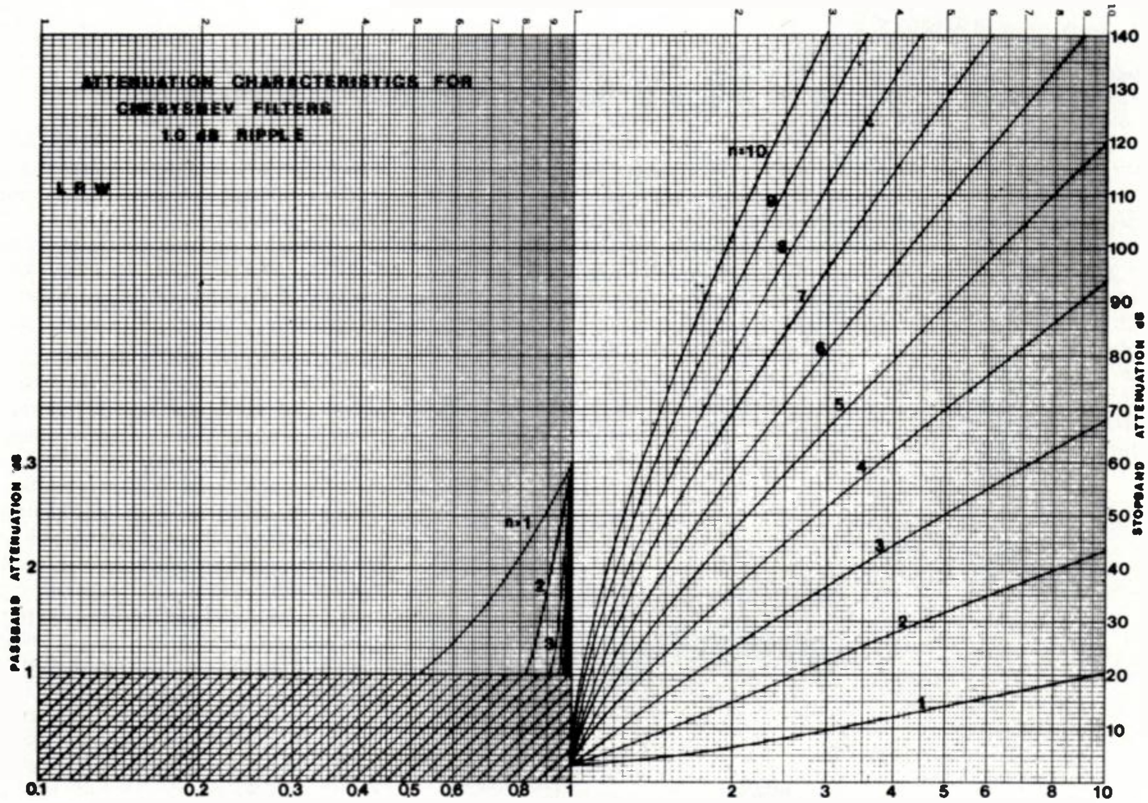

FIGURE 9

Program Listing:

```
000  76 LBL
001  12 B
002  86 STF
003  03  03
004  43 RCL
005  39  39
006  69 OP
007  01  01
008  43 RCL
009  38  38
010  69 OP
011  02  02
012  43 RCL
013  37  37
014  61 GTO
015  79 x̄
016  76 LBL
017  13 C
018  43 RCL
019  35  35
020  69 OP
021  01  01
022  43 RCL
023  34  34
024  69 OP
025  02  02
026  43 RCL
027  33  33
028  76 LBL
029  79 x̄
030  69 OP
031  03  03
032  43 RCL
033  36  36
034  69 OP
035  04  04
036  69 OP
037  05  05
038  91 R/S
039  76 LBL
040  16 A'
041  42 STO
042  03  03
043  32 X:T
044  43 RCL
045  30  30
046  69 OP
047  04  04
048  43 RCL
049  03  03
050  69 OP
051  06  06
052  91 R/S
053  76 LBL
054  17 B'
055  42 STO
056  04  04
057  43 RCL
058  25  25
059  69 OP
060  04  04
061  43 RCL
062  04  04
063  69 OP
064  06  06
065  65 ×
066  02  2
067  65 ×
068  89 π
069  95 =
070  33 X²
071  42 STO
072  04  04
073  91 R/S
074  76 LBL
075  18 C'
076  42 STO
077  05  05
078  43 RCL
079  32  32
080  69 OP
081  04  04
082  43 RCL
083  05  05
084  69 OP
085  06  06
086  65 ×
087  02  2
088  65 ×
089  89 π
090  95 =
091  42 STO
092  05  05
093  91 R/S
094  76 LBL
095  19 D'
096  42 STO
097  07  07
098  43 RCL
099  31  31
100  69 OP
101  04  04
102  43 RCL
103  07  07
104  69 OP
105  06  06
106  91 R/S
107  76 LBL
108  10 E'
109  42 STO
110  06  06
111  43 RCL
112  29  29
113  69 OP
114  04  04
115  43 RCL
116  06  06
117  69 OP
118  06  06
119  43 RCL
120  28  28
121  69 OP
122  04  04
123  43 RCL
124  06  06
125  69 OP
126  06  06
127  98 ADV
128  70 RAD
129  02  2
130  04  4
131  42 STO
132  00  00
133  00  0
134  42 STO
135  02  02
136  87 IFF
137  03  03
138  38 SIN
139  61 GTO
140  59 INT
141  76 LBL
142  38 SIN
143  71 SBR
144  65 ×
145  65 ×
146  02  2
147  95 =
148  72 ST*
149  00  00
150  69 OP
151  30  30
152  43 RCL
153  02  02
154  22 INV
155  67 EQ
156  38 SIN
157  61 GTO
158  50 I×I
159  76 LBL
160  59 INT
161  43 RCL
162  07  07
163  65 ×
164  02  2
165  55 ÷
166  01  1
167  07  7
168  93 .
169  03  3
170  07  7
171  95 =
172  22 INV
173  23 LNX
174  75 -
175  01  1
176  95 =
177  42 STO
178  08  08
179  85 +
180  02  2
181  95 =
182  55 ÷
183  43 RCL
184  08  08
185  95 =
186  23 LNX
187  42 STO
188  08  08
189  55 ÷
190  02  2
191  55 ÷
192  43 RCL
193  03  03
194  95 =
195  42 STO
196  09  09
197  22 INV
198  23 LNX
199  42 STO
200  10  10
201  35 1/X
202  94 +/-
203  85 +
204  43 RCL
205  10  10
206  95 =
207  55 ÷
208  02  2
209  95 =
210  42 STO
211  01  01
212  43 RCL
213  07  07
214  65 ×
215  93 .
216  01  1
217  95 =
218  22 INV
219  28 LOG
220  75 -
221  01  1
222  95 =
223  34 √X
224  35 1/X
225  42 STO
226  10  10
227  33 X²
228  75 -
229  01  1
230  95 =
231  34 √X
232  85 +
233  43 RCL
234  10  10
235  95 =
236  23 LNX
237  55 ÷
238  43 RCL
239  03  03
240  95 =
241  42 STO
242  10  10
243  94 +/-
244  22 INV
245  23 LNX
246  85 +
247  43 RCL
248  10  10
249  22 INV
250  23 LNX
251  95 =
252  55 ÷
253  02  2
254  95 =
255  42 STO
256  07  07
257  76 LBL
258  39 COS
259  71 SBR
260  65 ×
261  42 STO
262  08  08
263  43 RCL
264  02  02
265  65 ×
266  89 π
267  55 ÷
268  43 RCL
269  03  03
270  95 =
271  38 SIN
272  33 X²
273  85 +
274  53 (
275  43 RCL
276  01  01
277  33 X²
278  54 )
279  95 =
280  42 STO
281  09  09
282  43 RCL
283  02  02
284  42 STO
285  15  15
286  97 DSZ
287  15  15
288  30 TAN
289  02  2
290  65 ×
291  43 RCL
292  08  08
293  55 ÷
294  43 RCL
295  01  01
296  95 =
297  76 LBL
298  69 OP
299  72 ST*
300  00  00
301  43 RCL
302  08  08
303  42 STO
304  10  10
305  43 RCL
306  09  09
307  42 STO
308  11  11
309  73 RC*
310  00  00
311  65 ×
312  43 RCL
313  07  07
314  95 =
315  72 ST*
316  00  00
317  69 OP
318  30  30
319  43 RCL
320  02  02
321  22 INV
322  67 EQ
323  39 COS
324  61 GTO
325  50 I×I
326  76 LBL
327  30 TAN
328  43 RCL
329  00  00
330  85 +
331  01  1
332  95 =
333  42 STO
334  13  13
335  04  4
336  65 ×
337  43 RCL
```

```
338  10  10
339  65  ×
340  43  RCL
341  08  08
342  55  ÷
343  43  RCL
344  11  11
345  55  ÷
346  53  (
347  73  RC*
348  13  13
349  55  ÷
350  43  RCL
351  07  07
352  54  )
353  95  =
354  61  GTO
355  69  OP
356  76  LBL
357  65  ×
358  69  OP
359  22  22
360  53  (
361  02  2
362  65  ×
363  43  RCL
364  02  02
365  75  -
366  01  1
367  54  )
368  65  ×
369  89  π
370  55  ÷
371  02  2
372  55  ÷
373  43  RCL
374  03  03
375  95  =
376  38  SIN
377  92  RTN
378  76  LBL
379  50  I×I
380  57  ENG
381  00  0
382  42  STO
383  02  02
384  02  2
385  04  4
386  75  -
387  43  RCL
388  03  03
389  85  +
390  01  1
391  95  =
392  42  STO
393  00  00
394  73  RC*
395  00  00
396  55  ÷
397  43  RCL
398  05  05
399  55  ÷
400  43  RCL
401  06  06
402  95  =
403  42  STO
404  03  03
405  65  ×
406  43  RCL
407  04  04
408  95  =
409  35  1/X
410  42  STO
411  06  06
412  43  RCL
413  04  04
414  34  √X
415  35  1/X
416  65  ×
417  43  RCL
418  05  05
419  95  =
420  42  STO
421  05  05
422  43  RCL
423  06  06
424  42  STO
425  04  04
426  00  0
427  42  STO
428  06  06
429  00  0
430  42  STO
431  07  07
432  00  0
433  42  STO
434  08  08
435  00  0
436  42  STO
437  09  09
438  00  0
439  42  STO
440  10  10
441  00  0
442  42  STO
443  11  11
444  00  0
445  42  STO
446  12  12
447  00  0
448  42  STO
449  13  13
450  00  0
451  42  STO
452  14  14
453  00  0
454  42  STO
455  15  15
456  01  1
457  42  STO
458  02  02
459  01  1
460  04  4
461  42  STO
462  01  01
463  76  LBL
464  85  +
465  43  RCL
466  00  00
467  85  +
468  01  1
469  95  =
470  42  STO
471  06  06
472  73  RC*
473  00  00
474  65  ×
475  73  RC*
476  06  06
477  95  =
478  34  √X
479  35  1/X
480  65  ×
481  43  RCL
482  03  03
483  65  ×
484  43  RCL
485  05  05
486  95  =
487  72  ST*
488  01  01
489  69  OP
490  20  20
491  69  OP
492  31  31
493  69  OP
494  22  22
495  43  RCL
496  02  02
497  22  INV
498  67  EQ
499  85  +
500  00  0
501  42  STO
502  06  06
503  00  0
504  42  STO
505  02  02
506  02  2
507  04  4
508  42  STO
509  00  00
510  01  1
511  04  4
512  42  STO
513  01  01
514  76  LBL
515  75  -
516  43  RCL
517  27  27
518  69  OP
519  04  04
520  43  RCL
521  04  04
522  69  OP
523  06  06
524  43  RCL
525  01  01
526  85  +
527  01  1
528  95  =
529  42  STO
530  05  05
531  43  RCL
532  03  03
533  75  -
534  73  RC*
535  01  01
536  75  -
537  73  RC*
538  05  05
539  95  =
540  72  ST*
541  00  00
542  43  RCL
543  26  26
544  69  OP
545  04  04
546  73  RC*
547  00  00
548  69  OP
549  06  06
550  98  ADV
551  69  OP
552  22  22
553  43  RCL
554  02  02
555  22  INV
556  67  EQ
557  78  Σ+
558  22  INV
559  86  STF
560  03  03
561  22  INV
562  57  ENG
563  91  R/S
564  76  LBL
565  78  Σ+
566  43  RCL
567  26  26
568  69  OP
569  04  04
570  73  RC*
571  01  01
572  69  OP
573  06  06
574  98  ADV
575  69  OP
576  30  30
577  69  OP
578  31  31
579  61  GTO
580  75  -
```

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Parasitic Oscillation In Solid-

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In transistor RF power amplifiers, parasitic oscillation can occur in three basic forms; each can be caused by several different phenomena. Remedial measures for one cause generally are ineffective against other causes. The subject is complicated, and cures may be difficult, but the reason for oscillation need not be mysterious.

Introduction

Spurious oscillation of transistor RF power amplifiers is a long-standing problem. In general, oscillation of any amplifier is caused by unintended interaction between the output of one stage and the input of that stage or another stage. Preventing or curing such oscillation is particularly difficult in RF power amplifiers using bipolar junction transistors. This is because (1) there are many different possible modes of input-output interaction (many more than in vacuum-tube amplifiers) and (2) RF power amplifiers are usually required to operate without oscillation and without damage over an enormous range of load conditions never demanded of other types of power amplifiers, *e.g.,* 30:1 SWR, at all angles of reflection coefficient.

Even though an amplifier may operate normally under near-nominal load, it can be very difficult for the designer to ensure normal operation with any arbitrary *load* in a 900:1 range of impedance magnitude and ranging from almost purely inductive, through any R-L combination, through purely resistive, through any R-C combination, to almost purely capacitive. The difficulty is compounded by the fact that several different modes of oscillation could be encountered in the same amplifier, either simultaneously or under sets of operating conditions not greatly different, one from another.

Finally, different types of oscillations, which arise from entirely different causes, can display similar external symptoms. Hence, "cookbook" solutions can sometimes be effective, can be ineffective, or can even exacerbate the situation. This state of affairs has resulted in an aura of mystery surrounding the subject. The subject need not be mysterious, although it certainly is complicated and difficult. The design engineer should understand in detail the mechanisms of the various types of oscillation and the appropriate ameliorative techniques for each. Then he will be able to identify the cause(s) and to apply the appropriate remedy(s).

A thorough treatment of all causes of oscillation could be a book-length treatise. Here we shall treat in summary form several types of oscillation which are reasonably well documented elsewhere and shall treat in detail one type which has not been described previously.

Causes of Oscillation

Feedback in a Class A or AB Amplifier

Conceptually simplest is oscillation caused by unintended linear-component feedback paths in a Class A or AB amplifier. Here, the transistors are conducting throughout the RF cycle, and the well-known techniques of linear circuit analysis can be applied. (Strictly speaking, the transistor parameters change somewhat during the RF cycle, but an "averaged" set of parameters can be used.) Examples of such feedback paths are C_{CB} around one stage, or interstage coupling *via* the V_{CC} supply, the V_{BB} supply, or the ground return, or magnetic coupling between inductors.

Capacitive coupling which is negative at one frequency can easily become positive at another frequency, because the phase of voltage at a circuit node can change rapidly with frequency if the node impedance is determined by one or more inductors and one or more capacitors. That is almost always the case, if one accounts for parasitic inductances and capacitances, in addition to the components intentionally wired into the circuit.

Cure for This Type of Oscillation

The cures for this type of oscillation primarily involve considerations of physical construction. They include:

(a) better grounding,
(b) better power-bus bypassing,
(c) electrostatic shielding,
(d) magnetic shielding (closed high-conductivity loops between coupled inductors),
(e) better layout to reduce parasitic inductance or capacitance, and
(f) adding resistive loading to damp remaining undesired L-C resonances (a ferrite bead is effectively a low-value inductance shunted by a resistor).[1,2,3]

If the oscillation is not of large enough amplitude to drive the transistors into violently nonlinear operation, the oscillation will appear as a second signal superimposed on the desired (*i.e.,* arithmetically added to the desired signal). The oscillation may be at a frequency higher or lower than the intended operating frequency.

The oscillation may exist without a signal being applied, or it may be initiated by applying a signal. It may continue or cease after the signal is removed. It may occur only within a certain range of power-supply voltages. These aspects of amplifier behavior depend on the variations of the small-signal parameters of the transistor(s) with changes of instantaneous voltage and current. (For example, the instantaneous values of voltage and current may

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attain the values needed to sustain oscillation only when a signal is applied.)

Parametric Oscillation

Parametric oscillation is a nonlinear effect in which the mechanism supporting the oscillation is not feedback from output to input, but is pumping of a nonlinear reactance (e.g., C_{CB}) by a source voltage at a multiple of the oscillation frequency; thus the oscillation is at a subharmonic of the circuit operating frequency, *e.g.,* f/k, where f is the operating frequency and k is an integer. (See references 4 through 9A.)

Parametric oscillation is seen on a spectrum analyzer as a set of spurious spectral components flanking the carrier signal, at separations of f/k. In addition, there can be a set of low-frequency spectral lines, at frequencies nf/k, where n is an integer equal to or larger than one. If waveforms *(e.g.,* V_{CB}) are observed on a time-domain oscilloscope, parametric oscillation is seen as a sequence of different-size and/or different-shape waveforms of individual RF cycles. The cycles occur at the frequency f, and the sequence repeats every k cycles. This is referred to as k^{th}-order subharmonic oscillation.

Cure for Parametric Oscillation

One cure for subharmonic oscillation is to reduce the nonlinearity of the nonlinear reactance. For example, reverse-based semiconductor junctions can be operated so as to avoid the low-voltage region where the nonlinearity is strongest. Usually this involves a sacrifice of power efficiency.

Another cure is to add resistive damping (see Section "Preventing and Curing the Oscillation"). This too, involves a sacrifice of efficiency. Another way to reduce the nonlinearity of the capacitance is to add linear capacitance in parallel with it, *i.e.,* to "swamp" the nonlinearity. Although this can be possible at low frequencies, it becomes increasingly difficult to do at high frequencies, where the junction capacitance is already more capacitive than is desired at that point in the circuit.

Interaction Between Output Circuit and Base-Bias Circuit

The DC component of base current (strictly, the base current averaged over one cycle of the carrier frequency) is affected by the voltages and currents imposed on the transistor collector by the output circuit. Depending on the impedance of the base circuit, such a variation of base current may affect the base bias in subsequent cycles. That, in turn, may affect the collector current. That, in turn, will affect the output circuit. That may affect the collector current in a subsequent cycle, which would affect the base current, which would affect the base bias, which would affect the collector current. Depending on the transistor characteristics, the impedance of the base-bias circuit, and the impedance of the collector load circuit, one may have the necessary ingredients for sustained oscillation.[10,11]

The crucial ingredient is *memory* in the circuit, so that the operation in one RF cycle is able to influence the operation in a *subsequent RF cycle.* Here, the memory resides in the inductance of the base circuit (and in the bias-voltage bypass capacitor, if present) and in the energy-storing property of the collector load network.

The appearance of this type of oscillation is similar to that of parametric oscillation, except that the oscillation frequency need not necessarily be an integer subharmonic of the carrier frequency. (If k is large, it may be difficult to tell whether k is, in fact, an integer.)

Cure

The usual cure for this type of oscillation is to add resistive damping in the base-bias circuit, as a resistance in series with the choke that connects the base to its bias voltage (often zero volts). Alternatively, a lossy ferrite bead may be slipped onto the base choke lead, at the ground end.

Considering the mechanism which gives rise to the oscillation, one would expect that it would help to use as low a value of base inductor as possible (to reduce the memory from one cycle to another), and as low a value of base-bias-source bypass capacitor as possible, for the same reason. (Or alternatively, use extremely large values of L and C?)

Similarly, if the collector output circuit has low loaded Q, there will be little memory from one cycle to the next, hence little effect on the present cycle from things which occurred in previous cycles. (Alternatively, one could attempt to use such large values of loaded Q that the excitation of the network by the transistor in one cycle would cause only a small change in the voltages and currents in the network in that cycle, and hence only a small effect would be exerted back on the transistor in the next cycle?)

This author feels that the key to a successful strategy may reside in avoiding the presence of similar time constants in the base-bias circuit and the envelope response of the collector load network.

Interaction Between Output And Input Circuits via Thermal Feedback

Activities occurring in the amplifier output result in a certain amount of power dissipation in the transistor. This affects the transistor temperature to an extent determined by the thermal properties of the transistor and its heat sink. The time-scale of the temperature variation depends on the same factors. The transistor temperature, in turn, affects the RF electrical properties of the transistor. That, in turn, affects the RF performance, which may affect the temperature. Here we see another possible mechanism for interaction. The evidence for thermally induced oscillation is given by Muller.[12]

If thermally-induced oscillation occurs, one would expect that low thermal resistance of the transistor and its heat sink would be helpful. Additionally, one would expect that a high-efficiency amplifier (*e.g.,* Class E[13]) would cause less power dissipation to occur, and hence less heat to be applied to the thermal system, resulting in less thermal response.

Interaction Between Output and Input Circuits via Base Stored Charge

Another way in which feedback can take place, which appears not to have been reported previously, involves charge storage in the base region of a bipolar junction transistor. Consider an RF power amplifier in which the active device is a bipolar junction transistor which saturates during at least part of the time that the transistor is conducting collector current (many contemporary transistor power amplifiers operate this way, intentionally or unintentionally). Let the base drive be supplied from a current source, so that the drive current will not change if the transistor input impedance or input voltage changes as a result of the oscillation. (This makes the analysis simpler and does not affect the form of the final result. At the end of this section we consider the case of the drive being obtained from a source which is not a current source). The power-amplifier circuit is shown in Figure 1.

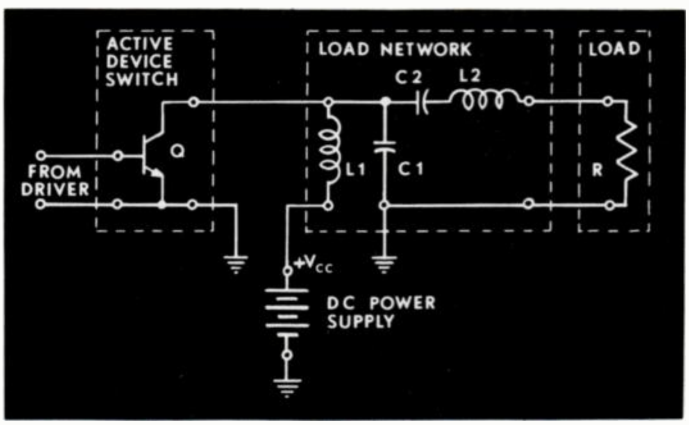


Figure 1. Power-amplifier circuit.

The transistor remains saturated during the transistor storage time. The storage time depends on the base current and the collector current, and can be predicted accurately from explicit analytical equations[14].

Suppose that a subharmonic oscillation is present, as shown in Figure 2, an oscilloscope photograph of the V_{CE} waveform. Note that, in different cycles of the waveform, the transistor is saturated for time intervals which are longer and shorter than would be the case in the absence of oscillation. (This example of subharmonic oscillation has $k \approx 20$; *i.e.,* the oscillation frequency is $\approx 1/20$ of the carrier frequency.)

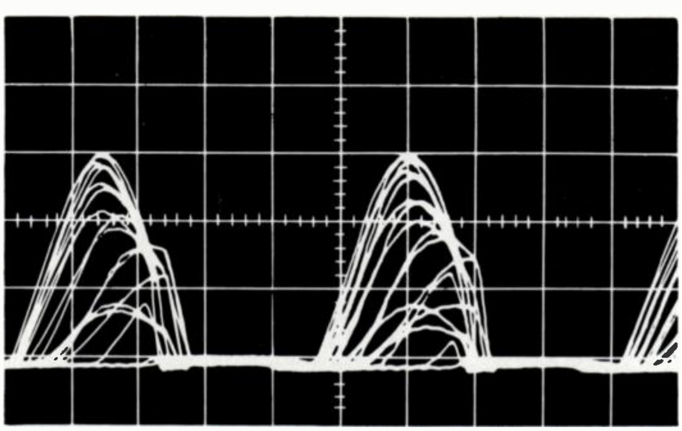


Figure 2. Subharmonic oscillation.

Consider what happens to the currents in L1 and L2 when the transistor "on" time is longer than the average value: the currents build up to higher values at the end of the "on" time than would otherwise be the case.

During the next conduction interval of the transistor, the transistor will conduct a larger collector current than would otherwise have been the case (the transistor conducts the current from L1 and L2). Because the collector current is larger, the storage time will be shorter, causing the total "on" time of the transistor to be shorter. The effect of this shorter "on" time is to cause the currents in L1 and L2 to be smaller at the end of the transistor "on" time than had been the case in the previous cycle.

Therefore, the collector current during the *next* conduction interval will be smaller than had been the case during the interval just described. The smaller collector current in the next conduction interval results in a longer storage time, extending the transistor "on" time, bringing the circuit back to the starting point of the cycle of subharmonic oscillation. Let I_L be defined as $I_{L1} + I_{L2}$.

The Mathematics of Oscillation

Expressing mathematically the sequence just described, oscillation can take place if:

$$\left(\frac{dI_L}{dT_S}\right)_n \bullet \left(\frac{dI_{C(n+1)}}{dI_{L(n)}}\right) \bullet \left(\frac{dT_S}{dI_C}\right)_{n+1} \bullet \left(\frac{dI_L}{dT_S}\right)_{n+1} \bullet$$

$$\left(\frac{dI_{C(n+2)}}{dI_{L(n+1)}}\right) \bullet \left(\frac{dT_S}{dI_C}\right)_{n+2} \geq 1, \qquad (1)$$

where the subscripts n, n + 1 and n + 2 refer to three successive cycles of the carrier frequency.

To a first approximation, the derivatives are the same in all cycles of the carrier waveform. Hence,

$$\left(\frac{dI_L}{dT_S}\right)^2 c^2 \left(\frac{dT_S}{dI_C}\right)^2 \geq 1. \qquad (2)$$

were $c \doteq dI_{c(N+1)}/dI_{L(n)}$. Taking the square root of both sides of (2) we obtain the condition for oscillation as

$$\left|\left(\frac{dI_L}{dT_S}\right) c \left(\frac{dT_S}{dI_C}\right)\right| \geq 1. \qquad (3)$$

The magnitude sign is applied to the left side of (3) because all three factors in (2) are squared.

The three factors are evaluated as follows:

$$dI_{L1}/dT_S = (V_{CC} - V_{CE(sat)})/L1 \qquad (4a)$$

$$dI_{L2}/dT_S \approx (V_{CC} - V_{CE(sat)})/L2 \qquad (4b)$$

$$dI_L/dT_S \approx (V_{CC} - V_{CE(sat)})(1/L1 + 1/L2) \qquad (4c)$$

$c < 1$, *dependent on circuit element values, and* (5)

$$dT_S/dI_C \approx -1/2fh_{FE}I_{B(off)} \qquad (6)$$

where f is the operating frequency and $I_{B(off)}$ is the average magnitude of the base turnoff current during the storage time. (In (6), $1/2fh_{FE}$ is the base charge required to support a unit increase of collector current (I_C) for a time duration of 1/2f [a half-cycle of the carrier frequency].) Substituting (4c), (5) and (6) into (3), we obtain the approximate condition for oscillation:

$$(V_{CC} - V_{CE(sat)})\left(\frac{1}{L1} + \frac{1}{L2}\right) \bullet c\left(\frac{1}{2fh_{FE}I_{B(off)}}\right) \geq 1. \qquad (7)$$

Experimental observations by this author show that there is less tendency toward this type of subharmonic oscillation if $I_{B(off)}$ is increased, if V_{CC} is decreased, and if L1 is increased, all in accordance with (7).

Increasing $I_{B(off)}$ can increase the risk of base-emitter junction reverse breakdown[16], decreasing V_{CC} can increase the risk of parametric oscillation involving the nonlinear C_{CB}, and increasing L1 might yield a combination of time constants of the base and collector circuits which might lead to oscillation involving feedback from output circuit to base-bias circuit.

Similar analyses could be performed for oscillation of orders other than K = 2. It might be useful to apply the mathematical methods of Penfield[15] in further analyses.

We shall now show that source admittance contributes to stability. If the input drive is not obtained from a current source, the "on" and "off" drive currents will vary from one cycle to another as the base-voltage waveform varies from one cycle to another (the duration of the "on" interval is the most strongly varying parameter of the base voltage waveform, but the amplitudes of the positive and negative portions of the waveform also vary somewhat). The base-voltage waveform, in turn, is affected by the collector current and the base "on" and "off" drive currents (this is a consequence of the storage time discussed above; the base-emitter voltage remains positive during the storage time).

Following the sequence of events as was done in the discussion above, but examining the effects on the base drive currents, it can be seen that source admittance contributes to stability and that $r_{bb'}$ and base and emitter lead inductances contribute to instability.

Let $r_{bb'}$ and the base and emitter lead inductances be zero, and let the driving source be a zero-impedance (infinite-admittance) voltage source. Then the transistor "on" time is controlled solely by the driving source, and is not at all influenced by variations of the current in the load. Then the subharmonic oscillation described above cannot exist.

Other Possible Modes of Subharmonic Oscillation

These can occur if the transistor *does not saturate* at any time during the RF cycle. The governing parameters for these modes of oscillation are C_{CB}, f_T and drive source impedance. Stability is enhanced by low C_{CB}, high f_T and low drive-source impedance. (High f_T can contribute to *instability* in an amplifier which is on the verge of oscillating because of ordinary small-signal linear-analysis feedback criteria.)

Lohrmann[7] and this author have both noticed that a chain of high-efficiency switching-mode amplifier stages is more prone to subharmonic oscillation than is a single resistively-loaded stage. The reason is not yet known in detail. This author suspects an interaction involving the nonlinearity and charge-storing nature of the emitter-base junction which is a load on the preceding stage, *via* a mechanism such as that discussed above.

This author has found the following to be an effective cure: (1) set up the interstage network (C1, L2, C2 of Figure 1) so that the collector voltage swings below ground at the end of the "off" interval and (2) provide a collector-emitter commutating diode to carry the reverse-polarity collector current and protect the base-emitter junction from excessive reverse voltage.

Load Current Drawn Through Base-Collector Junction

If the amplifier must tolerate, without oscillating, high load SWR (*e.g.,* up to 30:1), one must attend to the abnormal effects which can occur with very low values of load resistance. Depending on the amplifier design, it may then be possible for the collector to swing negative with respect to the emitter. Depending on how negative the base is at that time (and remembering that one must pay attention to the emitter-base reverse-voltage rating[16]), the base-collector junction may be forced into forward conduction. Then there is a *direct connection* between the input and output circuits.

Now consider the charge-storing capability of the base-collector junction, and we see, again, the ingredients for possible oscillation: coupling between input and output circuits, and memory inherent in the junction charge storage and in the inductors and capacitors in the input and output circuits.

This mode of oscillation has been noted briefly by three authors[17-19], but without explanation of the mechanism. A reasonably accurate mathematical analysis is possible, but this author is not aware of any such analysis having been published.

This author has suggested[17] and used a commutating diode across the transistor emitter-collector terminals to carry the load current if the collector voltage swings below that of the emitter. This can protect the emitter-base junction from damage, in amplifiers for which appropriate diodes are available (amplifiers of low-enough power rating, operating at low-enough frequencies). However, one then substitutes the charge-storage characteristic of the protection diode in lieu of that of the base-collector junction, and *oscillation* might still be possible, even though one has removed a possible destructive-failure mode.

When observing voltage waveforms at the base and collector, remember that the voltages are being observed at the transistor external terminals; the actual junction voltage differs from the observed voltage by the iR and Ldi/dt voltage drops in the internal leads from the chip to the external observing points. These voltage drops can be significant[16].

Preventing and Curing The Oscillation

Now that we have reviewed *some* of the possible reasons for oscillation in transistor RF power amplifiers, we can see why the subject has acquired such an aura of "mystery." *In principle,* there need be no mysteries: electronic components obey known physical laws and there is a physical reason for everything that happens.

But standing between that principle and the engineer, who is responsible for producing a reliable product at a reasonable price, is the limited time available to solve the problem, with an apparently unlimited number of possible modes of oscillation. Many of those modes of oscillation depend strongly on nonlinear effects. That makes them more difficult to analyze quantitatively than the small-signal feedback-type oscillations which are amenable to linear circuit analysis. Empirical work (slow and tedious) must then take the place of *a priori* design.

Follow the Scientific Method

What is the hard-pressed engineer to do? First, eliminate the avoidable causes of oscillation by using good construction techniques[1,2,3]. To cure the remaining causes of oscillation, follow the scientific method. Be quantitative when you can, to have some assurance that your "cure" is based on scientific fact, rather than on a lucky coincidence which may not be repeated in production. If you can't be quantitative *(e.g.,* because the mathematics is too complicated), be scientifically qualitative: observe the symptoms, postulate hypotheses, and test the hypotheses by making controlled experiments. Then apply the appropriate cure(s). Lastly, verify that the "cure" works over a suitable range of the pertinent circuit-element parameters, including temperature.

Damping

When resistive damping is called for, a series R-C combination can be connected from collector to base or from collector to ground, or a resistor can be connected in parallel with the collector DC feed inductor. A lossy ferrite bead slipped onto the lead of the collector feed inductor can provide damping if the inductor impedance is low enough at the frequency for which damping is needed, but a high impedance in that inductor will effectively remove the bead from the circuit. A resistor or a lossy ferrite bead in series with the base can be helpful in supplying damping, but can be harmful by adding lead inductance.

Identify the Type of Oscillation

To identify the type of oscillation, observe the output-stage collector-voltage waveform with an oscilloscope. If you can see an almost-normal carrier frequency waveform (the same size and shape on every cycle), with a smaller-amplitude different-frequency oscillation superimposed, first verify that the "oscillation" doesn't remain when the power is removed. (Don't laugh — this author once spent some time tracking down an "oscillation" which turned out to be scope-probe pickup from a nearby FM broadcast transmitter.) If the oscillation is genuine, it is probably the linear-circuit feedback-type oscillation. If the oscillation is at a frequency higher than the operating frequency, resistive damping should help. You may be able to change the impedances in the base and collector circuits to eliminate the oscillation, but it may return at a different load impedance or power-supply voltage. Collector-base neutralization may help.

If the carrier-frequency waveform is normal, but the smaller-amplitude oscillation is at a lower frequency, there may be interstage coupling *via* the V_{CC} or V_{BB} (if used) supply. Try operating the higher-power stage(s) and the lower-power stage(s) from separate power supplies, to establish whether the coupling is *via* the DC power bus.

If the size and/or shape of the individual RF cycles changes from one cycle to the next, and the cycle repeats in a few (e.g., five or fewer) RF cycles, the oscillation is likely to be parametric or one of the types involving base charge storage. If the oscillation cycle repeats over many cycles of RF, it is more likely to involve the base-bias circuit. Try changing the value of the base-feed inductor or the V_{BB} bypass capacitor (if any). If the oscillation period is directly proportional to the inductor (or capacitor) value, you have found a likely culprit.

One stabilizing measure sometimes seen on circuit diagrams is a series R-C damper connected across the V_{CC} bypass capacitor. This author cannot comment authoritatively on what mode of oscillation is being suppressed, because he has not observed that specific amplifier personally, and the circuit designer didn't say. One could hypothesize another mode of oscillation comparable to the one involving the base-bias network, but involving only the transistor and its output network. This hypothesized mode would be more likely to occur the more strongly the base is driven. One could observe the voltage across the V_{CC} or V_{BB} (if any) bypass capacitors.

Suppose one observes a low-frequency waveform, in synchronism with the modulation of the shape and/or amplitude of the RF cycles of collector-voltage waveform. Is that a *cause* of the oscillation, or an *effect* of it? It depends on the particular case. If the waveform is a *cause,* a damping network connected across the bypass capacitor can help to suppress the oscillation.

Conclusions

1. The problem is complicated: there are many possible causes of oscillation, many of which involve nonlinear properties of the transistor. A given amplifier might oscillate in several different modes, under different sets of conditions.
2. Eliminate the avoidable modes of oscillation by using good construction techniques.
3. For every remaining oscillation, there is a cause. Armed with some knowledge and persistence, you can determine the cause and probably can cure the oscillation. If other oscillations are found, you can probably cure them, too. Good luck! □

Postscript

The author welcomes correspondence and exchange of information on this subject.

References

A complete set of the 20 detailed references is available from the *author* by writing: Nathan O. Sokal, Design Automation, Inc., 809 Massachusetts Ave., Lexington, MA 02173. Please include SASE.

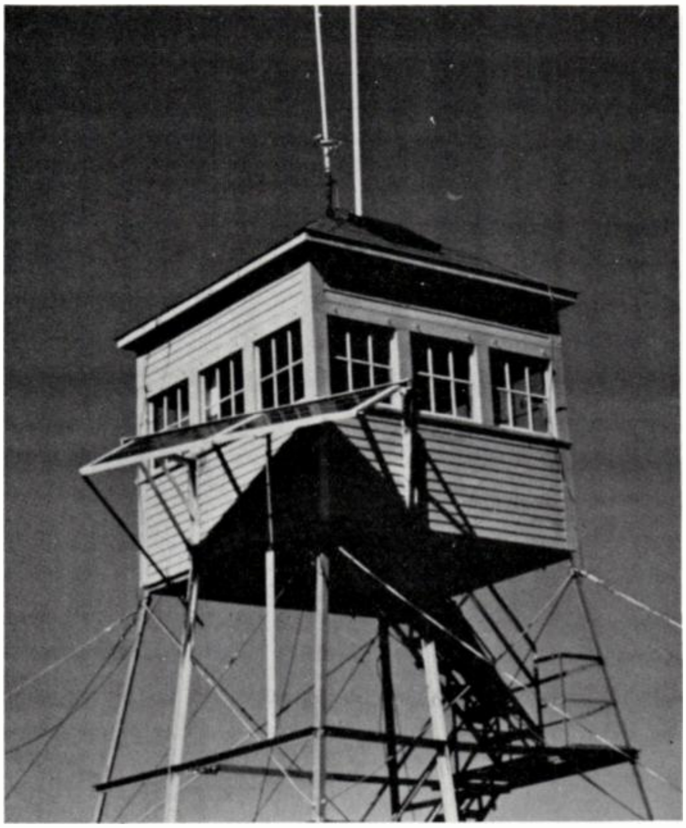
Notice

The Class E circuit is protected by U.S. Patent 3,919,656 and patents pending. Permission of the author is required before one may build a Class E circuit, even for experimental purposes. Licenses to build Class E amplifiers for experimental evaluation can be obtained, at no cost, by contacting N.O. Sokal at the above address. Commercial licenses are available by arrangement.

Acknowledgement

This material was first presented at the 1980 ELECTRO conference in New York in April. Kind permission for utilization of this information was provided by Electronic Conventions, Inc.

r.f. design does not normally solicit or accept manuscripts that have previously appeared in any published form or forum. However, due to the importance and relevance of this topic to the RF designer and the expanded audience it can serve, its been reprinted (and edited) herein. Editor



Solar-Electric Power

Solar cell operation and interconnection with storage batteries and a regulator as part of a remote-site communications application.

M.F. "Doug" DeMaw, ARRL, Inc., Newington, CT

Solar-electric power? How can this space-age power source be used by the RF engineer? Before this is answered by means of practical suggestions and examples, let's talk briefly about the sun and the abundance of energy it radiates for terrestrial use.

Power from the Sun

A radiant-energy nuclear power plant — the sun — exists some 93 million miles from the earth. This magnificent power source generates radiant energy at the rate of 3.8 x 10^{23} kW. Even though less than one bilionth of this energy reaches our planet's atmosphere, and of that amount only 60 percent impinges on the earth's surface (1.1 x 10^{14} kW) because of atmospheric filtering, ample energy remains for use by man. In practical terms we strikes a square meter of surface on a day of occluded sunshine. From this information we extrapolate that 10 hours of bright sunshine over the Gulf of Mexico can deliver sufficient energy to power the entire USA for six months. Comparatively speaking, our present electrical generating capability in the USA is roughly 5 x 10^8 kW, but only half that amount is utilized. This can be equated to the sun's energy striking a 1000 square miles of the earth's surface on a day of bright sunlight.

The author expresses his gratitude to the sales and engineering personnel at Solarex Corp. and Solar Power Corp. for their assistance in providing technical literature concerning solar arrays.

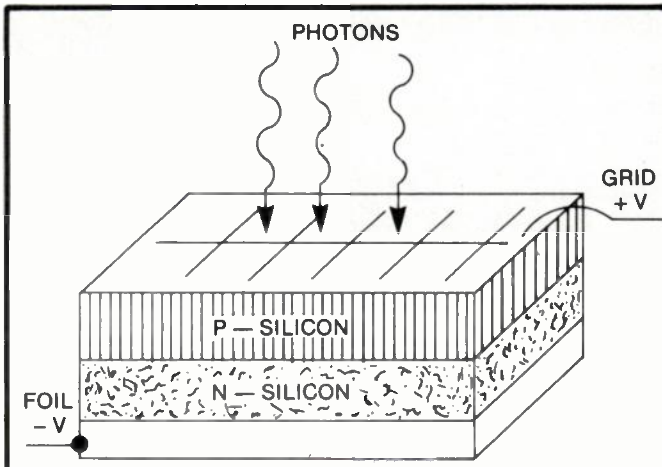


Figure 1. Structure of a single solar-electric cell.

The foregoing illustrates clearly that solar-electric power is no novelty. It is a practical source of power, even in regions where there are days when sunshine does not prevail.

Harnessing the Sun's Power

How can we put radiant energy from the sun to work? Various commercial entities have been using solar-electric power for quite some time. Notable among the applications are power sources for remote railroad signaling devices, land-mobile service vhf and uhf repeaters, spaceagency satellites and off-shore oil-drilling rigs. The technique is *simple* and *reliable.* Depending on the application, solar-electric power is cost-effective.

Arrays of solar-electric silicon cells are used to convert the sun's energy into dc voltage. Individual cells are connected in series to provide the overall output voltage desired. Typically, an array is structured to deliver up to 36 volts dc. The amount of current available is dependent upon the diameter or area of the individual cells (some are rectangular). Roughly 600 mA of current can be taken from a 55-mm cell. A 22-mm cell will yield 100 mA of current. A large cell of 89 mm can deliver 1.5 amperes of current in bright sunlight. Output voltage from any size solar cell is 0.5.

Figure 1 (p. 41), illustrates the structure of a single solar cell. A grid of wires traverses the top surface of the cell to provide electrical contact for the positive terminal. The negative lead connects to a metallic coating on the bottom of the cell. This coating serves also as a current collector for the cell. The cell is a p-n wafer type of diode which is typically 0.01 to 0.02 inch thick. When a photon from the sun strikes near the p-n junction a negative- and positive-charge pair are produced. The electron will move toward the n material and the hole will migrate to the p material. The resultant electricity can be made to flow through an external load to perform useful work.

A common type of solar-electric array contains 36 cells, series-connected, to power a system that operates from 13.6 volts. At peak sunlight, and without a load on the solar panel, some 18 volts of dc voltage can be measured, as shown in Figure 2.

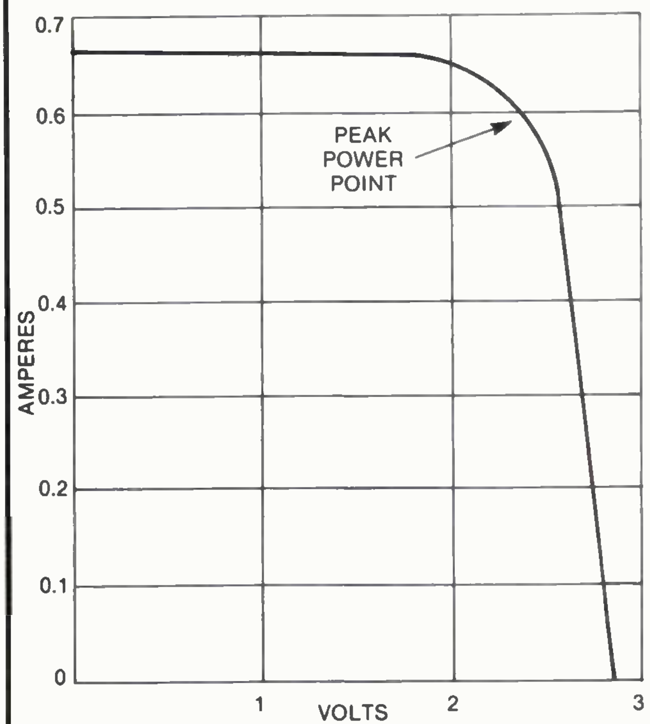


Figure 3. Peak-power curve showing voltage versus current.

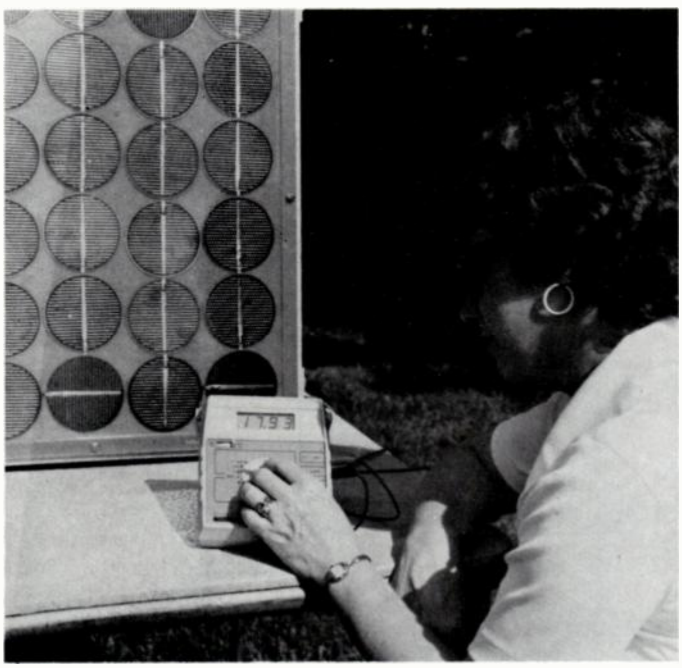


Figure 2.

A curve of voltage versus current is shown in Figure 3. The peak-power point is seen at the knee of the curve. Each of the five cells represented delivers 0.5 volt at 0.6 ampere. The curve was drawn from a Solar Power Corporation model 1200 assembly.[1] Each of the cells has a diameter of 57 mm. Roughly 0.16 ampere can be taken from each square inch of cell surface.

The current state-of-the-art illustrates the relatively inefficient manner in which solar cells operate: Only 11 to 12 percent of the total solar energy which hits the surface of a cell can be delivered to an external load. Yet, the technique is entirely practical.

Energy Storage

It is possible to utilize a solar panel by feeding its output directly to the equipment it powers. But, this means that the equipment can't operate during dark hours. A truly practical system uses storage batteries as a buffer system, thereby permitting round-the-clock and dark-day operation.

Batteries used in a solar-electric power system should provide a low self-discharge profile. Lead-antimony types should not be used because they have a self-discharg characteristic of 7 to 8 percent of the rated capacity per month. This can degrade to as much as 40 percent per month with age. Conversely, most automotive lead-acid batteries are satisfactory, especially the sealed "lifetime" varieties. NiCads are excellent also. They are more tolerant to overcharging than is true of most other batteries. A less desirable feature of NiCad batteries is the requirement that a 15 percent greater charging voltage over discharge voltage is needed: There is only a 5 percent differential with lead-acid batteries.

Although numerous automotive batteries can be used in parallel, it is possible to purchase lead-acid photovoltaic batteries with ratings as great as 1008 ampere hours. The choice will depend mainly on the size of the system required.

Regulating the Voltage

A basic solar-electric system is illustrated by the block diagram at Figure 4. D1 is necessary to prevent the stored voltage from bleeding back through the solar panel during dark hours: When no illumination from the sun is available, the solar cells function as a string of forward-biased diodes. D1 allows charging current to flow to the battery, but prevents the battery voltage from being discharged into the array. A Schottky-barrier diode is excellent since it has a 0.3-volt forward-voltage drop. Silicon diodes can be used, but they exhibit a 0.7 to 0.8-volt barrier voltage. Additional solar cells would be needed if silicon diodes were used, in order to compensate for the voltage drop.

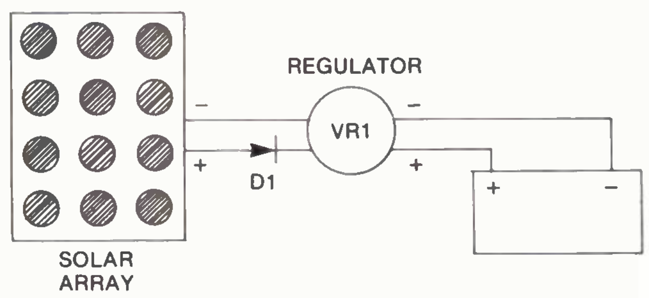


Figure 4.

A regulator is recommended, as shown in Figure 4, to prevent the storage batteries from being overcharged: A subsequent loss of electrolyte would result from constant overcharging.

An ideal regulator consumes no power from the system. Since an "ideal" regulator does not exist, a good compromise is a "floating" type of regulator. Such a device

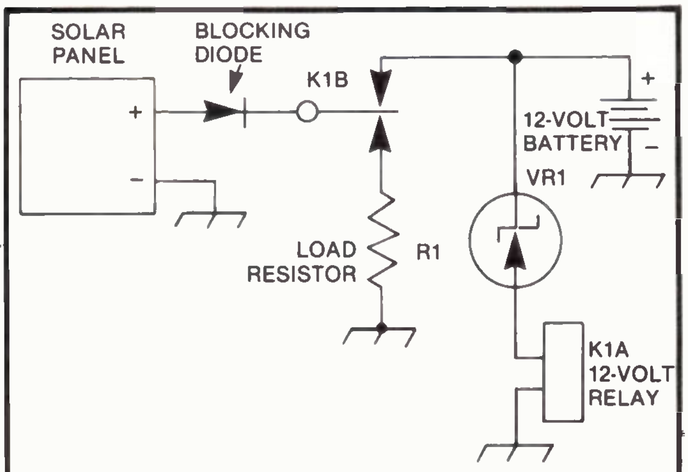


Figure 5. A "go-no-go" type of regulator.

can be built to proportion the array output while consuming only 0.03 ampere-hour per day. A regulator of this variety permits just enough current flow to keep the batteries fully charged. The remainder of the power is dissipated in a load resistor, as seen in Figure 5. The illustration shows a go-no-go regulator which uses a relay and a Zener diode. VR1 is selected in accordance with the dc resistance of the field coil of K1A. VR1 and K1A cause contact closure when the battery voltage reaches 15. R1 then dissipates the power from the solar array. When the battery voltage drops to approximately 12, the relay is de-energized and the charging cycle resumes.

A practical rule of thumb for using a regulator is: If the generator output exceeds the load requirements by 30 percent, use a regulator. For use below that amount a carefully matched generator-load condition will provide acceptable self-regulation in many instances. A practical example was demonstrated by the author when a 1.5-ampere array was used to charge a 12-volt automotive battery during operation with a communications transceiver (solid-state) which consumed 20 amperes during transmit and 0.7 ampere during receive. In the cw and ssb modes the duty cycle was such that the battery never fell below 11.7 volts. The highest measured level was 14 volts.

It should be said that solar panels will charge batteries even when full sunlight is not present. The current output is proportional to the brilliance of the sun. But on hazy and cloudy days, some charging will occur. On dull days the effect is somewhat the same as applying a trickle-charger to a battery.

Solar-Electric Power and An Application

OK, we've examined the technical aspects of solar-electric power. But, how does this fit into the picture when it comes to use? Consider this application: We need a communications relay station at a strategic point on a high hill or mountain, but no commercial power is available at the chosen site. The cost of having service brought to the location, plus the sometimes excessive rates charged to commercial users, rules out the installation plan. However, utilization of a solar-electric system provides an entirely practical solution to the problem. Since the estimated life span of most solar-electric systems today is 20 years, amortization of the equipment is no problem. In the long term, many dollars can be saved by avoiding commercial power at the site. Furthermore, network-pickup outages will be avoided during power-line failures where the relay is located. Reliability alone is a major benefit to the user.

A less exotic use of solar power in communication can be envisioned when remote pickups are handled at sites where commercial power is not available, and where it is impractical to use the power from an automobile. As one example, let's envision a newsman who is covering a forest fire high in the mountains. He is doing his remote over a period of several days, and does not have access to power for recharging the batteries of his radio equipment. A small solar array can be transported easily. It could be used to keep the newsman available with updates around the clock.

A Practical Commercial Installation

We can best demonstrate the utility of solar-electric power by reviewing what is being done atop Mt. Cardigan in New Hampshire. The Department of Public Works is servicing 800 square miles by means of a uhf fm repeater which is located atop the mountain. It is powered entirely by solar-electric means. Figure 6 (p. 44) contains a photograph of the installation.

There is no back-up gasoline generator at the site, and commercial power is not available. Standby drain for the repeater is 300 mA. During transmit periods the drain is 24 amperes. Normal dc voltage is 12. Transmit duty cycle is 15 percent for an 8-hour day. Operation is 365 days per year. The solar panels (two) each deliver 200 watts of peak power. In full sunlight the pair delivers 14 volts dc at 13 amperes each. This equates to 100 mW/cm^2 at 28° C. The installation was done in

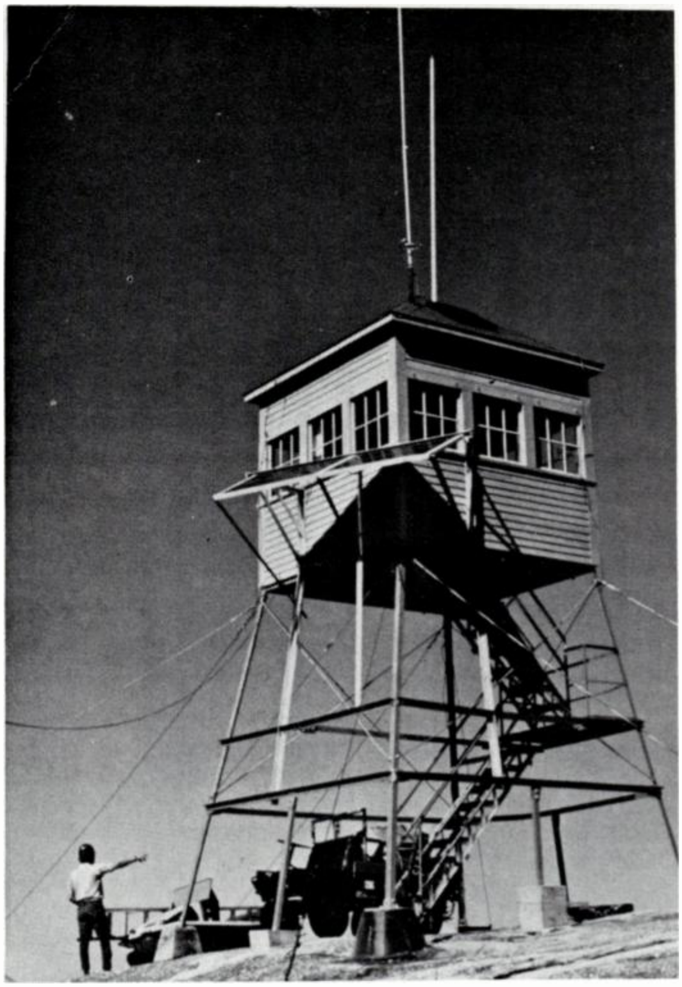


Figure 6. A two-panel array is deployed off the side of this repeater shack atop Mt. Cardigan in New Hampshire.

1975, at which time it cost $7000. This included the system shown in Figure 7. The battery is a 1008-ampere-hour unit. The system has proven reliable, safe and maintenance free to date.

Remote equipment which consumes substantial amounts of power can be powered in the same manner as the Mt. Cardigan repeater. Additional arrays would need to be placed in parallel, and the necessary number of batteries would be parallel-connected also. The equipment used in the solar-electric portion of the repeater was manufactured by Solarex Corp. of Rockville, Md.[2]

Maintenance Procedures

Actually, there is little that needs to be done to keep a solar-electric system running at peak effectiveness. It may be necessary from time to time to clean the ultraviolet stable silicone rubber covering over the solar cells. But, the material is self-cleaning for the most part. The dust and dirt washes away when it rains. Snow and ice do not adhere well to the protective covering of the panels. It is wise, however, to clean the windows during periodic inspections. At the same time the technician should check for water leakage, as water will destroy the cells.

The mounting hardware should be examined periodically to ensure tightness in maintaining the proper inclination

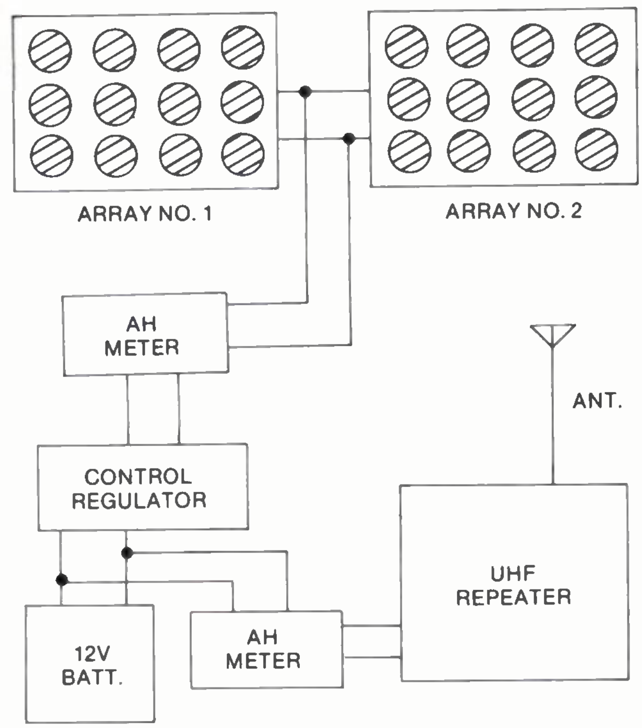


Figure 7. Block diagram of the Mt. Cardigan, NH repeater power system.

angle (45 to 65 degrees). In the northern hemisphere the arrays should face south. The reverse is true of installations in the southern hemisphere.

Conclusion

Perhaps you don't see solar-electric power being used in the immediate future of your communications operation. But, your long-term planning may be enhanced markedly by considering the utility and reliability of this new source of operating power. The cost of commercial power will continue to escalate. A solar array may represent your answer to a number of services connected with your application. □

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1. Solar Power Corp., Div. of Exxon, Woburn, MA 01801.
2. Solarex Corp., 1335 Piccard Drive, Rockville, MD 20850.

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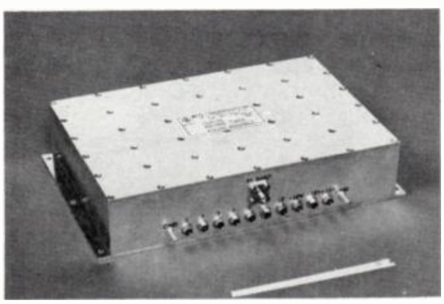
1. *Solar Electric Generator Systems* (operation and design concepts), by Solar Power Corp.
2. D. DeMaw, "Solar-Electric Power and the Amateur," *QST Magazine* for August, 1977, p. 24.
3. D. DeMaw "Solar Electric Power — The Present and Future," *IEEE Electro/78 Preprint*, Session 34.
4. D. L. Pulfrey, *Photovoltaic Power Generation*, by Van Nostrand Reinhold, a division of Litton, NY, NY 10020.

Voltage-Tuned Filter Assembly

The Zeta Labs.' Model 2155-01, voltage tuned filter assembly covers 20 MHz to 510 MHz in 6 bands. Only one RF input and one RF output connector are required through the use of TTL-compatible band selection and recombination. Each varactor-tuned filter has a 1.8 to 1 tuning range and requires a tuning voltage of zero to 10 volts; linearization to within plus/minus 4 percent of a best straight line fit is provided. The 6 dB bandwidth is 5 percent of the center frequency; 50 dB rejection is obtained at 40 percent bandwidth. Integral amplifiers provide 10 dB gain, 11 dB noise figure and 4 dB total variation over the full frequency range. The combined switching/tuning time is less than one millisecond. Input voltages are plus/minus 15 volts and plus 65 volts. Size is 5 in. x 10 in. x 2.5 in.

Contact Zeta Laboratories, Inc., 3265 Scott Blvd., Santa Clara, CA 95051. INFO/CARD #139.



Precision Noise Standard

Micronetics' new Type 15376 now offers a complete thermal noise standard. The compact instrument provides an accurate noise output suitable for noise source calibration and precise noise figure measurements. Its basic design consists of a precision resistive element at a stable elevated temperature, with an oven control of a zero voltage firing proportional type — thus being RFI quiet. A calculated insertion loss of the output transmission line is supplied with each unit.

Features include: high output; accuracy; multi-octave; stability; simple to operate; small compact size; optional rack mounting; thermocouple with front panel connector enables thermal noise standard temperature to be measured with the accuracy of the copper-constantan thermocouple adjacent to its resistive element; fine temperature adjustment accessible from rear panel of the instrument.

Specifications: frequency range — DC-18 GHz; characteristic impedance — 50 ohms; output — −2 dB excess noise ratio; VSWR — 1.25 max.; output connectors — precision type N (male) or APC-7 compatible connector; input power — 115/220V AC; size — 4 1/2" high, 8 1/2" wide, 14 1/2" deep (inches); weight — 8 lbs.

Contact Micronetics, Inc., 36 Oak Street, Norwood, NJ 07648. Circle INFO/CARD #138.

Grid Dip Oscillator

A tube-type grid dip meter for testing radio frequencies, RF chokes, oscillators, antennas, and similar devices, formerly manufactured by Millen, is now available from Caywood Electronics, Inc. of Malden, Massachusetts.

The Millen Model 90651-A Grid Dip Meter is an oscillating frequency meter that determines the resonant frequency of de-energized circuits. Accurate to ±2 percent, it covers a range of 1.7 to 300 MHz with 7 plug-in coils, and provides signal power output for use as an antenna bridge source. A semiconductor electronic voltmeter indicates output amplitude.

With 7 direct reading scales and a universal scale, the Millen Model 90651-A Grid Dip Meter weighs 3 1/2 lbs. and measures 7 1/4"L x 3 1/2"W x 3 3/16"H. The rugged, copper-plated unit and coils store in a sturdy 11 3/8"L x 5 1/8"W x 4"H carrying case. Additional coils for frequencies to 165 kHz and a 3' extension probe are optional.

The Millen Model 90651-A Grid Dip Meter is priced at $180, complete with 7 coils and case; each additional coil is $17.75.

Contact Caywood Electronics, Inc., Wade Caywood, 67 Maplewood Street, P.O. Drawer U, Malden, MA 02148. INFO/CARD #136.

Magnetic Field Intensity Meter

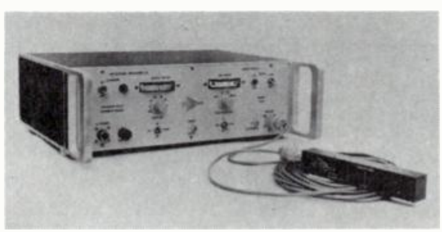
The Electro-Mechanics Company of Austin, Texas, a manufacturer of "state-of-the-art" Magnetic Field Intensity and Antenna systems for seventeen years, is introducing the Model 6640 Magnetic Field Intensity Meter.

Little research, design or prediction concerning low-frequency induction fields can be accomplished without good experimental and measurement instrumentation. The 6640 helps the researcher or designer by providing him with a necessary portion of the important data needed. Using the versatile variable-Mu magnetometer principle, the EMCO 6640 can help determine the effects of existing or man-made fields upon the particular area of endeavor.

Battery-powered, the EMCO 6640 is used for evaluation of the magnetic shielding effectiveness of enclosures, site surveys and general laboratory use. The small probe size permits use as a search tool for detecting localized sources of interference discovered during specification compliance testing.

The EMCO 6640 is particularly suited for EMI specification compliance testing which is described in MIL-STD-462 and MIL-STD-826A. The unique bandwidth and sensitivity of the 6640 also makes it extremely well suited for testing of the scope outlined in FED-STD-222.

This field-proven system differs from typical field intensity units in that the receiver can be directly calibrated because the sensor and receiver are electronically integral units. Also, the use of antenna and cable loss factors are not required for reduction of the output information to field intensity units.



Contact P.O. Box 1546, Austin, TX 78767. INFO/CARD #135.

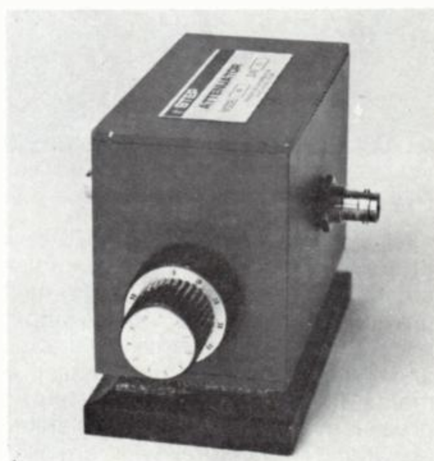
Bench Attenuators

Weinschel Engineering announces the addition of Bench Attenuators to their product line. The new series, 3050, 3051, and 3052, operate over the DC to 2 GHz frequency range and are offered in six standard attenuation ranges/steps (0 to 1 dB/0.1 dB steps, 0 to 10 dB/1.0 dB steps, 0 to 100 dB/10 dB steps, 0 to 110 dB/1.0 dB steps, 0 to 11 dB/0.1 dB steps, and 0 to 140 dB/10 dB steps). Custom attenuation ranges and increments also are available. All models are power rated at 1 watt average, 100 watts peak.

The 3050, 3051, and 3052 series exhibit a low VSWR, 1.20 to 1.35 maximum depending on model; a frequency sensitivity of 0.1 to 0.2 dB up to 2 GHz, and a repeatability of better than 0.1 dB for more than 1,000,000 steps at +75°C. RF leakage is greater than 85 dB below the input signal.

Connector options for the new series are female BNC and type N.

Contact Weinschel Engineering Co., Inc., Gaithersburg, MD 20760. Circle INFO/CARD #134.



Rotary Attenuators

Texscan announces the expansion of its rotary attenuator capability to 12.4 GHz. The RA-80 and RA-81 covers DC-12.4 GHz, offering 0-10 dB in 1 dB steps and 0-60 dB in 10 dB steps respectively with accuracies of ±0.4 dB, 0-10 dB, and ±3 percent 0-60 dB. These attenuators feature low VSWR, and 2 watts power handling capability.

Insertion loss is 0.4 dB to 8 GHz, and 0.6 dB to 12.4 GHz.

The RA-808 and RA-818 are identical packages covering the frequency range of DC-8 GHz. These attenuators are cost effective for those not needing higher frequency performance.

The RA-80 series attenuators use ceramic substrate resistive elements and a unique switching method (pat. pending) which allows Texscan to pass on to consumers a significant price savings.

These units find use in OEM instrumentation, such as signal generators, spectrum analyzers, and receivers as well as general purpose laboratory applications.

Contact Raleigh B. Stelle, Texscan Corporation, 2446 North Shadeland Ave., Indianapolis, IN 46219. Circle INFO/CARD #133.

1-520 MHz Service Monitor

Model 4200, a rugged 1 to 520 MHz Service Monitor has been introduced by Wavetek Indiana. This new test instrument, priced at $5920, includes a lab quality signal generator with a sweep generator function, a frequency measurement system, and an oscilloscope.

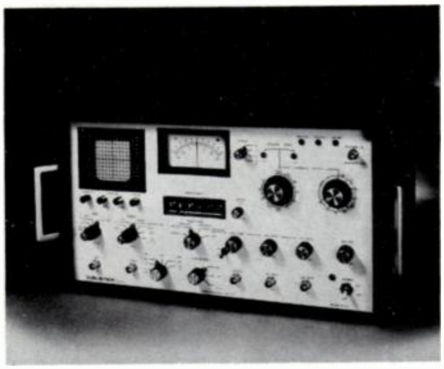
The signal generator section of the Model 4200 is a synthesized signal source with 0.0001 percent (1 ppm) accuracy, 50 Hz resolution, and an output range of 316mV to 0.0316μV. Complex modulation capability allows the generation of simultaneous audible and sub-audible tones (with external tone generator). A sweep generator mode permits testing broadband RF and IF circuits.

The measurement section of the test set has an input sensitivity of 2μV and measures carrier frequency and modulation of externally generated signals — including off-the-air signals.

The carrier frequency is indicated by lever/indicator switches and meter, and the CRT provides both spectrum and modulation information.

The oscilloscope on the Model 4200 may be used independently. It features a three position vertical sensitivity selector and three sweep rates.

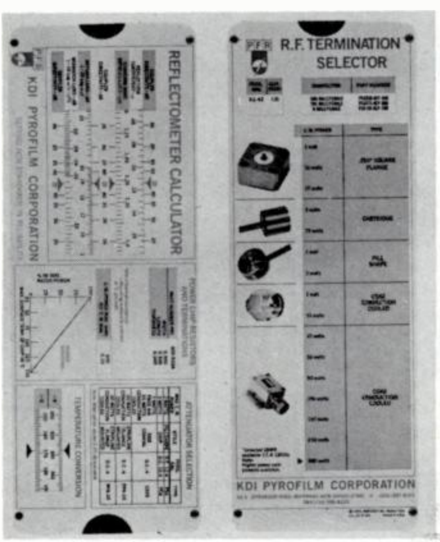
Contact Wavetek Indiana, Inc., 66 North First Avenue, P.O. Box 190, Beech Grove, IN 46107. INFO/CARD #112.



Free Reflectometer Calculator

KDI Pyrofilm is offering a new Reflectometer Calculator, temperature conversion and short form catalog all incorporated in one handy slide selector. The Reflectometer Calculator features an expanded VSWR scale for accurate and easy reading. The RF termination selector offers data on more than 42 most often specified RF terminations.

Contact KDI Pyrofilm Corporation, 60 South Jefferson Road, Whippany, NJ 07981, attention A. Arfin. Circle INFO/CARD #137.



Virgin Ruby Mica Capacitors

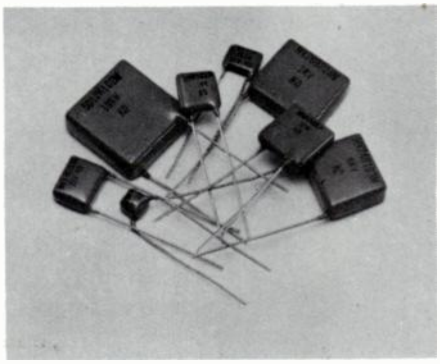
A new product line of ruby mica epoxy encapsulated capacitors is now available from KD Components.

Designed for military and commercial applications, the capacitors are available in a broad selection of capacitance and voltage values, giving design engineers maximum flexibility in selection.

Each capacitor is manufactured using virgin ruby mica, which is known for long term stability and low dissipation factor. Long life is assured by high insulation resistance.

The capacitors are available in ranges from 1 to 250,000 pFd at 100 to 3000 WVDC, tolerances as low as ±1 percent. Temperature range is −65 to +125°C.

Contact Mike Day, KD Components, 3016 S. Orange Ave., Santa Ana, CA 92707. INFO/CARD #132.

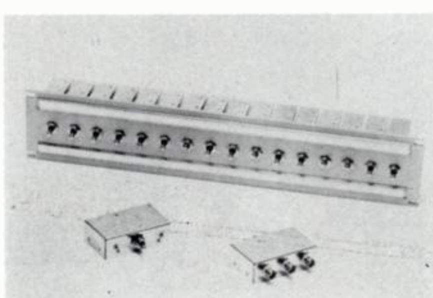


Modular A-B Data Switch

Trompeter Electronics has developed a unique coaxial, isolated ground, low frequency, modular A-B data switch designed to meet the varying needs of the data communications industry. Electrically each module is a manually operated single pole double throw switch with the shield as well as the center conductor switched, and the unused port terminated in a resistive load.

Each module is capable of independent operation. Up to sixteen modules can be mounted in one 3 1/2" x 19" standard rack mount panel. Additionally, these panels can be furnished with extended aluminum mounting brackets for attachment to other flat surfaces.

Contact Trompeter Electronics, Inc., 8936 Comanche Avenue, Chatsworth, CA 91311. INFO/CARD #131.



Broadband Power Amplifier

ENI announces the availability of the Model 2100L Broadband Power Amplifier. This completely solid state unit covers the frequency range of 10 kHz to 12 MHz with more than 100 watts of Class A linear output. The 2100L may be driven to its full power output by all commercial signal and function generators and it will accurately reproduce all input waveforms within its 10 kHz to 12 MHz range.

For applications where extreme linearity is not important the Model 2100L will supply up to 250 watts of power output, without regard to load impedance. It will operate continuously into any load impedance from an open to a short circuit.

Such applications as ultrasonics, RFI/EMI, laser modulation and general laboratory use are typical uses for this versatile unit.

The construction of the 2100L leaves nothing to be desired in terms of ruggedness and reliability. A built in regulated power supply and cooling system permits operation from any 115/230 VAC, 50 to 60 Hz line. A front panel output voltmeter/wattmeter accurately monitors the units output.

Contact Electronic Navigation Industries Inc., 3000 Winton Road South, Rochester, NY 14623. INFO/CARD #140.

Subminiature Fixed Chip Inductors

A series of subminiature fixed chip inductors that resist severe reflow soldering conditions are available from Piconics, Inc. of Tyngsboro, Massachusetts.

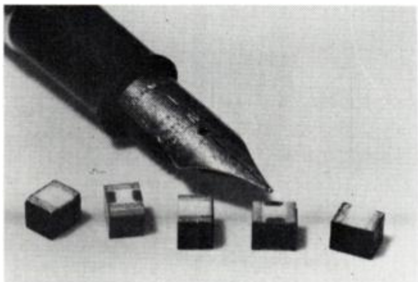
Piconics PG Series Inductors feature a ceramic substrate interlocked into a Dially Phthallate molded case to prevent disassembly during severe reflow soldering conditions. Internally welded for durability, the subminiature rectangular units have special metallization on the contact area to prevent leaching of the plating.

Measuring only 0.125" x 0.125" x 0.160", Piconics PG Series Inductors are produced to typical ±10 percent tolerances with inductance from 0.01

uh to 1.0 mH, and typical Q's from 45 at 200 MHz to 40 at 7.90 MHz; other values can be provided. A PK series with a black epoxy case is also available.

Piconics PG Series Inductors are priced at $10.74 each (1 to 24); PK Series at $6.25 (1 to 24), with quantity discounts.

Contact Piconics, Inc., 20 Cummings Road, Tyngsboro, MA 01879. Circle INFO/CARD #130.

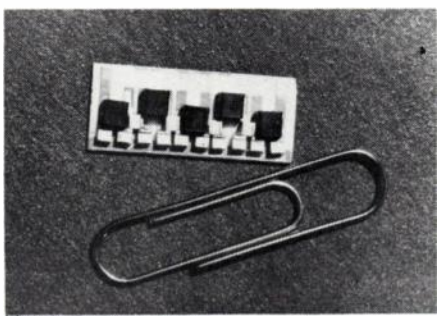


Chip Hybrid, RF Filters

Vanguard Electronics Company has developed a new product line of subminiature RF and microwave filters intended for OEM applications requring minimum size and weight. The new technique, using hybrid "chip" construction, is applicable in the 1 MHz to 1,000 MHz frequency range. These devices give excellent high "Q" performance in a very small volume.

The unit is a five-section bandpass filter used in the guidance receiver of a ballistic missile. It has a center frequency in the VHF band, with a 15 percent bandwidth. Total weight is less than 5 grams. Vanguard can custom design for other filter applications, including bandpass, lowpass, highpass and bandstop.

Contact Vanguard Electronics Co., 930 W. Hyde Park Blvd., Inglewood, CA 90302. INFO/CARD #128.



RF Circuit Design Software Package

CADEC (Computer Aided Design of Electronic Circuits) is an ROM software package to aid in the design and development of RF circuits. It is the only program available for the Tektronix 4051, 4052, 4054 Graphic Computing Systems that reduces design efforts, provides circuit optimization and gives results in frequency and time domain.

Unique program features of CADEC include the capabilities of optimization of circuits to measured or desired data, numerical and graphic output of results, reuse of calculated or measured results within a new analysis and Fourier Transform.

The program is running in the frequency domain and accepts active and passive elements as well as complex interconnections. The Fourier Transform capability allows for transformation of results into time domain to calculate the system answer on a large variety of periodic input time functions.

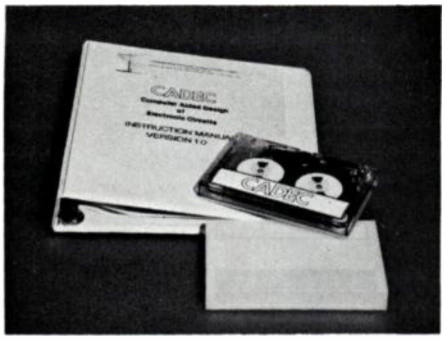
For maximum efficiency the program is based on the "twoport" analysis technique that does not require matrix inversions and is the fastest technique for basic computers.

One of the most significant features of the program is its op-

INFO/CARD 22

timization capability. Based on the search technique with presettable initial search distance, the program automatically changes more and more to a gradient approach, as the distance to the minimum reduces. This assures a high probability of finding the true optimum.

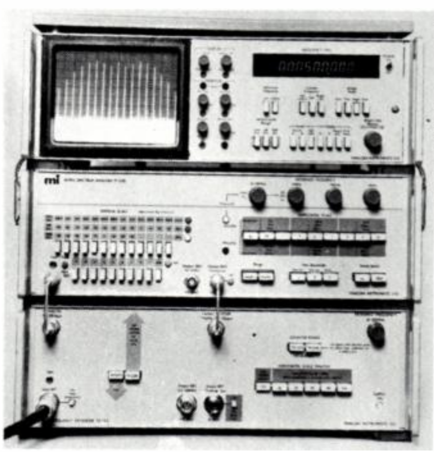
Contact Communication Consulting Corp., 52 Hillcrest Drive, Upper Saddle River, NJ 07458. INFO/CARD #125.



Spectrum Analyzer Frequency Extender

The Extender provides a range of sweepwidths from 20 Hz per division to the full 50 MHz to 1.25 GHz. All the exceptional features of Model 2370 are retained when it is used with the Extender, including 5 Hz filter bandwidth, built-in frequency counter which can measure spectral components to within 2 Hz. The tracking generator is an integral feature and provides a signal locked to within 2 Hz thru the entire range to 1.25 GHz.

The Marconi Spectrum Analyzer, Model 2370, and the Frequency Extender Model 2373, form a unique measuring system over the frequency range 30 Hz to 1250 MHz, with an exceptional ability to measure narrow spectra to 5 Hz resolution. It is particularly noteworthy that with the ease of operation, several automatic features are still retained.



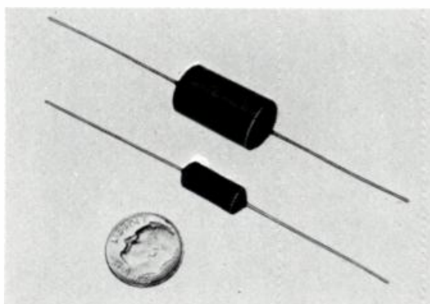
Contact Marconi Instruments, 100 Stonehurst Court, Northvale, NJ 07647. INFO/CARD #123.

Miniature Shielded Fixed Inductors

For wherever high density applications require shielding, as in power supplies, filters, telecommunications, switching circuits, tiny Series RL1123 and RL1124 shielded fixed coils offer excellent inductance to size ratio in relation to resistance.

Their inductances range from 1 μH to 47.0H and currents are rated from 0.0054 to 1.5 AC Amps. RL1123 is 0.5 inches diam. x 0.9 inches long, weighs 15 grams. RL1124 is 0.25 diam. x 0.7 long, weighs 5 grams. Both styles are made with the winding configured on a ferrite bobbin; the ferrite shield sleeve or "shell" is precisely set to ensure the specific inductance required. Both styles are epoxy sealed and non-flammable. For automatic insertion, a clear PVC "cushioning" sleeve is optional. Coils can be supplied pre-bent and cut at the factory at additional cost.

Contact Renco Electronics, Inc., 240 Old Country Road, Hicksville, NY 11801. INFO/CARD #127.



Automatic Antenna Tuner

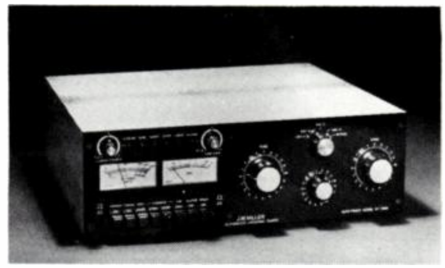
A new automatic antenna tuner for use with amateur, commercial and government communications systems has been introduced by the J.W. Division of Bell Industries in Compton, California.

Auto Track Model AT2500 antenna tuners can handle power in excess of 2500 PEP over a frequency range continuous from 3 to 30 MHz. Average automatic tune-up time is 15 seconds.

Front panel switch positions permit the use of three coaxial antenna outputs, one long wire antenna and one coaxial tuner bypass. Impedance 10-300 ohms. A direct reading SWR meter on the front panel is calibrated from 1:1 to infinity.

The PWR panel meter displays RMS with continuous (CW) carrier and automatically displays peak when in SSB mode in ranges of 0-250 W and 0-2500 W.

Contact J.W. Miller Division of Bell Industries, 19070 Reyes Avenue, Compton, California 90224. INFO/CARD #121.



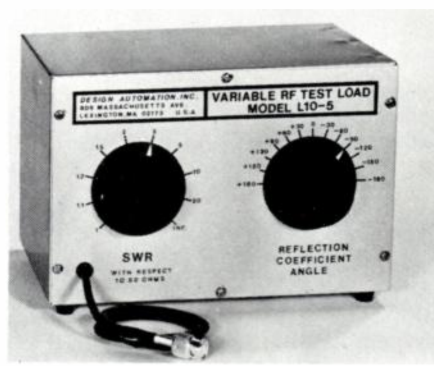
Variable Test Load Aids RF Power Amplifier Evaluation

A new, variable test load for RF power amplifiers and radio transmitters is being introduced by Design Automation, Inc. of Lexington, Massachusetts.

The Design Automation Model L10-5 is a 10.5-MHz variable test load that lets you determine if an RF power amplifier or radio transmitter can withstand arbitrary mismatched output loads without damage or spurious oscillation. Other standard test loads from 1 to 100 MHz are also offered.

With a 50-ohm nominal transmission-line impedance, the Design Automation Model L10-5 provides ten switch-selected values of SWR from unity to infinity (greater than 40), and continuously variable coverage of all 360° of reflection coefficient. Depending on SWR value, the test load can dissipate 5 to 20 watts.

Contact Design Automation, Inc., 809 Massachusetts Ave., Lexington, MA 02173. INFO/CARD #120.



Switchable HF Filter/Wattmeter System

The Model 5030 HF Filter/Wattmeter System is a compact, timesaving device on casters designed to increase productivity in metrology labs, manufacturing and users' facilities with frequent measurement and testing requirements, as well as at maritime or strategic installations where co-location interference is a problem.

This new self-contained high power HF Filter/Wattmeter System with a minimum of 60 dB attenuation of harmonics and spurious signals has eight discrete passbands between 1.5 and 35 MHz. Model 5030 offers low insertion loss and VSWR (1/2 dB and 1.5 max) at 1000 watts continuous duty. RF power is indicated on a unique dual pointer meter which displays forward and reflected power, as well as antenna or load VSWR simultaneously. A pair of rugged coaxial switches with better than 75 dB crosstalk isolation each selects eight passband ranges with cut-off frequencies at 2, 3, 4-1/2, 7, 10, 15 23 and 35 MHz. Attenuation of undesired signals is 60 dB or more from double the selected cut-off frequency to 1 GHz. An RF sample for spectrum analysis or frequency measurement is also provided.

Contact Bird Electronic Corporation, 30303 Aurora Road, Cleveland (Solon), OH 44139. INFO/CARD #119.

Wide Band UHF/VHF Amplifiers

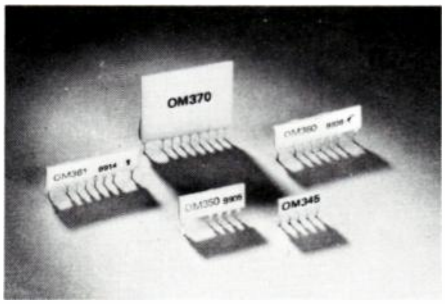
A line of low cost, high performance, prepackaged hybrid IC wide band amplifiers for CATV, MATV, and similar applications is being introduced by Amperex Electronic Corporation of Slatersville, Rhode Island.

Amperex Hybrid UHF/VHF Wide Band Amplifiers operate from a 12V supply voltage, and cover a 40 to 860 MHz frequency range. Produced as thin film circuits on ceramic substrates, the line consists of 1, 2, and 3 stage types, with gain ranging from

12 dB for the single stage amplifier to 28 dB for a 3-stage type.

Amperex Hybrid UHF/VHF Wide Band Amplifiers include five devices: ATF445/OM345 (12 dB gain, 99 dBuV output); ATF442/OM350 (18 dB gain, 100 dBuV output); ATF443/OM360 (23 dB gain, 105 dBuV output); ATF444/OM361 (28 dB gain, 105 dBuV output); and ATF446/OM370 (28 dB gain, 113 dBuV output). Higher gain is achieved by cascading two amplifiers.

Contact Amperex Electronic Corporation, Providence Turnpike/P.O. Box 98, Slatersville, RI 02876. Circle INFO/CARD #117.

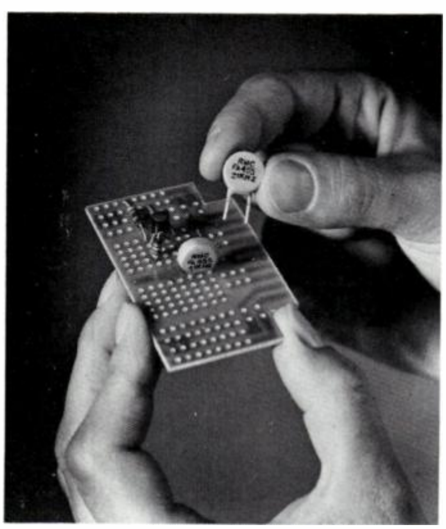


CR-40 Resonator, Low Cost Alternative to Quartz Crystals

The new CR-40 ceramic resonator, just introduced by Radio Materials Corporation, Chicago, Illinois, is a super-small, radial terminal, disc style package that provides a low cost alternative to quartz crystals. The CR-40's flat tab terminals permit it to be bent over flat against a PC board to maintain a low profile board. F_a is typically 455-600 kHz and F_r is 430-560 kHz. Only 3/8" in diameter, the CR-40's terminal spacing is compatible with other RMC resonator packages.

Ceramic resonators are useful in clock oscillators for computers, calculators and digital read-out instruments, in carrier current communication and/or alarm systems, in TV deflection circuit "sync" controls and in TV remote control systems. The small size of the CR-40 make it also especially adaptable to hand-held devices such as calculators, electronic games and TV remote control units. The resonator elements are assembled into a molded plastic case which is then sealed for high resistance to environmental moisture. They can be cleaned in aqueous detergent baths, in most organic solvents and are highly resistant to damage from soldering heat.

Contact RMC-Radio Materials Corporation, 4242 W. Bryn Mawr Avenue, Chicago, IL 60646. INFO/CARD #116.



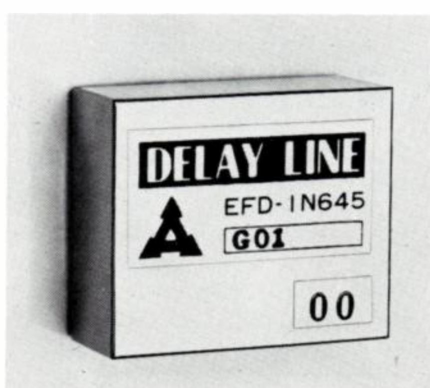
Ultrasonic Delay Lines

A family of wide-bandwidth, low-insertion-loss ultrasonic delay lines is now available from the Electronic Components Division of Panasonic Company. Their nominal frequencies range between 3.58 to 28.636 MHz and they offer delays ranging from 63 to 128 us.

Each new delay line consists of two proprietary (patent world-wide) piezoelectric ceramic transducers and a zero temperature coefficient glass plate. As an input electrical signal is applied to the input transducer, its electrical energy is converted into acoustical and then, after traveling through the glass plate, the output transducer converts it into an electric signal with appropriate phase delay.

All devices within the new family offer excellent temperature stability, low insertion loss (typically around 10 dB), small size (some low-profile units are only 12.7 mm or 0.5" high), operate over a wide temperature range (−10 to +60°C), and can tolerate relatively high input voltage (10 volts peak-to-peak).

Contact Panasonic, 1 Panasonic Way, Secaucus, NJ 67094. Circle INFO/CARD #114.



Thick Film Chip Resistors

A line of small, low cost, thick film chip resistors that replace more expensive thin film types in hybrid microelectronic applications is being introduced by International Manufacturing Services, Inc. of Portsmouth, Rhode Island.

IMS-7 Thick Film Chip Resistors can replace thin film chip resistors in the 0.030" and 0.040" size range, and offer resistances from 1 ohm to the megohm range with tolerances as close as ±1 percent. Elongated gold terminations permit multiple wire bonds to a single device.

Contact International Manufacturing Services, Inc., 50 Schoolhouse Lane, Portsmouth, RI 02871. INFO/CARD #115.

Resistor Organizer

Century's Econo-Pak Resistor Organizer provides a wide variety of resistor values in a sturdy attractive ACRO metal cabinet. . . and for far less than the cost of single resistors. A must for any shop or lab. Model 2515, 60 values, 1/4 watt, 5 percent, 25 per value, only $74.50; Model 2530, 60 values, 1/4 watt, 5 percent, 50 per value, only $99.50; Model 5015, 60 values, 1/2 watt, 5 percent, 25 per value, only $79.50.

Contact Century Electronics Corporation, 3511 North Cicero Ave., Chicago, IL 60641. INFO/CARD #109.

64 Page Shielding Manual/Catalog

Rochester, Indiana, Ad-Vance Magnetics' new 64-page 2-color shielding book has collected within its pages the major useful technical guideline data needed to design or choose the optimum magnetic shield for a given application.

Two-thirds of the book devoted to useful technical/engineering information about the entire magnetic field; only 1/3 devoted to usual catalog type data.

The 18 pages of technical/engineering articles, including reprints from various trade publications, all written by Ad-Vance Magnetics' engineering staff, help fill the gap between many users and the EMC specialists.

As a further help to those with magnetic shielding problems, 11 pages are devoted to 20 typical case histories of engineering solutions to such problems. There are 3 pages of basic calculation assists in shield design, 2 engineering reports on shielding effectiveness, and 1 1/2 pages on Helmholtz coil testing. The remaining pages of the 2 Engineering Sections contain various useful tables, graphs and materials trigraphs.

The Catalog Section illustrates and describes Ad-Vance Magnetics' facilities and products.

Contact Ad-Vance Magnetics, Inc., 625 Monroe Street, Rochester, IN 46975. INFO/CARD #98.

TRW Power Semiconductors Catalog

TRW Power Semiconductors has published Catalog 100E, a new large format, 20-page short-form catalog.

The booklet contains basic specifications for 465 power devices — switching transistors, Darlington transistors, switching diodes, Schottky rectifiers, Zener diodes, and Varicap varactor diodes.

There are photographs and engineering drawings of the various packages.

Contact TRW Power Semiconductors, 14520 Aviation Blvd., Lawndale, CA 90260. INFO/CARD #97.

Solid State Shortform Catalog

More than 500 devices are featured in this new 16-page shortform catalog by Solid State Devices, Inc. The broad product line includes ion-implanted semiconductors, power transistors, high-voltage transistors, ultra-fast recovery rectifiers, power hybrids, high-voltage rectifiers, and bridge assemblies.

It represents a variety of popular and readily available state-of-the-art products which can be selected to package preference and other major performance characteristics.

The shortform is organized so customers can easily determine which products meet their current or power and voltage requirements. If special processing is required, customers should forward specifications to Solid State Devices, Inc. for review.

Contact Solid State Devices, Inc. for your shortform catalog today. Solid State Devices, Inc., 14830 Valley View Avenue, La Mirada, CA 90638. INFO/CARD #96.

Thorstrand Properties And Applications Booklet

The Thorstrand™ family of electrically and thermally conductive structrual fabrics and resin preimpregnated materials is presented in a new brochure available from Hexcel, the Dublin, Calif.-based manufacturer of engineered materials. The booklet describes Thorstrand's physical and structural characteristics, and presents typical applications for the materials.

Thorstrand fabric reinforcements are woven from aluminum-coated glass fibers. The booklet reviews the fiber's electrical and mechanical properties and the thermal and electrical conductive characteristics of Thorstrand fabrics and prepregs. Hexcel will tailor Thorstrand composites to meet the requirements of a specific application.

Typical applications include electromagnetic interference shielding, lightning strike protection, heat and static electricity dissipation, and reflective surfaces for microwave antenna dishes or electrically conductive surfaces for antenna ground planes.

Contact Structural Products Division, Hexcel, 11711 Dublin Blvd., Dublin, CA 94566. INFO/CARD #100.

0.5-2000 MHz Module Brochure

This new 6 page brochure features a full line of RF and Microwave modular amplifiers in TO-12, TO-8 4 PIN dual in line and TO-3 packages. These amplifiers are standard off-the-shelf thick-film hybrids designed and manufactured under an extensive quality assurance program that fully complies with the requirements of MIL-Q-9858A and MIL-STD-883. Complete characterization of each family of components includes: gain, noise figure, VSWR and power output specifications for frequencies from 0.5 MHz to 2000 MHz.

Contact Optimax, P.O. Box 105, Advance Lane, Colmar, PA 18915. INFO/CARD #101.

EMI Filters Catalog

A new, expanded and revised catalog of EMI Filters has been released by Cornell-Dubilier — a manufacturer of electro-magnetic filters.

Described in the catalog is a series of all-purpose filters, to meet both national and international filtering requirements.

The simplicity of the design approach and the completeness of the series of filtering components makes this reference book an invaluable aid to designers with electronic noise problems.

For further information and a copy of the catalog, write to: Cornell-Dubilier Electronics, 150 Avenue L, Newark, NJ 07101. INFO/CARD #93.

How To Select The Right RF Signal Generator

A new 8-page Selection Guide for RF Signal Generators and Sources is now available. It describes Hewlett-Packard's signal generator capabilities in the frequency range from 10 kHz to 2600 MHz. Specification comparisons are made for 9 different generators ranging from the manually-tuned 8654A L-C type to the high performance 8662A Synthesized Generator.

The application selection chart compares critical parameters required for 9 separate measurement applications ranging from local oscillator substitution to the stringent out-of-channel radio test procedure. A single-sideband phase noise comparison chart for 5 generators appears for the first time and a glossary of terms rounds out the user-oriented information in this brochure. Capsule descriptions of each generator are provided.

"RF Signal Generators and Sources — A Selection Guide" is available from Hewlett-Packard free of charge.

Contact Inquiries Manager, Hewlett-Packard Company, 1507 Page Mill Road, Palo Alto, CA 94304. Circle INFO/CARD #95. □

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Classifieds

RF DESIGN ENGINEERS

Join a company on the leading edge of technology, creating new solutions to old problems. Engineers seeking challenges in low noise amplifiers, ultra-linear power amplifiers, low noise frequency-agile synthesizers or adaptive noise cancellation techniques in the HF/VHF spectrum should contact T. Joseph Daley, **Harris Corporation, RF Communications Division,** 1680 University Avenue, Rochester, NY 14610, (716) 244-5830; EXT 3328.

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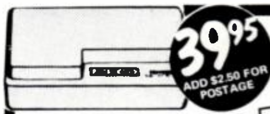

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