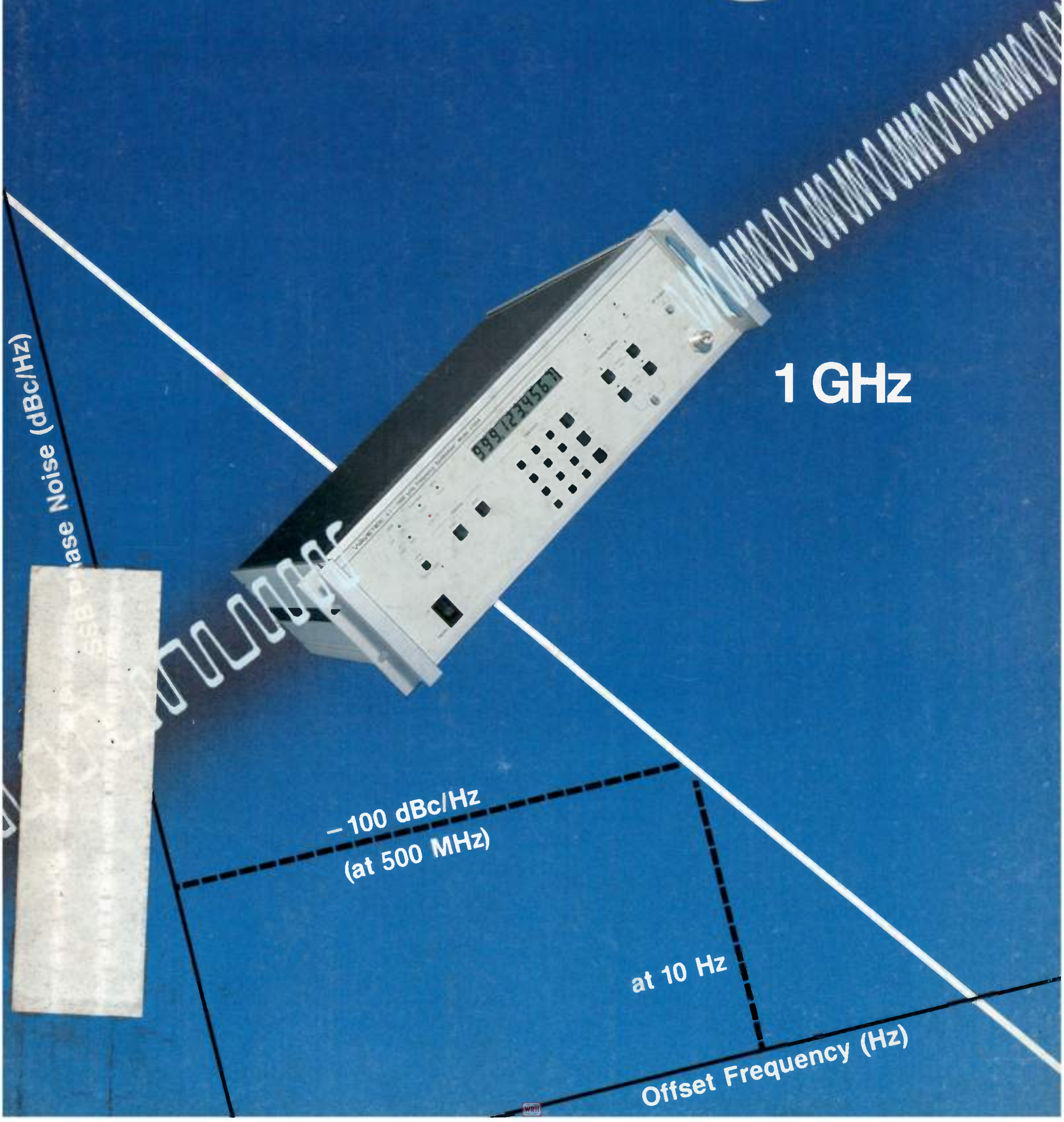
May/June 1984
A Cardiff Publication

rf design



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BLV91	2	900	6.5	12.5	SOT-172
BLU99	4	900	7.3	12.5	SOT-122
BLV92	4	900	8.0	12.5	SOT-171
BLV93	8	900	6.0	12.5	SOT-171
BLV94	15	900	6.0	12.5	SOT-171

400 to 512 MHz	MOBILE APPLICATIONS				
BLU60/12	60	470	4.8	12.5	SOT-119
BLU45/12	45	470	5.1	12.5	SOT-119
BLU30/12	30	470	6.0	12.5	SOT-119
BLU20/12	20	470	6.5	12.5	SOT-119
BLW82	30	470	5.0	12.5	SOT-119
BLW81	10	470	6.0	12.5	SOT-122
BLU99	5	470	10.5	12.5	SOT-122
BLW80	4	470	8.0	12.5	SOT-122
BLW79	2	470	9.0	12.5	SOT-122
BLX65	2	470	6.0	12.5	TO-39

175 MHz	MOBILE APPLICATIONS				
BLV75/12	75	175	7.0	12.5	SOT-119
BLV45/12	45	175	6.5	12.5	SOT-119
BLV30/12	30	175	8.2	12.5	SOT-119
BLW60C	45	175	5.0	12.5	SOT-120
BLW31	28	175	9.5	12.5	SOT-120
BLY89C	25	175	6.0	12.5	SOT-120
BFQ43	4	175	12.0	12.5	TO-39E
BFQ42	2	175	10.5	12.5	TO-39

30 to 900 MHz	BASE STATIONS				
Type	Power (W)	Freq. (MHz)	Gain (db) min.	VCC (V)	Package
BLW96	200	30	13.5	50	SOT-121
BLV25	175	108	10.5	28	SOT-119
BLV80/28	80	175	6.5	28	SOT-119
BLV33F	85	225	10.5	28	SOT-119
BLV36	120	225	10.0	28	SOT-161
BLU53	100	400	6.5	28	SOT-161
BLV97	30	860	6.5	24	SOT-171
BLV57	38	860	6.5	25	SOT-161

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BGY33	80-108	100	20	12.5	SOT-132
BGY35	132-156	150	20	12.5	SOT-132
BGY36	148-174	150	20	12.5	SOT-132
BGY43	148-174	150	13	12.5	SOT-132B
BGY40A	400-440	100	7.5	12.5	SOT-132C
BGY41A	400-440	150	13	12.5	SOT-132C
BGY40B	440-470	100	7.5	12.5	SOT-132C
BGY41B	440-470	150	13	12.5	SOT-132C
BGY40A	470-512	100	7.5	12.5	SOT-132C
BGY41C	470-512	150	13	12.5	SOT-132C
BGY45A	68-88	150	30	12.5	SOT-301-A-03
BGY45B	144-175	150	30	12.5	SOT-301-A-03
BGY46A	400-440	30	1.5	9.6	SOT-26NC
BGY47A	400-440	45	2.2	9.6	SOT-26NC
BGY47B	430-470	45	2.2	9.6	SOT-26NC
BGY47C	460-512	45	2.2	9.6	SOT-26NC
BGY22	380-512	50	2.9	12.5	SOT-75A
BGY23	380-480	2.5 WATTS	7	12.5	SOT-75A

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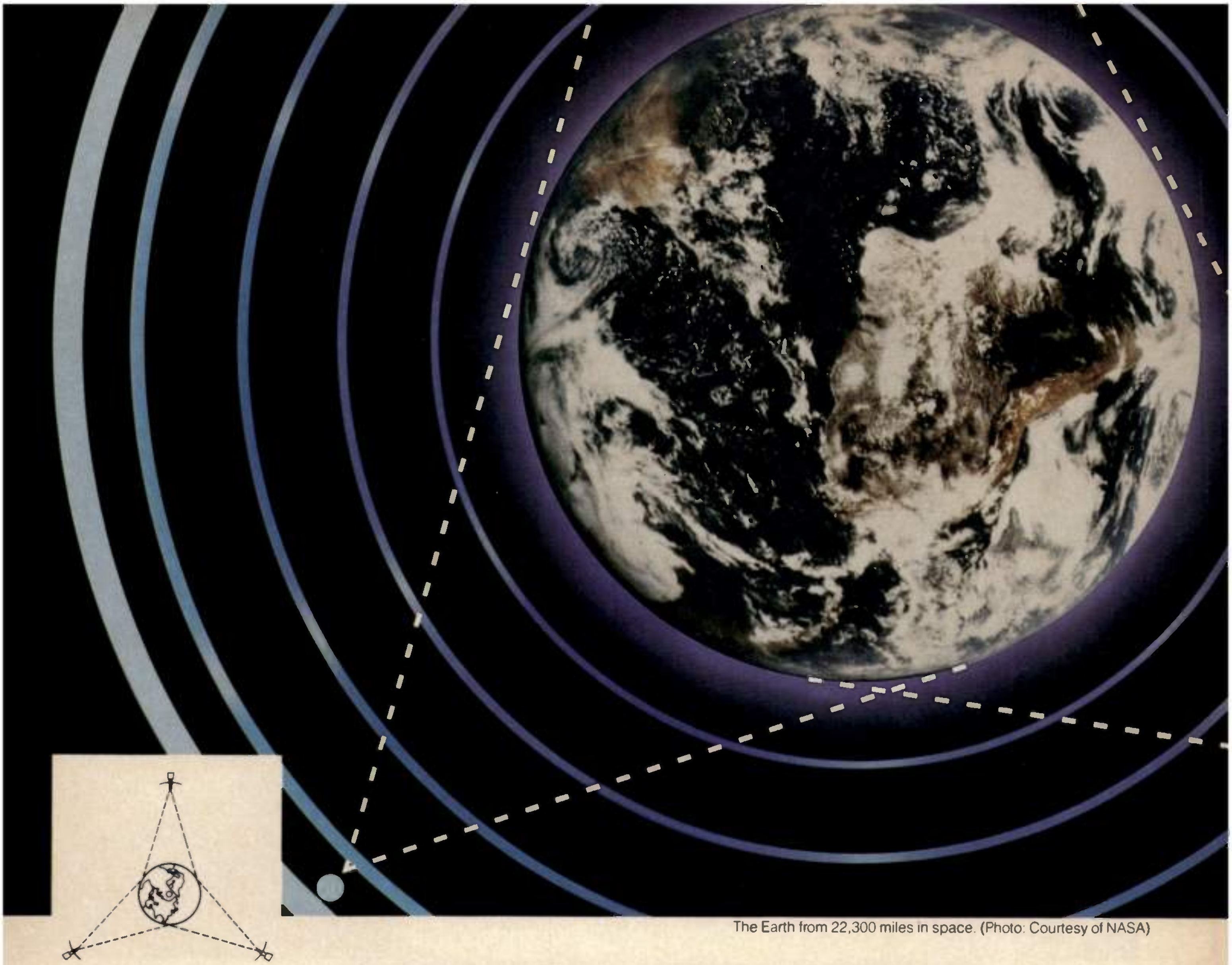
INFO/CARD 2



The Earth from 22,300 miles in space. (Photo: Courtesy of NASA)

Clarke's proposed
3-satellite system.

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INFO/CARD 3

F79 Rev. Orig

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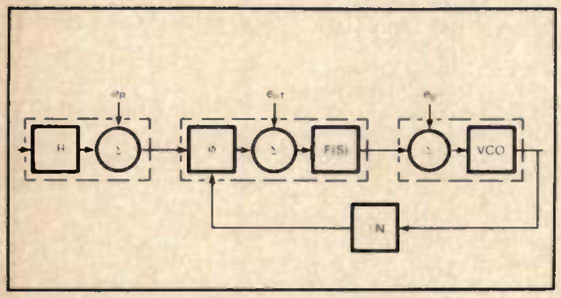
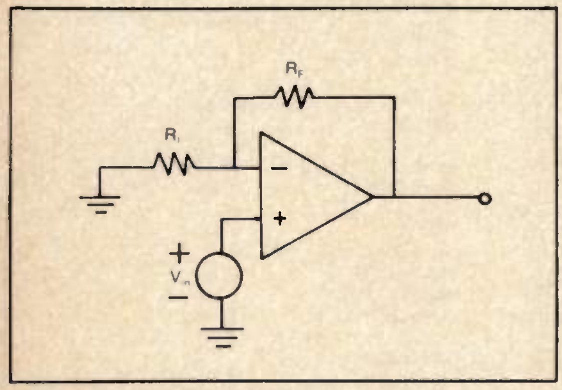


Synthesizer Design P. 42



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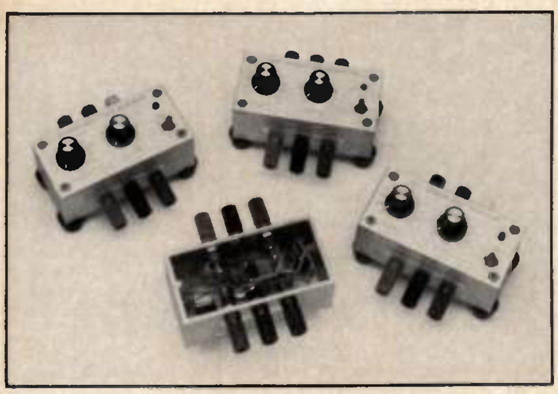

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Introducing:
The RF TECHNOLOGY EXPO 85

"Good idea. . .very much needed" said two out of three of our readers in a recent survey, indicating response to the project named above. Over 40% of you said you would be "inclined to attend". . .while 63% of you engineering managers said you would recommend the attendance of engineers you supervise and send 2.25 people, on the average. We are overwhelmed. . .and more than encouraged to take off the wraps and make it official.

We'd like our readers to be among the very first to know: *R.F. Design* magazine will sponsor a new conference and exhibit, for the same technology and the same people that we serve editorially. It will be called RF TECHNOLOGY EXPO, and will be held for the first time next January 23, 24, and 25 at the Disneyland Hotel, in Anaheim, California.

It's a pleasure to announce something which you know is needed, and not just an exploitative copy of somebody else's success. RF TECH EXPO is needed for the same reason that *R.F. Design* is needed: because nobody else is paying proper attention to RF circuit and system design techniques. The big electronic shows are too general and too digital, while the existing RF shows are too microwave, to be useful to true RF engineers and to the vendors trying to reach them.

Technical sessions at RF TECH EXPO will turn a rare spotlight on topics and equipment in kHz, MHz, and lower GHz frequencies. With your peers in other companies you'll be able to concentrate on new ideas and developments in such areas as RF design, EMI/RFI test and evaluation, RF computer-aided design, SAW devices, oscillator design, filter design, RF test equipment, satellite communications, 800 MHz applications. . .

In fact, you may want to step out and organize a session, or lead one, or author a paper. Well, here's your chance. We're still very early in the planning of an event we want to be just as useful to you as it can be. . .so why don't you help shape it? Feel free to call or write us directly. . .or you can use the return post card you'll find in this issue, labelled "CALL FOR LEADERS, AUTHORS, PANELISTS."

In any event, please plan to come. We placed it at the Disneyland Hotel, in the month of January, so you'll be encouraged to bring the whole family, relax. . .and get to know us, each other, and vendor/exhibitors. (Already committed, among the latter, are Motorola Semiconductor, TRW Electronic Components, John Fluke Manufacturing, Wavetek, Amperex, and others.)

The RF engineering fraternity needs this event, to generate the sense of community it should have, in the face of current pressures. I guess no one needs to tell you we're in an RF boom. . .spurred by a healthy demand for new and improved RF communications in military, industrial and consumer sectors of our economy. There's a lot to talk about, to exchange, to foster, to propogate.

We'll see you in Anaheim!

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INFO/CARD 94

Dear Sir:

I was surprised at the controversy my remarks about BASIC has sparked. I certainly don't think that BASIC is the "best" computer language — but I will say with certainty that there is more hardware capable of running BASIC than any other language in the world. There are better languages — in fact for most of the applications described in r.f. design I find Visicalc type programs to be extremely convenient. But the fact is that few machines have these programs installed. The real advantages of BASIC are:

More machines run BASIC than any other language;
Numerous pocket calculators run BASIC;
BASIC is relatively easy to move to another machine;
BASIC is easier to turn to calculator language than the reverse;
More machines run BASIC than any other language.

While other languages are more powerful, more elegant, and more modern, BASIC is still the most universal. Perhaps the controversy will die out now that new calculators from both T.I. and H.P. are programmed in BASIC.

Yours truly,
V.P. O'Neill

Dear Sir:

I must disagree in part with the opinion expressed by V.P. O'Neil II (letters, page 6, Sept./Oct. '83). The ideal situation would of course be to print all software languages for each engineering program. However, this does require that engineers are motivated by their particular computing needs to carry out this program translation or the work is carried out by a software person in the employ of a publishing company such as yours. If such translations are to be carried out then it is first necessary to inform engineers that said software, in a particular language, for a particular application, exists, and has sufficient software support to enable translation by those engineers. These translations must then find their way back to a collating department for publication in a book or valuable space devoted by your magazine for such translations. As such this would be a rather sporadic and random article, but nevertheless of some value.

The best approach, and most efficient in terms of engineers' time, would be to print the program in the three most widely used languages. In my opinion these should be Basic, HP41C, TI58/59, and a software person employed by your company to provide the missing program translations. This does require that programs submitted are sufficiently documented to make this feasible.

My reasons for the above statement are as follows:

1. An engineer should not waste himself as a resource translating software, in company time that is!
2. Software, by its nature, is a time consuming activity when being generated and only time saving when being run — correctly!
3. Up until a years ago, only the programmable calculator was available for desktop use and the alternative was a mainframe of some description.
4. The HP41C & TI58/59 calculators have now been used by experienced engineers for 5-6 years and have accumulated a large but dispersed potfolio of applied programs.
5. The TI59 is the only calculator to provide a respectable computing power, display and magnetic storage all in the one package — as yet no such "Basic" operating micro-computer provides all these benefits in one package.
6. I was fortunate, only recently, to obtain a TI59 for £75 (≈$113) which is at least a half to one-third the price I would have had to pay for a "Basic" operating microcomputer, and that does not include the TV or monitor which is a very cumbersome peripheral.
7. It will be at least a year or two more before any manufacturer will be selling a micro-computer with built-in disc storage, printer and display (l.c.d. or e.r.t.), and sufficient memory for most engineering requirements, that will be easily hand-carried like the TI59.
8 The cost of such a micro as defined in 7. will be beyond most U.K. engineer's personal pockets for quite some time, whereas in the U.S. differences in pricing strategy of micros will not be so prohibitive to engineers wishing to make such a purchase.
9. I am not trying to imply in 8. that my company, and others in the U.K., do not have "Basic" running micros in our labs because we do. The problem is in getting your hands on one the "instant" one needs to perform such calculations. This is overcome by owning one's own

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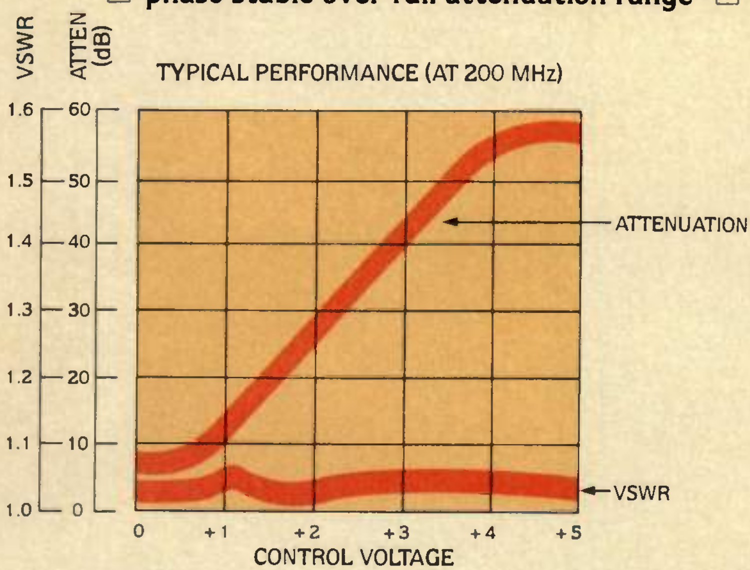

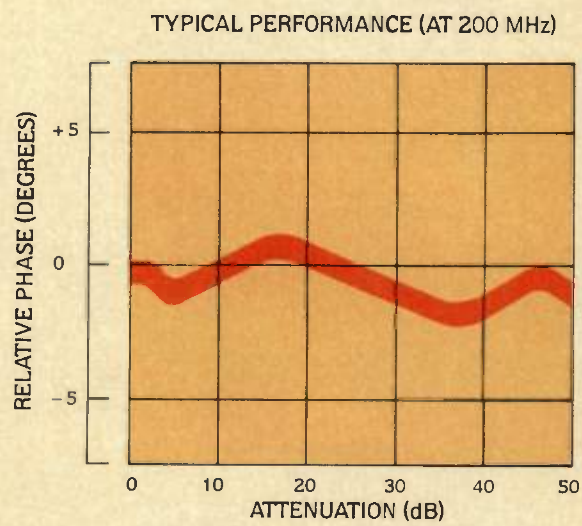

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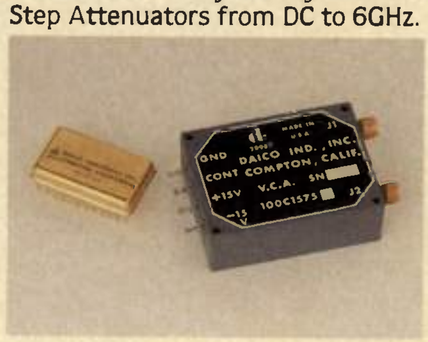

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calculator/micro in order to become a better engineer.

10. In conclusion, I would like to see the TI59 drop quite substantially in price as it nears the end of its "product life", in order that many more engineers can take advantage of all these useful, experience — supported TI59 programs. Please keep on printing them and the exceedingly useful article in r.f. design — from an appreciative self-training r.f. engineer.

Yours sincerely,
Mr. C. Levitt (Senior Dev. Engr.)
Motorola (Communications) Ltd.
Jays Close
Baringstoke.
Hampshire.
RG22 4PD.
England.

Antenna Article Comments

Dear Sir:

The article on gain of grounded monopole antennas by Ames and Edson was an interesting overview of the subject. Unfortunately, I find it a bit hard to swallow a definition of antenna gain that depends on the type of transmitting antenna at the other end of the radio circuit.

Antenna gain is a very slippery subject — the numbers you get depend heavily on the assumptions you start with. My thesis is that the gain of a grounded quarter-wave monopole is equal to the gain of a half-wave dipole using any reasonable assumptions.

For example, as was mentioned in the article, the total circuit loss (transmitter-to-receiver) of two half-wave dipoles in free space is the same as for two quarter-wave monopoles over an infinite ground plane at the same distance. It is true that the *field strength* from the monopole is 3 dB stronger than the dipole, but this is because of the infinite ground plane — there is only half as much volume to fill with energy as in the free-space case. A more fair comparison would be the monopole *vs* a dipole suspended over a ground plane. In this case the dipole is 3 dB better *at its favored radiation angle.* If you average (RMS) the dipole response over the peaks and nulls of the vertical radiation pattern, you again find an average loss equal to the monopole.

A final comparison would be between a system consisting of two free-space dipoles *vs* two "free-space" monopoles. A "free-space" monopole is one whose ground plane is large enough not to upset the driving-point feed impedance, but small compared to the distance between the antennas. (The "ground plane" antenna with 4 quarter-wave radial wires is a reasonable approximation.) In this case, both the half-wave dipole and quarter-wave wave monopole generate the same far-field and have the same total ciscuit loss.

gains as being equal you eliminate the paradox brought on by equation 7 in the article, and path loss can be defined independent of the type of antennas used. This results in a single gain figure for each antenna type and avoids the unset-

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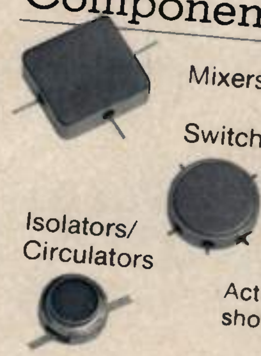

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EATON

tling necessity of assigning a negative gain (over isotropic) to a grounded quarter wave monopole.

Alan Bloom, Reliability Engineer
Hewlett-Packard Co.
Santa Rosa, CA 95404

Author's Answer

Dear Sir:

We agree with Mr. Bloom that antenna gain depends in a subtle way on one's initial assumptions. However, if one of the assumptions is the standard formula for gain (equation 1 of the article), then the gains of monopoles and dipoles must differ. One might be able to base a system of gains, capture areas, and transmission losses on a forced equality of the gains of dipoles and grounded monopoles, but we have not seen such a derivation carried to its logical consequences. We have followed the conservative approach of retaining the standard definitions of gain, which leads to a non-standard result for receiving surface waves, because our work often involves calculating field and signal levels in systems that include both space waves and surface waves, as well as both kinds of antenna. Previous attempts to avoid the distinctions in the article have led to confusion.

We would be the first to applaud a paper that derives a simpler set of self-consistent gains, but to be useful it would have to retain simple formulas for transmission loss and capture area, and apply to the same set of examples and conditions included in our article.

John Ames &
William Edson
SRI International
Menlo Park, CA 94025

Typo

Dear editor:

What appears to be a minor typo error appears in the article "High Performance VSWR Measurements" (March/April) 1984, page 32A. The received power is stated to be:

$$P_r = P_t G_r G_t \lambda^2/(4\lambda R)^2$$

whereas it has been shown to be represented by:

$$P_r = P_t G_r G_t \lambda^2/(4\pi R)^2$$

Thank you for a fine article.

Sincerely,
Vance Peterson
Motorola
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20 - 500	12.5	5.5/7.5	+24/+21	+42/+30	2:1	TO - 8	AM - 157
100 - 600	28	1.6/3.0	+19/+16	+30/+27	2:1	FP	AM - 160
5 - 1000	15	2.4/3.3	0/−3	+12/+8.5	2:1	TO - 8	AM - 173
5 - 1000	15	2.5/3.8	+4/+2	+17/+14	2:1	TO - 8	AM - 174
5 - 1000	15	3.0/4.2	+8.5/+7	+22/+19	2:1	TO - 8	AM - 175
5 - 1000	13	4.0/5.0	+13.5/+12	+30/+25	2:1	TO - 8	AM - 176
20 - 1000	9.5	2.0/3.8	+8/+4	+20/+18	2:1	TO - 8	AM - 154
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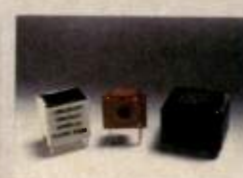

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CV-2250	3CX10,000U7	170–227	10 kW†
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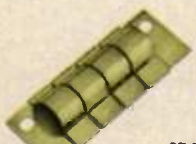

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Multiple Synthesis Techniques Optimize Instrument's Performance

Three synthesis techniques — Direct Digital, Direct Analog, and Phase Locked Loop — are combined in a new 1 GHz frequency synthesizer that provides excellent performance at a fraction of the price of previous designs.

By Phil Feinberg
Wavetek Corporation

The distinction between signal generators and frequency synthesizers is becoming more and more vague as advances in technology improve the performance of both types of signal sources.

Originally, "Signal Generator" referred to a device that contained some form of modulation with unspecified residual single sideband phase noise (SSB phase noise). A "Synthesizer," on other hand, was at one time thought of strictly as a very stable frequency source with no capability for modulation.

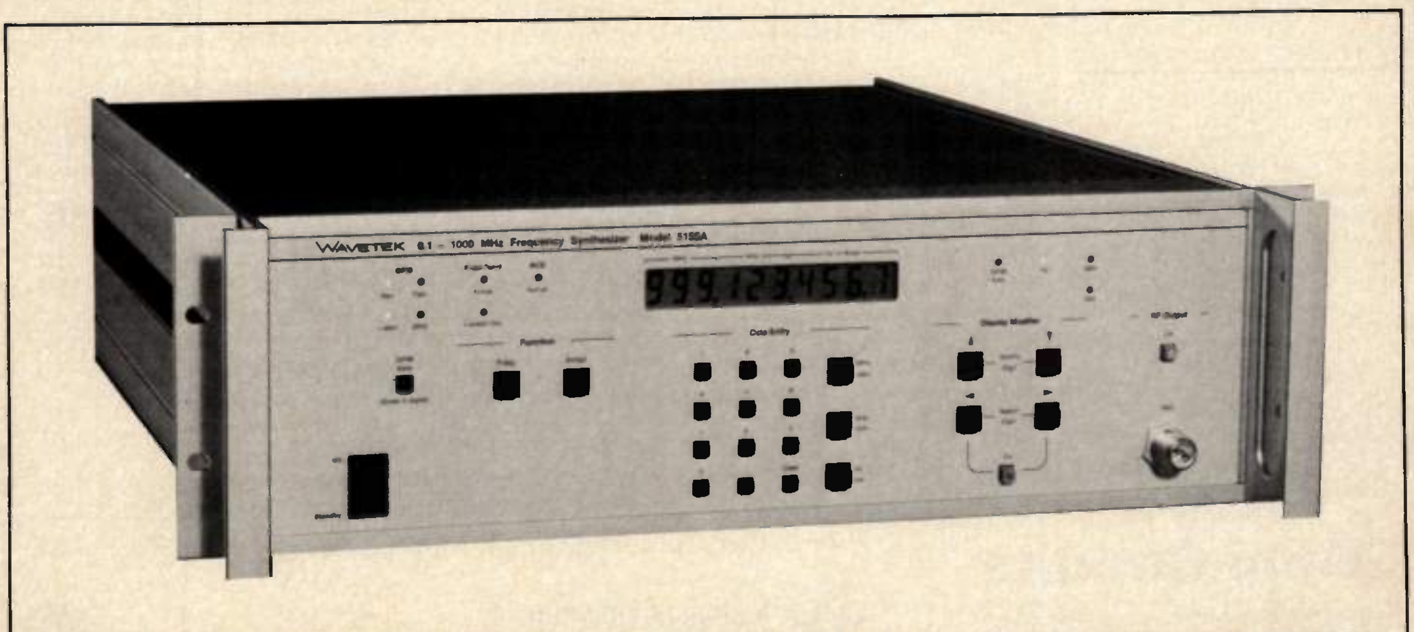
Now, however, stability in signal generators is markedly improved. Synthesizers can include some form of modulation, as well as being capable of very fast frequency switching with fine resolution, enabling simulation of a frequency modulated (FM) carrier signal.

As signal generators and frequency synthesizers approach each other on performance, it becomes more and more the application that defines the type of signal source one needs. With the growing importance of Secure Communications, Electronic Counter Measures (ECM), and Electronic Counter-Counter Measures (ECCM) on the one hand, and the reduction of communication channel spacing (from 25 kHz to 12.5 kHz to. . .) on the other hand, certain key specifications such as fast frequency hopping and good close-in phase noise are needed. These needs have brought about the development of a new type of synthesizer described in this article.

A Combined Approach

The Wavetek Rockland Scientific Model 5155A combines three different synthesis techniques in one instrument, Figure 1. It has unique performance capabilities over a 100 kHz to 1000 MHz frequency range, with excellent close-in (10 Hz offset) phase noise characteristics; typically -100 dBc/Hz at 500 MHz.

This synthesizer uses *Direct Digital* and *Direct Analog* techniques to achieve fast frequency switching in less than 1 microsecond, phase continuous hopping over a 100 kHz bandwidth, and resolution of 0.1 Hz or better. Several critical frequencies needed to achieve the intrument's wide bandwidth are generated by



a *Phase Locked Loop* (PLL).

For a better appreciation of this synthesizer design, more must be said about the advantages and limitations of various synthesis techniques.

Synthesizer Design

Except for the unique abilities of direct digital techniques in providing phase continuous switching, any synthesizer

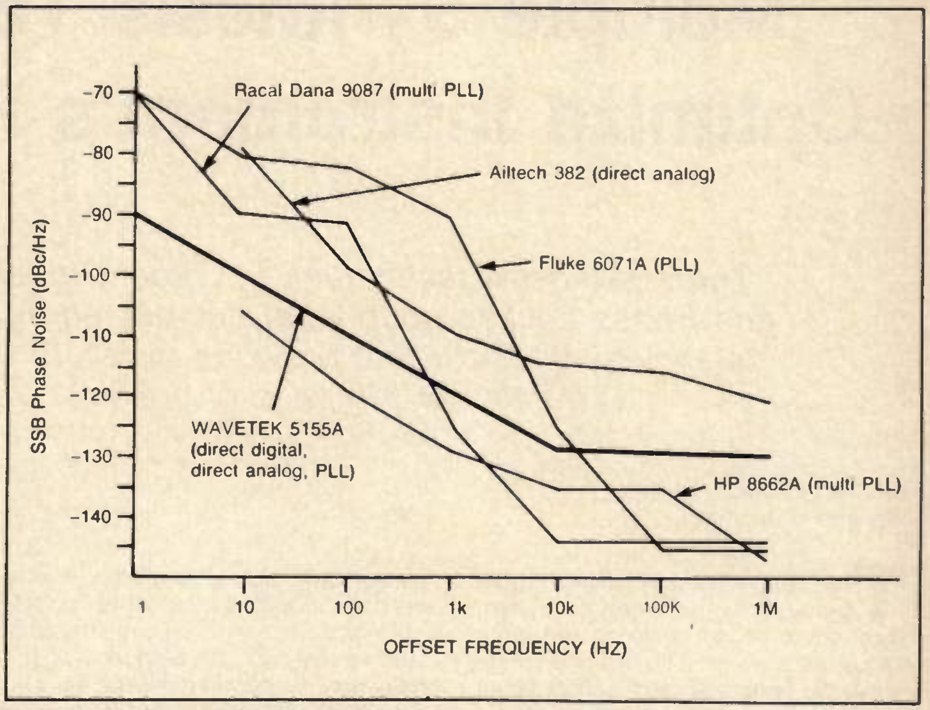


Figure 2. Typical Single Sideband Phase Noise Comparison of some Indirect (PLL and Multiloop PLL) and direct (digital and analog) synthesizers.

specifications can in theory be met by direct digital, direct analog, or phase locked loop designs as long as there are no limitations on packaging or size, power consumption, or cost. If SSB phase noise (measured in a 1 Hz bandwidth) is plotted against frequency, Figure 2, one can see that the different techniques can produce similar results. Cost usually determines which design is more acceptable.

In the practical implementation of meeting specifications within realistic budgets, however, one or more specific design goals usually determine whether one particular technique or another should be selected. Suppose, for example, that a frequency change must be performed in less than 10 microseconds. It is quite possible to switch this fast with a PLL design, but if a low spurious is also needed, a direct digital or direct analog approach may, as shown below, be more appropriate.

Indirect Synthesis

In its initial form, the Phase Locked Loop, Figure 3, was an often used synthesis technique because of its ability to generate non-standard frequency increments. This was extremely useful for those applications dealing with signals derived from a multiplication of a signal from a lower frequency synthesizer. Thus if 25 kHz were the specified increment for a system employing a 32 times multiplier, the PLL could generate the required step size of 781.25 Hz.

In a basic PLL system, a Voltage Controlled Oscillator (VCO) frequency is mixed with a variable set of frequencies to produce a different frequency close to a reference frequency. Alternatively, a *Digital Phase Locked Loop,* Figure 4, uses a variable ratio digital frequency divider to convert to VCO output to the reference frequency.

In both techniques, a phase detector then compares the downconverted VCO output to the stable reference frequency, with resultant differences generating an error voltage that drives the VCO to the proper frequency.

PLL design can be optimized to separately meet specifications regarding phase noise, spurious output levels, or switching speed. Simultaneously meeting requirements in *all* these areas is, however, a problem; PLL design demands that loop bandwidth be as narrow as possible for spurious considerations, as wide as possible for fast tuning times, and specification dependent for phase noise performance.

The phase noise requirements of a PLL further complicates optimizing overall design. The total phase noise of a well-designed PLL is composed of the sum of

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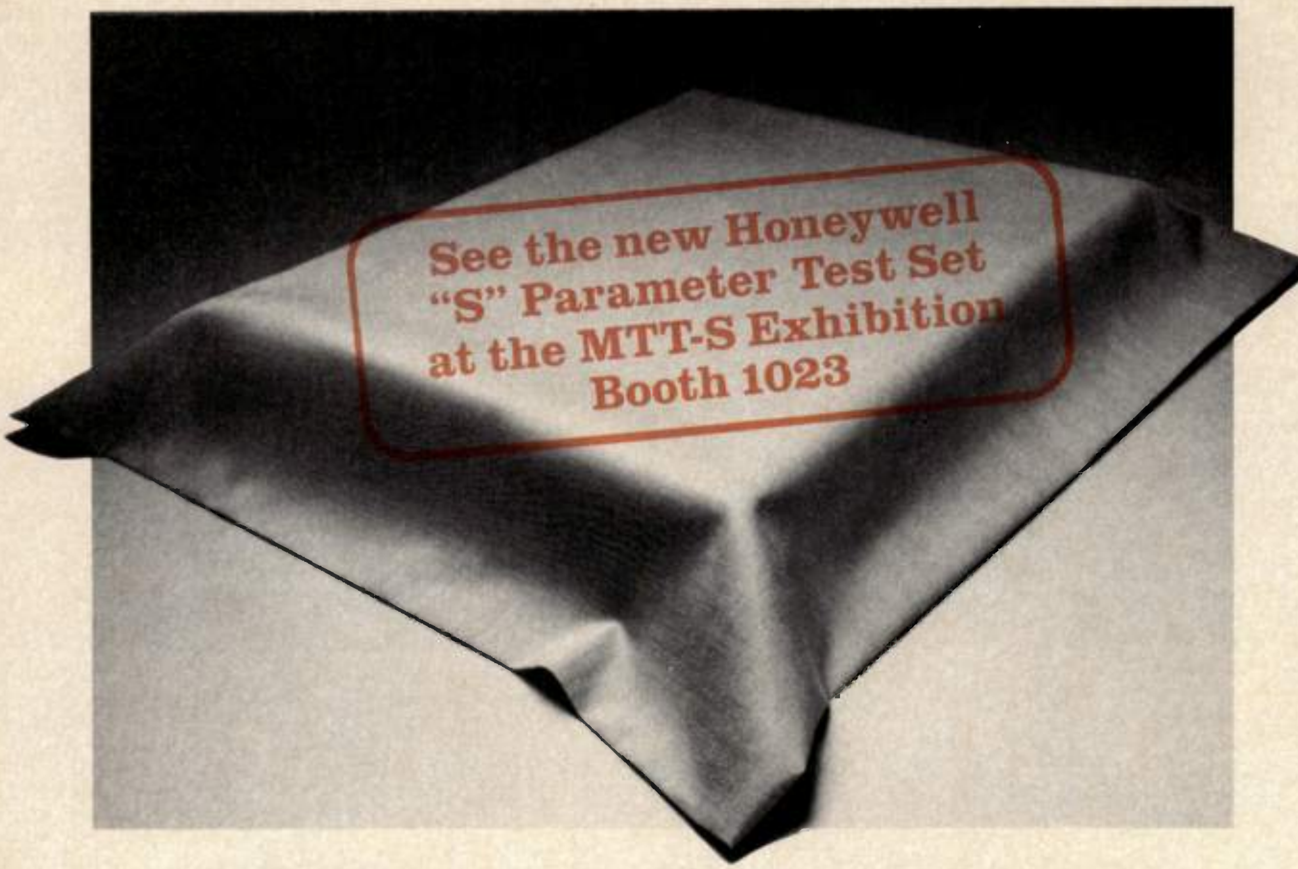

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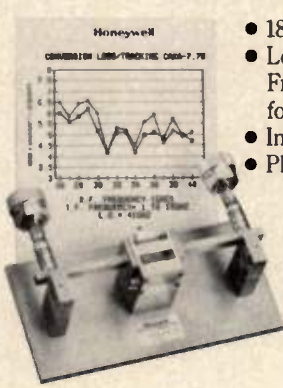

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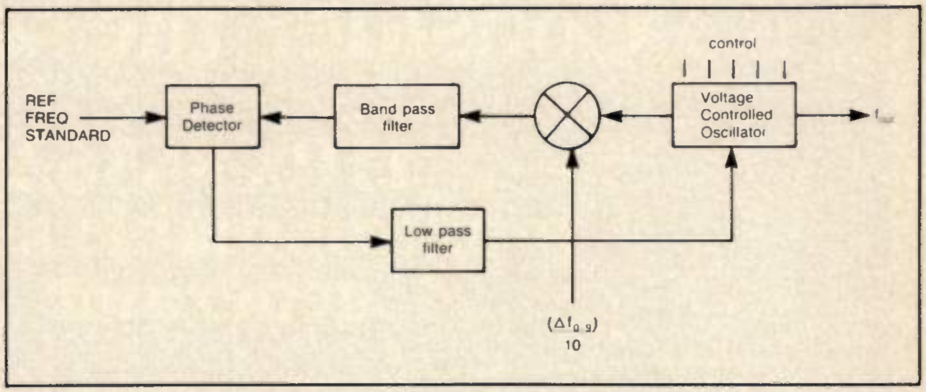

Figure 3. Phase Locked Loop (PLL) Block Diagram

the residual phase noise of the PLL plus the phase noise of the reference frequency standard.

The PLL acts as a low pass filter with respect to the reference standard so that within the PLL loop bandwidth (close to the carrier), the total PLL phase noise is composed of the noise of the phase detector, the divider, and the reference standard multiplied up to the final PLL frequency.

Outside the loop bandwidth, however. the PLL acts as a high pass filter with respect to VCO noise. Far from the carrier, total PLL noise is therefore equal to VCO free-running noise, Figure 5.

In recent years, the ancillary sections of PLL synthesizers — user interface, remote programming, and secondary features including automatic and manual sweep — have been made simpler through the application of more sophisticated microprocessor designs. In addition, wideband loops have been used

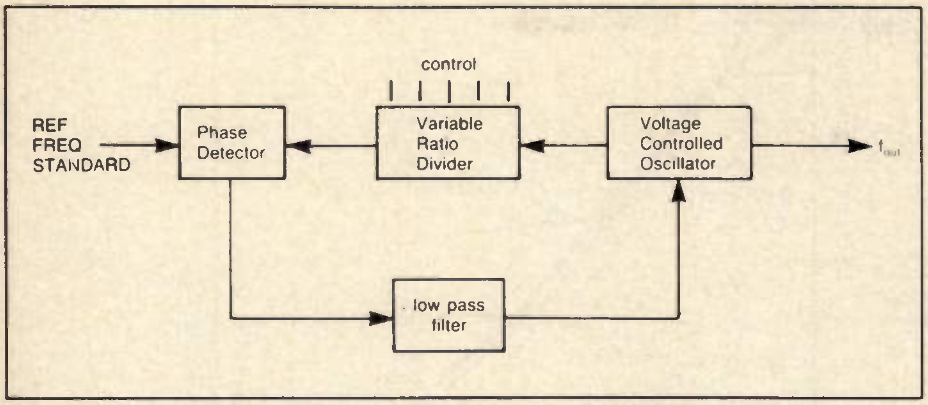

Figure 4. Digital Phase Locked Loop Block Diagram

to improve switching speed over previous designs, and multiple loops and automatic loop bandwidth switchover will considerably improve close-in PLL phase noise. Systems and circuits can also be designed specifically for low noise. Accordingly, PLL performance has been improved to compete with direct synthesizers in terms of close-in phase noise and switching speed.

Cost is perhaps the most important reason for choosing a PLL synthesizer. The enhancements descibed above, however, result in increased cost compared to a basic Phase Locked Loop design. If design goals call for very low close-in phase noise (<1 kHz offset frequencies) combined with a switching speed of less than several milliseconds, low spurious response, *and* fine frequency resolution of 0.1 Hz or better, other synthesizer types may have to be considered to achieve desired performance at the most economical price.

Direct Analog Synthesis

One well known form of direct analog synthesis is the "double-mix-divide" technique illustrated in Figure 6. The input signal is the same frequency as the output except that the latter also includes the next decade digit immediately after the decimal point. With this technique, designers have a basic circuit or module that can be repeated in series as many times as is necessary to achieve a desired resolution.

In the final design of such a synthesizer, a drift cancellation loop (DCL), is often included to provide the wide frequency coverage demanded of modern frequency synthesizers. As shown in Figure 7, the DCL uses a VCO with coarse frequency steps and a range of variable frequency signals to translate the input to the DCL to the final output frequency. The effect of VCO phase noise is reduced by the addition-subtraction process inherent in the DCL circuitry, but the phase noise of the synthesized signal still contributes to the overall phase noise of the synthesizer.

The double-mix-divide technique has numerous advantages:

1. Final output switching speed is high, Figure 8, because it is controlled by the fast switching time of RF switches for the frequency increments, and by the very short delays associated with double-mix-divide decades.
2. Since circuits can be repeated in series, as many modules as required can be daisy-chained together to produce a final output with resolution as fine as 0.01 Hz. Better resolution is theoretically possible and limited only by the amount of available space and power.
3. Residual phase noise does not degrade as resolution is added in the synthesis chain. At the end of the synthesis block, the 1/10 frequency divider provides up to 20 dB improvement in phase noise and spurious response to compensate for any signal degradation during the double-mixing process.
4. At offset frequencies close to the carrier, total phase noise is dominated by the phase noise of the reference standard multiplied by the final synthesizer frequency. For offset frequencies far from the carrier, however, phase noise is limited by residual noise associated with the synthesized frequencies and (to a lesser extent) VCO noise in the drift cancellation loop.

Direct Digital Synthesis

At intervals equal to the period of a reference standard, Direct Digital Synthesis generates, in a digital phase ac-

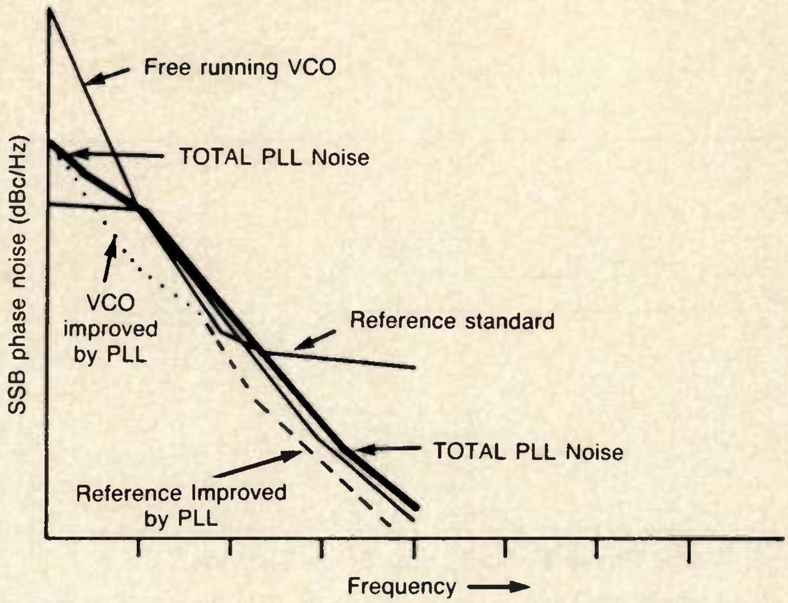

Figure 5. VCO phase noise and the effect of the PLL on phase noise performance.

cumulator (Figure 9), linearly increasing phase values for the desired sine wave, Figure 9. The slope of the resultant phase ramp is directly proportional to the selected frequency.

A Read Only Memory (ROM) with a sine function "look-up" table converts the digital phase values to digital samples of a sinusoidal waveform. A Digital-to-Analog Converter (DAC) then produces a staircase approximation to the sinewave, with the resulting waveform rich in high frequency components. The low pass filter removes these components and provides a pure sine wave output.

The DAC, since it restricts overall bandwidth and can introduce spurious and harmonic components into the final output, is the limiting factor determining overall performance of direct digital synthesis. Also, a 12-bit DAC operating at less than 10 MHz is all that is practical with present technology. This in turn defines the size of the ROM, since any increased performance by the sine ROM will be masked by DAC limitations.

Other problems occur when the selected frequency is not an exact submultiple of the reference frequency. Under such conditions, ROM phase quantization errors are exhibited and spurs will be generated at offset frequencies directly proportional to the number of points in the sine table.

Despite these limitations, applications exist that can make use of the unique advantages of direct digital synthesis. Those advantages are:

1. Phase continuous switching is made possible, since the phase accumulator retains the last phase value prior to a frequency change and the new frequency can start with that value.
2. Frequency switching speeds of less than 1.5 microseconds are possible since the only relevant delays are those through the digital circuitry and the output low pass filter. For the DDS technique, "programming delay" is more appropriate nomenclature than "switching speed."
3. Frequency update rates on the order of the reference standard are theoretically possible although several clock cycles may be more realistic.
4. Phase control is possible either by resetting the phase accumulator to zero phase or by setting an arbitrary value (providing a parallel load into the accumulator).
5. Frequency resolution is limited only by the number of bits in the accumulator and values of 0.001 Hz or better are easily obtainable across the entire frequency band.
6. Construction of a DDS synthesizer requires virtually no circuit alignment (except the DAC and low pass filter) and uses readily accessible low cost integrated components.

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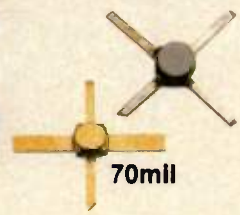

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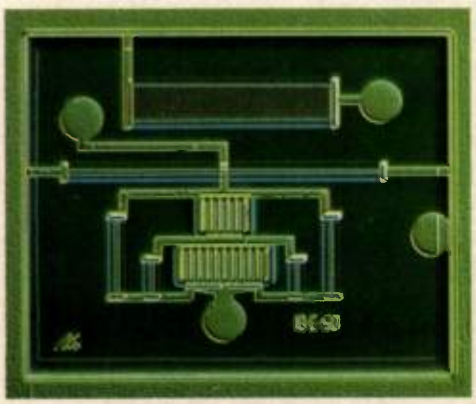

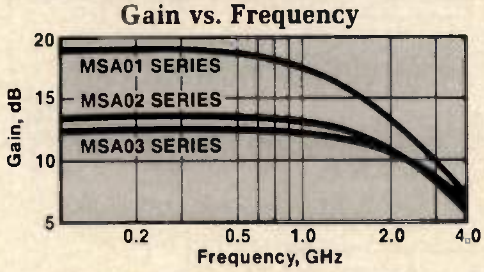

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The Model 5155A Synthesizer

Combining Phase Locked Loop circuitry, Direct Analog Synthesis, and Direct Digital Synthesis into one instrument, Figure 10, the Wavetek Model 5155A HF-UHF frequency synthesizer provides the primary benefits of each of the basic synthesizer types described above.

A patented* Direct Digital Synthesis technique is used to generate lower frequency increments from the 10 kHz digit to the 0.1 Hz digit. This circuit does the work of six double-mix-divide modules, reducing the space requirements, component count, alignment, and test time, while increasing reliability. The DDS also enables phase-continuous switching over the entire 0.1 to 1000 MHz frequency range as long as only the DDS increments are changed. In accordance with the earlier discussion of direct digital synthesis, output signal phase control is also possible. With a simple modification to the existing circuitry, an external TTL signal can be used to increment the phase of the final frequency by 90° and any multiples thereof.

Since the spurious response of the DDS technique is not as good as the response dictated by the design goals, the 100 kHz and 1 MHz digits are obtained with direct analog techniques. At the output of the double-mix-divide section of the 100 kHz digit, the divider improves both phase noise and spurious response of the DDS (the input to the double-mix-divide section) to an accept-

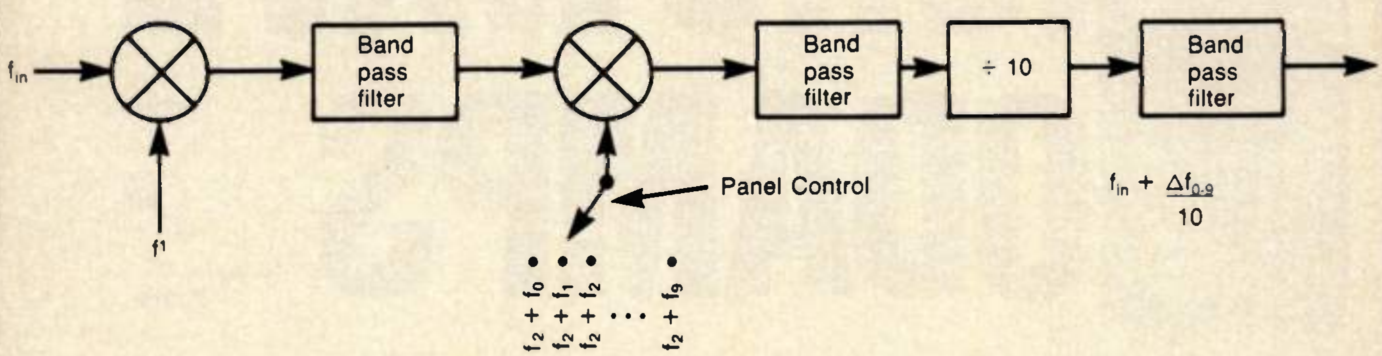

Figure 6. Direct Analog Synthesis Block Diagram (double-mix-divide)

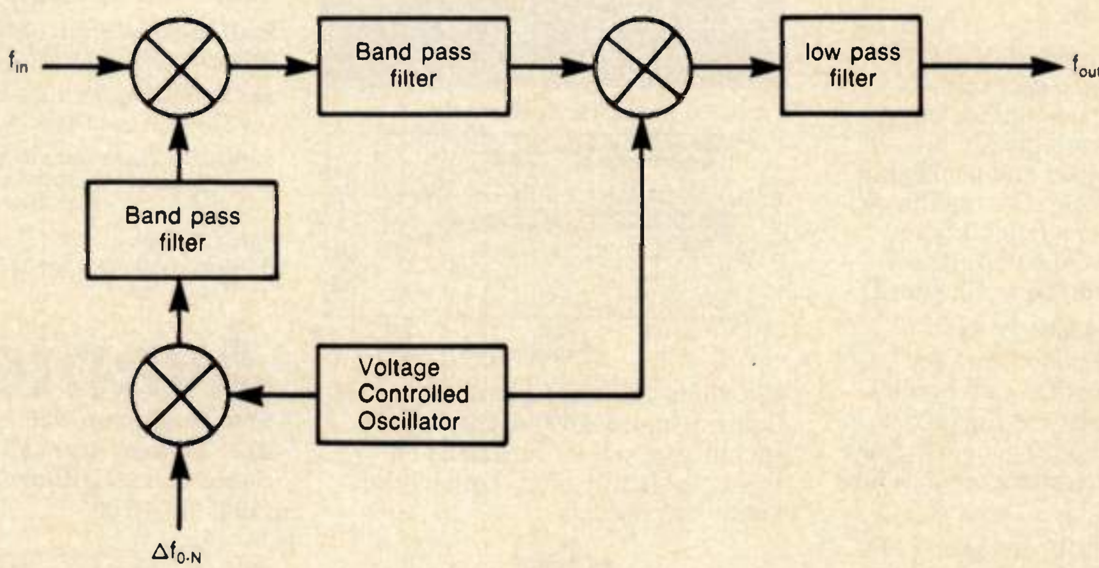

Figure 7. Drift Cancellation Loop (DCL) Block Diagram

*U.S. Patent number 3,735,269

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able level.

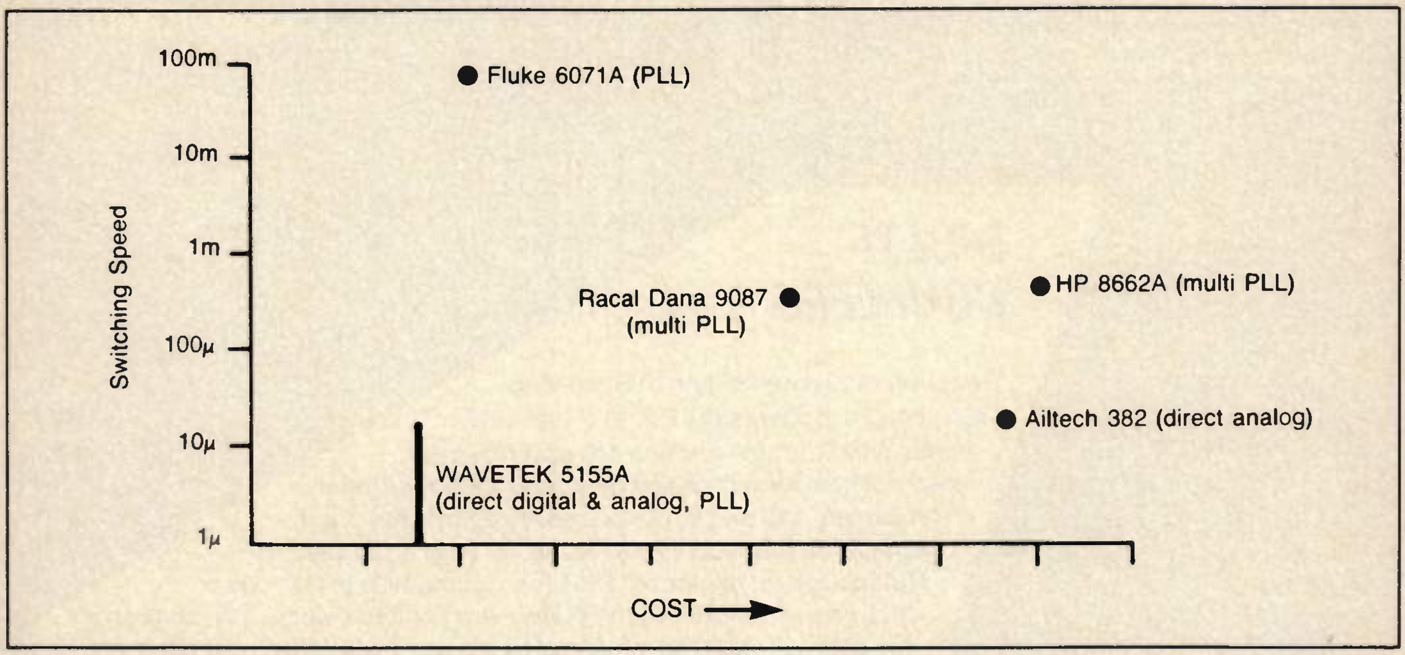
The remaining digits are generated with a UHF cancellation loop utilizing a locked VCO to generate the range of frequencies needed to move a 10 MHz band anywhere in the frequency range of the instrument. Locking is used to improve reliability and VCO phase noise characteristics at lower offset frequencies. The PLL design was selected so that loop bandwidth provides low phase noise as defined in the design goals while being large enough to maintain the desired fast switching speeds.

Performance

Combining synthesis techniques gives the Wavetek Model 5155A Frequency Synthesizer unique and impressive specifications, including:

- Wide frequency coverage: 0.1 to 1000 MHz

Figure 8 — Switching Speed Comparison



The new Model 5155A Synthesizer is ideal wherever a very pure, high frequency signal source is needed at a reasonable price...in the laboratory and in production for communications or radar.

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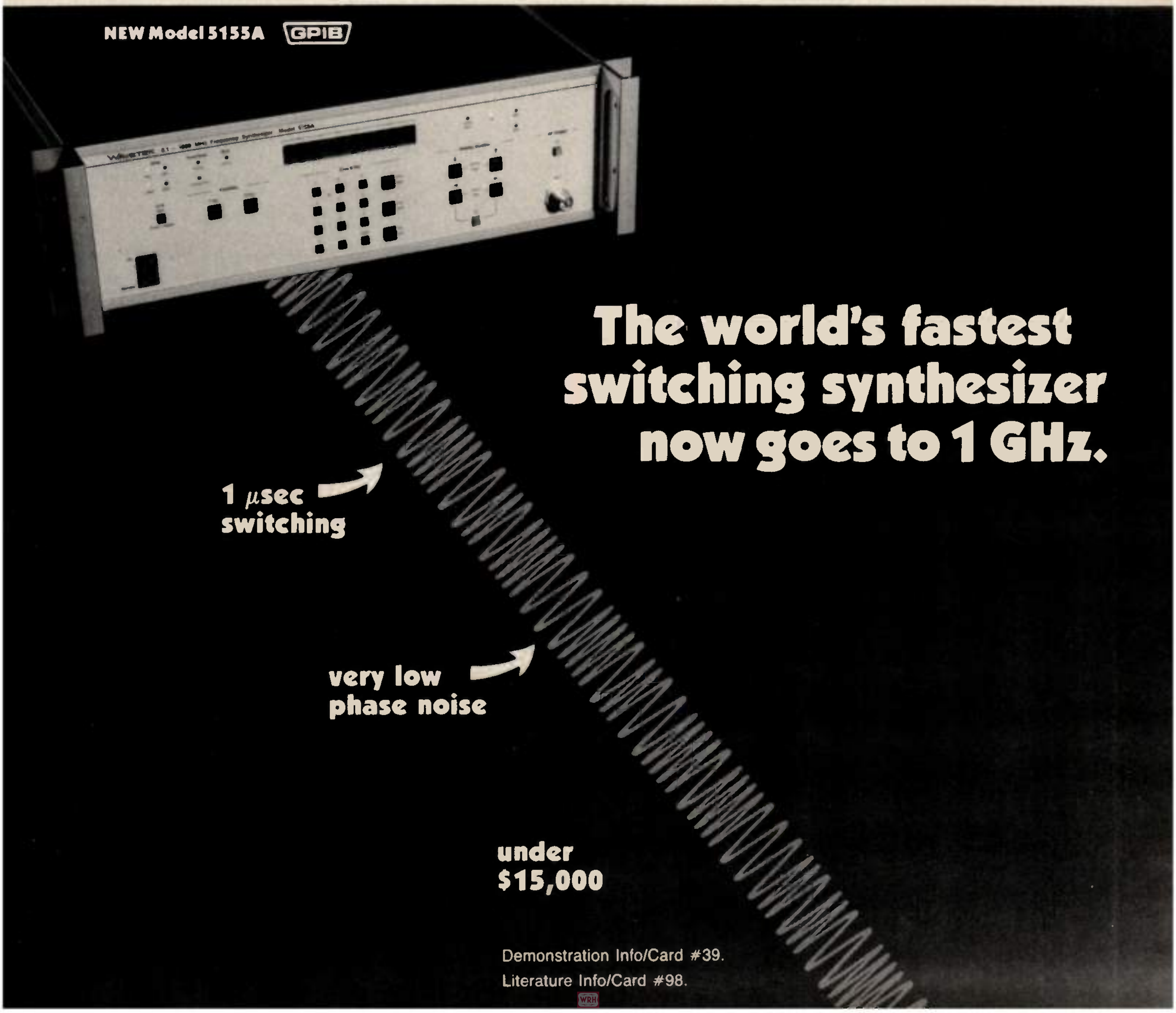

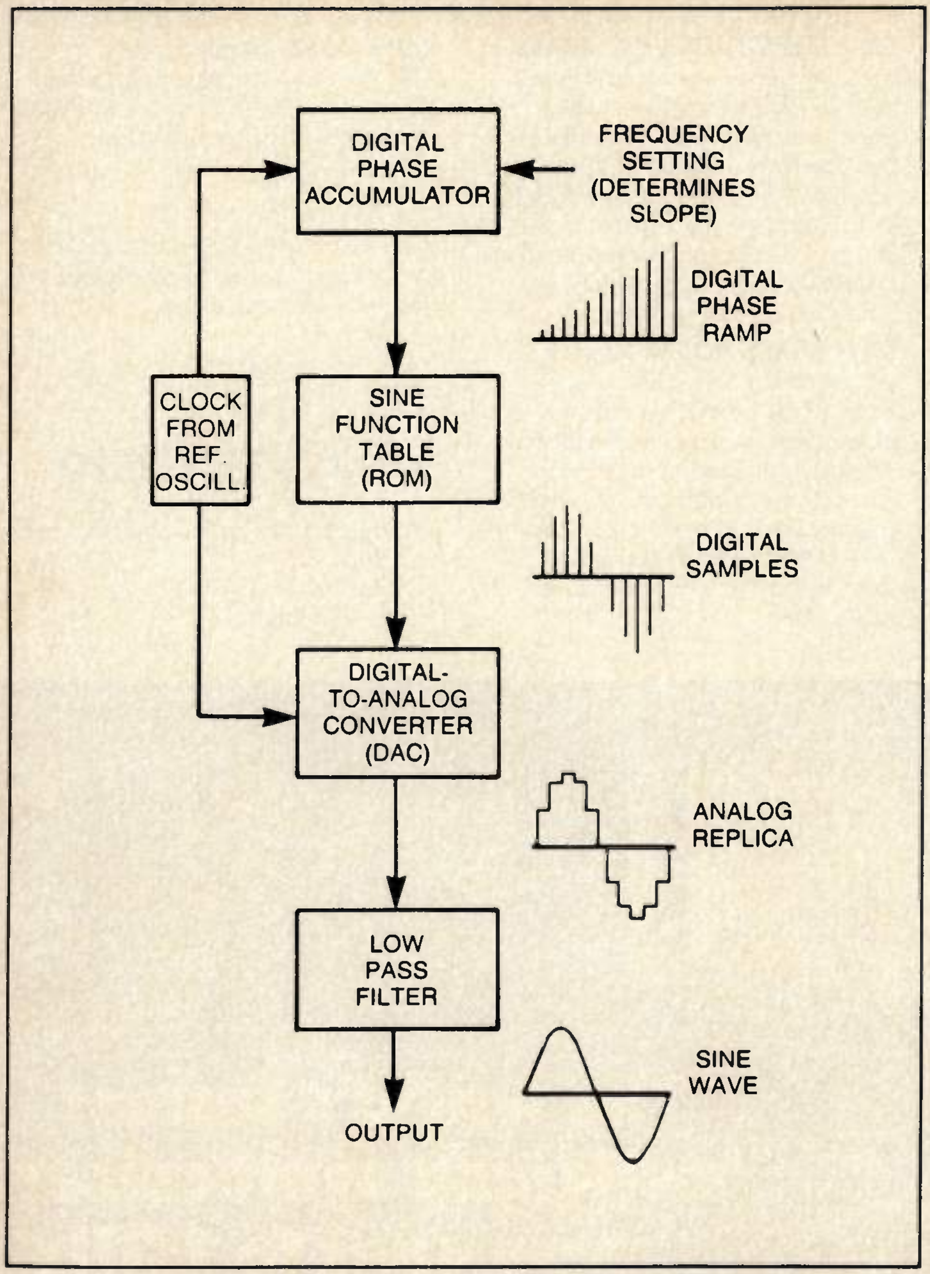

Figure 9. Direct Digital Synthesis Block Diagram

- Fine resolution: 0.1 Hz
- Phase-continuous frequency switching: 100 kHz bandwidth
- Fast switching speed: <1 microsecond for frequency changes less than 10 MHz
- Excellent close-in phase noise: typically -110 dBc/Hz at 100 Hz offset for a 500 MHz carrier frequency, and -90 dBc/Hz at 1 Hz offset

Summary

Since no one synthesis method can satisfy all requirements, the performance of a frequency synthesizer can be optimized by properly using different methods in conjunction with one another. Cost is often the overriding factor in determining synthesizer performance, but design ingenuity can play an even more important role.

In the Wavetek Model 5155A HF-UHF synthesizer, several techniques — Direct Analog, Direct Digital, and Phase Locked Loop — were used to increase performance while maintaining a close watch on overall cost. Direct digital synthesis is used to control component count while providing ultra-fast switching speeds with phase-continuous frequency changes. Direct analog synthesis and a fast switching PLL, on the other hand, maintain low noise and fast switching while providing a wide frequency coverage not possible with direct synthesis alone.

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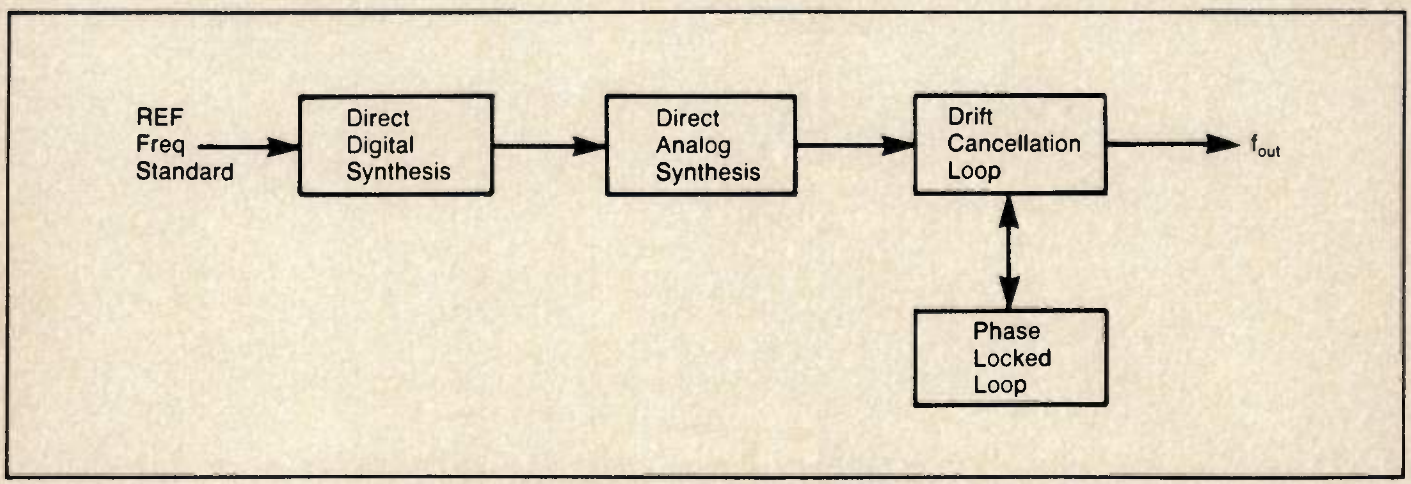

Figure 10. Wavetek Model 5155A Simplified Block Diagram

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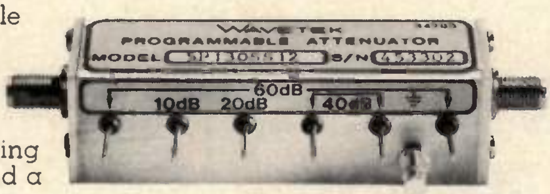

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Low-Power VHF/UHF Synthesizer Design

A background in phase-noise sources and estimating techniques as applied to frequency synthesizer design.

By Henry W. Anderson
Watkins-Johnson Company
Palo Alto, CA 94304

Introduction

Frequency synthesizers are crucial elements in modern communications receivers; their performance can enhance or limit overall receiver effectiveness. Phase noise is a principal measure of synthesizer performance. This article provides the reader with a background in phase-noise sources and estimating techniques, and leads into the discussion of a specific synthesizer design. Design goals and circuit implementation are also discussed. Measurements are presented to show design results and areas for improvement. Following the measurements is a brief discussion of synthesizer performance effects on the overall receiver.

Phase-Lock Loop Background

Synthesizers, as do all phase-lock loops (PLL), have many sources of phase noise. The three sources discussed here are shown in Figure 1. They are frequency-reference phase noise. (e_R), phase detector and loop-filter noise (e_nT), and voltage-controlled oscillator (VCO) phase noise (e_v). Estimating the impact of these phase-noise sources is important in the initial stages of a synthesizer design. Estimates are also valuable for comparing or evaluating existing designs.

Frequency-reference phase-noise spectrum information can be gleaned from reference-oscillator data sheets. Phase-noise information is typically provided by a graph of the single-sideband phase-noise spectral density, L (f), with dimensions dBc/Hz. This data and the divider ratio, R, allow the reference oscillator phase-noise spectrum to be translated to the divider output. The governing relationship is, 20 log (1/R). Note, however, that a finite lower limit to e_R exists regardless of how large R becomes. This lower limit is determined by the technology used in the divider. The counter division ratio R, the counter technology, and the reference-oscillator phase-noise spectrum all have to be taken into account to minimize frequency-reference effects on overall synthesizer

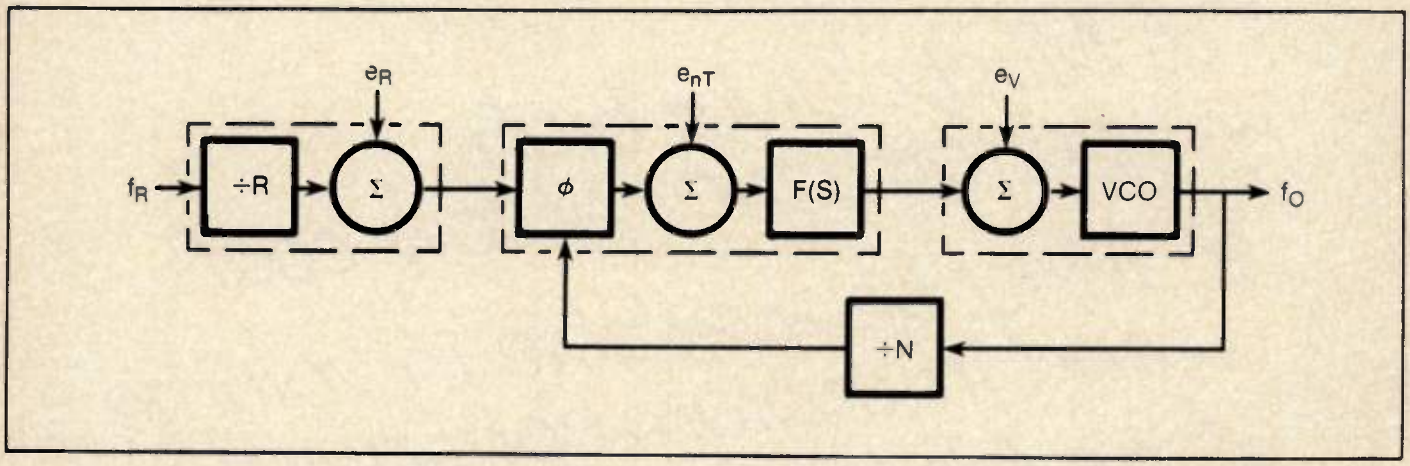

FIGURE 1. SYNTHESIZER PHASE NOISE SOURCES BLOCK DIAGRAM.

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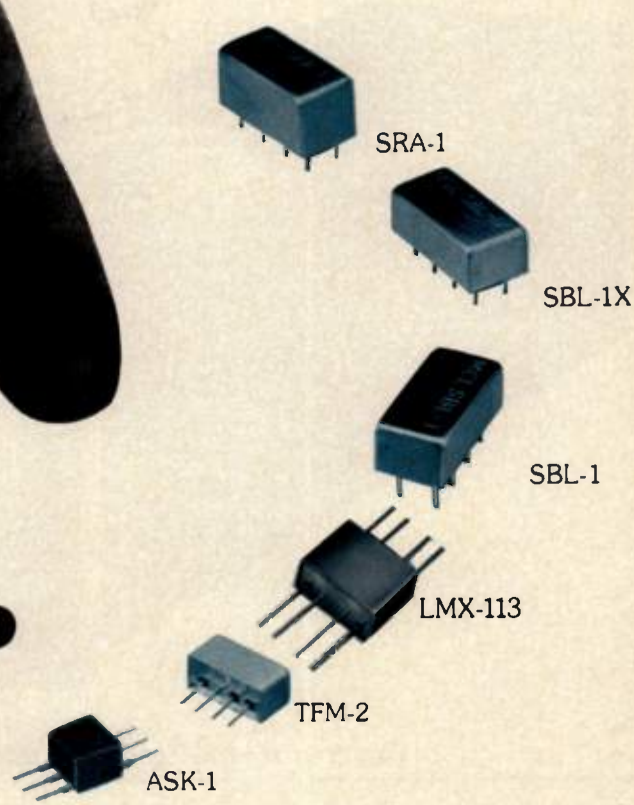

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SBL-1	world's lowest cost industrial mixer, only $4.50, metal case	1-500	DC-500	5.5 typ.	6.5 typ.	50 typ.	45 typ.	35 typ.	3.95 (100) 4.50 (10-49)
SBL-1X	industrial grade, rugged all-metal construction	10-1000	5-1000	6.0 typ.	7.0 typ.	50 typ.	40 typ.	30 typ.	5.95 (1-4)
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noise.

Phase-detector output and loop-filter input noise are modeled as one source, e_{nT}. This often-overlooked source is usually the limiting phase-noise contributor inside the synthesizer's loop bandwidth. A technique for estimating the effect of e_{nT} is obtained by taking the Laplace transform transfer function from e_{nT} to the synthesizer output. Since the area of interest is inside the loop bandwidth, the obtained transfer function can be simplified to:

$$L\ (f_m) = 20 \log \frac{N E_{nT}(f_m)}{K_p} \text{ dBc/Hz}$$

E_{nT} (f_m) is the loop-filter input equivalent of noise-voltage spectrum (V/$\sqrt{}$Hz), which can be obtained from manufacturer data sheets. The phase-dectector gain constant K_p, in V/radian is the detector ouput-voltage range divided by its range in radians. Note that the above equation does not contain the loop gain, but only N, E_{nT} and K_p. Therefore, to reduce the contribution of this noise source to the synthesizer-ouput phase noise, three measures can be taken.:

1. select a different frequency plan that allows a longer division ratio, N.
2. choose a lower input-equivalent noise-voltage loop amplifier.
3. use a higher-gain phase detector.The

The first two options are straightforward, therefore, only the third will be discussed in detail.

Gain constants vary with the type phase detector. A popular TTL digital/frequency detector has an output swing of 1.5 volts and a range of 4π radians; therefore, it has gain constant of 0.12 volts/radian. A similar CMOS circuit has a gain constant of 0.4 volts/radian when operating from a 5-volt supply, or 0.72 volts/radian when operated at 9 volts. A discrete circuit sample-and-hold phase detector operating with a 10-volt output swing has a gain constant of 2.0 volts/radian. Comparing the phase-detector contants, a 24-dB phase-noise improvement is realized by selecting the sample-and-hold detector over the TTL phase/frequency type. It is also seen that the CMOS circuits offer performance between these two extremes.

Estimating the VCO contribution to synthesizer phase noise requires knowledge of the frequency range (ΔF) and the available tuning voltage range (ΔV). This information is used to calculate the VCO gain constant, K_{VCO}(MHz/volt):

$$K_{VCO} = \frac{\Delta F + M}{\Delta V} \text{ MHz/volt}$$

M = frequency overlap or design margin.

Next, assume a residual noise voltage, E_n, riding on the VCO tuning voltage in-

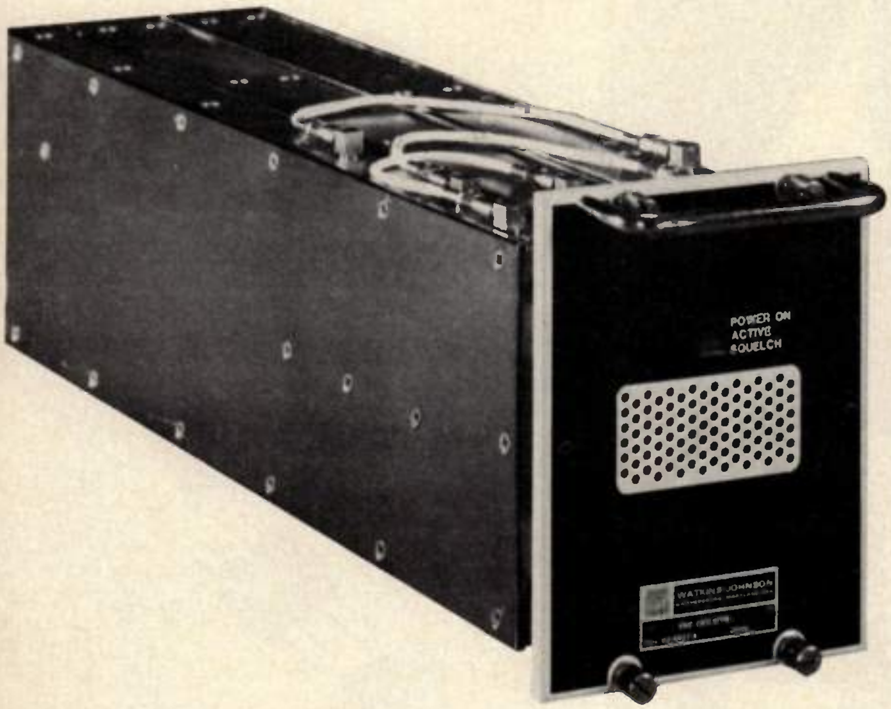

Figure 2. WJ-8627 series receiver

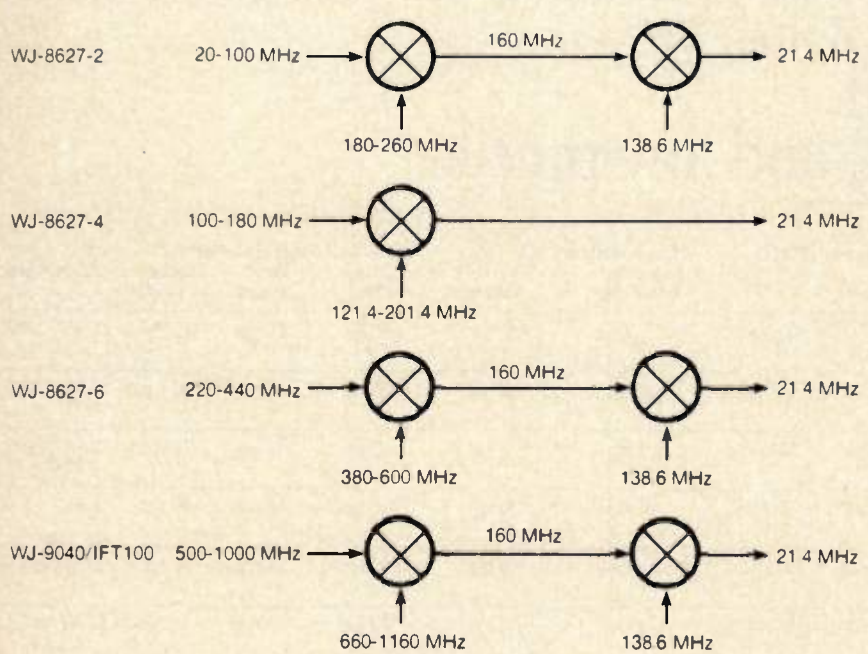

FIGURE 3. WJ-8627 RECEIVER SERIES FREQUENCY PLANS.

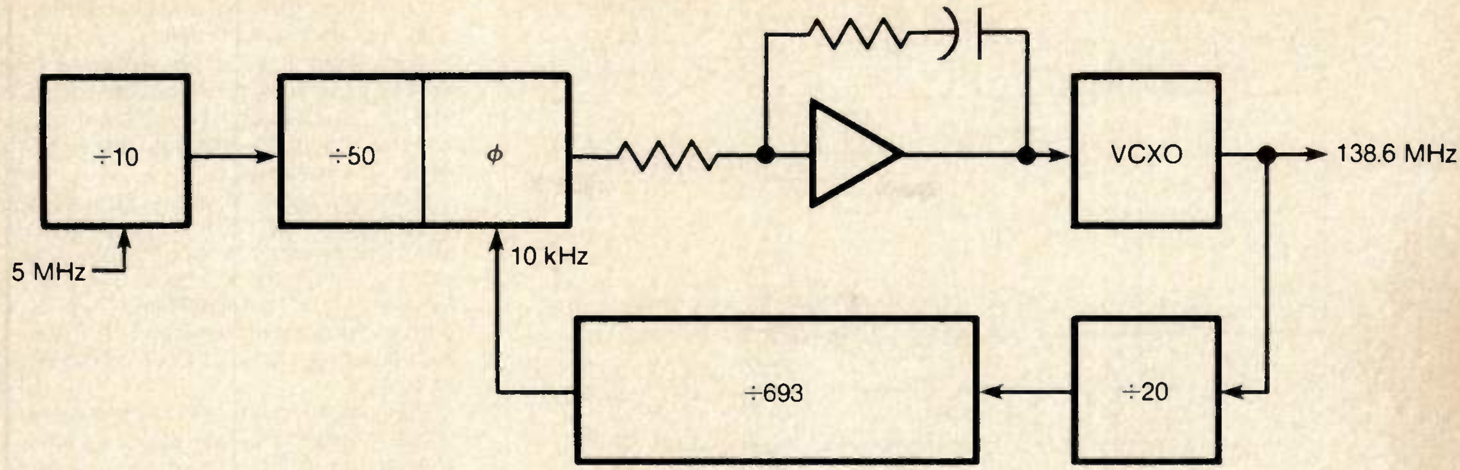

FIGURE 4. SECOND LO SYNTHESIZER BLOCK DIAGRAM.

put, E_n and K_{VCO} are then used to calculate the VCO's incidental frequency modulation (IFM):

$$IFM = K_{VCO} E_n \quad \text{Hz in 1-Hz bandwidth}$$

A realistically achievable lower limit for E_n is 0.1 μV. The VCO phase-noise spectrum is then obtained by using:

$$L(f_m) = 20 \log \frac{IFM}{\sqrt{2}\, f_m} \text{ dBc/Hz}$$

Looking at these two relationships, only two ways to improve phase noise are noted: Lowering the value assumed for E_n, which, in an actual system may be impossible, or reducing K_{VCO}. The VCO gain constant, K_{VCO}, can be lowered by increasing the available tuning-voltage range or by reducing the oscillator frequency range. These last two parameters are not usually at the sole discretion of the synthesizer designer, since power supply voltage and other system limitations may apply. However, using band switching in the VCO accomplishes the desired reduction of K_{VCO}. A limit on the number of band switches, however, is imposed by physical circuit limitations. These limitations are imposed by layout constraints and/or the losses associated with the band-switching circuitry.

The discussion of PLL phase-noise sources provides a model for looking at synthesizer phase noise and techniques for making estimates. These techniques are simplified and must be expanded for an actual design. They can, however, be used for quick comparisons between designs and for looking at the effects of circuit trade-offs within a design. Starting with these simple estimation techniques, the low power, low phase-noise synthesizers of the WJ-8627 series receivers were designed. A typical WJ-8627 receiver is shown in Figure 2.

Design Goals

Design goals established for the new series of recievers include low power consumption, improved performance, commonality between units and circuit simplicity.

A goal of one-half the power consumption of the existing design was set. Therefore, all design decisions were made with power as a primary concern. Higher-efficiency amplifiers were considered, new low-power technology explored, and frequency plans evaluated for their impact on power consumption.

The performance improvement goal was characterized by a 45-dB FM ultimate signal-to-noise ratio (S/N) specification, with no video bandwidth restricting filtering (less than B/2 cut-off). This related directly to a more stringent synthesizer phase-noise requirement. The relationship between receiver incidental frequency modulation and measured FM ultimate S/N, shown below, was used.

$$\Delta f_{RMS} = \frac{.707\,(.3B)}{10^{\frac{S/N}{20}}} \quad \text{Hz in a B-Hz bandwidth}$$

Δf_{RMS} = incidental frequency modulation in a specified bandwidth, B.

B=IF bandwidth in Hz

The Δf_{RMS} value was then linked to the single-sideband phase-noise spectrum, L (f_m), by the following equation, evaluated with f_m equal to the IF bandedge (B/2):

$$L(f_m) = 20 \log \frac{\Delta f_{RMS}}{\sqrt{2}\, f_m \sqrt{B/2}} \text{ dBc/Hz}$$

This point and a -20 dB/decade line through it define the required phase-noise performance for a given S/N goal. Improved FM detector and video circuitry capable of sustaining the 45-dB level is also required.

Commonality of circuitry designs, printed-circuit boards, chassis, and frequency plans increase potential manufacturing flexibility and reduce maintenance training. The use of similar circuits increases production, field technicians' familiarity with the various WJ-8627 series receivers, and is also greatly enhanced by common connector placement on all functional modules. A flexible frequency plan is required to allow the circuit commonality goal to be met.

Circuit simplicity provides the long-term benefits of easy, straightforward alignment and troubleshooting, thus eliminating the requirement for highly trained personnel to handle routine maintenance.

Circuit Implementation

In designing the WJ-8627 series of receivers, trade-offs had to be made in circuitry to fulfill the goals of low power, high performance and flexibility, while still maintaining a simple design.

The frequency range to be covered was divided into four coverage bands: 20 to 100 MHz, 100 to 180 MHz, 220 to 440 MHz, and 500 to 1000 MHz. Frequency plans for each frequency band were considered individually, and then in combination, to provide maximum commonality. The final frequency plans are shown in Figure 3. The common intermediate frequencies of the dual conversion plans allow common circuits to be used in all cases. Note that a fixed 2nd local oscillator (LO) frequency is used. Synthesizing a fixed frequency has the design advantages of low power and high performance. Also, a fixed 2nd LO requires that all receiver tuning occur in the 1st LO, thus providing the flexibility to choose a single conversion frequency

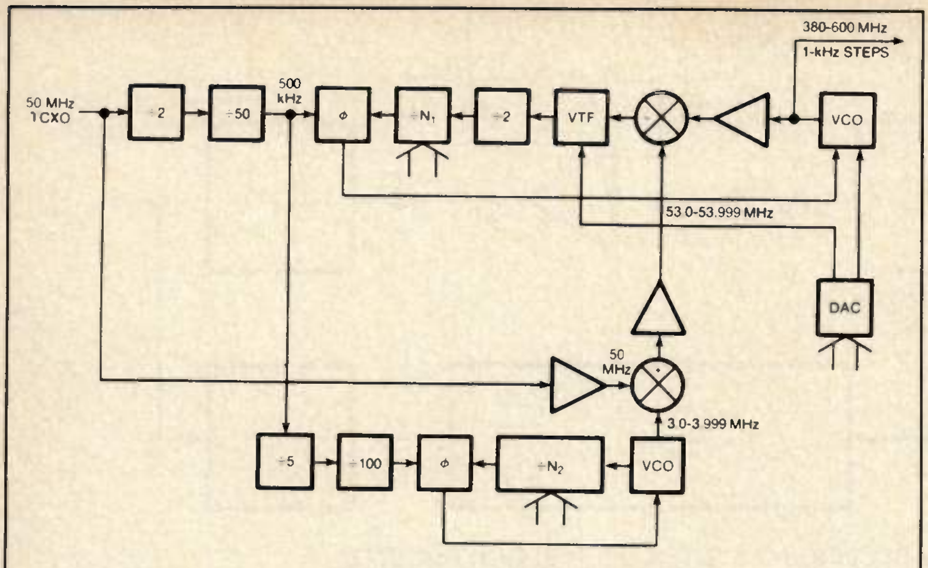

FIGURE 5 FIRST LO SYNTHESIZER BLOCK DIAGRAM

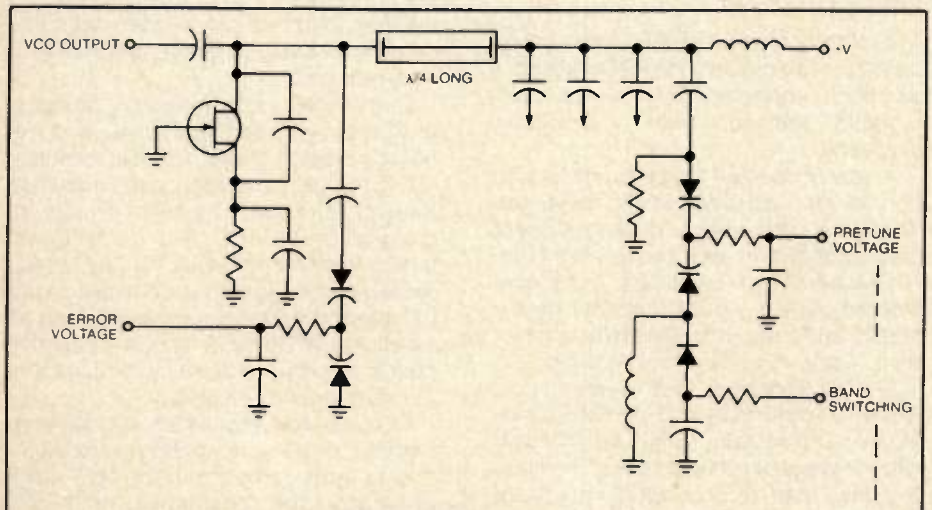

FIGURE 6 MULTIBAND VCO SKETCH

scheme, as in the 100-to-180 MHz band, by simply eliminating the 2nd LO. A closer look at Figure 3 reveals that the 1st LO frequencies are relatively low. Since power consumption of roughly proportional to frequency, low LO frequencies help conserve power.

Turning to the synthesizers, let's look at the circuit implementations that met the design goals for the 220 to 440 MHz frequency range. The fixed-frequency 2nd-LO synthesizer has been developed around a voltage-controlled crystal oscillator (VCXO). Figure 4 shows a 2nd-LO block diagram. The excellent phase-noise performance was inherent in the 2nd-LO design. CMOS large scale integrated circuitry, coupled with low-power prescaling, resulted in minimal power consumption, and a single production adjustment provided alignment ease.

The 1st-LO synthesizer will be addressed in three major sections: the fine frequency PLL, the upconverter, and the output PLL. A block diagram is given in Figure 5.

Some important factors of the fine-frequency PLL design are the VCO, the CMOS digital dividers, and the sample-and-hold phase detector. The low-frequency VCO provides very good phase-noise performance with low power consumption. CMOS dividers in both the reference and N_2 dividers greatly reduce power consumption over typical bipolar (TTL) designs. Selection of the sample-and-hold phase detector was based on its superior phase-noise and reference side-band performance, compared to other types discussed previously.

The upconverter circuit provides two functions. First, it allows a low-frequency, high-performance, fine-frequency PLL to be injected into the output PLL at useable frequencies. Second, it filters the unwanted mixer products to keep these spurious products from entering the output PLL. Note that the 50-MHz frequency oscillator is amplified and used as the upconverter LO. This provides an extremely low noise LO without the need to generate it by more complicated means.

Both amplifiers in the upconverter are designed using power amplifier techniques that enhance efficiency.

The output PLL will be presented in several parts in the following discussion: The phase detector, N_1 divider, voltage-turnable filter (VTF), digital-to-analog converter (DAC) and VCO.

A sample-and-hold phase detector is used again, not only because of its superior performance, but also to carry common circuitry in both the fine-frequency and output PLLs. This increases the similarity between both PLLs, thus lowering cost and troubleshooting time.

Previous N_1 dividers had been large power consumers, typically 2.5-to-3.5 watts in the VHF/UHF frequency range, but design improvements enable power consumption to be reduced to 1.5 watts. The selection of an output PLL reference frequency of 500 kHz and a divide-by-2 prescaler was determined on the basis of providing the lowest power-consumption design available. Further reductions in power will become possible as the next generation of digital logic becomes commercially available.

The VTF is the key component in eliminating mixer-related spurious responses in the output PLL. It must eliminate spurious respsonses without adding appreciable phase shift and, therefore, instability to the PLL. Reduced labor costs are achieved by realizing all resonator coils with microstrip lines.

The DAC circuit provides coarse tuning of the VCO and and tuning voltage required by the voltage-tuned filter. Low output noise voltage is required in those applications to reduce potential AM-to-PM conversions, which can severely degrade synthesizer phase-noise performance. CMOS integrated circuits and a band-gap reference meet the above requirements. They also consume very little power.

The output PLL VCO is the most complex and critical circuit in the 1st LO synthesizer design. Poor performance in this critical circuit can overshadow the entire design. The specific oscillator chosen is a quarter-wave transmission-line type. Figure 6 shows a sketch of the VCO circuit. Inherent mechanical stabiltity, low signal radiation, and the elimination of the need for a high-Q coil are factors in the oscillator selection. The multiband VCO reduces K_{VCO}, and thus, reduces phase noise. This VCO design is used in all frequency range receivers to increase circuit commonality. A five-band design is used in the 380-to-600 MHz synthesizer shown.

Performance Measurements

Performance measurements were made on a 220-to-440 MHz receiver. Total power consumption of the receiver measures 14 watts. Eight watts is

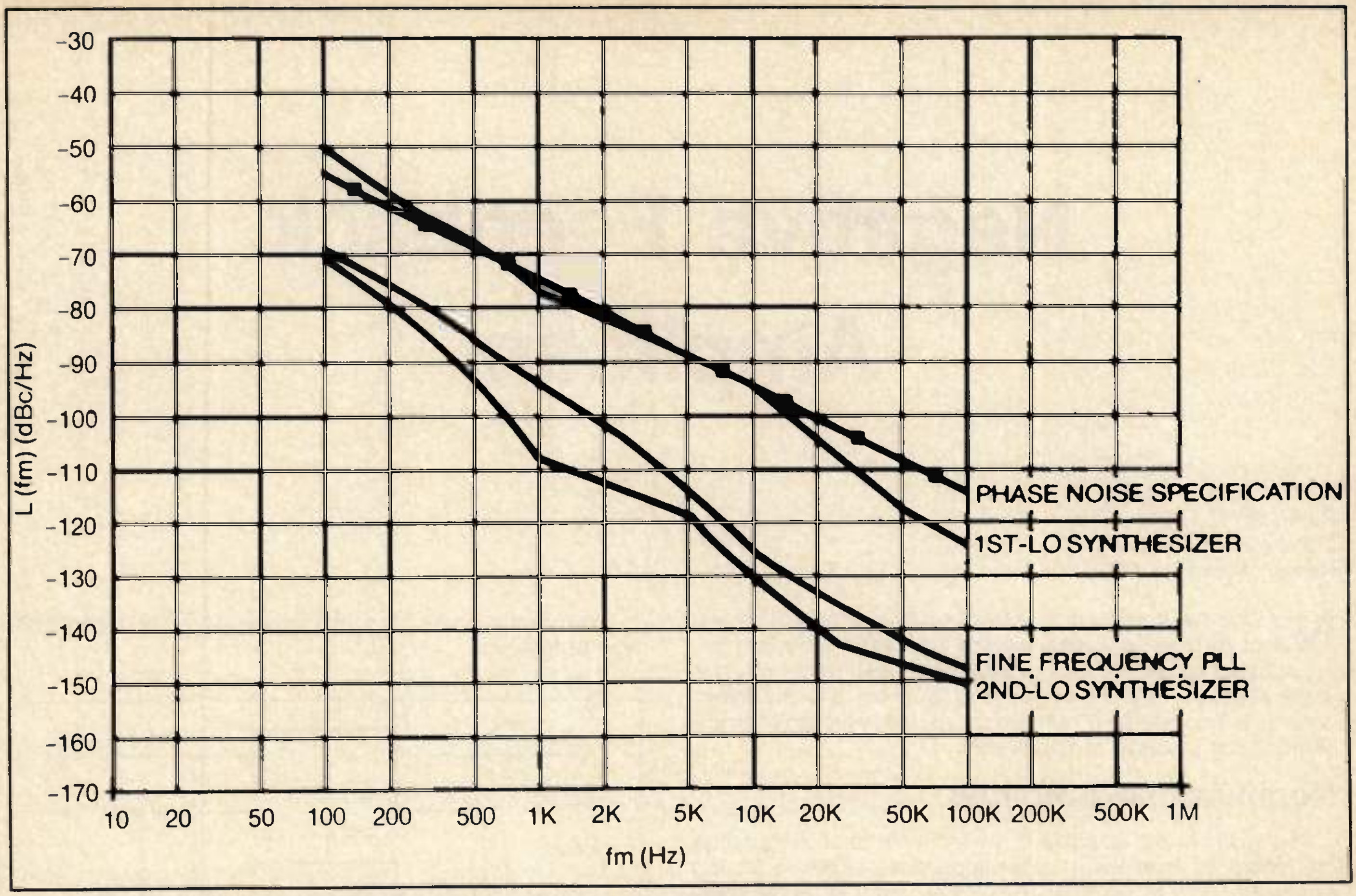

FIGURE 7. WJ-8627-6 SYNTHESIZER PHASE NOISE MEASUREMENTS.

dissipated in the synthesizers. Both LO synthesizers are housed in a common chassis consisting of one-third the receiver volume. A free-air temperature rise of 16°C was measured in this module.

Synthesizer phase-noise performance measurements are shown in Figure 7. Measured performance for the 2nd-LO PLL, fine-frequency PLL and 1st-LO synthesizer are presented. Also shown is the required phase-noise performance derived from the 45-dB FM ultimate signal-to-noise ratio goal. Second-LO performance is 30 dB better than required. The fine-frequency PLL phase noise is approximately 20 dB below the specification. The 1st-LO synthesizer measures to the required specification. Ultimate FM measurements of 46 dB indicate that the overall receiver phase noise integrates to below the design specification.

The overall receiver phase-noise performance is determined by the 1st-LO synthesizer output PLL. Further investigation reveals that the VCO is the primary contributor. Therefore, improving the VCO phase noise directly improves receiver performance. Since the measurements were recorded on a 5-band VCO, the PLL background discussion for reducing K_{VCO} is again ap- Adding more bands would decrease VCO phase noise. This fact has been utilized in the development of the synthesizers for the other receiver frequency bands, and better phase-noise performance has been verified.

Performance Implications

What are the implications of low power consumption and low phase-noise performance? Low power consumption allows convection cooling, thus eliminating acoustic and electrical noise, additional power, and the problems associated with mechanical vibration due to the presence of a fan. The costs associated with forced-air cooling are also eliminated. Electronic circuit reliability rapidly increases as the stress of high temperatures is reduced, thus increasing the mean time between failures and reducing maintenance costs. Lower phase-noise levels allow higher signal-to-noise ratios, thereby enhancing post-detection processing effectiveness. Reciprocal mix, which is characterized by the loss of small-signal sensitivity in the proximity of a large signal, is also reduced.

Conclusion

A simple phase-noise model for frequency synthesizers has been presented. The phase-noise model is useful in the early stages of a synthesizer design to analyze trade-offs. This is shown in its application to comparing types of phase detectors. It is also useful in evaluating existing designs. The PLL background section is followed by a discussion of a compact-receiver synthesizer design. Design goals and implementation highlights of the WJ-8627 VHF/UHF handoff receiver series have been presented. Measured performance of a WJ-8627-6 (220-to-440 MHz) receiver synthesizer is given, and its implication to receiver performance has been briefly discussed.

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2. Grebenkemper, C. John, *"Local Oscillator Phase Noise and Its Effect on Receiver Performance,"* Watkins-Johnson Company, San Jose, California, October 1981.

3. Martin, Larry, *"Noise-Property Analysis Enhances PLL Designs,"* EDN, September 16, 1981.

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Negative Feedback Amplifiers

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Negative feedback manipulates an amplifier's parameters. Most of these changes, except for loss or gain, are improvements for the majority of situations. This article will look at the effect of feedback on gain and impedance levels. Other parameter improvements of feedback are the reduction of distortion and the increase of bandwidth.

Noninverting Amplifier

The noninverting amplifier is a very important configuration that offers an increase of input impedance in return for the sacrifice of gain magnitude. The closed loop gain, A′, is given by the following formula:

$$A' = \frac{R_F + R_I}{R_I} \tag{1}$$

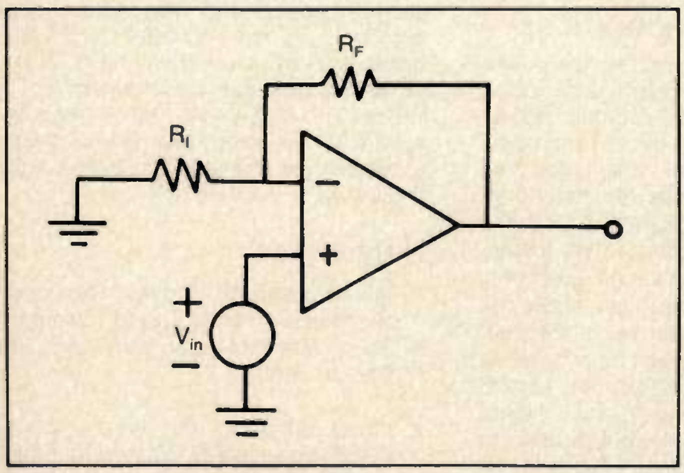


Figure 1. Noninverting Amplifier

Effect of Open-Loop Gain On Closed-Loop Gain

The noninverting amplifier is a negative feedback amplifier that corresponds to the most classical type of negative feedback. It has a voltage summation at the input (the input voltage plus the feedback voltage) and a current summation at the output. Because of this arrangement it is sometimes identified as series-parallel since series is associated with voltage summations and parallel with current summations.

The circuit in figure 2 corresponds to a generalization of this type of feedback:

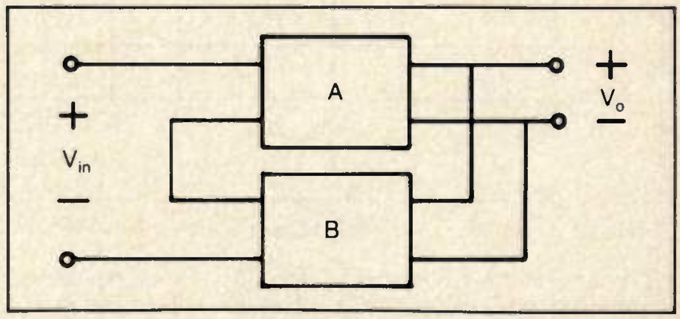


Figure 2. Block Diagram of Negative Feedback

In figure 2, the block shows that "A" represents the open loop gain of the amplifier and that block "B" represents the feedback loop. The closed loop gain A′ can now be calculated.

$$V_{in} = \frac{V_o}{A} + BV_o$$

$$AV_{in} = V_o\,(1 + BA)$$

$$A' = \frac{V_0}{V_{in}} = \frac{A}{1 + BA} \tag{2}$$

The value B is the fraction of the output voltage that is fed back to the input. This value is given by the division of the output voltage across the resistors R_I and R_F.

$$B = R_I\,/\,(R_I + R_F\,)$$

When A is larger, A′ reduces to 1/B which is identical to equation 1.

The factor 1 + BA can be shown equivalent to the open-loop to closed-loop gain ratio:

$1 + BA \approx BA$

$$BA = \frac{R_I}{R_I + R_F} \times A = \frac{A}{A'} \tag{3}$$

It is often more convenient to compute the gain ratio than 1 + BA.

Effect of Feedback on Input Impedance

Without feedback, the input impedance would be the R_{in} of the amplifier. But when the feedback loop is closed, the voltage at V(–) will rise from zero to just under V_{in} causing the voltage, and hence the current, to be much smaller than would be expected. This decrease in current caused by the negative feedback makes the apparent size of R_{in} extremely large. The output voltage, V_o is given by the input voltage times the noninverting gain.

$$V_o = A' V_{in} = \frac{A}{(1 + BA)} V_{in}$$

The differential voltage across the input resistance, V_{id}, is just the output voltage divided by the open loop gain.

$$V_{id} = \frac{V_o}{A} = \frac{V_{in}}{1 + BA}$$

$$I_{in} = \frac{V_{id}}{R_{in}} = \frac{V_{in}}{(1 + BA)R_{in}}$$

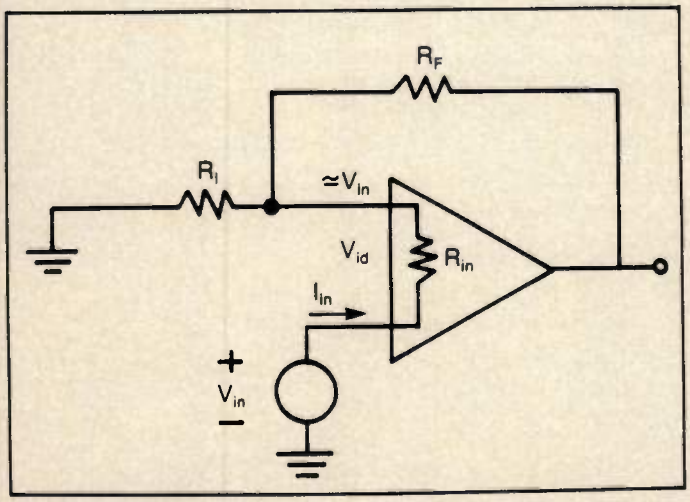


Figure 3. Input Voltages

The impedance is given by the input voltage divided by the input current.

$$Z_{in} = \frac{V_{in}}{I_{in}} = \frac{V_{in}}{\frac{V_{in}}{(1 + BA)R_{in}}} \tag{4}$$

$$Z_{in} = (1 + BA)R_{in}$$

Inverting Amplifier

The inverting amplifier does not have the advantage of increased input resistance, but does have other assets such as a simpler closed loop gain formula.

$$A' = -\frac{R_F}{R_I} \tag{5}$$

Effect of Open-Loop Gain on Closed-Loop Gain

The inverting amplifier is an example of a type of negative feedback that is sometimes called parallel-parallel. This designation refers to the fact that current summation occurs at both the input and the output due to the parallel connection at both places.

The inverting amplifier is show in figure 4.

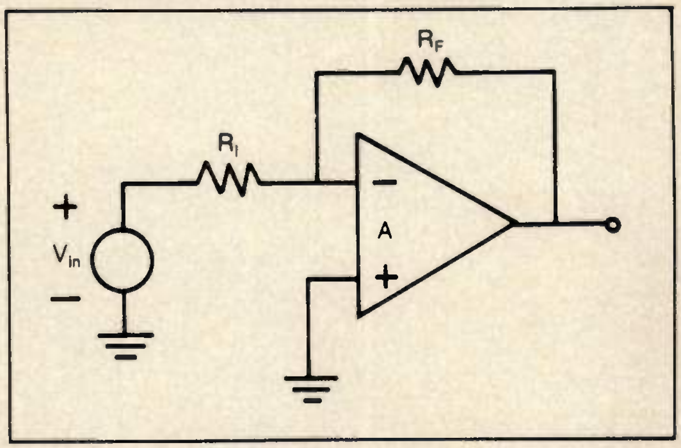


Figure 4. Inverting Amplifier

The action of the op-amp holds the voltages at the inverting and noninverting inputs close to each other. Since the noninverting input is at ground, the inverting input will be close to ground. This effect is called virtual ground. The virtual ground at the inverting input causes V_{in} and R_I to behave as a current source. This effect is shown in figure 5.

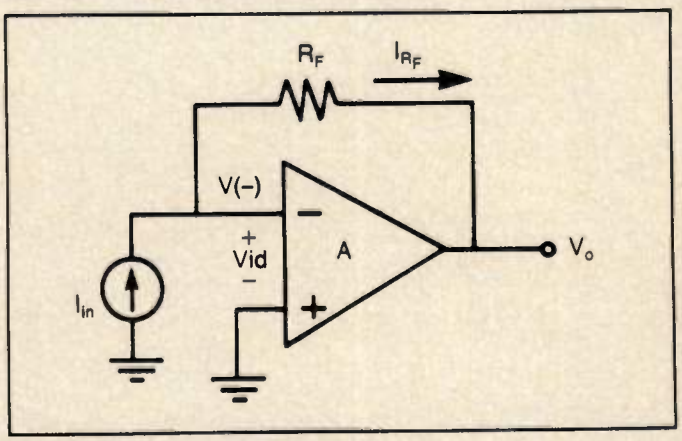


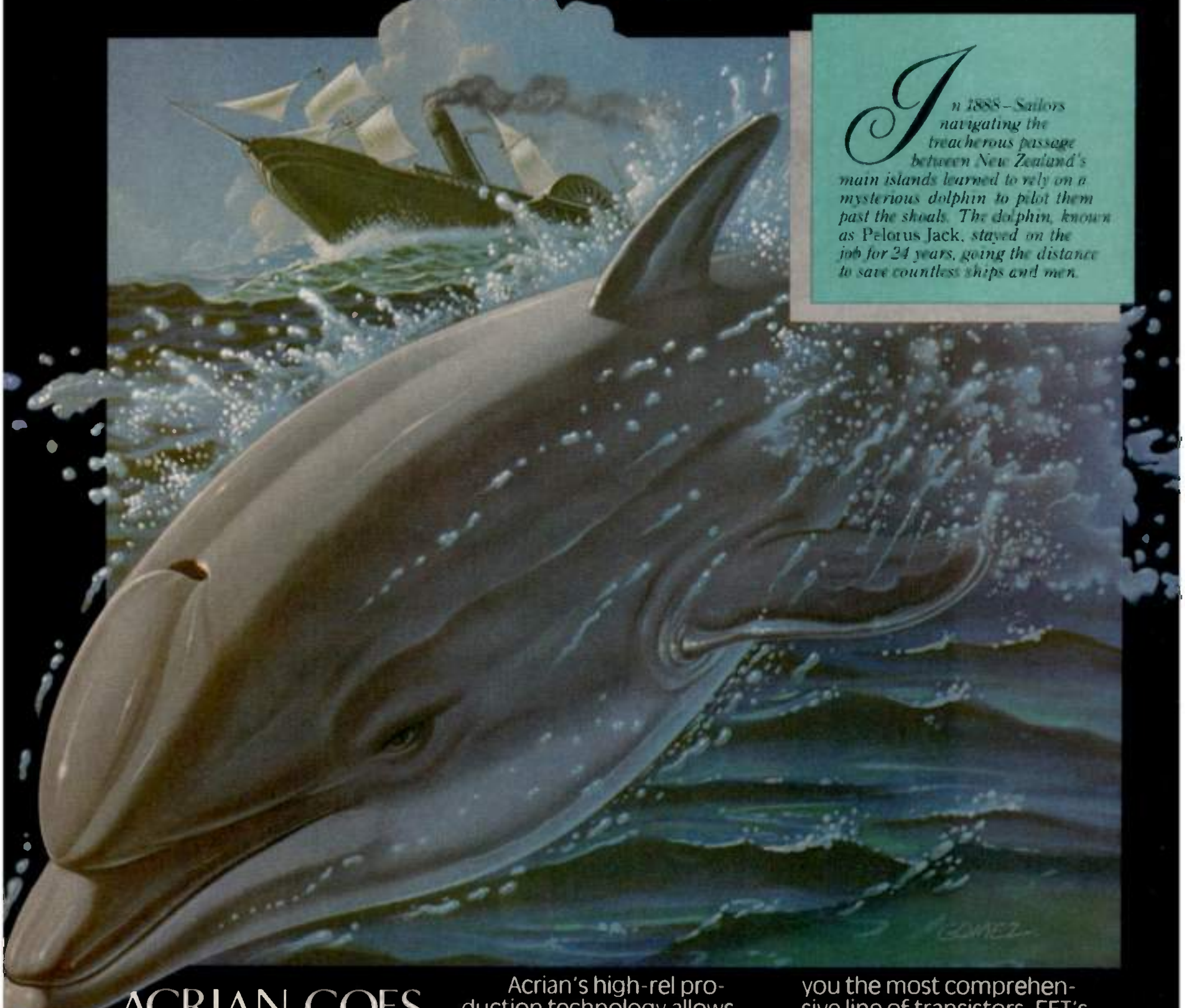
Figure 5. Current Source Effect

In analyzing the circuit in terms of current, note that the feedback resistor current is approximately equal to the input current because of the high input impedance of the op-amp.

$$I_{in} \approx I_{RF}$$

$$\frac{V_{in}}{R_I} = \frac{-V_0}{R_F}$$

GOING THE DISTANCE



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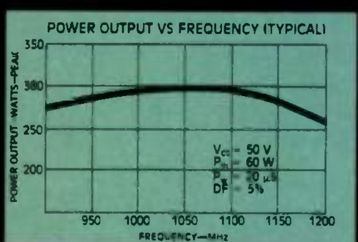

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Which gives the approximate closed-loop gain equation for the circuit:

$$A' = -R_F/R_I$$

The op-amp does not hold V(–) perfectly at zero, causing a small error voltage.

$$V_{id} = \quad V(-) = \frac{-V_o}{A}$$

This error voltage slightly modifies the currents that will flow in the two resistors by adjusting the voltages that appear across each resistor.

$$\frac{Vin - Vid}{R_I} = \frac{-(Vo-Vid)}{R_F}$$

$$R_F(V_{in} + \frac{V_o}{A}) = -R_I\,(V_o + \frac{V_o}{A})$$

$$-(R_IV_o + \frac{R_IV_o}{A} + \frac{R_FV_o}{A}) = R_FV_{in}$$

$$\frac{Vo}{Vin} = \frac{-R_F}{R_I+R_{I/A}+R_{F/A}} = \frac{-AR_F}{RI+RF+RIA} = \frac{\frac{-AR_F}{R_F+R_I}}{1+\frac{R_I\,A}{R_F+R_I}} \qquad (6)$$

$$A' = \frac{-A\,(1-B)}{1+BA}$$

The equation reduces to equation 5 for large A when RI / (R_I + R_F) is substituted for B.

Effect of Feedback on Input Resistance

The signal is not connected directly to the op-amp input in the inverting amplifier configuration. This causes the input impedance to not benefit from the potential high input impedance of the op-amp.

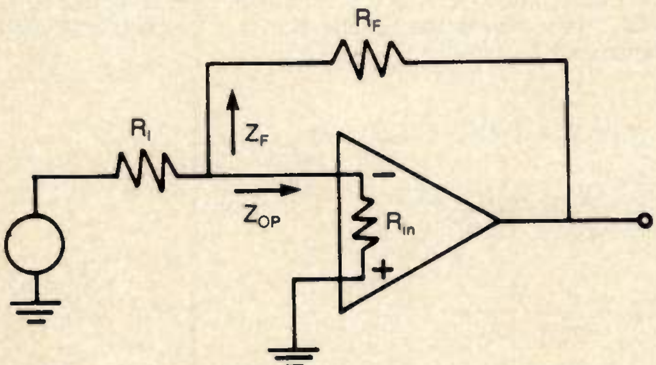

Figure 6. Input Impedance

The input impedance will be the input resistor in series with the parallel combination of the impedances of the two paths designated Z_F (for feedback path) and Z_{OP} (for op-amp path).

Miller's Theorem

It turns out that the apparent impedance looking into the input side of R_F is reduced by the open loop gain. This effect is known as Miller's Theorem. Miller's Theorem states that an impedance path (resistor, capacitor and inductor) that is connected across an inverting amplifier has its impedance reduced by one plus the voltage gain (1 + A). This effect can be easily calculated. Note that Miller's Theorem applies only to a component that is connected from the output to the inverting input of an amplifier and is effected by the gain between the points that it is connected. That is, the Miller resistor in Figure 6 is connected across the open-loop not the closed-loop gain.

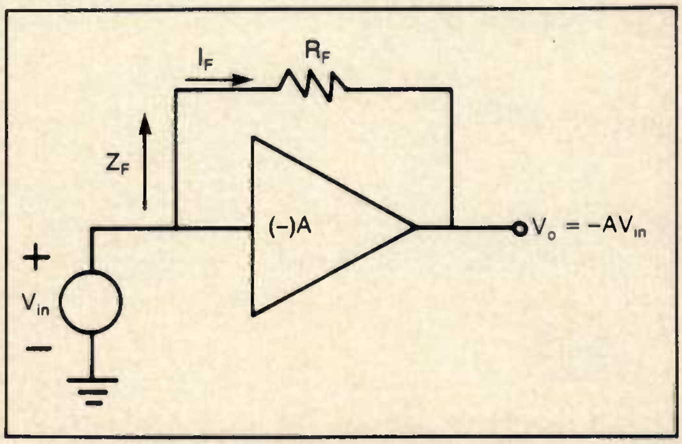

Figure 7. Miller Resistance

The apparent impedance at the input side of R is given by Ohms Law as:

$$Z_F = \frac{V_{in}}{I_F}$$

Because of the action of the inverting amplifier, the voltage at the output, which is also the other side of R is increased to $-AV_{in}$. This causes the voltage across R to be dramatically increased.

$$V_R = V_{in} - (-AV_{in}) = V_{in}(1 + A)$$

$$I_F = \frac{V_R}{R_F} = \frac{V_{in}\,(1 + A)}{R_F}$$

$$Z_F = \frac{V_{in}}{V_{in}(1 + A) / R_F}$$

$$Z_F = \frac{R_F}{1 + A} \qquad (7)$$

This result now allows us to determine the input impedance to the entire inverting op-amp amplifier.

$$Z_{in} = R_I + \frac{R_F}{1 + A} || R_{in}$$

If A is large, the R_F contribution will be extremely small compared to R_I.

$$Z_{in} \approx R_I \quad (8)$$

Output Impedance of the Inverting and Noninverting Amplifier

To determine the output impedance of active circuits, it is necessary to examine the development of voltages in the circuit when driven from the output. The input is removed from the signal source and grounded. This makes the inverting and noninverting amplifiers appear the same so that the result will apply to either configuration. A voltage source which will be called V_o is attached to the output. The output impedance is then the ratio of that voltage, V_o, and the current that results.

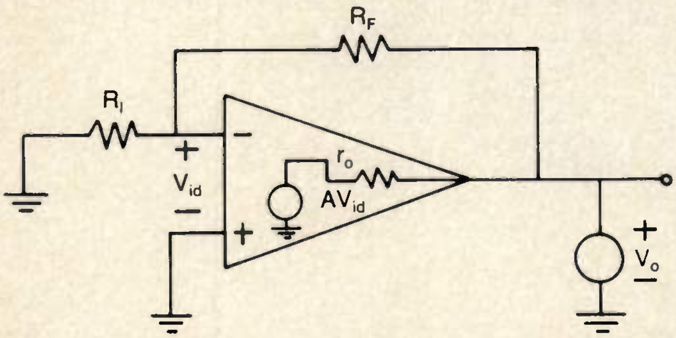

Figure 8. Circuit for Calculating Output Impedance

The voltage that will be developed at the input is determined by the feedback ratio, B, since V_o falls across R_F and R_I as a voltage divider.

$$V_{id} = \frac{R_I}{R_I + R_F} V_o = BV_o \quad (9)$$

This voltage is amplified by the op-amp itself and so is increased by the open loop gain to $-AV_{id}$. The minus sign enters from the fact that the voltage BV_o in the above equation is presented to the inverting input.

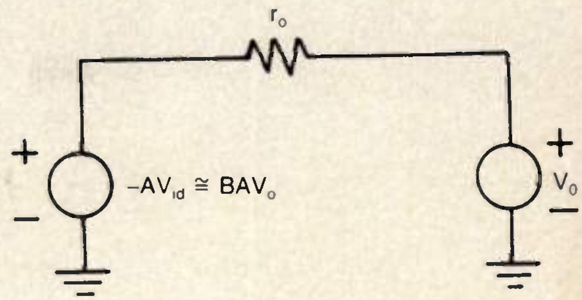

Figure 9. Voltage Across the Output Resistance

The quantity $-AV_{id}$ is equal to $-BAV_o$, found by multiplying both sides of Equation 10 by $-A$. It can now be seen why negative feedback reduces the effect of output impedance. Without feedback the voltage across the output impedance r_o would have been V_o. The presence of feedback has dramatically increased the voltage across r_o to:

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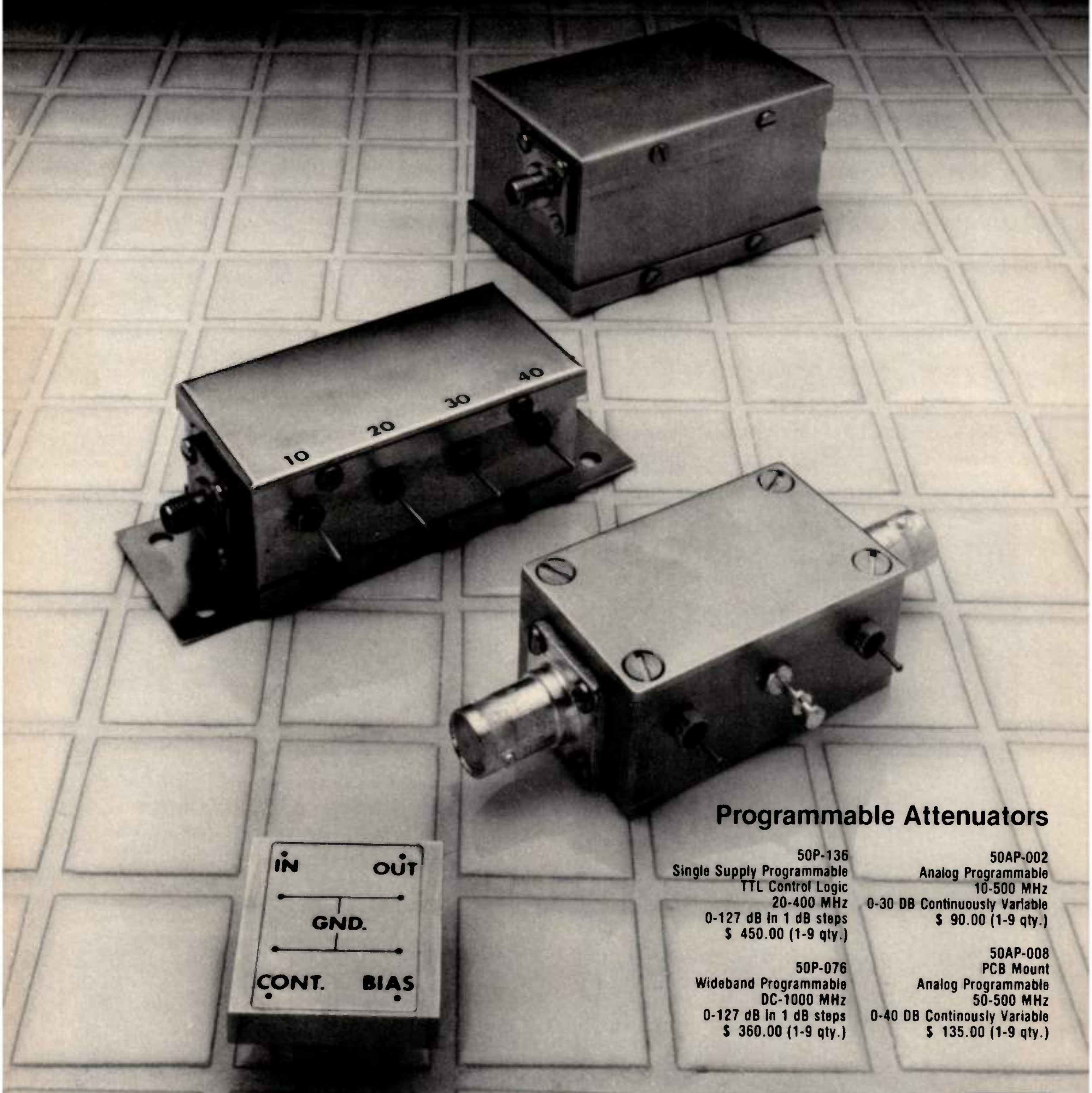

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$V_{ro} = V_o - (-BAV_o)$

$V_{ro} = (1 + BA)V.$

This rise in voltage due to the negative feedback and the amplification by the open-loop gain increases the current above what would be expected based on V_o alone. Hence a reduced apparent resistance.

$$Z_o = \frac{V_o}{I_{ro}} = \frac{V_o}{(1 + BA)\, V_o / r_o}$$

$$Z_o = \frac{r_o}{1 + BA} \qquad (10)$$

In order to examine the combined output impedance, the effective size of R_F from the output side must be determined. To express the size of the voltage at the input side of R_F, express the differential input voltage in terms of A.

$$V_{id} = \frac{-V_o}{A}$$

The voltage across R_F is the difference between the output voltage and V_{id}.

$$V_{R_F} = V_o - (-V_o/A) = (1 + 1/A)V_o$$

$$V_{R_F} = \frac{A + 1}{A} V_o$$

The apparent impedance due to R_F will reflect this voltage.

$$Z_F = \frac{V_o}{I_{R_F}} = \frac{V_o}{\frac{A + 1}{A} V_o / R_F}$$

$$Z_F = \frac{AR_F}{A + 1} \qquad (11)$$

This result is the other part of Miller's Theorem taken from the output side of a Miller resistor.

The composite output impedance of the amplifier with feedback can now be found as the parallel combination of these two effective resistance sizes.

$$Z_O = \frac{r_o}{1 + BA} \; || \; \frac{A}{1 + A} R_F$$

$$Z_o \approx \frac{r_o}{1 + BA} \qquad (12)$$

Summary

Negative feedback reduces the gain of an amplifier to a lower value; a value that is determined primarily by external resistors. This allows for good precision in gain setting and good temperature stability of gain since resistor coefficients are much more controllable than active device parameters. This resistor determination of gain quality is a good approximation as long as the open-loop gain is much greater than the close-loop gain.

Output impedance of an amplifier is reduced by the open-loop to closed-loop gain ratio allowing the amplifier to act as an extremely low-resistance source. Input impedance in the non-inverting amplifier is increased by this gain ratio. The inverting amplifier tends to be a low input impedance device because of the effect of the apparent resistance on the feedback element known as Miller's Theorem.

Basic Program for Designing an RF Amplifier Using an Inherently Stable Device

A program written in Basic that performs the same calculations as a previously published program (May/June 1982) for the TI-59 programmable calculator.*

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School of Electrical Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

Programmable calculators have been an extremely valuable asset to RF designers. These very reliable and portable devices can do more calculations in a few minutes than can be done manually in hours. One disadvantage of these calculators, however, is that a considerable amount of time is usually required to develop software. Another disadvantage is that they are very input/output limited. Until recently the only alternative was to use a large computer to do these tedious calculations. Large computers, however, are not as accessable or as convenient to use as a calculator which can be carried in a brief case or even a pocket.

Recently new small, portable computer featuring full keyboards and using Basic language have become available. These machines fill the gap between calculators and personal or large computers and thus designers now have available three levels of computing power.

One of these new portable computers in the Texas Instruments CC-40*. This computer is about the size of a textbook and is battery powered. It has a built in 31 character 5x8 dot matrix liquid crystal display and is therefore usable stand alone on your desk or on the bench. A peripheral port allows interfacing to printers, mass storage, or other accessories including an RS-232 interface. The CC-40 has a standard typewriter keyboard and a numeric keypad. The computer uses standard ASCII characters and has both upper and lower case alphabetic characters.

The following program demonstrates the advantages of using a higher level language. This program calculates the Linvill stability factor, optimum source and load terminations, and the transducer gain for an inherently stable device whose Y parameters are known. This program performs the same calculations as a previously published [1] program for the TI-59 programmable calculator. The TI-59 program took 449 steps but the basic program takes only 38 lines. Furthermore the basic program contains many lines dedicated to making the program interactive. The CC-40 has an additional advantage of up to 31 alphanumeric characters for both prompting and displaying output. The program is written to be stand alone, however, it is a simple matter to add statements to print output.

*A registered trademark of Texas Instrument, Inc.

Using the Software

Use of the software is extremely simple as the CC-40 prompts the user to enter data and warns the user if the device is potentially unstable. After the Y parameters of the device are entered the computer calculates C, GS, BS, GL, BL and GT stops with C displayed. Successive pressings of enter will display the rest of the output in the order given above. If the device is potentially unstable (C≤0 or C>1) the operator is alerted and execution is halted.

To run the program simply push the run key (or type run from the keyboard) and press the enter key. The computer will display each of the following lines for approximately 1 second.

OPTIMUM TERMINATIONS FOR AN

INHERENTLY STABLE DEVICE

ENTER THE Y PARAMETERS

The user will then be prompted to enter the real and imaginary parts of y_i, y_r, y_f, and y_o in that order.

g_i = ?

b_i = ?

.

.

.

b_o = ?

Appendix B - Program Listing

```
100 REM ***********************************
110 REM *   OPTIMUM TERMINATION PROGRAM   *
120 REM * FOR AN INHERENTLY STABLE DEVICE *
130 REM *           AUGUST 1983           *
140 REM ***********************************
150 DIM G(2,2),B(2,2)
160 DISPLAY "OPTIMUM TERMINATIONS FOR AN":PAUSE 1
170 DISPLAY "INHERENTLY STABLE DEVICE":PAUSE 1
180 DISPLAY "ENTER THE Y PARAMETERS":PAUSE 1
190 INPUT "gi=?";G(1,1)
200 INPUT "bi=?";B(1,1)
210 INPUT "gr=?";G(1,2)
220 INPUT "br=?";B(1,2)
230 INPUT "gf=?";G(2,1)
240 INPUT "bf=?";B(2,1)
250 INPUT "go=?";G(2,2)
260 INPUT "bo=?";B(2,2)
270 P=G(1,2)*G(2,1)-B(1,2)*B(2,1)
280 Q=G(1,2)*B(2,1)+G(2,1)*B(1,2)
290 M=SQR(P^2+Q^2)
300 C=M/(2*G(1,1)*G(2,2)-P)
310 IF C<1 THEN IF C>=0 THEN 360 ELSE 320
320 DISPLAY "DEVICE POTENTIALLY UNSTABLE":PAUSE
330 DISPLAY USING 350,C:PAUSE
340 STOP
350 IMAGE LINVILL STAB. FACTOR C=#.###
360 DISPLAY USING 350,C:PAUSE
370 GS=SQR((2*G(1,1)*G(2,2)-P)^2-M^2)/2/G(2,2)
380 BS=-B(1,1)+Q/2/G(2,2)
390 GL=GS*G(2,2)/G(1,1)
400 BL=-B(2,2)+Q/2/G(1,1)
410 DISPLAY USING"GS=#.###^^^^",GS:PAUSE
420 DISPLAY USING"BS=#.###^^^^",BS:PAUSE
430 DISPLAY USING"GL=#.###^^^^",GL:PAUSE
440 DISPLAY USING"BL=#.###^^^^",BL:PAUSE
450 YFM2=G(2,1)^2+B(2,1)^2
460 R1=(G(1,1)+GS)*(G(2,2)+GL)-(B(1,1)+BS)*(B(2,2)+BL)
470 I1=(G(1,1)+GS)*(B(2,2)+BL)+(B(1,1)+BS)*(G(2,2)+GL)
480 DEN=(R1-P)^2+(I1-Q)^2
490 GT=4*GS*GL*YFM2/DEN
500 GTDB=10*LOG(GT)
510 DISPLAY USING"GT=##.##dB",GTDB:PAUSE
520 STOP
```

After b_o is entered the computer does the calculations. If the device is potentially unstable "DEVICE POTENTIALLY UNSTABLE" is displayed. Pushing enter will then result in the Linvill stablility factor being displayed. If the device is inherently stable, the value of C will be displayed. Successive pressings of enter will display GS, BS, GL, BL and the transducer gain GT in dB in that order.

Example

Calculate C, optimum terminations, and GT for a device with the following Y parameters.

$$\begin{bmatrix} y_i\, y_r \\ y_f\, y_o \end{bmatrix} = \begin{bmatrix} 8.5 + j3.5 & 0\text{-}j.2 \\ 40 - j20 & .35 + j.75 \end{bmatrix} \quad \text{all in mmhos}$$

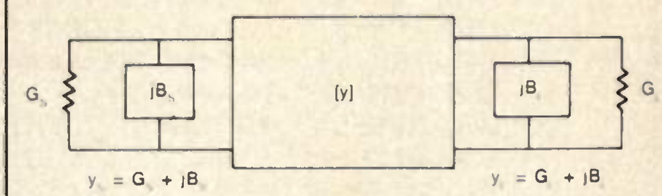

Figure 1. Amplifying Device with Terminations.

Appendix A - Definitions and Equations

$$[y] = \begin{bmatrix} y_i y_r \\ y_f y_o \end{bmatrix} = \begin{bmatrix} g_i + jb_i & g_r + jb_r \\ g_f + jb_f & g_o + jb_o \end{bmatrix}$$

$$C = \frac{|y_f y_r|}{2g_i g_o - \mathrm{Re}\,(y_f y_r)} \tag{1}$$

$$G_T = \frac{4G_S G_L |y_f|^2}{|(y_i + y_S)(y_o + y_L) - y_f y_r|^2} \tag{2}$$

$$G_S = \frac{[(2g_i g_o - \mathrm{Re}(y_f y_r))^2 - |y_f y_r|^2]^{1/2}}{2g_o} \tag{3}$$

$$B_S = -b_i + \frac{I_m(y_f y_r)}{2g_o} \tag{4}$$

$$G_L = \frac{[(2g_i g_o - \mathrm{Re}(y_f y_r))^2 - |y_r y_f|^2]^{1/2}}{2g_i} = \frac{G_S g_o}{g_i} \tag{5}$$

$$B_L = -b_o + \frac{I_m(y_f y_r)}{2g_i} \tag{6}$$

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INSERTION LOSS	
10-2000 MHz	1.7 dB max.
2000-2500 MHz	2.7 dB max.
ISOLATION	
10-500 MHz	40 dB min.
500-1000 MHz	30 dB min.
1000-2000 MHz	25 dB min.
2000-2500 MHz	20 dB min.
SWR	1.5 max. ("on" state)
SWITCHING SPEED	1 μsec. (max.)
MAXIMUM RF INPUT	+20 dBm
CONTROL	+5 V (5 mA max.)
OPERATING TEMPERATURE	−54°C to +100°C
STORAGE TEMPERATURE	−54°C to +100°C

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PSW 1211	$29.95

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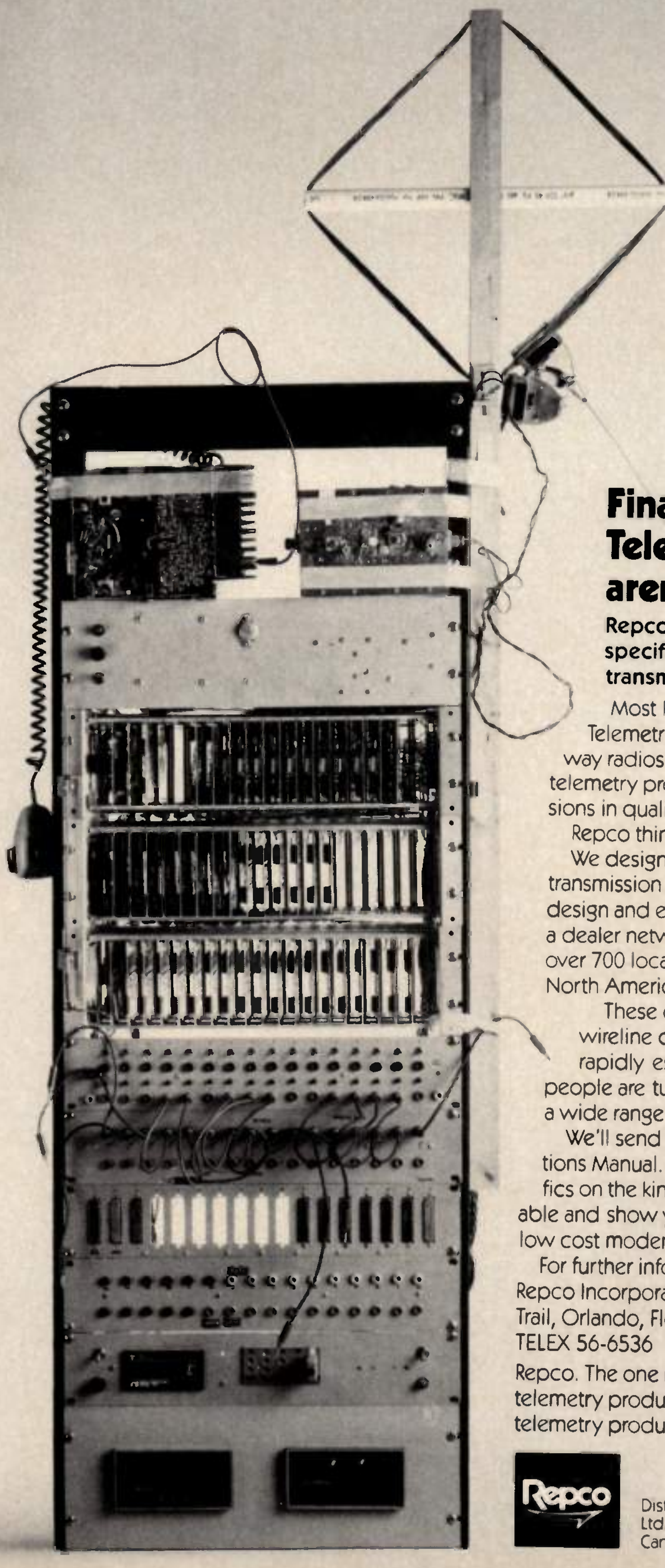
INFO/CARD 50



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INFO/CARD 51

The computer will calculate and display the following.

C = .899
GS = .623E-02
BS=-.149E-01
GL = .256E-03
BL=-.122E-02
GT = 21.45dB

As mentioned above the program was kept simple to compare it to the TI-59 program. Users can easily add print commands or change the prompts to customize the program to suit their needs. Also, since Basic Programs are easy to read, the program can easily be modified to run on other machines.

References

D.R. Hertling, R.K. Feeney, "Design of RF Amplifiers, Part II: Using Inherently Stable Devices," *r.f. design*, Vol 5, No. 3, pp. 30-33, May/June 1982.

Second Solution

As a second solution to the program offered by D.R. Hertling and R.K. Feeney in the previous article (Basic Program for Designing an RF Amplifier Using an Inherently Stable Device) we offer a version written for the Commodore 64*. This program was written by Jeff Schoenwald of Rockwell International Science Center, Thousand Oaks, CA 91360.

*Commodore 64 is a registered trademark of Commodore Business Machines, Inc.

```
READY.

100 REM ****************************
110 REM *   OPTIMUM TERMINATION    *
115 REM *PROGRAM FOR AN INHERENTLY*
120 REM *     STABLE DEVICE        *
130 REM *    MODIFIED FOR THE      *
135 REM *  COMMODORE-64 COMPUTER   *
140 REM ****************************
145 PRINT CHR$(142),""
150 DIM G(2,2),B(2,2)
155 POKE53280,13:POKE 53281,15:PRINT"":PRINT""
160 PRINT"      OPTIMUM TERMINATION FOR AN"
170 PRINT"       INHERENTLY STABLE DEVICE"
175 FOR T = 1 TO2000:NEXT:PRINT""
180 PRINT"      ENTER THE Y PARAMETERS":FOR T=1TO2000:NEXT
185 PRINT "",CHR$(14)
190 INPUT"        GI=";G(1,1)
200 INPUT"        BI=";B(1,1)
210 INPUT"        GR=";G(1,2)
220 INPUT"        BR=";B(1,2)
230 INPUT"        GF=";G(2,1)
240 INPUT"        BF=";B(2,1)
250 INPUT"        GO=";G(2,2)
260 INPUT"        BO=";B(2,2)
270 P=G(1,2)*G(2,1)-B(1,2)*B(2,1)
280 Q=G(1,2)*B(2,1)+G(2,1)*B(1,2)
290 M=SQR(P↑2+Q↑2)
300 C=M/(2*G(1,1)*G(2,2)-P)
310 IFC<1 THEN IF C>0 THEN 360
320 PRINT CHR$(142),"      DEVICE POTENTIALLY UNSTABLE"
330 PRINT"      LINVILL STAB. FACTOR C= ",C
340 END
360 PRINT"      LINVILL STAB. FACTOR C= ",LEFT$(STR$(C),5)
370 GS=SQR((2*G(1,1)*G(2,2)-P)↑2-M↑2)/2/G(2,2)
380 BS=-B(1,1)+Q/2/G(2,2)
390 GL=GS*G(2,2)/G(1,1)
400 BL=-B(2,2)+Q/2/G(1,1)
410 PRINT"     GS= ",GS
420 PRINT"     BS= ",BS
430 PRINT"     GL= ",GL
440 PRINT"     BL= ",BL
450 YFM2=G(2,1)↑2+B(2,1)↑2
460 R1=(G(1,1)+GS)*(G(2,2)+GL)-(B(1,1)+BS)*(B(2,2)+BL)
470 I1=(G(1,1)+GS)*(B(2,2)+BL)+(B(1,1)+BS)*(G(2,2)+GL)
480 DEN=(R1-P)↑2+(I1-Q)↑2
490 GT=4*GS*GL*YFM2/DEN
500 GTDB=10*LOG(GT)/LOG(10)
510 PRINT"     GT= ",LEFT$(STR$(GTDB),6),"DB"
520 END

READY.
```

Impedance Matching Program Using Stern's Stability Factor

By Bert K. Erickson
General Electric Company
Syracuse, N.Y.

Computations for amplifier impedance matching, maximum gain, and stability are interrelated to the extent that independent evaluations are seldom satisfactory. While impedance matching is simple, stability involves characteristic equations and maximization techniques that are difficult to analyze and require computers to perform the calculations. The stability factor proposed by Stern has withstood the test of time and has become easier to use with the availability of microcomputers. Linvill's stability factor is also well known as a simple procedure for evaluating the source and load admittance that will provide maximum gain for a device that is inherently stable. While optimum gain is an objective, most amplifier matching networks are designed with the conductance larger than normal to diminish parameter variations and to make potentially unstable devices perform as useful amplifiers.

With Stern's stability factor defined as

$$k = \frac{2(g_{11} + G_s)(g_{22} + G_L)}{|y_{12}y_{21}| + \mathrm{Re}\,(y_{12}y_{21})} \qquad (1)$$

it is obvious that k can be made to exceed unity as required for stability by simply increasing either G_S or G_L. However with the transducer gain defined as:

$$G_T = \frac{4|y_{21}|^2 G_S G_L}{|(y_{11}+Y_S)(y_{22}+Y_L) - y_{12}y_{21}|^2} \qquad (2)$$

an arbitrary choice for G_S or G_L will not provide as much gain for the same value of k as can be obtained from Stern's equations.[1] The computation of these values for Y_S and Y_L unfortunately involves finding the roots of a 3rd order equation and the suggestion is often made that one of the approximate solutions be used. A popular approximation involves mismatching G_S to g_{11} and G_L

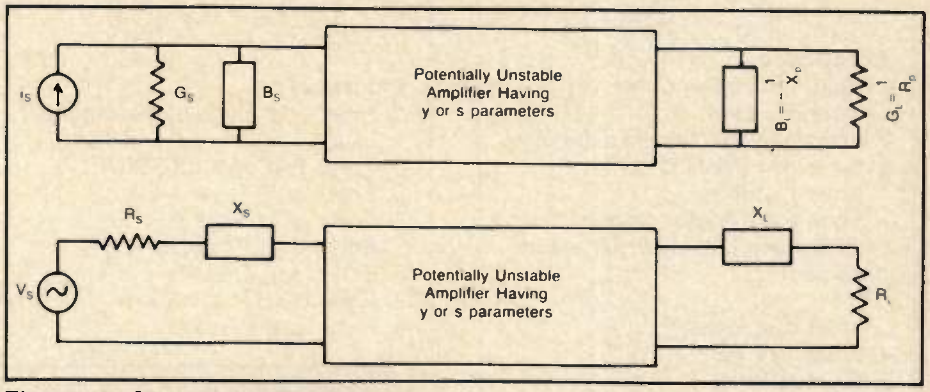

Figure 1. Circuit Configurations

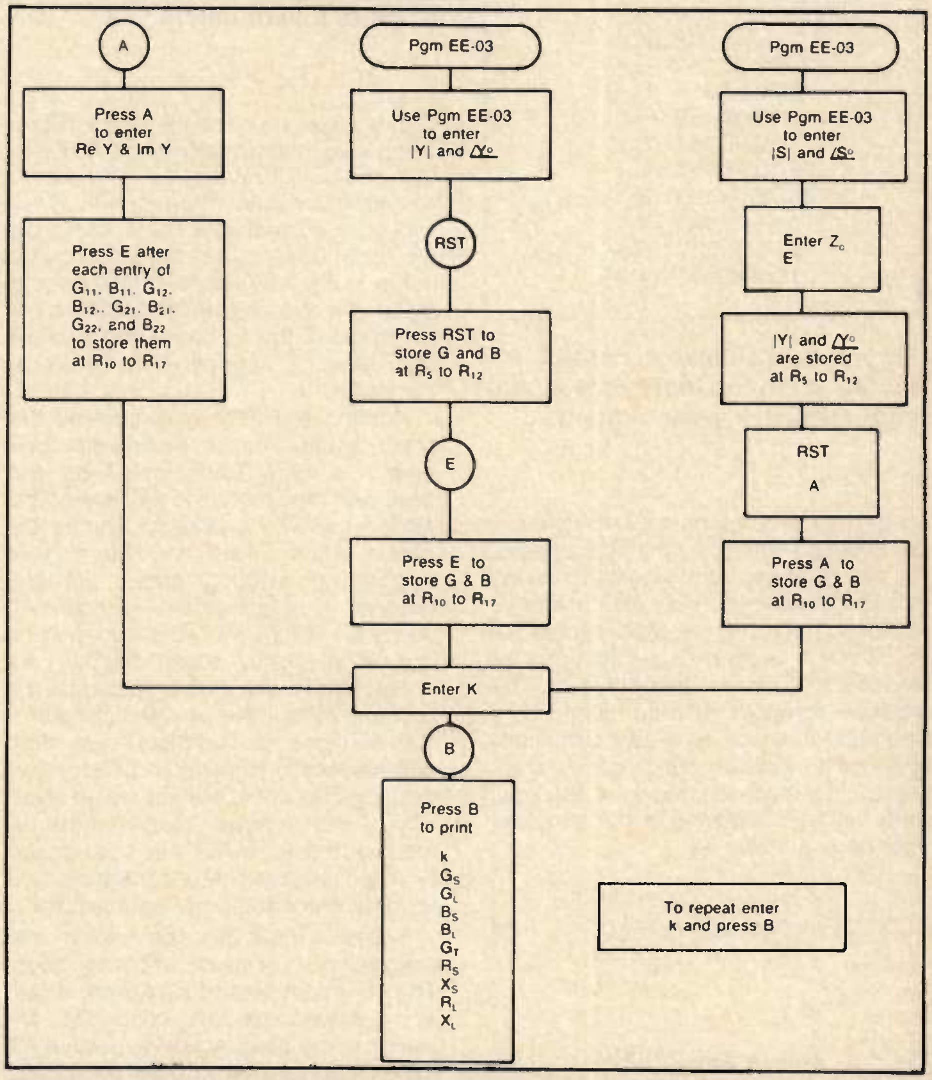

Figure 2. Flow Diagram for TI 59 Impedance Matching Program Using Stern's Stability Factor

Given: g_{11} = 1.5 E-03
b_{11} = 3.5 E-03
g_{12} = 0.0
b_{12} = −3.0 E-04
g_{21} = 5.6 E-02
b_{21} = −1.1 E-02
g_{22} = 1.0 E-04
b_{22} = 7.5 E-04
k = 10

Procedure:

1. Read both sides of the magnetic card.
2. Press A to address the subroutine.
3. Enter g_{11}; Press E
   Enter b_{11}; Press E
   (Look at the display before pressing E because the value will not be printed)

   Enter b_{22}; Press E
4. Press INV EE
5. Enter k; Press B
6. Wait for the following lines to be printed.

10.	(k)
.0306959311	(G_S)
.0020463954	(G_L)
−.0112486458	(B_S)
−.0012665531	(B_L)
22.18348764	(G_T)
28.72074199	(R_S)
10.52482993	(X_S)
353.3207819	(R_L)
218.6769591	(X_L)

Figure 3. Calculator control required when the input data is real and imaginary y parameters.

Given: $|s_{11}|$ = 0.792
$\angle s_{11}$ = −107.4
$|s_{12}|$ = 0.070
$\angle s_{12}$ = 26
$|s_{21}|$ = 1.995
$\angle s_{21}$ = 81.1
$|s_{22}|$ = 0.659
$\angle s_{22}$ = −60.8
k = 10

Procedure:

1. Read both sides of the magnetic card
2. Press 2nd pgm 03 SBR CLR
3. Enter $|s_{11}|$; Press x ⇄ t
4. Enter $\angle s_{11}$; Press A
5. Enter $|s_{12}|$; Press x ⇄ t
6. Enter $\angle s_{12}$; Press B
7. Enter $|s_{21}|$; Press x ⇄ t
8. Enter $\angle s_{21}$; Press C
9. Enter $|s_{22}|$; Press x ⇄ t
10. Enter $\angle s_{22}$; Press D
11. Enter 50; Press E
12. Press RST to emit from EE Pgm 03
13. Press 2nd A (Wait for the polar y parameters to print)
14. Enter k; Press B
15. Wait for the following lines to be printed.

10.	(k)
.0126035888	(G_S)
.0100365508	(G_L)
−.0297546207	(B_S)
−.0147390775	(B_L)
12.77199845	(G_T)
12.07023061	(R_S)
28.49546583	(X_S)
31.56418452	(R_L)
46.35327123	(X_L)

Figure 4. Calculator control required when the input data is a set of polar s parameters.

to g_{22} by the same ratio.[2] This ratio can be obtained from k and the y parameters. B_s and B_L follow from substitution in additional equations. The y parameters for a bipolar transistor will usually show that b_{22} is much larger than g_{22}, allowing b_{22} to represent B_L as a first estimate. This relation forms a starting point for a method of successive approximations that can provide surprisingly good results. Assuming matched conditions, the input and output admittance of the transistor can be expressed as:

$$Y_S^* = G_S - jB_S = y_{11} - \frac{y_{12}y_{21}}{y_{22}+Y_L} \quad (3)$$

$$Y_L^* = G_L - jB_L = y_{22} - \frac{y_{12}y_{21}}{y_{11}+Y_S} \quad (4)$$

Given values for k and the y parameters, Stern's equations assign fixed values for G_S and G_L, leaving B_S and B_L as unknown variables. Starting with $Y_L \approx G_L - jb_{22}$, an approximate value for Y_S^* can be calculated. Now substituting this value in Eq. 4 an improved estimate for B_L can be obtained, and the process can be repeated until B_L converges to values that have a difference as small as desired.

Hertling and Feeney discovered that this iteration could be readily programmed for a TI59® calculator and described the program in the March/April 1982 issue of *r.f. design*.[3] During the period when Linvill and Stern were publishing articles about stability analysis, y parameters were dominant and s parameters were thought to be desirable. Today most devices are characterized with s parameters and it is convenient to have analysis programs that will accept s parameter data. With due respect to Hertling and Feeney, at this point we would like to present a version of their program that uses the EE module to enter either y or s parameter data and requires only one magnetic card for data entry and program execution.

Figure 1 indicates the known and unknown parts of the circuit configuration. The y or s parameters for a device, known at prescribed operating conditions, are stored in the data registers, a value for k is entered, and the unknown source and load admittance or impedance will be printed as an output. The program will accept y parameter input data in either rectangular or polar form and s parameter data in polar form. Figure 2 shows a flow diagram for the sequence of calculator control required for each type of input. Figures 3 and 4 show examples of the control sequence required to produce the results listed in references 3 and 4 for y and s parameters. G_T is the transducer gain in dB, Y printouts are in mhos and Z printouts are in ohms. The labels shown in parentheses are not printed. Enter a different k and press B for another printout. There is no need to read the magnetic card before additional sets of data are entered and run through the program. A program listing is included for readers who may desire to reproduce this program.

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References

1. Hejhall, R., "RF Small Design using Admittance Parameters," Motorola Semiconductor Products, Inc., Application Note 215.
2. Hardy, J.K., *High Frequency Circuit Design*, Preston, 1979.
3. Hertling, D.R. and Feeney, R.K., "Design of RF Amplifiers Part 1: using Potentially Unstable Devices," *r.f. design*, March/April 1982, pp. 30-33.
4. Hertling, D.R. and Feeney, R.K., "RF Amplifier Design Program," *r.f. design*, March/April 1983, pp. 32-35.

TI 59 Impedance Matching Program Using Stern's Stability Factor

000	76	LBL	048	76	LBL	096	43	RCL
001	11	A	049	17	B'	097	14	14
002	01	1	050	42	STO	098	42	STO
003	00	0	051	00	00	099	03	03
004	42	STO	052	01	1	100	43	RCL
005	00	00	053	07	7	101	15	15
006	91	R/S	054	42	STO	102	42	STO
007	76	LBL	055	01	01	103	04	04
008	15	E	056	76	LBL	104	36	PGM
009	72	ST*	057	79	x̄	105	04	04
010	00	00	058	73	RC*	106	13	C
011	69	OP	059	00	00	107	42	STO
012	20	20	060	72	ST*	108	18	18
013	91	R/S	061	01	01	109	53	(
014	76	LBL	062	69	OP	110	24	CE
015	16	A'	063	31	31	111	33	X²
016	01	1	064	97	DSZ	112	85	+
017	08	8	065	00	00	113	32	X:T
018	42	STO	066	79	x̄	114	42	STO
019	00	00	067	91	R/S	115	29	29
020	36	PGM	068	76	LBL	116	33	X²
021	03	03	069	50	I×I	117	54	)
022	16	A'	070	43	RCL	118	34	√X
023	71	SBR	071	01	01	119	42	STO
024	50	I×I	072	72	ST*	120	42	STO
025	36	PGM	073	00	00	121	19	19
026	03	03	074	69	OP	122	43	RCL
027	17	B'	075	20	20	123	10	10
028	71	SBR	076	43	RCL	124	42	STO
029	50	I×I	077	02	02	125	21	21
030	36	PGM	078	72	ST*	126	43	RCL
031	03	03	079	00	00	127	42	STO
032	18	C'	080	69	OP	128	22	22
033	71	SBR	081	20	20	129	71	SBR
034	50	I×I	082	92	RTN	130	33	X²
035	36	PGM	083	76	LBL	131	42	STO
036	03	03	084	12	B	132	23	23
037	19	D'	085	42	STO	133	99	PRT
038	71	SBR	086	20	20	134	43	RCL
039	50	I×I	087	99	PRT	135	10	10
040	02	2	088	43	RCL	136	42	STO
041	05	5	089	12	12	137	22	22
042	61	GTO	090	42	STO	138	43	RCL
043	17	B'	091	01	01	139	16	16
044	76	LBL	092	43	RCL	140	42	STO
045	10	E'	093	13	13	141	21	21
046	01	1	094	42	STO	142	71	SBR
047	02	2	095	02	02	143	33	X²

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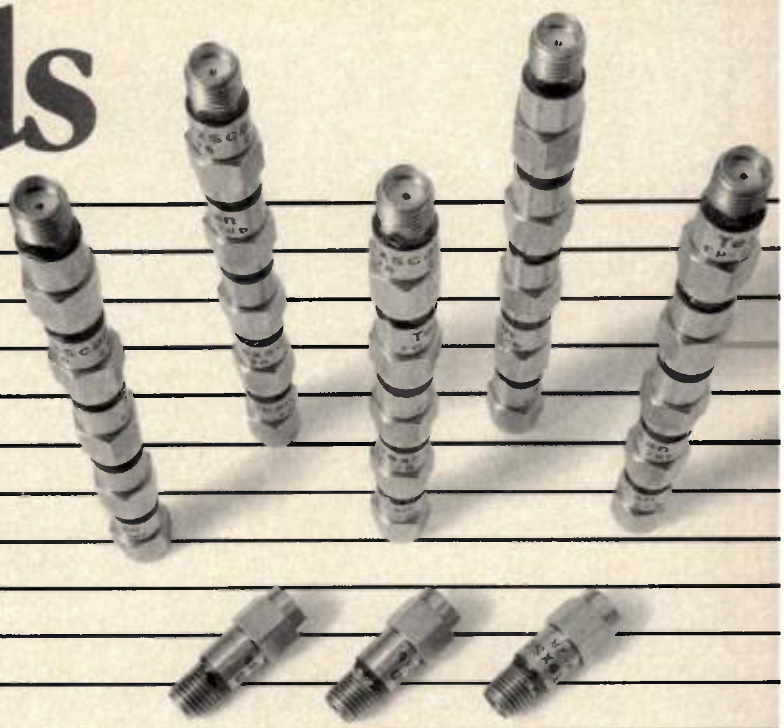
INFO/CARD 55

```
144  42  STO
145  25   25
146  99  PRT
147  61  GTO
148  23  LNX
149  76  LBL
150  33  X²
151  53   (
152  53   (
153  43  RCL
154  20   20
155  65   ×
156  53   (
157  43  RCL
158  19   19
159  85   +
160  43  RCL
161  18   18
162  54   )
163  65   ×
164  43  RCL
165  21   21
166  54   )
167  55   ÷
168  53   (
169  02   2
170  65   ×
171  43  RCL
172  22   22
173  54   )
174  54   )
175  34  √X
176  75   -
177  43  RCL
178  21   21
179  54   )
180  92  RTN
181  76  LBL
182  23  LNX
183  43  RCL
184  17   17
185  94  +/-
186  42  STO
187  26   26
188  76  LBL
189  42  STO
190  43  RCL
191  18   18
192  42  STO
193  01   01
194  43  RCL
195  29   29
196  42  STO
197  02   02
198  53   (
199  43  RCL
200  16   16
201  85   +
202  43  RCL
203  25   25
204  54   )
205  42  STO
206  03   03
207  53   (
208  43  RCL
209  17   17
210  85   +
211  43  RCL
212  26   26
213  54   )
214  42  STO
215  04   04
216  36  PGM
217  04   04
218  18  C'
219  43  RCL
220  10   10
221  42  STO
222  03   03
223  43  RCL
224  11   11
225  42  STO
226  04   04
227  36  PGM
228  04   04
229  10  E'
230  36  PGM
231  04   04
232  17  B'
233  32  X:T
234  94  +/-
235  42  STO
236  24   24
237  43  RCL
238  18   18
239  42  STO
240  01   01
241  43  RCL
242  29   29
243  42  STO
244  02   02
245  53   (
246  43  RCL
247  10   10
248  85   +
249  43  RCL
250  23   23
251  54   )
252  42  STO
253  03   03
254  53   (
255  43  RCL
256  11   11
257  85   +
258  43  RCL
259  24   24
260  54   )
261  42  STO
262  04   04
263  36  PGM
264  04   04
265  18  C'
266  43  RCL
267  16   16
268  42  STO
269  03   03
270  43  RCL
271  17   17
272  42  STO
273  04   04
274  36  PGM
275  04   04
276  10  E'
277  36  PGM
278  04   04
279  17  B'
280  32  X:T
281  42  STO
282  30   30
283  53   (
284  53   (
285  24  CE
286  85   +
287  43  RCL
288  26   26
289  54   )
290  55   ÷
291  43  RCL
292  26   26
293  54   )
294  50  |X|
295  32  X:T
296  93   .
297  00   0
298  00   0
299  01   1
300  22  INV
301  77   GE
302  34  √X
303  43  RCL
304  24   24
305  99  PRT
306  43  RCL
307  30   30
308  94  +/-
309  42  STO
310  26   26
311  99  PRT
```

Fixed Pads



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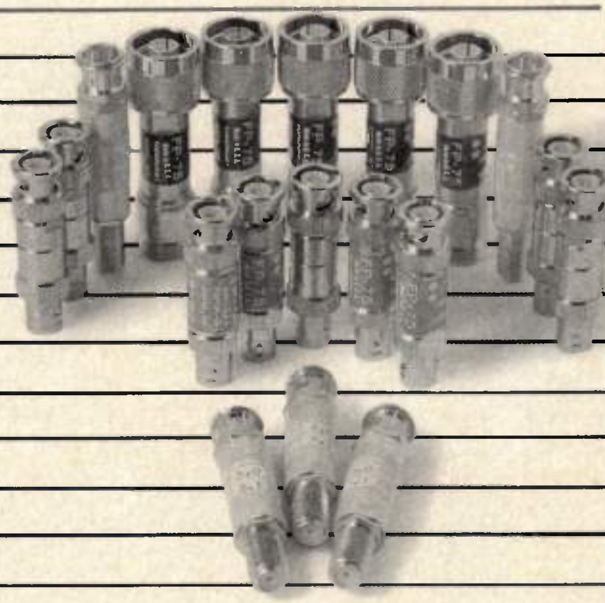
1,2,3 and 6dB, ±0.3/10 to 20 dB,±0.5
FP-28 High Specification Series
DC 12 GHz, SMA, 2W
1,2,3 and 6dB, ±0.3/10 to 20dB,±0.5

HFP-50 High Power Pads
DC—1 GHz, 50 ohms, 10W
1,2,3,6,10,20dB, BNC/TNC/N



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```
312  61  GTO
313  35  1/X
314  76  LBL
315  34  √X
316  43  RCL
317  30   30
318  94  +/-
319  42  STO
320  26   26
321  61  GTO
322  42  STO
323  76  LBL
324  35  1/X
325  53   (
326  43  RCL
327  10   10
328  85   +
329  43  RCL
330  23   23
331  54   )
332  42  STO
333  01   01
334  53   (
335  43  RCL
336  11   11
337  85   +
338  43  RCL
339  24   24
340  54   )
341  42  STO
342  02   02
343  53   (
344  43  RCL
345  16   16
346  85   +
347  43  RCL
348  25   25
349  54   )
350  42  STO
351  03   03
352  53   (
353  43  RCL
354  17   17
355  85   +
356  43  RCL
357  26   26
358  54   )
359  42  STO
360  04   04
361  36  PGM
362  04   04
363  13   C
364  42  STO
365  27   27
366  32  X↕T
367  42  STO
368  28   28
369  43  RCL
370  12   12
371  42  STO
372  01   01
373  43  RCL
374  13   13
375  42  STO
376  02   02
377  43  RCL
378  14   14
379  42  STO
380  03   03
381  43  RCL
382  15   15
383  42  STO
384  04   04
385  36  PGM
386  04   04
387  13   C
388  94  +/-
389  44  SUM
390  27   27
391  32  X↕T
392  94  +/-
393  44  SUM
394  28   28
395  53   (
396  53   (
397  43  RCL
398  27   27
399  33  X²
400  85   +
401  43  RCL
402  28   28
403  33  X²
404  54   )
405  35  1/X
406  65   ×
407  04   4
408  65   ×
409  43  RCL
410  23   23
411  65   ×
412  43  RCL
413  25   25
414  65   ×
415  53   (
416  43  RCL
417  14   14
418  33  X²
419  85   +
420  43  RCL
421  15   15
422  33  X²
423  54   )
424  54   )
425  53   (
426  24  CE
427  28  LOG
428  65   ×
429  01   1
430  00   0
431  54   )
432  99  PRT
433  02   2
434  03   3
435  42  STO
436  00   00
437  71  SBR
438  66  PAU
439  02   2
440  05   5
441  42  STO
442  00   00
443  71  SBR
444  66  PAU
445  91  R/S
446  76  LBL
447  66  PAU
448  73  RC*
449  00   00
450  42  STO
451  33   33
452  33  X²
453  69  OP
454  20   20
455  85   +
456  73  RC*
457  00   00
458  42  STO
459  34   34
460  33  X²
461  54   )
462  35  1/X
463  42  STO
464  35   35
465  65   ×
466  43  RCL
467  33   33
468  54   )
469  99  PRT
470  43  RCL
471  35   35
472  65   ×
473  43  RCL
474  34   34
475  54   )
476  94  +/-
477  99  PRT
478  92  RTN
479  00   0
```

Active Transistor Bias Regulators

By Gary McCollum
California Eastern Laboratories, Inc.
Santa Clara, CA

Bipolar and GaAs FET transistor biasing can be a problem during testing or evaluation. With bipolar transistors, when dual power supplies are used they must be continuously re-adjusted, for as the device heats up, h_{FE} rises and therefore, the collector current increases. The other alternative is a handful of resistors and/or potentiometers for different voltage and current conditions. With GaAs FETs, the problem is their sensitivity to both voltage and current.

These four bias regulators were developed to overcome these difficulties. They are constant voltage, constant current, with the voltage and current independently adjustable.[1,2,3] The four versions cover most biasing requirements for NPN or PNP bipolars, and small signal GaAs FETs.

Circuit Operation

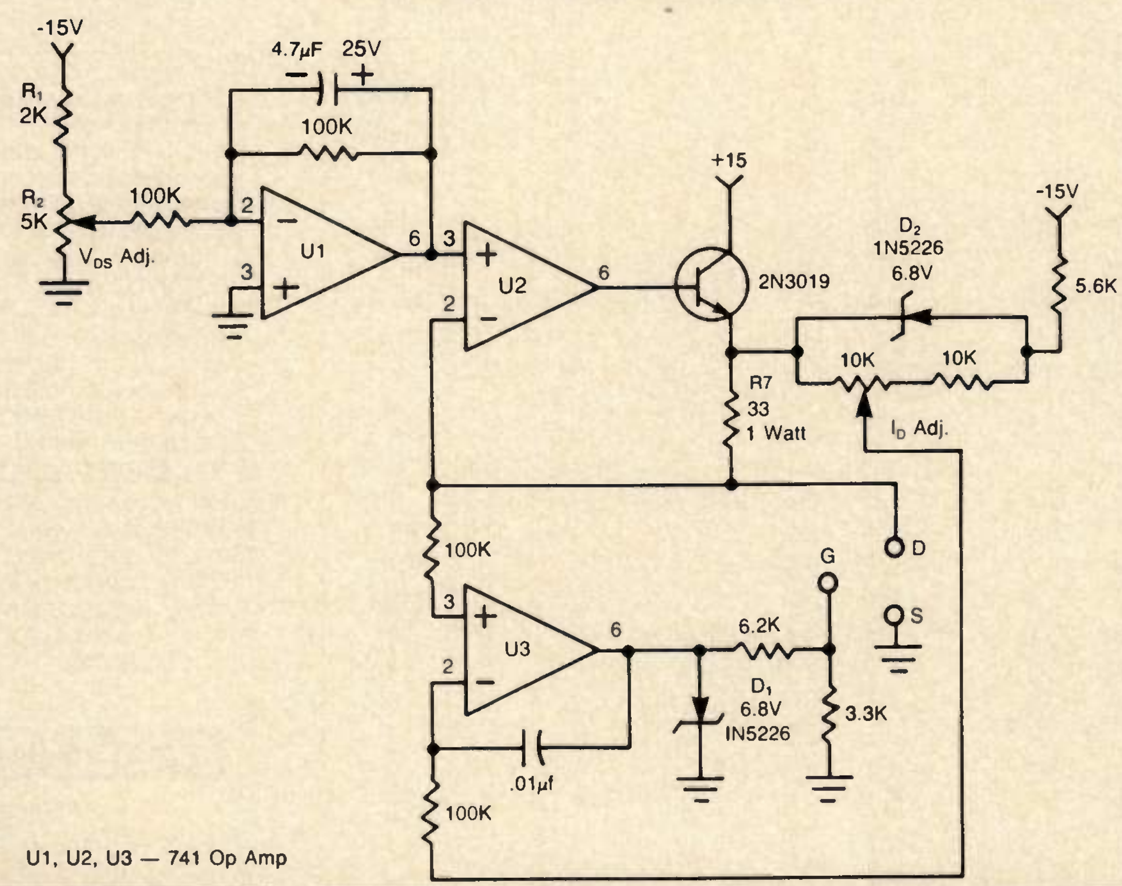
Circuit No. 1 is for biasing N channel GaAs FETs. V_{DS} is variable from 0 to +10 volts, and I_D is variable from 0 to 100 mA. When the plus and minus supply is turned on, integrator U1 ramps to the voltage set by the voltage divider R1-R2. U2 "bootstraps" R7 so that the set voltage is independent of the IR drop. U3 sets the gate voltage to match the IR drop in R7 with a fraction of the reference zener D2 voltage. Zener diode D1 clamps the gate voltage from going more than a few hundred millivolts positive or a few volts negative.

Circuits 2, 3, and 4 for bipolar transistors operate similarly. The difference being the elimination of integrator U1, as ramping on of the bias voltages is not required for bipolar transistors.

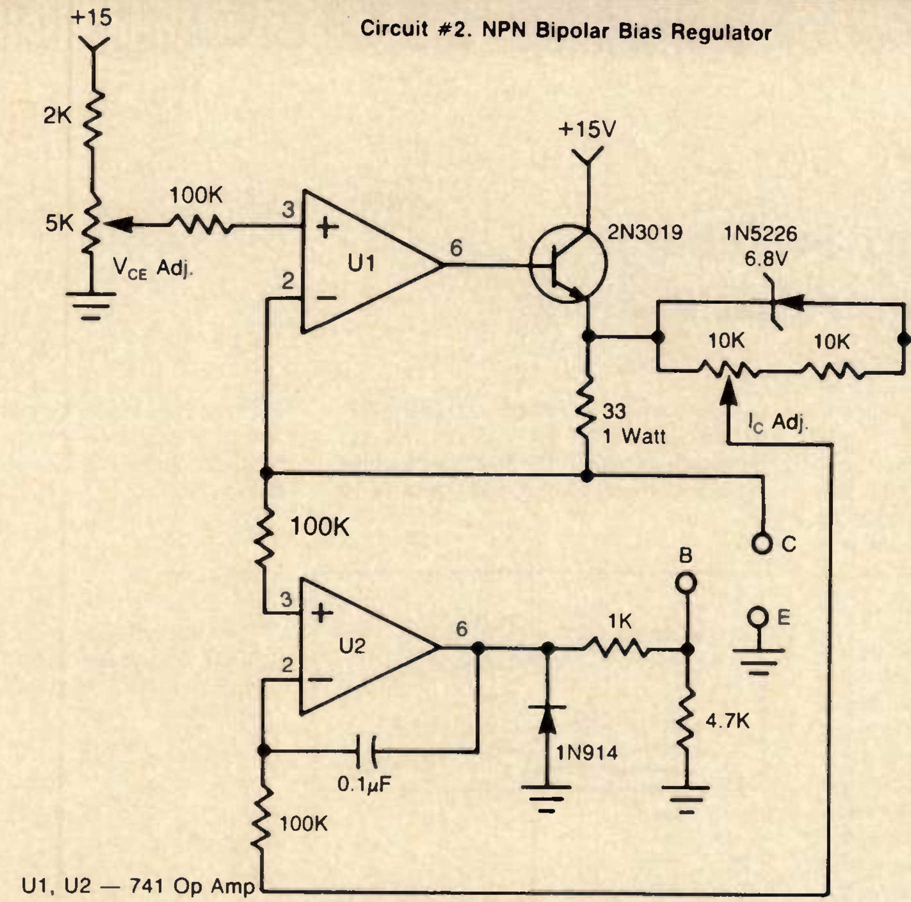
References

1. D. Lane, CEL, "Smart" Bias Supply for Delicate MW Transistors. *Microwave Journal*, 6/78, pp. 126 & 142.
2. G. McCollum, CEL Application Note AN80901, Two Stage GaAs FET LNA Bias Supply, 8/81.
3. G. McCollum, CEL, Application Note AN81901, FET Bias Supply, 11/81.

Circuit #1. N-Channel GasFet Bias Regulator

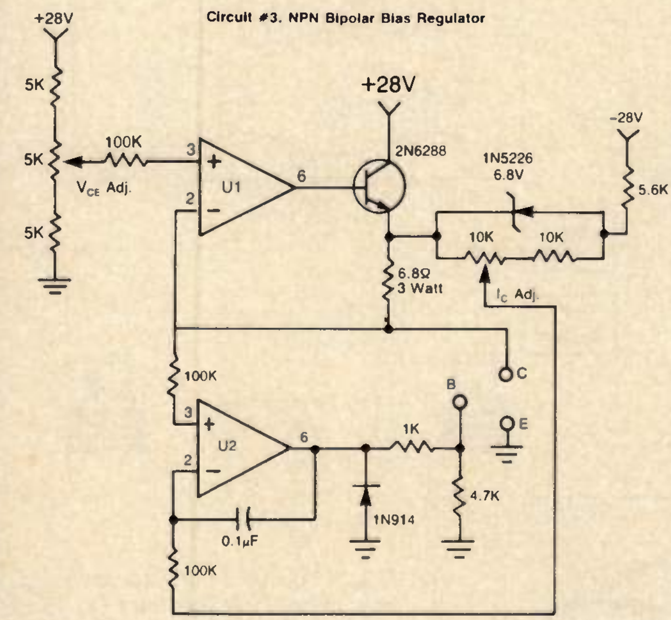


U1, U2, U3 — 741 Op Amp



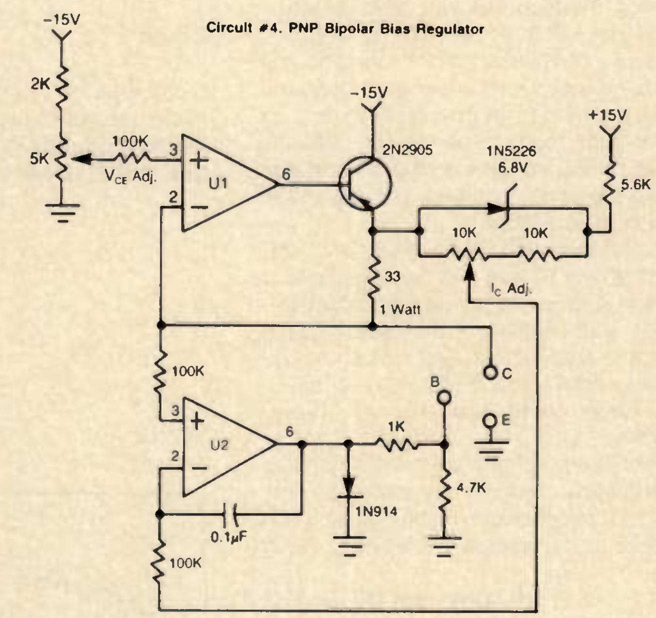
Circuit #2. NPN Bipolar Bias Regulator

U1, U2 — 741 Op Amp



Circuit #3. NPN Bipolar Bias Regulator

U1, U2 — MC1436 Op Amp



Circuit #4. PNP Bipolar Bias Regulator

U1, U2 — 741 Op Amp

All-Matched Port Switching for Medium-Power Applications

For certain microwave signal switching applications, the switching "trees" require use of SPDT models with all-matched ports. This means that the unused secondary port gets switched to an internal matched load. A typical application might be where two active amplifiers or sources are combined in an SPDT switch, as shown in Figure 1.

By using the HP 33311B Coaxial Switch, or other similar industry models, the internal 50 ohm terminations of the switch are connected to the unused secondary port, thus providing a well-matched load for either unused amplifier.

With a power rating of 1 watt for each internal termination, such a switch easily handles most instrumentation jobs, where signal generators and amplifier output powers are in the 10-100 mw range.

In other system test applications, such as transponders with 5-10 watt plus outputs, another solution must be sought. Fortunately, a 5-port version of the same HP 33311B SPDT Coaxial Switch switch serves this higher power requirement.

Model HP 33311B-C05 has both internal 50 ohm terminations removed and each replaced with another broadband SMA connector. In operation then, 1 or 2 external medium-power terminations serve to absorb the unused channel, up to the full power carrying capacity of the switch. See Figure 2.

With a specified insertion loss of 0.5 dB at 18 Ghz, a 10 watt average signal passing through would provide approximately 1.1 watt heating of the switch frame which is well heat-sinked. Thus, the application of Figure 2 with 10-watt external loads could easily serve 10-watt signals.

Excellent repeatability results from use of edge-line design which switches only the center conductor. After one million switchings, repeatability is typically <0.03 dB.

The switch operates from DC-18 GHz with <1.4 SWR at 18 GHz. It also features isolation of >90 dB between ports. The actuating mechanism momentarily requires 24 Vdc (5 Vdc optional) at 3 watts. They automatically disconnect after the 30 ms switching time.

SPDT and 5-port switches shown can be automatically programmed via the HP-IB bus by use of HP's 11713A Attenuator/Switch Driver. Each HP 11713A provides logic and drive power for as many as 10 switches, either via the bus or by manual pushbutton on the front panel. Thus, even relatively complex switch matrices can be automated.

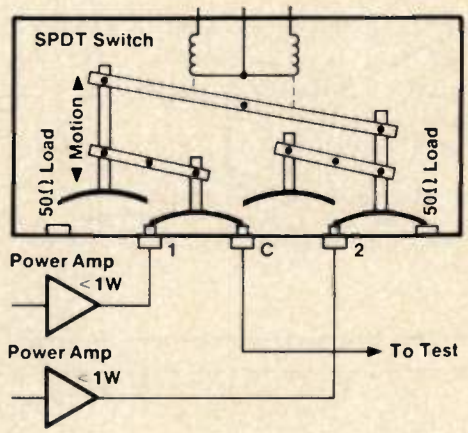


Figure 1.

All-matched ports of SPDT switch automatically terminate unused signals.

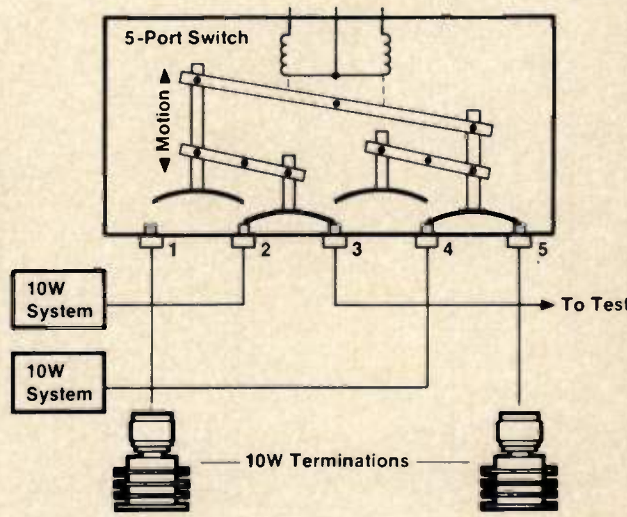


Figure 2.

5-port version of same switch applies unused medium-power signals to external power loads.

HP-33311B-C05 5-port Coaxial Switch is compact and operates from DC-18 GHz with 90 dB isolation.

Announcing three new series in our attenuator family

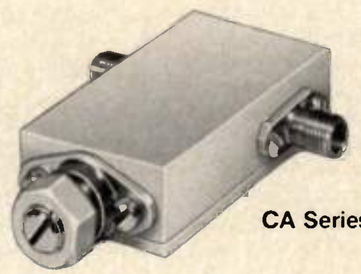
MDA Series
Miniature Programmable Attenuators

Advanced electrical construction of this series utilizes one EMI-RFI filter per bit and all bits interconnected to a single common filter for the opposing polarity. Standard units are arranged in binary sequence but other attenuation steps and control voltages are available.

You get top performance, excellent electrical characteristics in miniature sizes. Sizes as small as 1" x 1" x 2.5". Attenuation as high as 127 dB. VSWR is 1:3:1 @ 500 MHz and 1:4:1 @ 1 GHz. Logic: 4, 6 and 8 bit. Switch life: 10 million operations. Switch speed: 6 milliseconds.

CA Series
Continuously Variable Attenuators

Select from 14 model numbers in a wide range of frequency bands up to 18 GHz. Lightweight and as small as 2.375" x 1.734" x .500". Attenuation as high as 40 dB. VSWR is 1:5:1 to 1:8:1 based upon range. Impedance: 50 Ohms. -65°C to +125°C minimum temperature range. Screwdriver adjustment allows the attenuation to be set and held for extended periods of timé.



CA Series

CAL Series

CAL Series
Continuously Variable Attenuators

These lightweight, little attenuators are big on performance. Only 1.581" x 1.500" x 1.100". Attenuation as high as 25 dB. Frequency range: DC to 400 MHz. Impedance: 50 Ohms. Srewdriver adjustment with locking nut allows the attenuation level to be set and held. Resettability is 0.2 dB.

We listened to your specifications. Now they are found in our series MDA, CA and CAL. All designed in a variety of models to meet your needs. All built to our high standards of construction and accuracy. Contact us today for your requirements.

Alan

Alan Industries, Inc.
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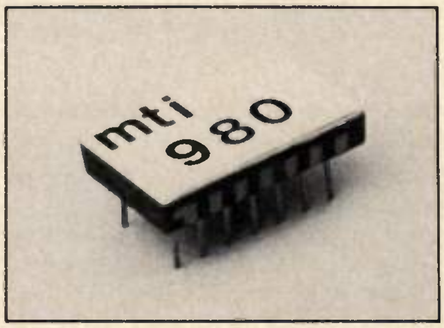
Phone: (812) 372-8869

Attenuators: Programmable • Cam Actuated • Rotary • Manual Switch • Fixed • Continuously Variable
Accessories: Loads • Dividers • Terminations • RF Fuses • Bridges

INFO/CARD 59

Wideband Amplifier

MEL TEC, Division of EPSCO, Incorporated announces the availability of its Model 980 Wideband Amplifier. Extremely high input impedance and high current output capability are combined with pin-programmable gains of 10X, 5X, 2X and 1X for use with passive transducers, sensors, and conventional linear networks up to 250 kHz. Thick film microelectronics technology is used to produce the

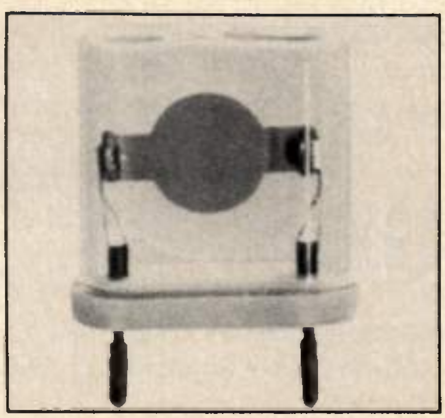


amplifier which is packaged in a low-profile ceramic 14 lead DIP, or in a metal package for high noise environments requiring welded sealing. The Model 980 may be used to drive 50 and 75 ohm systems with very low distortion (<0.1% up to to 250 kHz), and can be operated over a -55°C to +125°C temperature range. Quiescent supply current for the Model 980 is typically 10mA. The Model 980 delivery is stock to six weeks. Pricing (ceramic): qty 1-9 at $39.00 ea
qty 10-24 at $35.00 ea
qty 25-99 at $32.00 ea

MEL TEC, Division of EPSCO, Incorporated, Westwood, MA 02090, NFO/CARD #139.

Quartz Resonators

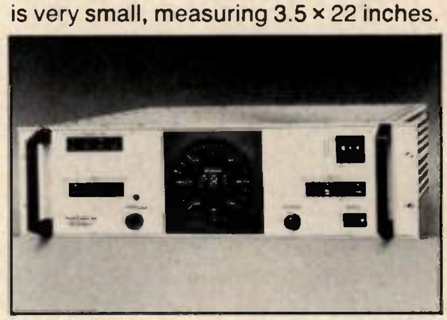
A new line of ultra-precision quartz resonators will be produced in a recently-completed manufacturing clean room at Colorado Crystal Corporation in



Loveland. The certified facility provides the conditions necessary for an advanced generation of 5th-overtone, 10-MHz crystals at AT- and SC-cut (stress compensated) configurations. Both offer substantial improvements in many areas including: increased nominal Q (1.25 million for the AT and 1.3 million for the SC cut), better short term stability, reduced aging changes, and lower phase noise. Use of a clean environment for all critical processes after cutting — cleaning, plating and packaging — results in a finished crystal with state-of-the-art specifications and improved yields. **Colorado Crystal Corporation, Loveland, CO 80537, INFO/CARD #138.**

Automatic Radio Direction Finding Systems

The TC-5100 series of Automatic Radio Direction Finders cover the HF/VHF/UHF frequency range. One DF antenna and processor operates from 1.5 to 1000 MHz covering a wide range of modulations (AM, FM, CW, SSB, Pulse, etc.) and applications. The DF processor uses a patented phase/amplitude technique to determine a line of bearing (LOB). System response time is better than 100 milliseconds. The patented DF antenna is very small, measuring 3.5 × 22 inches.



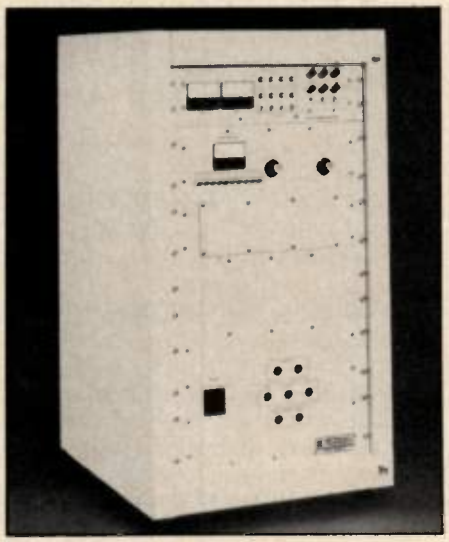
The TC-5100 may be integrated with the most standard single IF channel surveillance and test receivers. Several versions are available for manpack, mobile, or fixed site operation. **Tech Comm, Inc., Ft. Lauderdale, FL, 33314, INFO/CARD #136.**

Frequency Management Devices

A revised 20-page "Guide to Quartz Frequency Management Devices," has recently been published by CTS Corporation, Knights Division, Sandwich, Illinois. The Knights Division, a member of the Electronic Products Group, manufactures quartz crystal products for use in the data processing, communications, instruments and equipment and military markets. The 2-color quartz management guide features photographs and outline drawings of available crystal products. Included are complete electrical and mechanical specifications of both standard and custom designs of precision, military, and microprocessor crystals; TCXO-TCVCXO, ovenized, S.C. cut, voltage controlled crystal and hybrid clock oscillators; and standard/discriminators and custom filters. Crystal performance curves and a MIL versus commercial cross reference for MIL-equivalent crystals are contained in this guide. **CTS Corporation, Knights Division, Sandwich, IL, 60548, INFO/CARD #137.**

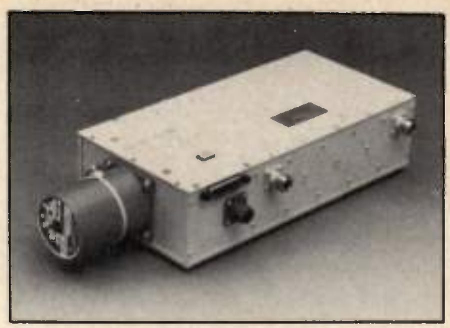
1200W RF Generator

RF Plasma Products has recently introduced a new compact, solid state 1200 watt RF Generator. Available in 13.56 MHz or 40.68 MHz, the HFS-1200G RF Generator is designed to be mounted on a 19" rack or in a single cabinet measuring 24" wide, 27" deep and 41" high. All controls, control switches, meters and LED status lights are front panel mounted and access to the equipment is provided by a hinged door and easily removable covers. The HFS-1200G generator consists of a crystal controlled oscillator, solid state buffer driver and a one tube power amplifier that is air cooled. The output circuit is a conventional "PI" tank with front panel controlled variable capacitators for both tune and load. **RF Plasma Products, Inc., Cherry Hill, NJ 08003, INFO/CARD #135.**



Tunable Bandpass Filters

Telonic Berkeley Inc. has introduced a series of tunable bandpass filters that offer continuous tuing without the resetability problems of servo feedback. The Telonic Berkeley TCD Series Tunable Bandpass Filters are iris coupled, 0.05dB Tchebyschev design cavities available in three and five section configurations. Each section is capacity loaded to tune over a 2:1 frequency range. The result is a high Q filter that provides minimum insertion loss and is tunable over any one octave in the 32 MHz to 3 GHz band. A self-contained microprocessor based on control provides easy interface with the customer's digital system. The unit is automatically tunable to any center frequency within the range of the filter array. RS232, IEEE-488 (GPIB) and 8-4-2-1 parallel BCD interfaces are available. The standard bandwidth is 5% of center frequency and tuning resoltuion is 0.5% of center frequency. In addition to the TCD Series, a TCK Series of tunable bandpass filters is also available that features



microprocessor controlled multi-octave systems for continuous tuning over as many as six octaves. Complete TCK Series systems, with power supplies and RF bandswitching included, are effectively "black box" type multi-octave tunable filters. Available options include special octave tuning ranges, special bandwidths (2% to 8% of center frequency), and special customer configuration interfaces. The TCD 32-63MHz Series 3-Section Tunable Bandpass Filter is priced at $2400.00 with 6-8 weeks delivery ARO. The TCK 2-Octave, 3-Section system in priced from $5600.00 with delivery 8-10 weeks ARO. **Telonic Berkeley, Inc., Laguna Beach, CA 92652, INFO/CARD #133.**

Software for EMI Testing

New, for HP 8568 and 8566 Spectrum Analyzer systems is the HP 85864A EMI Software, a general purpose BASIC program for automating MIL-STD and commercial EMI testing. Operation of the software requires no programming experience, and only minimum knowledge of sepctrum analyzer operation. The user

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can select from a library of common conducted and radiated tests (supplied), or easily configure his own tests. Test results can be stored in the data library and plotted in various formats for a permanent hard copy record. And the diagnostic features of the software/analyzer combination permit the rapid analyses of emissions. The new HP 8586A software, listed at $3020, runs on HP Series 200, Models 226 and 236 computers. An HP 85650A Quasi-Peak Adapter provides quasi-peak detection for commercial testing.

Hewlett-Packard Company, Palo Alto, CA 94304, INFO/CARD #165.

RG Chip Resistors

The Resistive Products Division of TRW offers product specifications for its recently introduced line of RG chip resistors in a new 4-page color bulletin. The bulletin includes performance data such as characteristics, limits, and test methods. Tape packaging specifications, ordering information, and color band identification is furnished through illustrations. Additionally, each bulletin includes a photograph and outline drawings which provide dimensional information. RG chip resistors are designed for surface mounting and automatic placement where low TC (less than 100 ppm/°C) and tolerances to 1% are required. They are also designed for applications where superior solderability is necessary — their hot solder-dipped nickel contacts withstand prolonged immersion in solder with no dewetting of contacts. **TRW Electronic Components Group, Boone, NC 28607, INFO/CARD #134.**

10-Watt Power Module

Acrian, Inc., has announced the UTVA PM10, a 10 watt peak sync reference ultra linear UHF TV power module for broadcast bands 4 and 5. It was designed for use as a driver or output stage in low power television transmitters or transponders. THe UTVA PM10, which functions across 470-860 MHz, offers excellent linearity, 9dB power gain, 1dB gain ripple, and 15dB input return loss. Output return loss is also 15dB. The UTVA PM10 has excellent IMD performance (test conditions: P-sync 10W (-8, -16, -7)) IMD 1 is -54 dBc and IMD 2 (test conditions: P-sync 10W (-8, -16, -10)) is -56. The UTVA PM10, part of Acrian's line of broadcast power modules, is currently available at a cost of $654.50 in 100-piece quantities. **Acrian, Inc., Cupertino, CA 95014, INFO/CARD #140.**

Digital IC's Utilizing GaAs

Harris Microwave Semiconductor, Inc., recently announced the release for general sale of two devices in a family of products which have been developed to take advantage of the processing speed improvements made possible by the inherent capabilities of gallium arsenide over silicon-based technology. These first devices offer typical processing speeds five times those possible with silicon ECL products of similar complexity. These products are the HMD-11141-1, a four-bit Universal Shift Register, and the HMD-11016-1, a divide by 2/4/8 binary counter. The principal applications for these first products are expected to be in high speed signal processing at the interface between microwave and digital portions of electronic warfare and communications systems and in test instrumentation equipment. The Shift Register performs the standard operations of shift left, shift right, parallel and serial outputs and hold, accepting either serial or parallel inputs and operates with clock inputs of 1400 MHz (1.4 GHz) typical and 1.0 GHz minimum. ECL products with similar functions operate at rates under 400 MHz. The Binary Counter provides simultaneous synchronous outputs at one half, one fourth, and one eighth the data rate input, working with input data rates of 1.8 GHz minimum and 2.2 GHz typical. The divider can be used in counting and frequency synthesizer functions and, with the Shift Register, has been demonstrated to execute multi-

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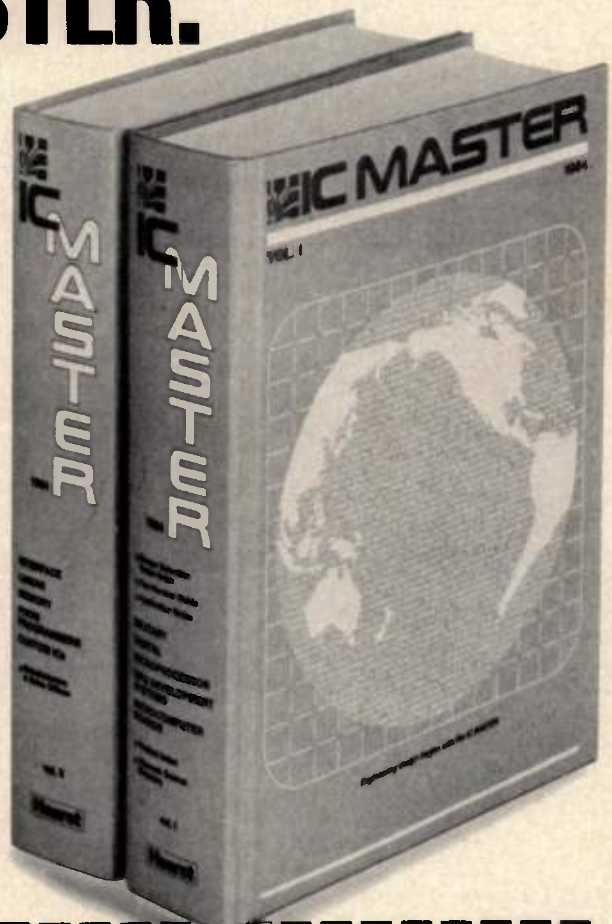

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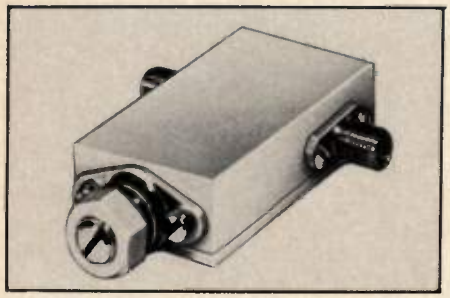
plex/demultiplex operations. The HMD-11141-1 and HMD-11016-1 are available two weeks ARO and are priced at $393.00 (U.S.) each at 100 pieces. **Harris Microwave Semiconductor, Milpitas, CA 95035, INFO/CARD #141.**

Continuously Variable Attenuators

Two new series of continuously variable miniature attenuators have been announced by Alan Industries, Inc. They are the CA series with a selection of frequency ranges to 400 MHz. Impedance rating for each series is 50 Ohms. Fourteen model numbers in the CA series offer attenuation ranges of 10, 20, 30 and 40 dB depending upon the frequency range selected which are: 1-2 GHz; 2-4 GHz; 4-8 GHz; 8-12.4 GHz and 12.4-18 GHz. Insertion loss (max.) is 0.5 dB up to 4 GHz and 0.75 dB from 4-18 GHz. VSWR is 1.5 to 1.8 based upon range.



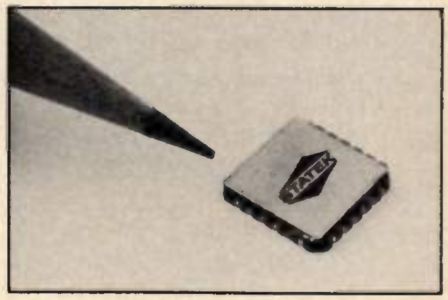
Dimensions: 2.375 × 1.734 × .500 inches. Prices from $195 to $235. Three model numbers in the CAL series offer attenuation ranges of 0-25, 0-15 and 0-10 at frequencies of DC-50, DC-200, and DC-400 MHz, repectively. VSWR for the DC-400 MHz is 1.4 and is 1.2 for the others. Dimensions: 1.581 × 1.500 × 1.100 inches. Price $95 each. **Alan Industries, Inc., Columbus, Indiana 47202, INFO/CARD #142.**

Power Amplifier and Transistor Series for Cellular Applications

California Eastern Laboratories, Inc., announces NEC's MC5313A power amplifier module series and the NEM0900 power transistor series for cellular applications. The MC5313A covers the 825-845 MHz cellular frequency range with high power output of 10 W typical, 20dB gain and typically 35% efficiency. Its three stage design with individual supply pins allows optimum design flexibility. This thick film, broadband UHF power module is designed for 13.8 volt operation at temperatures ranging from -40 to 110° C. It can withstand an infinite output mismatch at 16.5 volt supply and 6 watts output, making it highly suited for operation in hostile environments. The NEM0900 series of NPN epitaxial UHF power transistors are designed specifically for base stations in the 800-960 MHz bands. This 24 volt, common base series is available in a low cost metal ceramic stripline package in power levels of 30, 40 and 60 watts. **California Eastern Laboratories, Inc., Santa Clara, CA 95050, please circle INFO/CARD #143.**

Surface-Mountable Oscillator

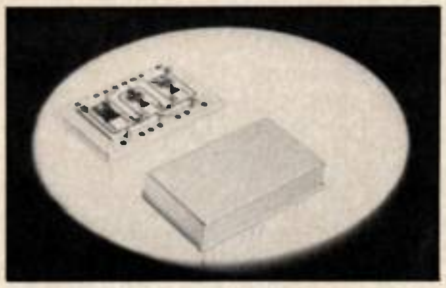
A series of surface-mountable crystal oscillators just announced by Statek Corp. are claimed to have the smallest size and lowest power consumption of any surface-mountable oscillator available, from 2 MHz down to 10 kHz. Model SQXO-2-SM oscillator draws 2 mA at 2 MHz and only 0.2 mA at 10 kHz. It is packaged in a standard 24-pin leadless ceramic chip carrier 0.4 × 0.4 × 0.085 in. Standard calibration tolerances are: (A)

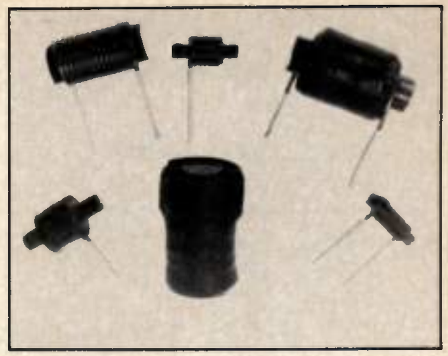


±0.018% and (B) ±0.03%. Frequency-temperature stability is typically ±0.02% from -40 to +85° C. Shock resistance is 1000g, vibration 10g. Price: approximately $50, 100 quantity. Delivery 10 to 12 weeks. **Statek Corp., Orange, CA 92668, INFO/CARD #144.**

MIC Electronic Attenuators

KDI Electronics, Inc., Engelmann Division has announced the DAP1023 Electronic Attenuator. Using MIC thick film technologies, the device has an attenuation range from 0 to 42 dB in 6 dB steps. This unit is designed for use between .9 GHz and 1.2 GHz with a VSWR less than 1.5 to 1 and a maximum insertion loss of 4 dB. The DAP1023 is hermetically sealed in a plug-in package and operates over the temperature range from -54° C to +85° C. **KDI Electronics, Inc., Whippany, NJ 07981, INFO/CARD #145.**





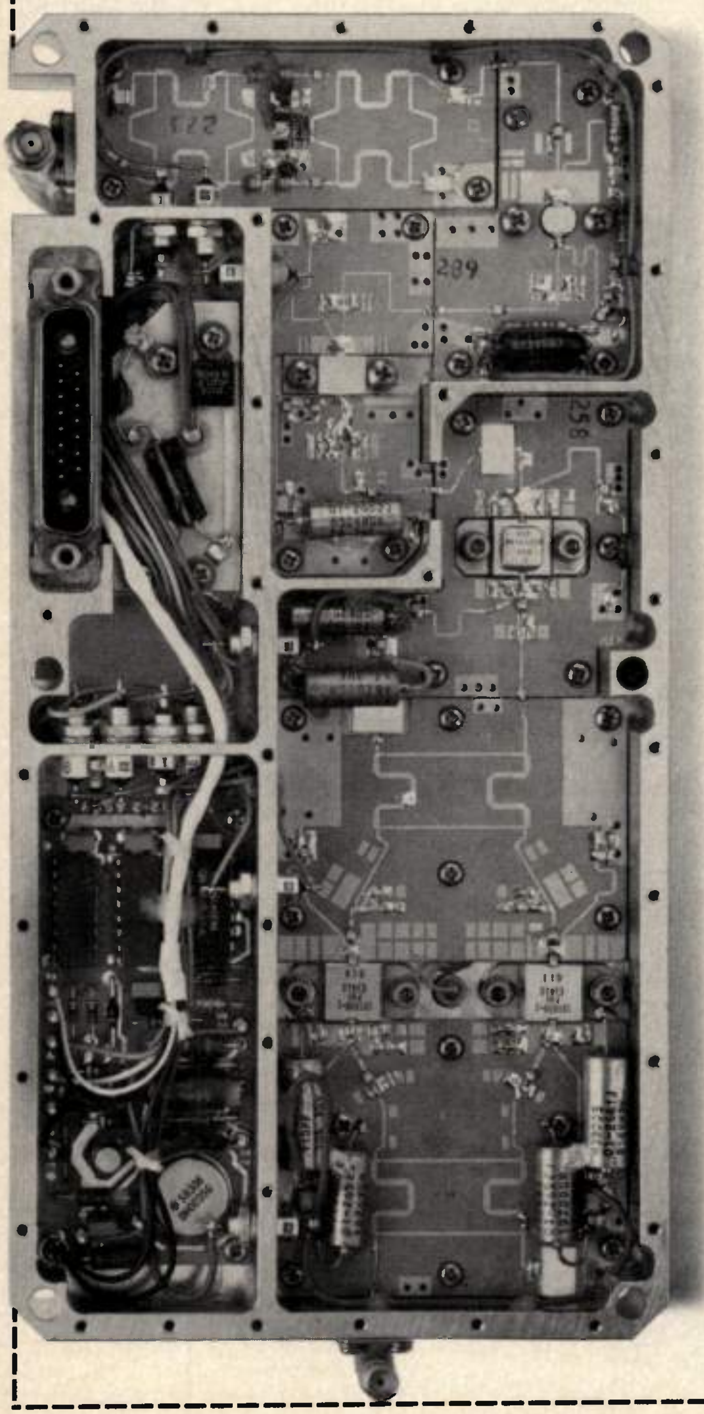
Ferrite Core Chokes

A new line of ferrite core chokes featuring a wide range of inductances and currents has been introduced by South American Development Corporation. With inductances from 0.27 to 100,000 microhenries, current ratings from 0.1 to 32 amperes, and energy storage up to 0.007 watt-seconds, these chokes are designed for use in power, audio and RF applications. Unit costs begin at $0.17 in production quantities. **South American Development Corp., Hyde Park, NY 12358, INFO/CARD #147.**

RF Small Signal Bipolar Devices

The MRF571, MRF572 and MRF573 feature ion-implanted arsenic emitters and gold metalization for reliability.

LOOK AT ALL THE SPACE YOU SAVE WITH RT/DUROID 6010.



The large, empty space on the left is brought to you by RT/duroid® 6010—the new soft substrate from Rogers that can shrink a circuit by 30%. And let you design in higher quality and reliability to boot.

MAKE CIRCUITS 30% SMALLER. AND INFINITELY BETTER.

RT/duroid 6010 has a dielectric constant as high as many ceramic substrates—yet it's soft, durable and easy to work with. It lets you position components much more compactly, without resorting to touchy ceramics. And components—with their interconnecting traces—can be etched on a single board, virtually eliminating wirebonding. That means faster assembly. Superior reliability. And cost savings, across the board.

SHED UNWANTED INCHES, FAST.

On RT/duroid 6010, one board can do the work of several. Or an oversize board can shrink to fit an undersize space. And you'll get all the 6010 you need, quickly and cost-efficiently. That's a promise from Rogers.

SEND FOR A FREE SAMPLE.

Just mail the coupon, or call 602-961-1382. We'll have you designing on RT/duroid 6010 faster than you can say, "Think small".

ROGERS

Rogers Corporation
Microwave Materials Division
Box 3000
Chandler, AZ 85224
602-961-1382

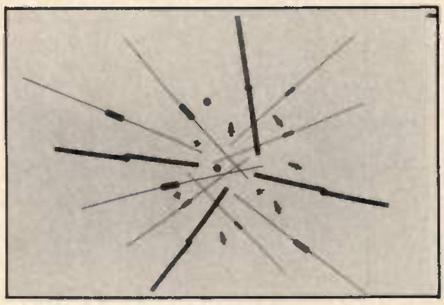
Please send a free sample of space-saving RT/duroid 6010 to:

Name ____________________
Title ____________________
Company ____________________
Address ____________________
____
City ____________ State ______
Zip ____________________
Telephone ____________________

Because the exceptional fine-line geometry allows lower noise and higher gain at high frequencies, the devices can be used in numerous general purpose applications ranging from 0.5 GHz to 2.0 GHz. The MRF570 series is an excellent choice for low noise pre-amplifiers, oscillators, mixers, multipliers and power microwave converters for receiving and transmitting purposes. **Motorola Semiconductor Products, Inc., Phoenix, AZ 85036, INFO/CARD #146.**

Silicon Tuning Varactors

M/A-COM Semiconductor Products, Inc. announces their new MA-4K000 series of abrupt junction high, capacitance silicon tuning varactors. These varactors, utilized in general tuning and AFC applications, feature high breakdown voltage, high Q and thermal oxide passivation. These devices are the logical choice where high reliability and low leakage are important design criteria.

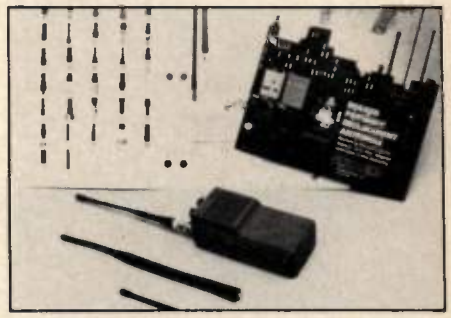


This series of diodes is ideally suited for tuning applications in many radio, TV and AFC circuits from HF to VHF frequencies. **M/A-COM Semiconductor Products, Inc., Burlington, MA 01803, INFO/CARD #148.**

Circuit Analysis Software

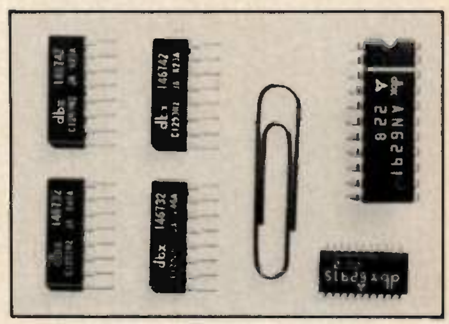
Communications Consulting Corp. has introduced its CADEC™ software package for analysis and optimization of virtually any type of electronic circuit. The program runs in the frequency domain and allows the interconnection of active

and passive elements, as well as complex interconnections. Fourier Transform capability allows transformation of results into the time domain, and all results can be displayed both in tabular and graph formats. CADEC™ is available for the Tektronix 4051/52/54, the H-P 9845B/C, H-P Series 200 machines (9816/26/36), and H-P Series 500 (H-P 9020) Systems. **Communications Consulting Corp., Upper Saddle River, NJ 07458, please circle INFO/CARD #149.**



800 MHz Antennas

Two new models of 800 MHz portable antennas have been introduced by Centurion International. Specially designed for new cellular radio applications, the 800 MHz antennas are extremely durable, and are available for immediate shipment. The "Tuf Duck" ¼ wave whip antenna for 800-1,000 MHz features a .130 diameter cable radiator, encapsulated in high gloss PVC, with an approximate length of 3½ inches. The "Tuf Duck" Style E antenna for 800-1,000 MHz use is a ¼ wave flexible coaxial antenna with elevated feed point and strain relief base. Approximate length is 8 inches. **Centurion International, Inc., Lincoln, NE 82846, INFO/CARD #150.**

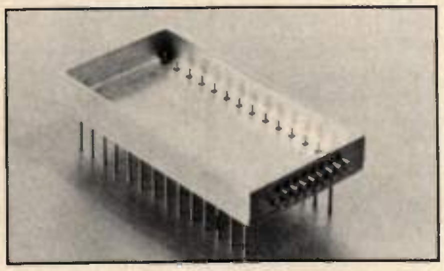


TV-Stereo System IC

Three integrated circuit (IC) configurations have been announced by dbx Inc. for the dbx TV-stereo system, which was recently selected as the industry standard for television stereo broadcasting. (The IC chips, above, were photographed with a standard-size paper clip to provide a sense of scale.) The smaller IC at the top left is designed for applications where space is at a premium. Its SO-package style makes it ideal for portable sets. The large IC to the left of the paper clip is for low-cost implementations. Its 22 pin DIP (dual in-line package) contains all the circuitry needed to provide the heart of the dbx-TV noise reduction system. The four IC chips to the right of the paper clip are designed for ultra-high quality implementations. The SIP (single in-line package) keeps space requirements down for these ICs. **dbx Inc., Newton, MA 02195, INFO/CARD #151.**

Dual In-Line Header

ASPE, Inc., announces the latest addition to its line of new generation flat packs, an innovative combination flat pack and dual in-line header. A high performing unit, it is available at substantially reduced cost,



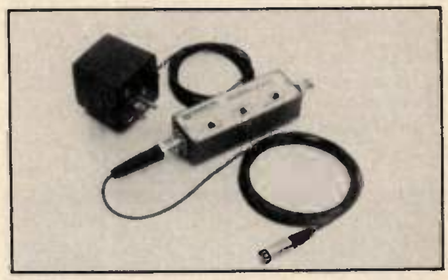
thanks to advanced production techniques employed in manufacture. The new flat pack's two-piece construction is sealed on two different planes to extremely tight tolerances, and helium leak-tested to exceed military specifications by a factor of three. **ASPE, Inc., Fairfield, NJ 07006, INFO/CARD #152.**

Power Meter

This microprocessor controlled, digital power meter incorporates significant circuit developments, providing the user with auto-range, auto-cal, auto-zero average time and power-up mode selection, power linearity correction and full GPIB compatibility. Virtually eliminated are the problems of zero drift and range errors. Accuracy is 0.5%, supported by comprehensive self-checking and diagnostic facilities. High efficiency in automatic test applications can be achieved with the Marconi 6960 by the ability to select response speeds down to an exceptional 25ms. Automatic calibration is a unique feature of the 6960, and is performed by a few key strokes to turn on the internal 50MHz power reference, adjust the gain for the sensitivity and then turn off the power reference. Model 6960 is priced at $2,250 and is available for delivery within 45 days. **Marconi Instruments, Northvale, NJ 07647, INFO/CARD #153.**

AC Magnetic Field Analyser

Magnatek Corporation has introduced a new AC Magnetic Field Analyser designed to detect power frequency disturbance from stray magnetic flux generated by transformers, motors, generators, or other noise makers in electronic enclosures. Magnetic flux can inhibit performance factors of sensitive electronic



components, such as cathose ray tubes, disc drives, magnetic files and circuit conductors. The Magnatek probe and integrator have been developed to analyse the stray flux field density and its derivative in power frequency ranges of 40 Hz to 10K Hz. The analyser's probe is a calibrated pickup coil sensitive to the derivative of flux density (dB/dt). The actual value of flux density (B) is measured by passing the probe output through an integrator whose signal can be sensed by any oscilloscope or high impedance AC meter. **Magnatek Corporation, Boulder, CO 80301, INFO/CARD #154.**

1 GHz and 2 GHz Synthesized Generators

Texscan announces the availability of two new synthesized signal generators covering from 10 Hz to 1 GHz (SSG-1000) and 10 Hz to 2 GHz (SSG-2000). Tuning in 10 Hz steps (20 Hz, SSG-2000), the output level is from -137 dBm to +13 dBm in 0.1 dB steps. The SGG-1000 uses a fundamental oscillator over its full frequency range, giving excellent spectral purity. Advanced frequency synthesis gives fast lock (less than 5 mSecs, 10 MHz step) and good SSB noise performance (130 dBc, 10 kHz away at 100 MHz.) The 2 GHz unit (SSG-2000) uses frequency doubling from 1 to 2 GHz with sub-harmonics greater than 25 dB down, and a tuning step of 20 Hz. Internal frequency, amplitude or phase modulation is provided with frequencies from 10 Hz to 99.9 kHz in 10 Hz steps. A non-volatile memory stores up to 10 front panel setups and both instuments are programmable using IEEE 488 or HPIL. Reverse power protection up to 50 W is provided as standard. Delivery is 12 to 16 weeks ARO. **Texscan Corporation, Indianapolis, IN 46226, please circle INFO/CARD #155.**

Automatic HF Measuring for Capacitance, Q-Factor, and ESR

An automated system is now available from Boonton Electronics to measure capacitance, Q-factor, and effective series resistance (e.s.r.) of capacitors and forward-biased PIN diodes with high repeatability to 2.0 GHz. Based on a resonant-line method pioneered by Boonton and described in ASTM F752-82 and the Department of Defense-approved EIA-RS-483-1981 standards, the 174 system includes, besides the resonant line, a 1021 r.f. signal generator, a 9200A r.f. millivoltmeter, and an H-P 85B controller together with appropriate software. Although the device under test must be

manually inserted into the resonant line, either in series at the short-circuited end of the line or in shunt at the open-circuited end, the system then proceeds through a self-prompting menu to establish proper test frequencies and levels, fit observed data to a "universal resonance curve," and calculate and display the measurement values. A two-channel version is also available, consisting of one additional resonant line and associated hardware, which allows one line to be loaded while a measurement is under way on the other line to improve throughput. Values of capacitance can range from a fraction of a picofarad to greater than 1000 pF, depending on the mode of insertion and the test frequency. Test levels do not exceed 3 mA or 0.2 V. Price: Model 174, $27,945. Availability: 6 weeks. **Boonton Electronics Corporation, Randolph, NJ 07869, INFO/CARD #156.**

Temperature Compensated Miniature Filters

A complete series of Highpass, Lowpass, Bandpass and Band Reject Filters with temperature coefficients of less than 10 ppm/°C are available from KW Engineering. A typical device exhibits a center frequency of 250 MHz, with a 1 dB bandwidth of 5 MHz. The shift in center frequency over an operating temperature range of -55° C to +125° C is ±200 kHz Maximum. Approximate size is 1.3 × 0.6 × 0.3 inches. This series of filters are available in frequency ranges from 100 MHz to 5 GHz. The devices have been designed to meet or exceed the requirements of MIL-STD-202F. **KW Engineering, Inc., San Diego, CA 92111, INFO/CARD #157.**

Continuously Variable Coaxial Attenuators

RLC Electronics announces the extension of its continuously variable attenuator line. The attenuators are designed for low frequency operation of DC-800MHz and offer low insertion loss and VSWR. This is accomplished with good impedance matching and level attenuation. They are available in 50 ohms or 75 ohms with Type N, TNC, BNC and SMA connectors and in attenuation ranges from 0-20dB. The units meet the environmental requirements of MIL-A-3933 and would be used where a continuous adjustment of signal level would be required. **RLC Electronics, Mt. Kisco, NY 10549, INFO/CARD #158.**

Synthesized Signal Generator

Comstron has announced the availability of a Synthesized Signal Generator, Model 740A, for under $10,000 with all these features: AM, FM, phase and pulse modulation. Excellent in-close phase noise. Spinwheel and keyboard entry of all functions. Non-volatile memory for 40 complete configurations. 20 mSec. settling time.

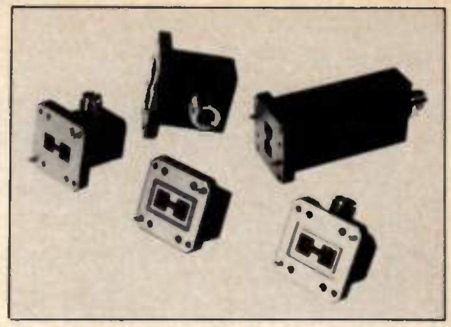
INFO/CARD 75

INFO/CARD 76

Superb level accuracy. 10 Hz resolution across entire frequency range. IEEE-488 bus programming. The RF frequency coverage over the range 100 kHz-1120 MHz (doubler option from 560 MHz) is derived from a crystal reference driving a 10 Hz steps synthesizer, thus producing the desired features of accuracy, stability and spectral purity. The modulation and output stages have been designed to comply with with the requirements of radiocommunications, with amplitude, frequency, phase and pulse modulation facilities (optional). The precision attenuator is protected against accidental reverse power. Ease of operation is achieved by a microprocessor which services the front panel controls, and allows remote programming of the instrument by the IEEE 488 bus. Delivery is 4 to 6 weeks ARO. Price $7,600; 560 MHz doubler to 1120 MHz $900.00; and pulse moculation is $1,000. **Comstron Corporation, Freeport, NY 11520, please circle INFO/CARD #166.**

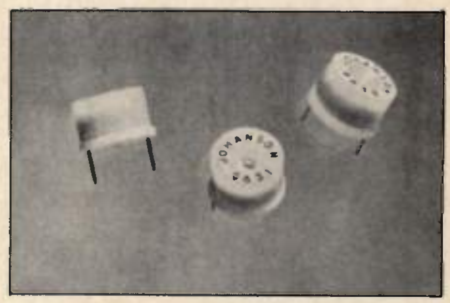
Waveguide To Coax Adapters

A new series of high power double-ridge waveguide to coax adaptors with operating frequencies over the entire waveguide band is being introduced by Continental Microwave and Tool Company, Inc. Continental Double-Ridge Waveguide To Coax Adaptors feature power ratings from 500 to 1000 WATTS-CW, depending on size and configuration. Operating over the entire waveguide band, they are offered in top wall and end launch designs. Available in 4 standard sizes from WRD-650D28 thru WRD-350D24, Continental Double-Ridge Waveridge To Coax Adaptors are constructed from 6061 aluminum and finished with a high temperature coating. VSWR nominal is 1.25/1; max is 1.50/1 Continental Double-Ridge Waveridge To Coax Adaptors are priced according to configuration, size, and quantity with delivery from stock to 4 weeks. **Continental Microwave and Tool Company, Inc., Bradford, MA 01830, INFO/CARD #128.**



Variable Capacitors

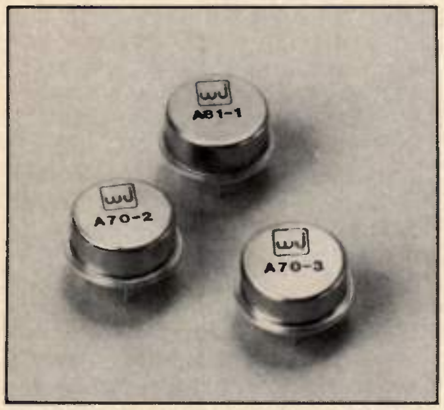
Seal-Trim® Variable Ceramic Capacitors are now available in a housing designed to facilitate automatic tuning. Available in capacity ranges of .5-2.5pF to 6-25pF. Size .180" dia.; height .11" above board. Printed circuit terminals are .020" wide spaced on .140" centers. Tapered top guides .025" square drive tuning tool into precise alignment.



Seal-Trim® Capacitors are high performance Thin-Trim® variable ceramic capacitors encapsulated in a protective housing which inhibits intrusion of dirt, dust, solder flux and cleaning agents during assembly and environmental contamination during use. They are designed for applications including crystal trimming, filter networks, interstage coupling, microprocessor clocks, and impedance matching. Price: 9630 Series $0.65 each in 10,000 piece order quantities. Delivery: 4 to 6 weeks. **Johanson Manufacturing Corporation, Boonton, NJ 07005, INFO/CARD #127.**

High-Efficiency Amplifiers

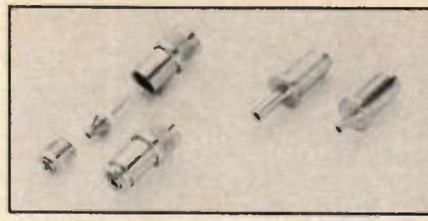
Three new high-efficiency models have been added to Watkins-Johnson Company's TO-8 amplifier line. The WJ-A70-2 provides output power of +19.0 dBm across the 10 to 250 MHz frequency range. The amplifier supplies 8.5 dB of gain with a noise figure of less than 3 dB.



The WJ-A70-3 is a high-power version of the WJ-A70-2, delivering +22.5 dBm of output power. The WJ-A81-1 covers the 20 to 250 MHz frequency range. It provides output power of +12.5 dBm with a 2 dB typical noise figure and consumes only 18 mA of DC current. **Watkins-Johnson Company, Components Applications Engineering, Palo Alto, CA 94304, INFO/CARD #126.**

TNC Connector Series Designed For Cellular Radio Applications

Automatic Connector, Inc., a major manufacturer of R.F. coaxial connectors, cable assemblies, microwave components and fiber optic connectors, has developed a new miniaturized TNC connector series to meet the demanding dpecifications of the cellular radio. The new TNC series is a low cost, high performance coaxial connector suited for critical applications and environments. It features a "value engineered" design using screw machine components. The connector is smaller and lighter in weight than the standard TNC connectors, but is intermateable. Mating face gaskets and a specially designed backnut weatherproof the connector for outside environments. The new series consists of a "D" hole type bulkhead mounted cable jack that is designed for mounting on the radio as the antenna connections. It uses a crimp style cable termination to assure a cost effective volume oriented assembly procedure. The mating plug connector utilizes the improved Automatic wedge-lock® style cable termination. This design approach has fewer loose components and reduces your normal cable assembly time by more than 50% over the standard "UG" type connectors. The



connector requires no special assembly tooling. The center contact is soldered and the backnut is clamped against the cable braid, thus providing excellent signal continuity and superior cable retention. The connector is also totally field serviceable. **Automatic Connector, Inc., Commack, NY 11725, INFO/CARD #124.**

Portable VHF/CATV/UHF Signal Level Meter

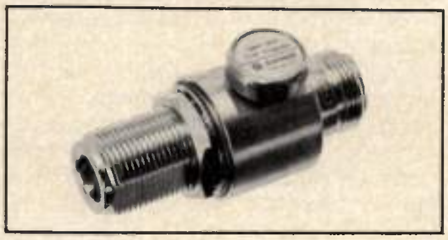
A portable VHF/CATV/UHF Signal Level Meter that covers 50 MHz to 450 MHz and 470 MHz to 810 MHz in four bands and features easy tuning, automatic turn-off to conserve battery life, built-in speaker, large easy-to-read meter, and three 20 dB attenuators to provide measurements from -30 dBmV to +60 dBmV has been introduced by B&K Precision/Dynascan Corporation. Designated Model 430, the unit can be used in a wide variety of applications including television an FM antenna installation and servicing;

INFO/CARD 78

satellite antenna site selection and installation; MATV and CATV installation, maintenance and servicing; and checking rf output on VCRs and home computers. B&K-Precision test instruments are sold through electronic distributors. The Model 430 Signal Level Meter is priced at $850. Available: In Stock. **B&K-Precision/Dynascan Corporation, Chicago, IL 60639, INFO/CARD #123.**

Coaxial NEMP-Protectors

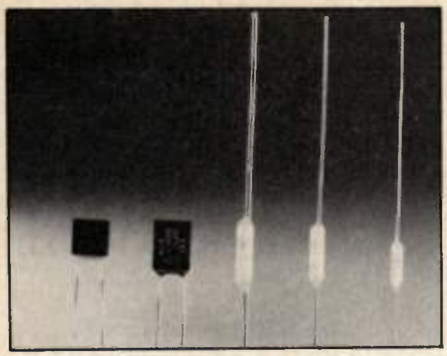
SUHNER Series 3402 Protectors are used to protect communication equipment against the effects of a nuclear electromagnetic pulse (NEMP). They feed coaxial lines RF-shielded into protected areas but divert surge voltages induced by a NEMP to ground. The gas-filled surge arrestor is mounted directly between the outer and center conductors whilst optimum impedance matching is maintained. This ensures an excellent current loading capacity and virtually loss-free operation at frequencies up to 2500



MHz with low VSWR. This new design (patent pending) is available with series N and 7-16 connectors. SUHNER Series 3402 Protectors are also used to protect against damage caused by lightning. **Huber & Suhner Ltd., CH-9100 Herisau, INFO/CARD #159.**

Thermal Cutoffs

A new line of thermal cutoffs is now being introduced into North America by Chatham Components, Inc., Chatham, New Jersey. Manufactured by Uchihashi Metal Industrial Company, LTD., Japan, Elcut Thermal Cutoffs are the ultra in miniature., They are non-resettable and because of a unique surface treatment process, maintain long term temperature stability. All cutoffs are housed in non-electrically conductive cases and most have UL, CSA and/or VDE approval. There are five series of cutoffs available totaling over thirty types. The "01" Series features operating temperatures ranging from 74° C to 164° C with electrical ratings of 2 amperes and 250 volts. The "02" Series features operating temperatures ranging from 74° C to 145° C, 5 A and 7 A, 125 V. "03" Series has operating temperatures ranging from 74° C to 164° C, 2 A, 250 V. The "X" Series operates at 100° C to 187°, 3A and 5A, 250 V. And lastly, the "U5" Series operates at 100° C to 147° C, 2 A and 2.5



A, 250 V. The ultra-miniature size of Elcut Thermal Cutoffs and non-electrically conductive cases allows unparallel design possibilities and tremendous cost reductions. Chatham Components maintains a sizeable inventory and delivery on items not in stock takes usually less than four weeks. **Chatham Components, Inc., Chatham, NJ 07928, INFO/CARD #160.**

Tubular Bandpass Filters

Coleman Microwave Company is proud to introduce a complete line of tubular bandpass filters. Available are 5 sizes ranging from .250-1.250 inches diameter. The tubular design opens up a wide variety of package and connector styles, as well as lower cost. Filters are available over a frequency range of 20-12000 MHz. Prices and delivery available upon request. **Coleman Microwave Co., Edinburg, VA 22824, INFO/CARD #161.**

Times-44 Frequency Multiplier

The AX44-100-60 is an unconditionally stable times-31 frequency multiplier with an input frequency of 100 MHz. The input power is 10 dBm and the output power is 13 dBm. All harmonics and subharmonics are less than -60 dBc. DC voltage is 15 volts. Size: 1.4" × 2" × 4". Price: $2200. Delivery: 60 days. Other models available with input frequencies from 10 MHz to 150 MHz. **A.I. Grayzel, Inc., Needham, MA 02194, please circle INFO/CARD #162.**

Feather-Weight Headset

Telex has introduced a super light headset for hand-held landmobile transceivers. The ProCom 352-IC weighs a mere 2.6 ounces when worn with the headband. However, the snap-on headband is removable so the headset weighs only one ounce and can be clipped directly onto eye or sunglass frames for even greater convenience. When using the headset, the radio remains on the operator's belt. There is no longer any need to hand hold the radio for communications. The headset is equipped with an in-line push-to-talk switch which also clips to belt. The headset plugs directly into ICOM or Ten-Tec hand-held transceivers. The unit carries a suggested list price of $129.95 and is available now at local two-way radio dealers. **Telex Communications, Inc., Minneapolis, MN 55420, INFO/CARD #163.**

Transmitter Detector

Tactix has announced the release of a portable wide-band transmitter detector designed to counter the threat of eavesdropping. The TTX-310 is a professional, ultra-sensitive receiver that allows an untrained user to detect and locate the presense of eavesdropping devices within minutes, even in a highly active broadcasting area. Utilizing the latest

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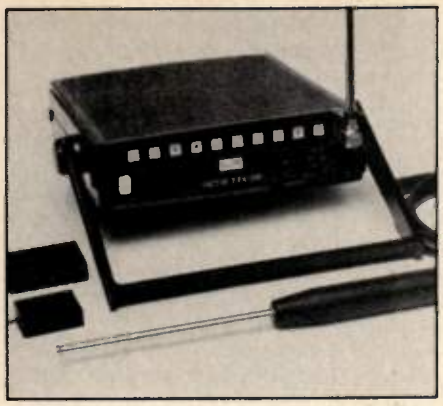
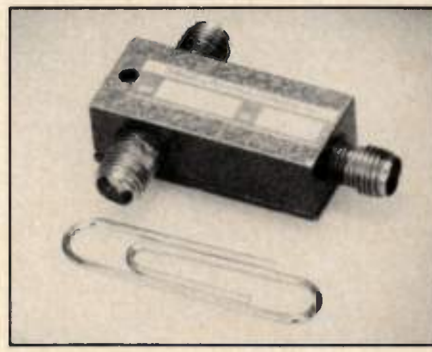


technology, the TTX-310 incorporates R.F. hybrid circuitry and 10 high intensity light emitting diodes to form a bargraph which instantly displays user proximity to transmitter. With a detection range from 1 MHz to 1.3 GHz, this desk top detector will give immediate warning when someone wearing a bugging transmitter enters the room; even with sub-carrier and difficult to detect low power "wireless microphone" types. The Tactix-310 model comes fully equipped with a rechargable battery, charger, telescoping antenna, and a hand held probe to allow quick, yet highly accurate sweeps. Special features include a "silent" or "chirp" transmitter alarm function, which can be pre-set to notify the user in either audio or visual output when transmitter is nearby, or when someone enters the room with a covertly disguised one. An L.E.D. displayed battery check circuit to check battery power level is standard. Encased in a rugged structural resin plastic covering, this unit is equally at home in the field, the office, hotels, automobiles, and business meetings; yet it remains under 5 pounds. The overall compact size is 9"L × 8.5"W × 2.5"H. **Tactix, Belmont, CA 94002, INFO/CARD #164.**

2 Way Miniature Power Divider

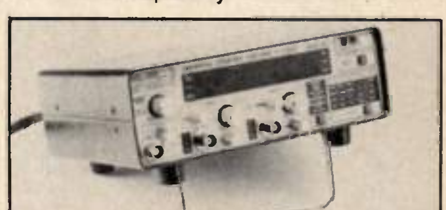
Sage Laboratories, Inc., is now offering the 2 way model FP3230 Miniature Power Divider that operates in the 2-18 GHz frequency range. it has an isolation from 17 dB at 2 GHz to 20 dB at 3 GHz and greater than 24 dB from 5-18 GHz.



This miniature power divider also offers 1.5/1.4 maximum input/output VSWR, amplitude unbalance of .2 dB maximum, phase unbalance of 4 degrees maximum and an insertion loss of 1.3 dB maximum. Dimensions of this unit are 1.25 × .50 × .38 inches. **Sage Laboratories, Inc., Natick, MA 01760, INFO/CARD #110.**

Universal Counter

A universal counter which can function as a unit event counter, frequency counter and microwave counter to 1.3 GHz is now available from OK Industries Inc. Designated Model 502, it can measure: period, from 500ns to 10s with resolution selectable to 100ps; frequency ratio (FA/FB) with periods averaged 1, 10, 100, or 1,000; and time interval (A to B) from 500ns to 10s with resolution selectable to 100ps. The 502 offers all the features and flexibility of the 200 MHz Model 501, plus microwave capability. For added versatili-



ty, the 502 has three inputs: an "A" input DC to 200 MHz, an "A" input 50 MHz to 1.3 GHz, and a "B" input DC to 2 MHz. In addition, the 200 MHz and 2 MHz inputs offer 1M ohm impedance, while the 1.3 GHz input offers 50 Ohm impedance and features a preamplified prescaler for superior sensitivity. Delivery is stock to 4 weeks. Cost is $875.00. **OK Industries Inc., Bronx, NY 10475, INFO CARD #111**

New Literature

Coaxial Cable Catalog

A new coaxial cable catalog, "RF Transmission Line, The Complete Catalog and Handbook," has just been released by Times Fiber Communications, Inc. (TFC), an affiliate of Insilco Corporation. The 42 page catalog includes a selection guide and application notes which engineers and purchasing agents will find helpful. A complete guide to the most recent series of MIL-C-17 coaxial cables is also included. **Times Fiber Communications, Inc., Wallingford, CT 06492, INFO/CARD #172.**

Electronic Materials Catalog

Electro-Science Laboratories is now distributing its new 1984 catalog. Thick film materials described in the catalog include cermet conductors, resistors and dielectrics, materials for surface mounting including solder pastes and organic adhesives, materials for packaging, hybrid circuits, flexible circuits, pc boards, optoelectronics, sensors and high frequency applications. **Electro-Science Laboratories, Inc., Pennsauken, NJ 08110-0596, INFO/CARD #170.**

Electronic Hardware Catalog

Promptus Electronic Hardware, Inc., has published and released the new 1984 Catalog of their complete line of Electronic Hardware. This 220-page edition features illustrations and descriptions of Promptus' large off-the-shelf inventory of shoulder screws, retainers, panel screws, male and female swage type stand-offs, pusher screws, washers, handles, and much more. **Promptus Electronic Hardware, Inc., Long Island City, NY 11105, INFO/CARD #171.**

RF and Microwave Selector Guide and Cross Reference

Motorola's new RF and Microwave Selector Guide and Cross Reference (SG46R2) now is available. The guide has been revised and contains all the updated information concerning Motorola's broad line of RF Semiconductors. **Motorola Semiconductor Products Inc., Phoenix, AZ 85036, INFO/CARD #173.**

Industrial Catalog

Joseph Electronics recently announced publication of a new industrial catalog No. 050. This attractive 496-page catalog features comprehensive specifications covering more than 100 major product lines. **Joseph Electronics, Niles, IL 60648, INFO/CARD #174.**

Oscillator Guide

Now available from Dale Electronics, Inc., is a 7-page catalog featuring complete specifications for Dale oscillators. Products include: Hybrid Crystal Clock Oscillators in Resistance Welded Metal Packages and ceramic plus Temperature Compensated Crystal Oscillators. **Dale Electronics, Inc., Columbus, NE 68601, INFO/CARD #175.**

Antenna Catalog

Centurion International has published a new, eight-page catalog on their "Tuf Duck" line of portable antennas. The new catalog lists more than 20 antenna models, including the company's new 800 MHz antennas for cellular radio applications. Plus, Centurion's full line of connector styles to fit virtually any portable radio on the market is included. Also included in the catalog are several other new additions to the Centurion line, including a 5/8 wave VHF gain antenna, a new 1/4 wave flexible whip antenna for UHF, a 1/2 wave flexible cable antenna for UHF, and the Tuf Duck "Slim Mini" 3-inch antenna for 118-225 MHz. **Centurion International, Inc., Lincoln, NE 68501, INFO/CARD #176.**

Electronic Test Instuments Catalog

Global Specialties (an Interplex Electronics, Inc., company) has completed its 1984 edition of "Instuments for Testing and Design," a full-time catalog of the more than 80 precision test instruments, logic probes, logic monitors and solderless prototyping systems associated with the Global name. The catalog also features several new products, including the Global-Data® line of high quality computer peripherals. The Global catalog offers an overview of each product category, followed by detailed descriptions and specifications. Of particular note is the recently-introduced 1301 triple power supply which boasts separate 5 VDC (fixed) and variable 5 to 18 VDC outputs. Take a look, too, at the new Model 6002 1 GHz Frequency Counter with frequency measurements from 5 Hz to 1 GHz, and period measurement too! **Global Specialties, New Haven, CT, 06509, INFO/CARD #115.**

Sourcebook for the Telecommunications Industry

COMPUCON, INC., a subsidiary of A.C. Nielsen Company, announced the availability of their latest industry study, "Unraveling Opportunities in Business Communications — Voice and Data", Volume Two. This comprehensive communications industry study contains valuable information on private voice and data networking including six industry surveys of over 400 respondents. Separate chapters are devoted to such topics as circumvention of the public switched network, rescue common carrier markets and local area network. **COMPUCON, INC., Dallas, TX 75380-9006, INFO/CARD #116.**

Power Supply Engineering Handbook

A new 116-page Engineering Handbook from the Power Products Group describes over 700 different linear and switching power supplies and DC/DC converters available from Compower Corp., Stevens-Arnold Inc., and Power Products Division. This handbook also includes a comprehensive 22-page technical section on "Principles of Power Conversion". Important topics include: linear power supplies, switching power supplies, DC/DC converters, power converter testing, power converter application, and thermal management and reliability. In addition, a Power Conversion Glossary defines over 100 of the common terms used with power supplies and DC/DC converters. **Power Products Group, Pompano Beach, FL 33069, INFO/CARD #117.**

RF/Microwave Instrumentation Catalog

Polarad has issued their new 8 page RF/Microwave Instrumentation catalog. Specifications and information on more than 14 instruments are described. **Polarad Electronics, Lake Success, NY 11042, INFO/CARD #118.**

Electrolytic Capacitor Catalog

United Chemi-Con, Inc. has just issued its new 256-page catalog of aluminum electrolytic capacitors. This catalog is the most comprehensive to be published on this product line and the table of contents reads like an encyclopedia of capacitors. The catalog portion details 45 different series; from the Alchip micro-miniature series that is used like a chip capacitor and has a capacitance value as low as .1μF, to the MWU series designed for large frame computer use that has a capacitance value greater than 1.6 farads. **United Chemi-Con, Inc., Rosemont, IL, 60018, INFO/CARD #112.**

Wiring and Cabling Catalog

Complete guidelines for selecting and installing coax, twinax/triax & quadrax cabling used in computer networks and data distribution systems are described in a new, free 50 page catalog, from the manufacturer, Trompeter Electronics of Chatsworth, California. The catalog describes and illustrates thousands of items for installing and distributing hard-wired multi-terminal computer networks for compliance with recent fire prevention regulations. Over 30 families of plugs, jacks, panels, looping plugs, cable assemblies and termination hardware in coax, twinax/triax or quadrax versions are included for such related applications as telecommunications, telephone, TV broadcast, CATV, CCTV, ETV, missile and space telemetry and aircraft for information transmission and retrieval. **Trompeter Electronics, Inc., Chatsworth, CA 91311, please circle INFO/CARD #113.**

Instrument Rental Catalog

Continental Resources, Inc. recently issued its 1984 Electronic Instrument Rental Catalog. This 68-page catalog, featuring over 1500 items, contains extensive listings of analyzers, meters, oscilloscopes, generators, microprocessor development systems, recorders, telecommunications equipment, and more. All items appear with full specifications and monthly rental rates. Instruments are fully tested, calibrated (traceable to the National Bureau of Standards), and guaranteed to meet manufacturer specifications. **Continental Resources, Inc., Bedford, MA 01730, INFO/CARD #119.**

Automated Scalar Network Analyzer Brochure

This new 18-page brochure describes Wiltron's family of ten automated scalar network analyzer systems covering the 10 MHz to 40 GHz range. Included is the new precedent-setting Model 5669, which covers the entire 10 MHz to 40 GHz range with a single *coaxial* test port. Optional units are described that offer accuracy that is equivalent to 60 dB directivity and that automatically locate faults in transmission lines. All units feature high directivity and test data from which system residual errors have been subtracted to achieve the highest measurement accuracy. **WILTRON Company, Mountain View, CA 94042-7290, please circle INFO/CARD #120.**

Connector Catalog

A new edition of TRW Cinch Connectors Distributor Catalog No. CD-12A that provides complete data on the wide range of the Division's products is now available through the TRW Cinch Connector Authorized Distributor Network. Included are complete mechanical, electrical, and environmental specifications, dimensional drawing with conversions to millimeters, product illustrations, and easy-to-read distributor product part numbers. **TRW Electronic Components Group, Elk Grove Village, IL 60007, INFO/CARD #121.**

Full-Line Catalog

A comprehensive, 92-page catalog, featuring a complete line of production tools, test equipment and accessories for the electronics and telecommunications industries, is now available from OK Industries Inc. The catalog spans over 150 products which are widely used in such areas as wire-wrapping, circuit design troubleshooting and repair, and pc board assembly, rework and testing. The 12 product sections covered are: New Products, Solder/Desolder Tools; IC and Component Handling Tools; PC Boards & Accessories; Production Aids & Accessories; Screwdrivers, Pliers & Cutters; Enclosures, Fans, 19" Sub-racks; Test Equipment; Wire Wrapping Tools and Accessories; Wire and Cable; and Wire Wrapping Machines. **OK Industries Inc., Bronx, NY 10475, INFO/CARD #114.**

Hand Tool Catalog

A new, 144-page catalog now being issued free by Electronic Tool Co., Inc., of Pleasantville, New York, is a comprehensive buyer's guide illustrating and describing hundreds of hand tools, tool kits, test equipment and related products. Included in the newly revised ETCO catalog is an expanded section covering a complete line of tool kits of interest to personnel involved in repair, maintenance and servicing of electronic and electro-mechanical equipment. Name brand hand tools, in addition to an extensive coverage of test equipment are also fully illustrated and described in detail with important specifications. A special section of the catalog lists prices for all the product shown. **Electronic Tool Co., Inc., Pleasantville, NY 10570, INFO/CARD #132.**

Optoelectronics Catalog

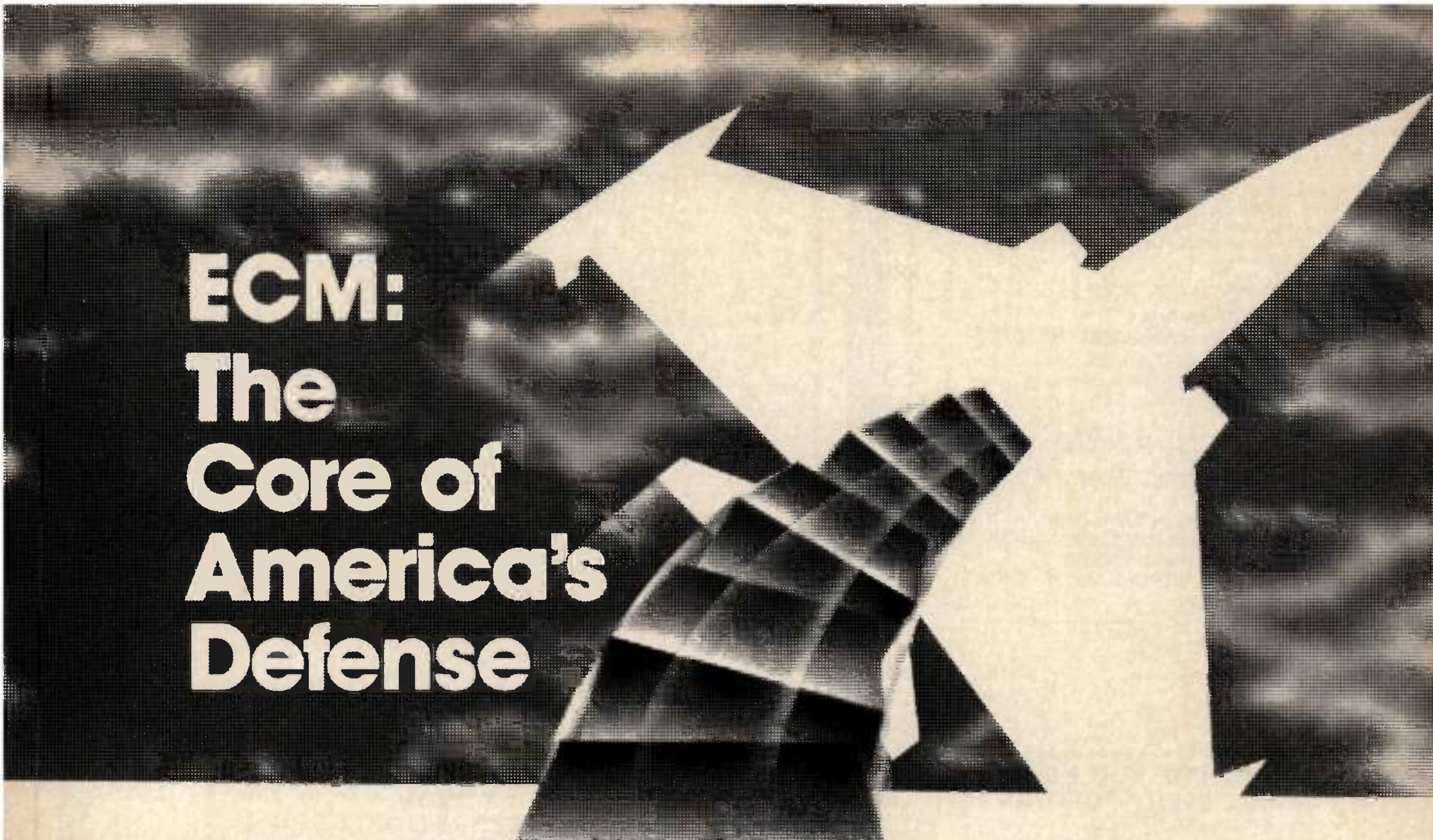
International Devices, Inc. has released a 12-page, full color catalog containing detailed information on its broad line of LED lamps, and its more than 90 varieties of numeric, alphanumeric and dot matrix displays. The catalog contains information on International Devices' industrial quality LED lamps; ultra-bright LED lamps; two-chip LED lamps; integrated resistor LED lamps; tri-state LED lamps; low profile LED lamps; rectangular LED lamps; single and double digit numeric/overflow displays; low current GaP numeric displays; and 0.50-inch digit height alphanumeric and dot matrix displays. Data information features, dimension drawings, mechanical and electrical specifications, connections and selection guides. **International Devices, Inc., Santa Ana, CA 92704, INFO/CARD #131.**

Test Accessories Catalog

A 128-page catalog of electronic test accessories — test leads, patch cords, cable asemblies, adapters and black boxes — has been published by ITT Pomona Electronics. This 1984 catalog of test accessories features specifications and photographs of 817 products, 80 of which are new products. **ITT Pomona Electronics, Pomona, CA 91766, INFO/CARD #130.**

VSWR Systems & RF Accessories Catalog

Telonic Berkeley Inc. has released an 8-page catalog covering its complete line of VSWR Systems and RF Accessories. The catalog includes descriptions, photos and specifications for Telonic Berkeley's broad line of VSWR Detectors, TRB Series Rho-Tectors, Terminations and Mismatches, TRK Series Kits, Coaxial Switches, Series 8500 RF Detectors, Fixed Value Coaxial Attenuators, and TLP Filters. **Telonic Berkeley Inc., Laguna Beach, CA 92652, INFO/CARD #129.**



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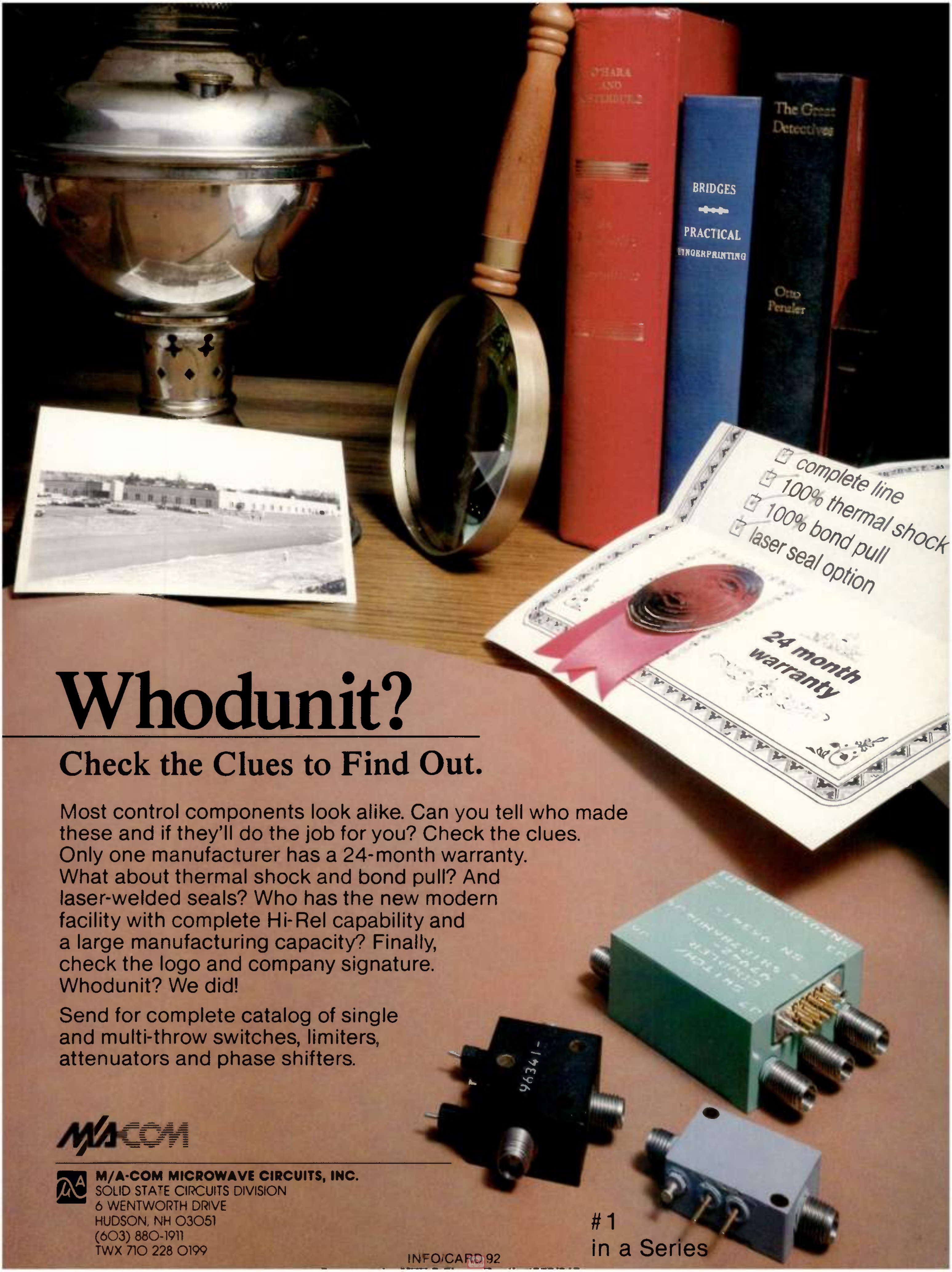
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ZHL-42 SPECIFICATIONS

Frequency	.7 to 4.2 GHz
Gain	30dB Min.
Gain Flatness	±1.0dB
Power Out @ 1dB CP	+29dBm Min.
VSWR In/Out	2.0:1 Max.
Noise Figure	7.5dB
Supply	+15V @ 690mA
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