January/February 1981

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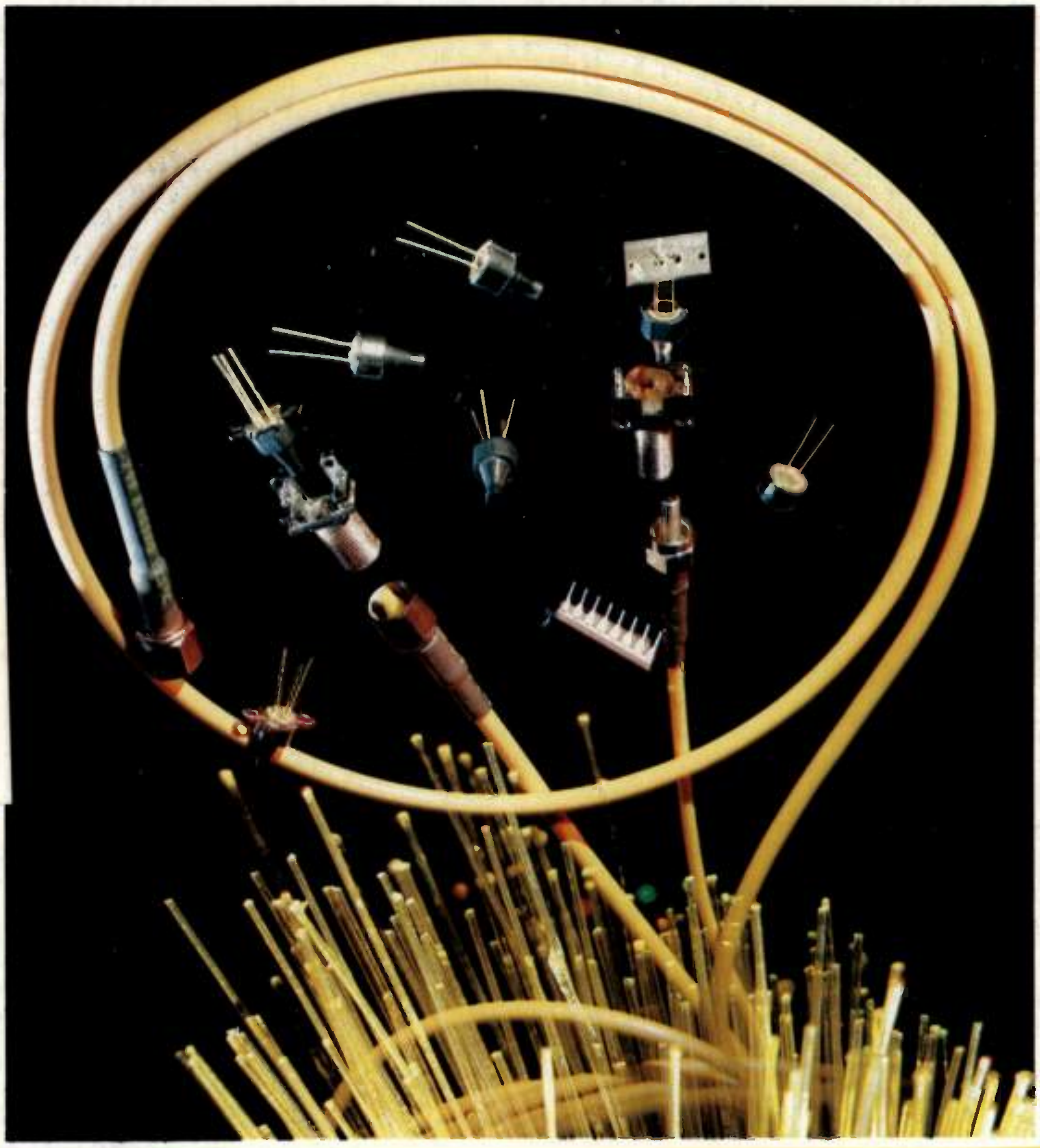
rf design



The RF Designer and Fiber Optics
Wideband Monofilar Autotransformers
Fractional N PLL Frequency Synthesizer

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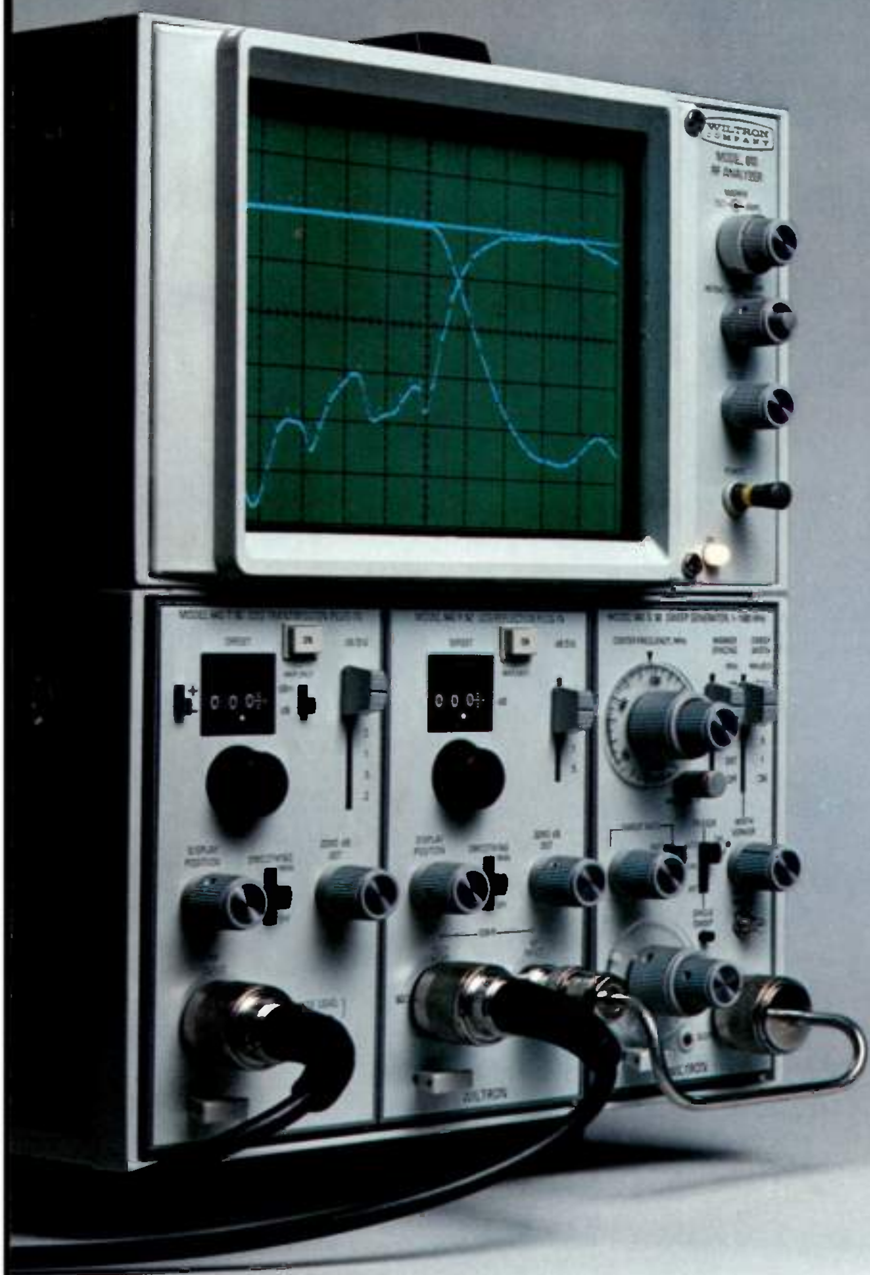

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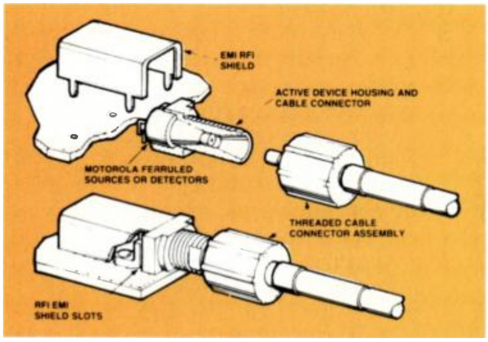
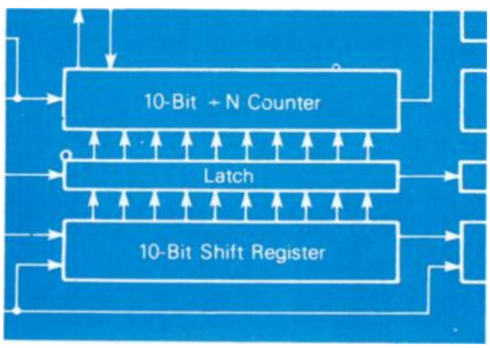
INFO/CARD 2

r.f. design

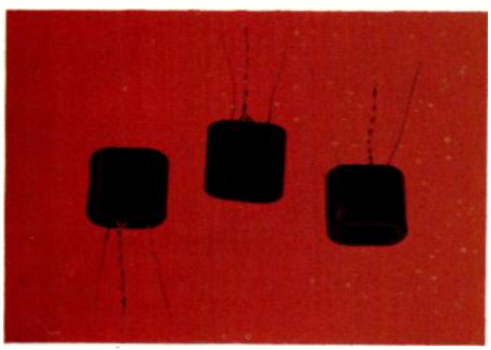
January/February 1981



Fiber Optics



Low-Noise Frequency Synthesizer



Wideband Monofilar Autotransformers

January/February Cover Display of the latest in fiber optic ferruled devices, connectors and cables is illustrated. (Thanks to Bill Preiss, art director and John Fernez, photographer of Motorola's Marketing Communications Department.) **1**

The RF Designer and Fiber Optics Parameters and application notes on fiber optic devices and cables ranging from ILD's, LED's, IDP's through plastic and glass cores. **10**

Low-Noise Frequency Synthesizer Using Fractional N Phase-Locked Loops A detailed discussion of a high-resolution synthesizer presented on a theoretical and operational basis. **20**

Wideband Monofilar Autotransformers Part 1 This article takes the mystery out of autotransformer design. It is a comprehensive, practical discussion replete with useful charts. **38**

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January/February 1981. Volume 4, No. 1. r.f. design (ISSN 0163-321X) is published bi-monthly by Cardiff Publishing Company, a subsidiary of Cardiff Communications, Inc., 3900 S. Wadsworth Blvd., Denver, Colo. 80235. (303) 988-4670. Controlled circulation postage paid at Denver, Colorado. Please address subscription correspondence and Postmaster, please send PS form 3579 to P.O. Box 1077, Skokie, Ill. 60077. Subscriptions: Domestic $10, Canada & Mexico $15 per year; foreign $20 per year. Please make payment in U.S. funds only Single copies available at $3 each.

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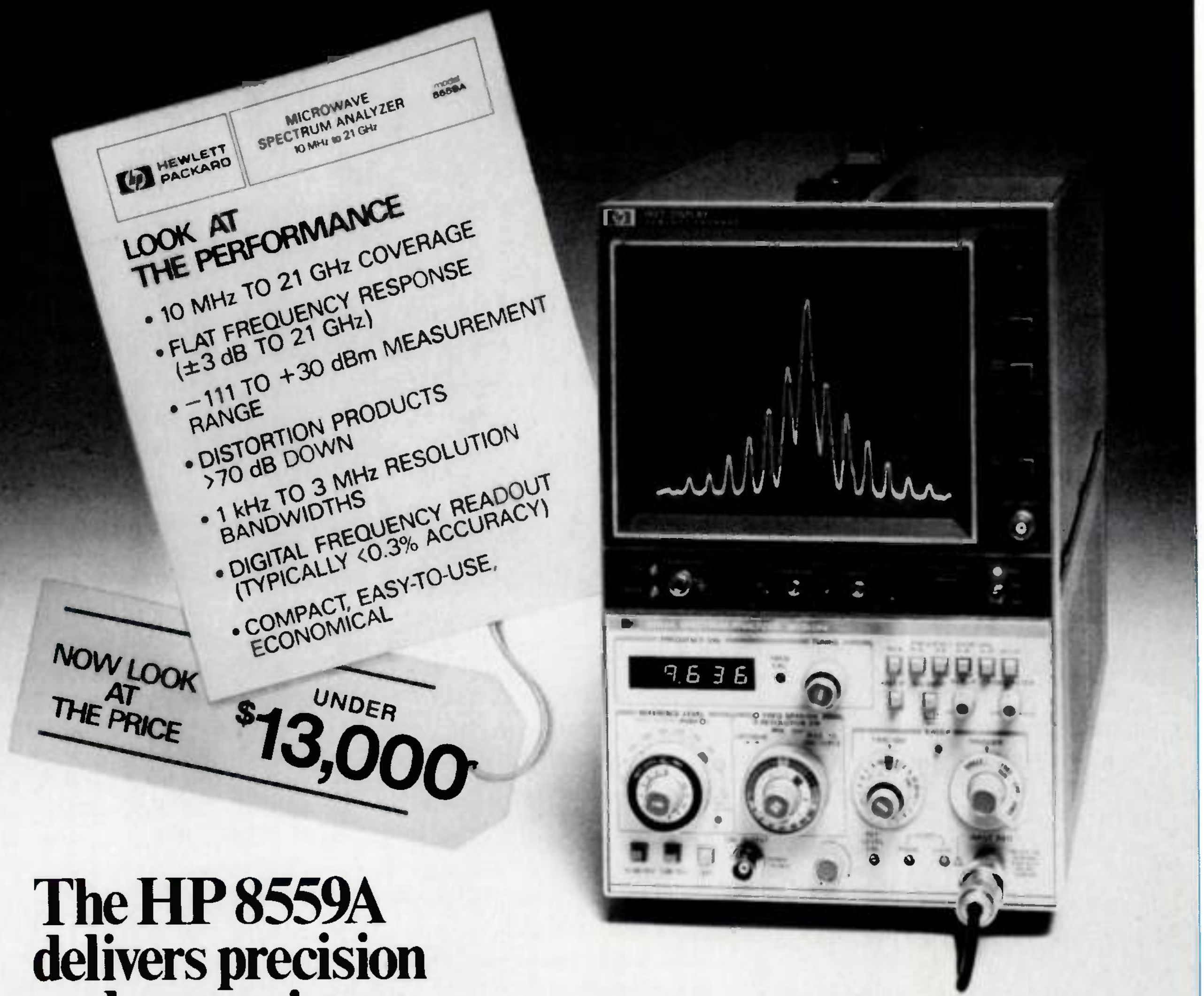

The HP 8559A delivers precision and convenience for a wide range of applications.

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*Domestic U.S. price only.

53102A

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INFO/CARD 3

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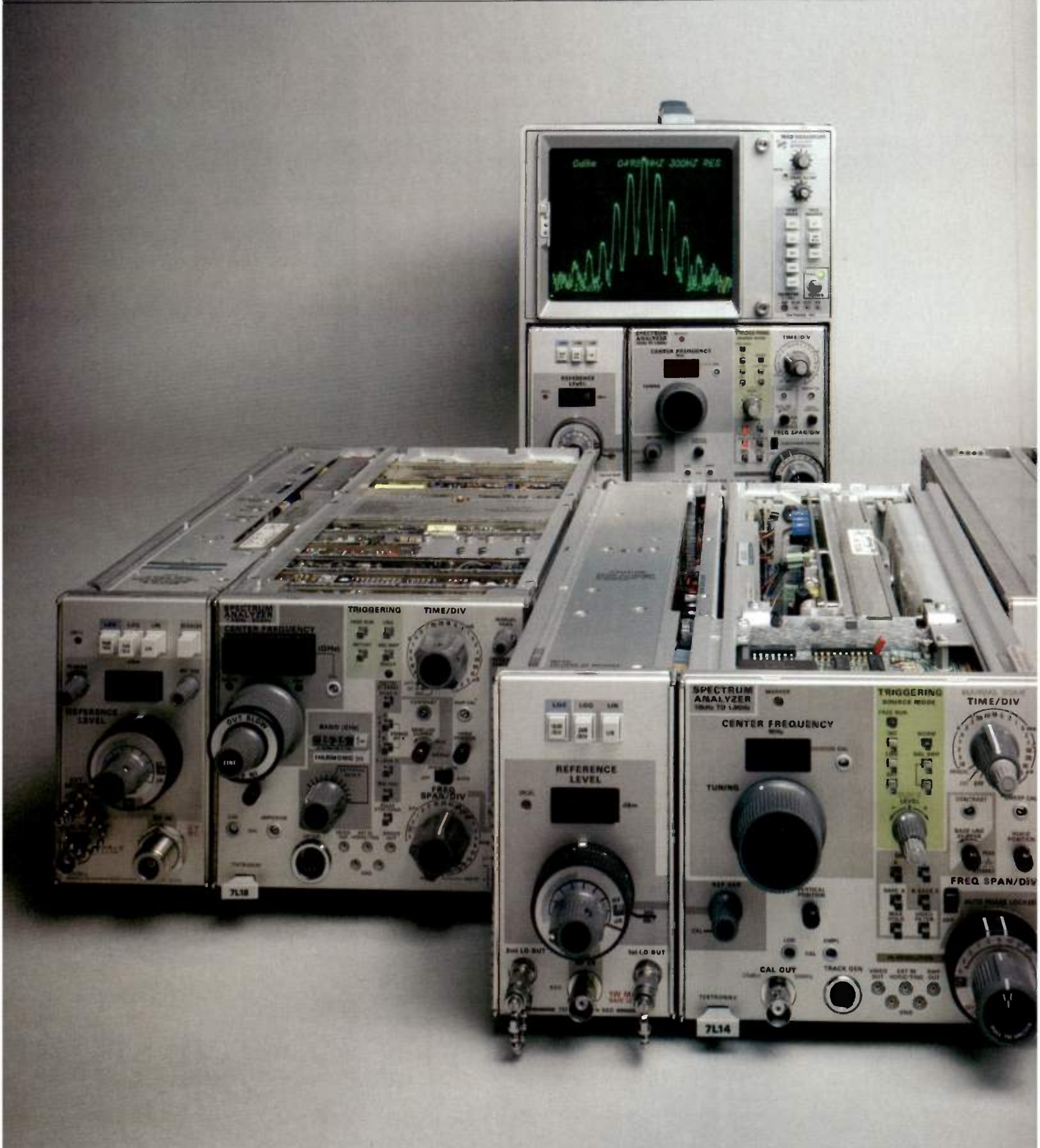

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All three instruments feature digital storage for flicker-free displays that are easy to interpret. This provides averaging and peak detection; accurate waveform comparisons; stores for long periods to measure amplitude changes and frequency drift.

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With a 7000 Series mainframe on your bench, you select the spectrum analyzers that fit your requirements. And they interchange quickly with 30 other Tektronix test and measurement plug-ins. Use the powerful mainframe for logic analyzer, oscilloscope and other measurements.

New 10 KHz to 1.8 GHz 7L14 completes the 20 Hz to 60 GHz digital storage plug-in team.

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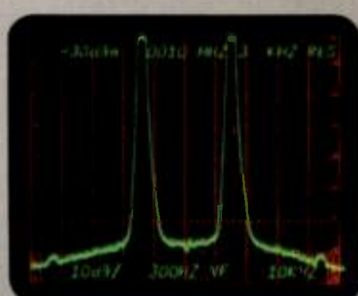

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Thanks for the Help . . . Here's What I'd Like to Do for You

First a status report — *r.f. design* is alive and well. Perhaps it's a bit premature to say it, but I will anyway — *r.f. design* is now on healthy financial ground and growing. You, the readers numbering 25,000 strong, are the main reason the magazine has continued and prospered. Your enthusiastic support and help have been outstanding. The letters, feedback cards, submitted articles and correspondence to the wonderful people who advertise within our pages are much appreciated and noted. Thank you very much.

Jim Herman of Motorola, Ulrich Rohde of Rohde and Schwarz and Alex Burwasser, consultant to Fair-Rite Products, have provided us with three diverse technical articles this issue, crammed-packed with useful and immediately applicable information.

In the spirit of using these pages as a forum I'm going to propose something and I need your opinion. After many conversations and letters between ourselves the following idea was born — RF designers, i.e., the good ones, are very busy (that's all of us, of course) and do not have time to waste during our 8+ hour workdays (this includes UPOT). When we need specific components for a design we search through our memories, our files, friends, magazines, data handling systems and *directories.* Without mentioning any names there are some prestigious volumes available numbering in the thousands of pages, and everyone has a copy of at least one of them on his or her desk. But there's something bothering me.

As an RF engineer I would like to see product information formulated somewhat differently. When I need, for example, disc ceramic capacitors I would like to know: the self-resonant frequency, the temperature coefficient (positive, negative or zero), the form factor, the availability . . .

This last item — availability — is extremely important. How many times have I consulted one of the directories and called tens of OEM's inquiring about their XYZ component only to find that such and such are made in small quantity during the third quarter of a full moon the last Tuesday of the month during total eclipses over Bangor. What I'm asking for, I guess, is: What percentage of company business is the XYZ component that I'm interested in?

I would like to take a crack at putting together an *r.f. design* buyers guide along these lines. It would probably number 300-350 pages, have six or seven lines of rigidly-formulated information, and include entries from over 70 percent of all the RF houses in this country.

Please tell me by means of the special feedback/idea card on page 36 if you want it and then delve very deeply into the specifics you want covered on each type of component and instrument. You are the experts and only you know exactly what you need to know from day to day.

Advertisers — do I have a surprise for you. Ginny Chapman has joined our sales force and all the adjectives apply — intelligent, informed, interested and dynamic — if she hasn't already, she'll be talking to you soon.

To end this meandering missive let me just say thanks again for your support and please drop by *our booth* at Electro 81 in April in New York City. I look forward to meeting all of you there.

Rich Rosen

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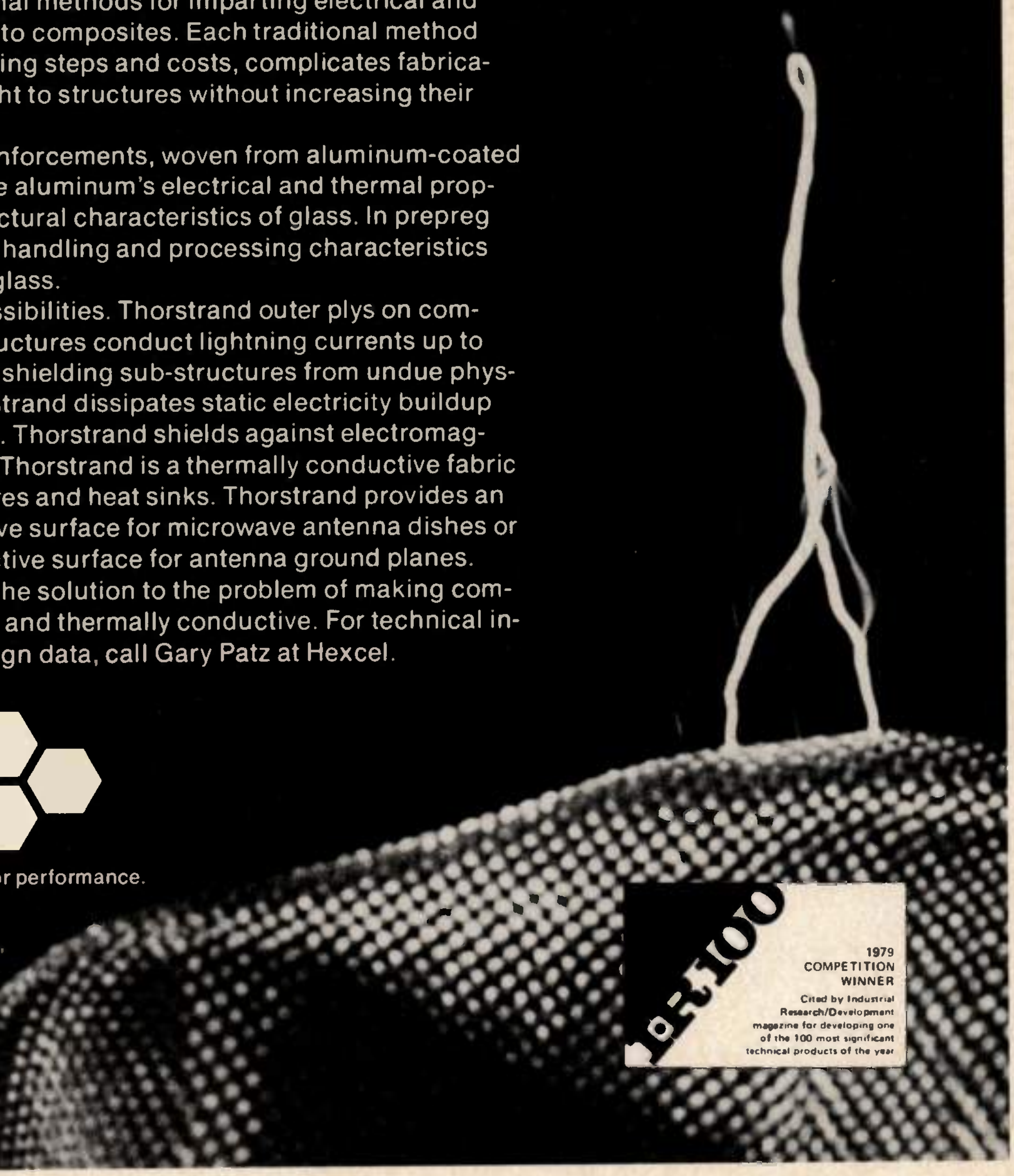


The RF Designer and Fiber Optics

Parameters and application notes on fiber optic devices and cables ranging from ILD's, LED's, IDP's through plastic and glass cores.

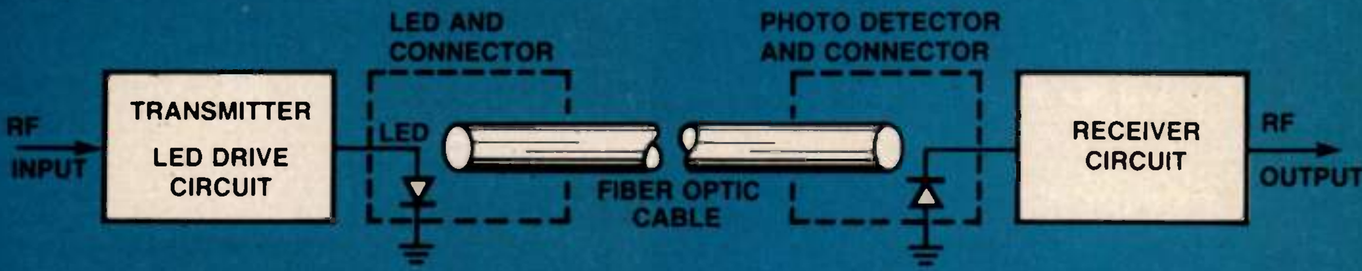


Figure 1. Basic Fiber Optic Transmission System.

James C. Herman
Motorola Semiconductor Group
Mesa, AZ

Double and triple coaxial braid as well as solid sheath cable and cable assemblies have become a way of life to most RF system designers. His problems are a mixed bag of ground loops, isolation, longitudinal transients, high voltage protection, noise, and a myriad of other things that plague his systems' performance, not to mention the FCC requirements to reduce spurious signal radiation levels.

Fiber optics technology offers many advantages and unique solutions to the RF designer's problems. The RF designer should acquaint himself with this new technology and evaluate its cost-performance trade-offs in his specific application.

This article, a general and basic overview, will address some of the advantages of fiber optics to the RF application, survey the fundamental components of a fiber optic system, and identify several applications that use fiber optics to eliminate RF system problems.

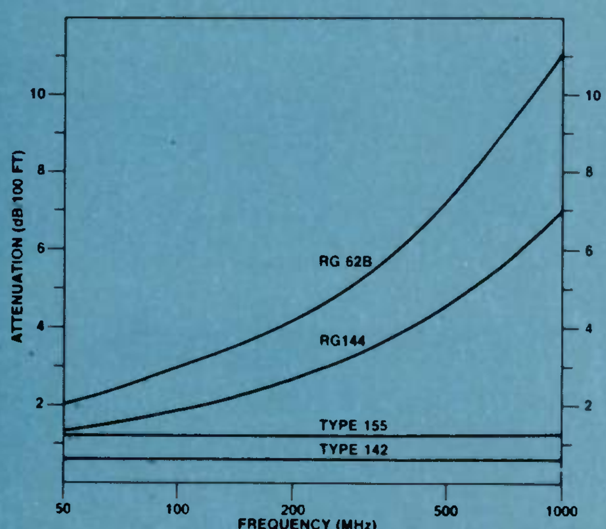


Figure 2. Comparison of Coaxial to Fiber Optic Cable (Attenuation Versus Frequency)

What is Fiber Optics?

Fiber optics is a method of communicating analog or digital signals through a non-inductive/non-conductive, dielectric medium like glass of plastic core cables. (See Figure 1.)

The fiber optic system consists of a light source and light detector, cable to semiconductor connectors, and the fiber optic cable. The transmitter converts the input signal to an analog or digital-modulated light signal which is communicated through the fiber optic cable to a light detector. The light detector converts the optical energy back into a usable electric form.

Except for the conversion to and communication by light energy the fiber optic system is similar to existing RF systems. Even the modulation type and rates as well as the carrier frequencies may remain unchanged.

The advantage of fiber optic systems to the RF designer are:

egress of RF radiation and EMP. Furthermore, several cables may be harnessed together without crosstalk or electromagnetic coupling.

- Because of the RFI immunity the flexible fiber optic cable eliminates the need for rigid coaxial cable assemblies and associated harnessing problems. It also reduces size and weight as well as assembly and installation labor costs.
- Ground loops and high voltage isolation as well as

surge protection problems are virtually eliminated when fiber optic cable is used. Since the cable is a dielectric it cannot short circuit thus does not pose a fire hazard.

- Fiber optic cables exhibit lower attenuation, frequency independency and better temperature stability as compared to coax. (See Figure 2.)

Until recently this new technology has been too expensive and system components were not readily available.

This has changed as indicated in Figure 3. It illustrates the cost history and projected cost of fiber optic cable compared to coaxial cables as a function of time. Similar cost projections can be plotted for semiconductors as well as connectors suggesting similar cost learning curves which make fiber optics more attractive each year.

In addition to the component cost reduction, component standardization has occurred. The EIA, IEC, and IEEE standards committees are promoting interchangeable components as well as establishing standards for device characteristics and measurement techniques.

Component manufacturers are currently introducing comparable components which provide alternative — second source — parts. Interchangeable cable, connectors and semiconductors are currently available.

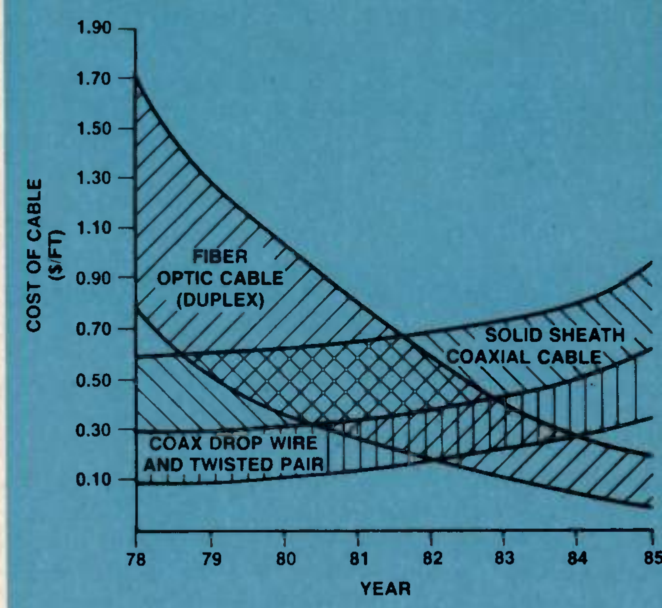


Figure 3. Cable Cost Projection Versus Time for Coaxial and FO Cables.

Basic Component Considerations

Four segments of the fiber optic system that are important to highlight are: semiconductor source, semiconductor detector, cable and connectors.

The **optical source** may be an infrared laser diode *ILD* or a light emitting diode *LED*.

The ILD is usually applied to long distance transmission of CATV and telephone signals. It has a narrow optical beam and may launch greater amounts of power into small diameter fiber optic cores than an LED. Also, the ILD has much higher frequency modulation rates than an LED and a narrower frequency spectrum.

These advantages, however, are offset with several disadvantages making the ILD less attractive to the average short distance RF system. These disadvantages include cost, wavelength, power output drift with temperature, non-linear output, and sensitivity to power supply surges.

The LED is less expensive, is an easy to use optical source and can be designed for use over a wide range of RF frequencies. In addition, the wavelengths of popular LED's (800-900 nm) are compatible with transmittance windows of most fiber optic cables. (Figure 4.)

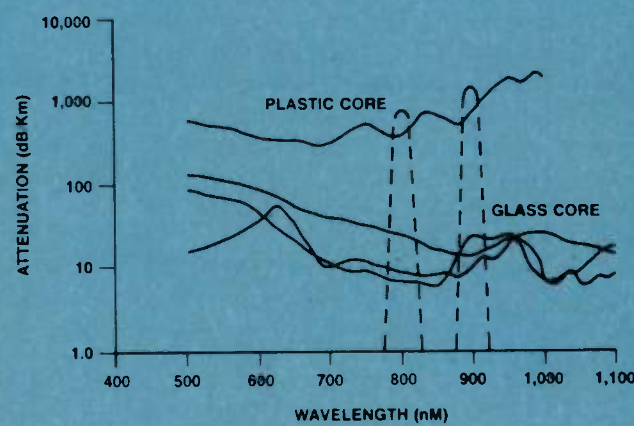


Figure 4. Attenuation Versus Wavelength For Several Fibers.

With proper drive circuitry, for example the MOSFET driver in Figure 5, the LED transmitter bandwidth and linearity should be quite adequate for most RF applications.

Compared to ILD's, typical LED harmonic distortion levels are low. It should be noted that the second and third order products are dependent upon drive current and temperature.

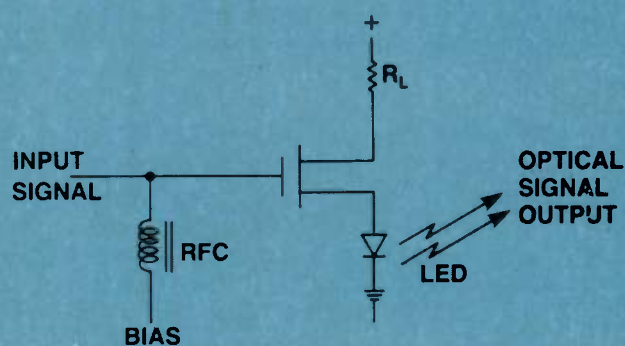


Figure 5. MOSFET LED Drive Circuit.

Detectors may be selected from a variety of expensive avalanche photo diodes (APD) to inexpensive pin diodes and integrated detector preamplifiers *IDP's*.

APD's are usually selected for their avalanche gain characteristics. These characteristics are desired in CATV and other high quality systems like telephone trunk systems. The high operating voltage and sensitivity to temperature change make them less attractive for practical short to intermediate system lengths where input optical power levels are high.

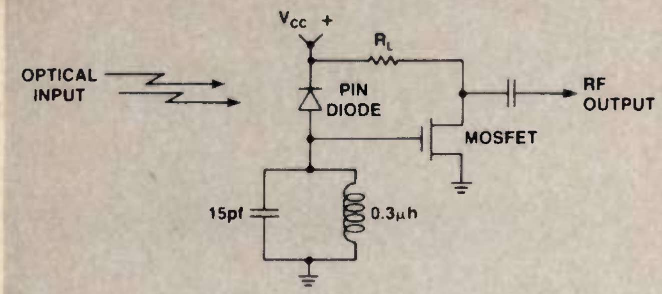


Figure 6. 70 MHz Optical Detector.

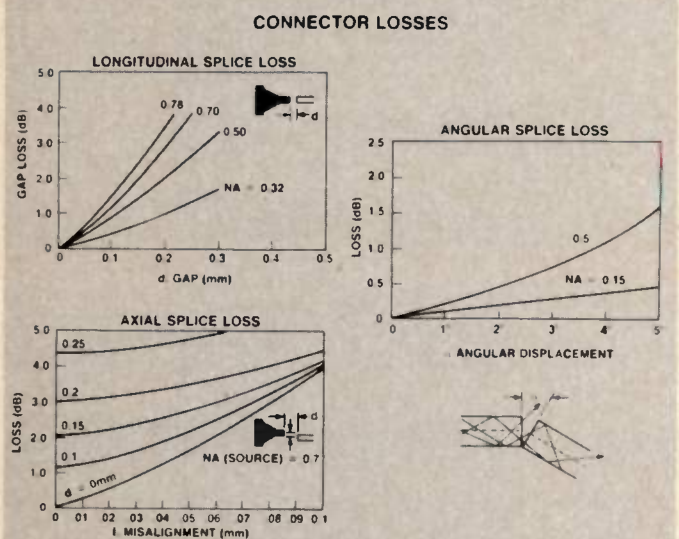


Figure 7. Connector Losses.

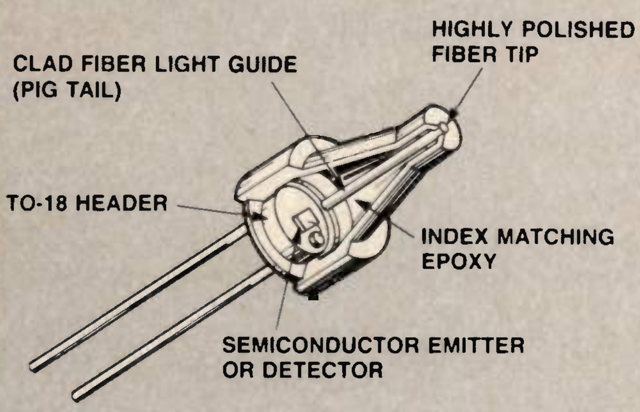


Figure 8a. Ferruled Semiconductor.

Considering costs and technical tradeoffs we find that the pin diodes and IDP's are better suited to the average non-telecommunication RF application, particularly in systems where the available optical energy exceeds the accumulated system losses and reserve power levels. (System loss budget.) Also, the performance of pin diodes and IDP's match the LED's peak spectral response and their switching speed is maximum.

High impedance pin diodes are easy to utilize in RF optical receivers. Figure 6 depicts a basic 70 MHz, I.F. optical receiver circuit using an FET front-end.

The pin diode's receiver performance is limited by high impedance output leads that are readily susceptible to RFI and capacitive loading by the printed circuit board (PCB). Motorola elected to integrate the photodiode and associated transimpedance amplifier and assemble it into an easily shielded package. The high signal level output leads are low impedance and much more immune to RFI than the pin diode leads. Furthermore, the IDP's photodiode parasitic capacity is effectively reduced which helps to extend the upper frequency limit — now approaching 50 MHz.

Fiber optic cables are readily available in plastic fiber core as well as glass core materials. Cable construction includes a wide variety of configuration, protective strength member and jacketing. Fiber optic cables are usually manufactured by existing coaxial cable vendors. This rather mature product utilizes similar coaxial construction techniques. The real difference is that the copper center conductor is now a glass or plastic core filament.

Plastic core fibers are limited in their operational temperature range. However, their durability makes them attractive to designers who require cables that tolerate pinching, flexing, and twisting. Although these attenuation characteristics seem high, 1 dB/meter at 800-900 nm, this large diameter core, high numerical aperture fiber may be used in many practical RF applications.

Glass core fibers are classified as step index, quasi-step index, and graded-index fibers. These cables are being used in automotive, consumer, industrial control, computer, and telecommunication applications.

Glass core diameters are becoming standardized. Popular core sizes are 200 μm, 100 μm, and 50 μm diameters.

1) 200 μm core is more readily connectored and seems more applicable to industrial control, automotive and consumer environments.

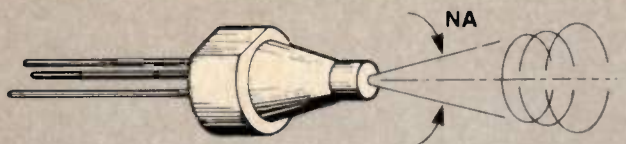
2) The 100 μm core fibers have wider bandwidths and lower attenuation. These cables are finding many applications in computer and industrial control systems.

3) 50 μm core fibers have the lowest attenuation and the widest bandwidth. These are best suited for long-haul telecommunication-type systems.

Glass core fiber optic cables are readily available in single and multi-cable structures.

Their low attenuation, compared to plastic fiber core cables, in the 800-900 nm range as well as numerical aperture (N.A.) and bandwidths should satisfy most RF applications.

N.A. is defined as the sin θ of the acceptance angle of light rays that will propagate through the fiber optic core. Light rays exceeding this acceptance angle will not propagate through the fiber and will be lost through the core cladding. Thus, it is important for the system designer to consider the N.A. of his source and detector devices as well as the N.A. of cables he may be splicing together.



NO OPTICAL EXPERTISE REQUIRED

OPTICAL PORT IS PRETERMINATED FIBER OPTIC CABLE

MAINTAINS SEMICONDUCTOR IDENTITY

DEVICE IS FIELD REPLACEABLE

Figure 8b. Ferruled Semiconductor.

In addition to N.A. loss another important loss characteristic that must be considered is the diameter — ratio loss. When two cables of different core diameter are spliced together the light ray flux from a larger diameter fiber will be attenuated as the ratio of core areas when coupling to a smaller diameter fiber.

Connector manufacturers offer a wide variety of connectors. Both cable splice and chassis (bulkhead) connectors, are currently available in many sizes, shapes, performance and price ranges. Plastic and metal materials are currently available. Cable-to-cable splicing requires an adequate connector design to minimize interface (connector) loss. The connector loss (Figure 7 is composed of an angular, longitudinal and axial misalignment of the fiber optic core to be spliced. Remember there is also the diameter-ratio loss and Numerical Aperature loss to be considered during system-loss budget calculations. The connectors become an extremely important part of the system, at the cable to semiconductor interface. Efficient optical coupling from the semiconductor fiber optic core is achieved with a short pig-tail of fiber core assembled into part of a connector ferrule. (See Figure 8a and 8b.)

This finished semiconductor source or detector assembly fits into and becomes an integral part of the active connector (bushing) assembly. Figure 9, shows an exploded view of the active connector assembly which

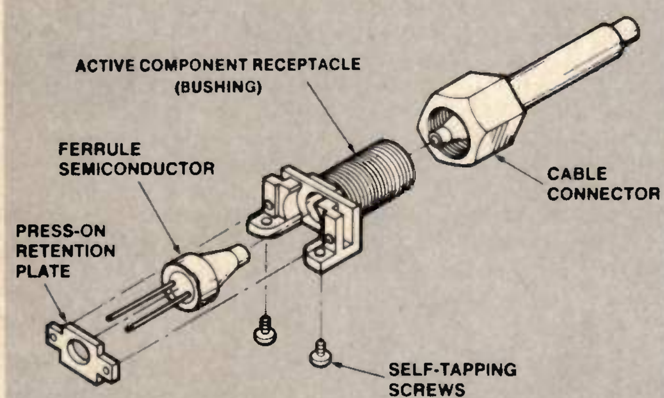


Figure 9. Fiber Optic Active Connector.

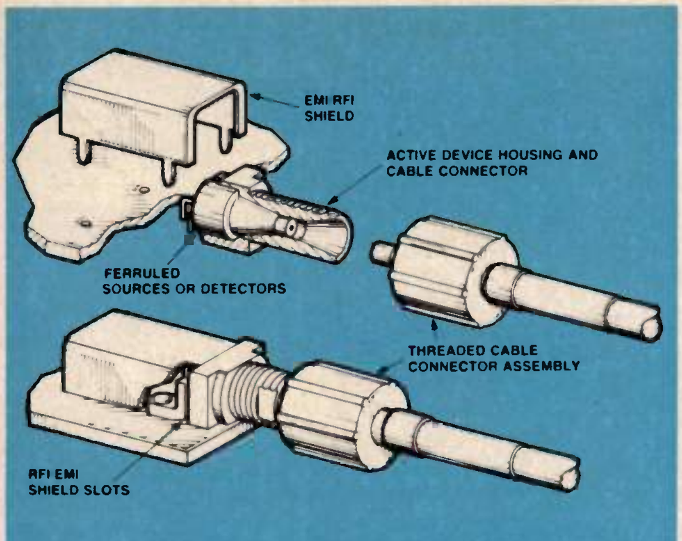


Figure 10. Active Connector with RFI Shield.

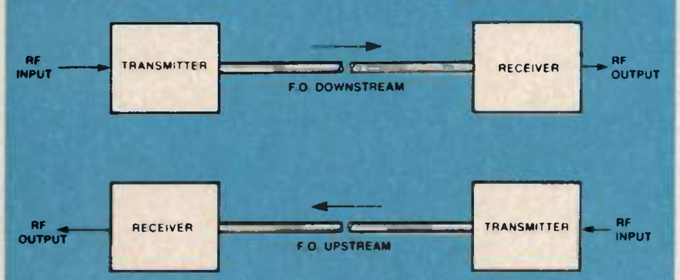


Figure 11. Two-Way Duplex System.

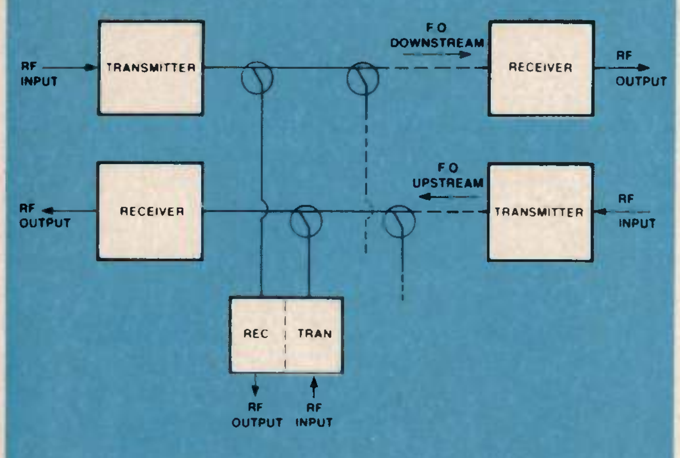


Figure 12. Two-Way Duplex Distribution System (Passive Couplers)

now permits efficient coupling of the semiconductor to any fiber diameter or type (plastic or glass core). These active connector bushings are available from AMP, Inc. and Amphenol (SMA styles).

These connectors also provide heat sinking of the LED source and allow RFI shielding of the pin diode and IDP detectors.

A cutaway view of an active connector assembly is shown in Figure 10. The semiconductor detector becomes RFI shielded once assembled into the connector bushing. Furthermore, the connector has slots to accept a complete RFI protective cover which may shield the entire receiver.

The RF designer should also note the RF cavity (cross-sectional view of connector) that forms part of his receiver RFI protection. Spurious signals on axis with the cable are rejected by this filter cavity which appears as a high-pass filter with cut-off frequency beyond the requirements for most RF applications.

The System

The system designer with off-the-shelf inexpensive components may now assemble a fiber optic system to perform his RF function. Simple design rules define the total system *loss budget calculation* to assure a system gain margin that is adequate for variations with time and temperature as well as the cable and connector losses, and other component performance trade-offs.

As a first step we start by converting the transmitted and received power levels into dBm. The difference between transmitted and received levels we define as total system loss budget.

$$\text{Power in dBm} = 10 \log_{10} \frac{\text{power in } \mu w}{1000}$$

We may now total all of the losses in our transmission path. These include N.A. loss, diameter ratio loss, connector losses, cable attenuation, directional coupler losses, etc. These losses we subtract from our total system loss budget to obtain our system gain tolerance.

Numerical aperture loss (N.A.).

$$\text{NA loss} = 20 \log_{10} \frac{NA_1}{NA_2}$$

where NA_1 = NA of source cable
NA_2 = NA of receive cable

$$\text{Diameter ratio loss} = 20 \log_{10} \frac{dia_1}{dia_2}$$

Where dia_1 = core diameter of source fiber
dia_2 = core diameter of receive fiber

To this tolerance we should include approximately 3 dB for LED power output degradation with time. Also, we should consider additional connector losses (change with time and repeated mating); 1 dB per connector is a good rule of thumb.

Systems have been designed using LED's, pin diodes and IDP's which have sufficient system gain tolerances to permit transmission of RF for more than one kilometer.

Testing

Testing the fiber optic system is similar to testing coaxial systems. Most of the test equipment for proper fiber optic system design, test, and maintenance are currently available. Optical time domain reflectometers, optical power meters, and optical multimeters, have reduced the new technology to a more practical level — similar in most respects to coaxial systems we now work with.

Where Do We Use It?

Several approaches to system design are possible. We may use two simplex systems connected in such a way to provide two-way communication (Figure 11). Or, we may distribute the signals using optical passive couplers (Figure 12).

The optical splitters and directional couplers are, however, very expensive and require some care in utilization. These high technology devices are not yet practical for the short to intermediate non-telecommunication system.

A simple optical splitter may be readily assembled using two smaller diameter fiber optic core cables mated to one larger fiber optic core cable. (See Figure 13.)

Another approach to inexpensive distribution of signals utilizes an active splitter concept. (See Figure 14.)

Active Splitter Distributed Network

The duplicate of this system may be turned around and used upstream to form a two-way fiber optic system.

This active (repeater) splitter approach, similar to CATV systems, has the advantage of eliminating need for large dynamic range receivers, reduces receiver sensitivity

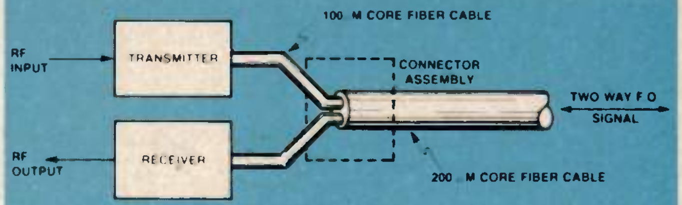


Figure 13. Simple Optical Power Splitter.

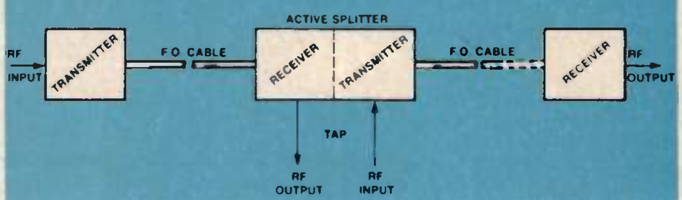


Figure 14. Active Splitter Distributed Network.

requirements, and normalizes signal gain levels. Other system configurations are possible.

Unlike coaxial systems the fiber optic system lends itself to wavelength multiplexing as well as other modulation schemes. All of the popular modulation techniques such as AM, FM, PCM, etc., may be transmitted over the fibers.

Applications

Several satellite earth station systems are installed with trunk lines communicating RF signals via fiber optic cables. These systems utilize wideband analog and RF modulation techniques to transport television and telephone signals. These systems are similar to existing CATV trunk applications and have proven the technology of fiber optic communications.

The fiber optic system is also attractive to CATV trunks because of the reduced repeater requirement (12 to 1 reduction) and the immunity to longitudinal sheath currents and lightning outages. CATV systems are currently using fiber optics in several wideband multi-channel systems as well as in studio networks.

The natural immunity of the fiber cable to RF egress and ingress makes it attractive for status monitoring applications. RF test equipment may be totally isolated from the systems under test in the screen room, anechoic chamber, antenna pattern test and aircraft EMI/RFI test facilities. These are only a few of the RF applications now utilizing fiber optic links.

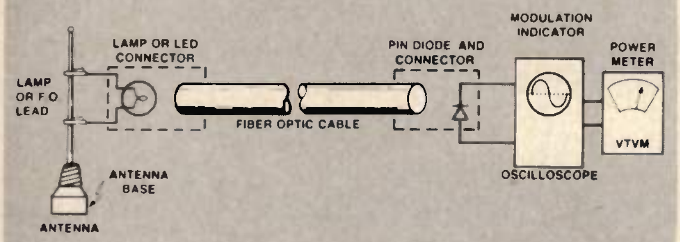


Figure 15. Antenna Monitoring Using Fiber Optics.

Novel Applications

Remember those simple amateur radio power output meters? The ones with simple tank and DC meter or the lamp attached to the antenna used to peak transmitter power?

Consider connecting a fiber optic cable to that lamp and continuously monitoring antenna peak power performance from our remote base station via the nonconductive lightning-free fiber optic cable. In Figure 15, an LED tank circuit has been constructed that rectifies the RF carrier power and intensity modulates the LED. This optical energy is supplied via a fiber optic cable to a remote base station where LED intensity and modulation rates are continuously monitored — continuous antenna performance achieved.

Application of fiber optics to a multi-channel phase-locked transmitter may provide several advantages. (See Figure 16.)

This is accomplished by utilizing one LED optically — coupled to several fiber optic cable cores all located within one connector. The other side of the cables are connected to different transmitters. Since each cable

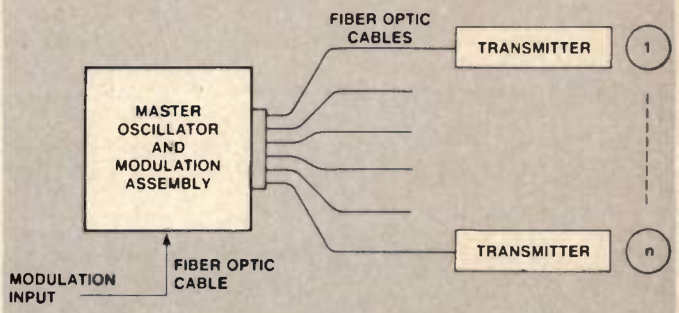


Figure 16. Multi-Channel Transmitter.

carries the same optical energy the transmitters may be phase-locked together. This is achieved with no RF interference to other in-cabinet circuits. One particular application represents a cost reduction by eliminating expensive solid sheath preformed cable assemblies. Maintenance time on the equipment was also reduced.

Internal to the receiver chassis fiber optics has also challenged coaxial cable. Consider the application of a fiber optic link between an RF oscillator assembly and the receiver front-end. The fiber optic link offers greater RF isolation between the oscillator and the RF input. It also provides a simple solution to oscillator radiation within the receiver enclosure.

Conclusion

We have briefly opened the window of the new fiber optics technology to you, the RF designer.

We have suggested the availability of necessary components to do an adequate RF design and at a reasonable cost. It is recommended that where cost is a major issue, evaluate the complete system, installation, assembly, labor and repair costs for comparison — fiber optics may be justified.

The advantages of fiber optics communications alone makes it an attractive technology. Applications will become more numerous as the RF designer innovates and applies fiber optics to his system.

The basic and general overview we have provided should be complemented by further reading. A list of readily available references are included. □

References

1. E.H. Hara, K.O. Hill, B.S. Kawasaki, and D.C. Johnson "The Use of Optical Power Combiners for Multiplexing Multiple Television Sources in Single-Fiber Optical Systems," *IEEE Transactions on Cable Television*, Vol. CATV-4 No. 2, April 1979.
2. Horst Gempe "Applications of Ferruled Components to Fiber Optic Systems," *Motorola Applications Note AN804*, April 1980.
3. F.D. Kink, J. Straus, O.I. Szentesi "High-Radiance Long-Lived L.E.D.'s for Analogue Signaling," *Proceedings IEE* Vol. 123, No. 6, June 1976.
4. "Designers Guide to Fiber Optics" *EDN* Magazine Cahners Publishing Company, Boston, Mass., 1978.

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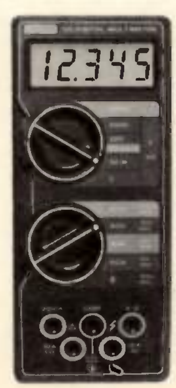

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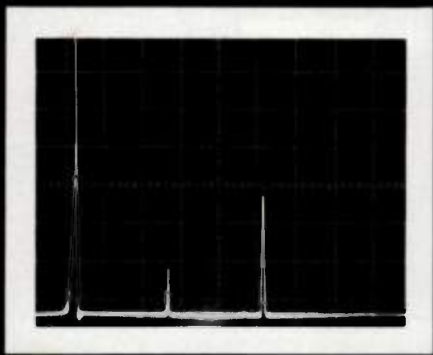

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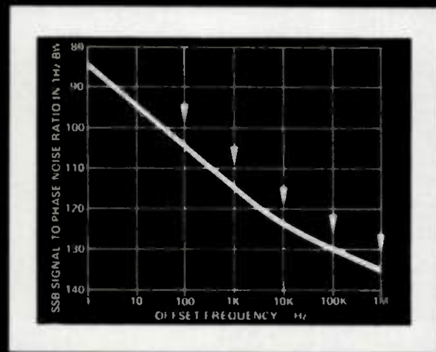

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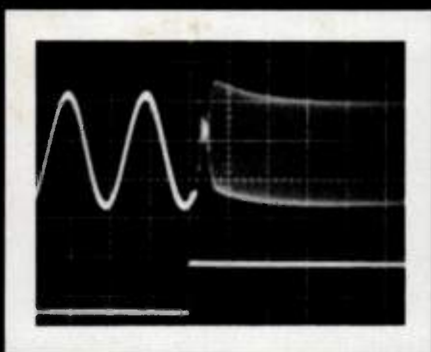

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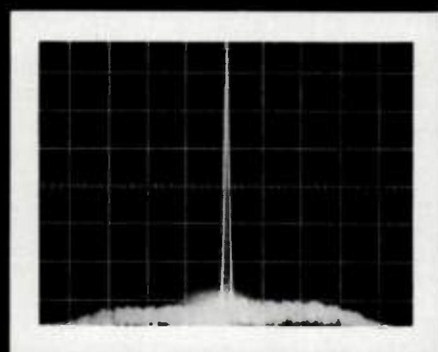

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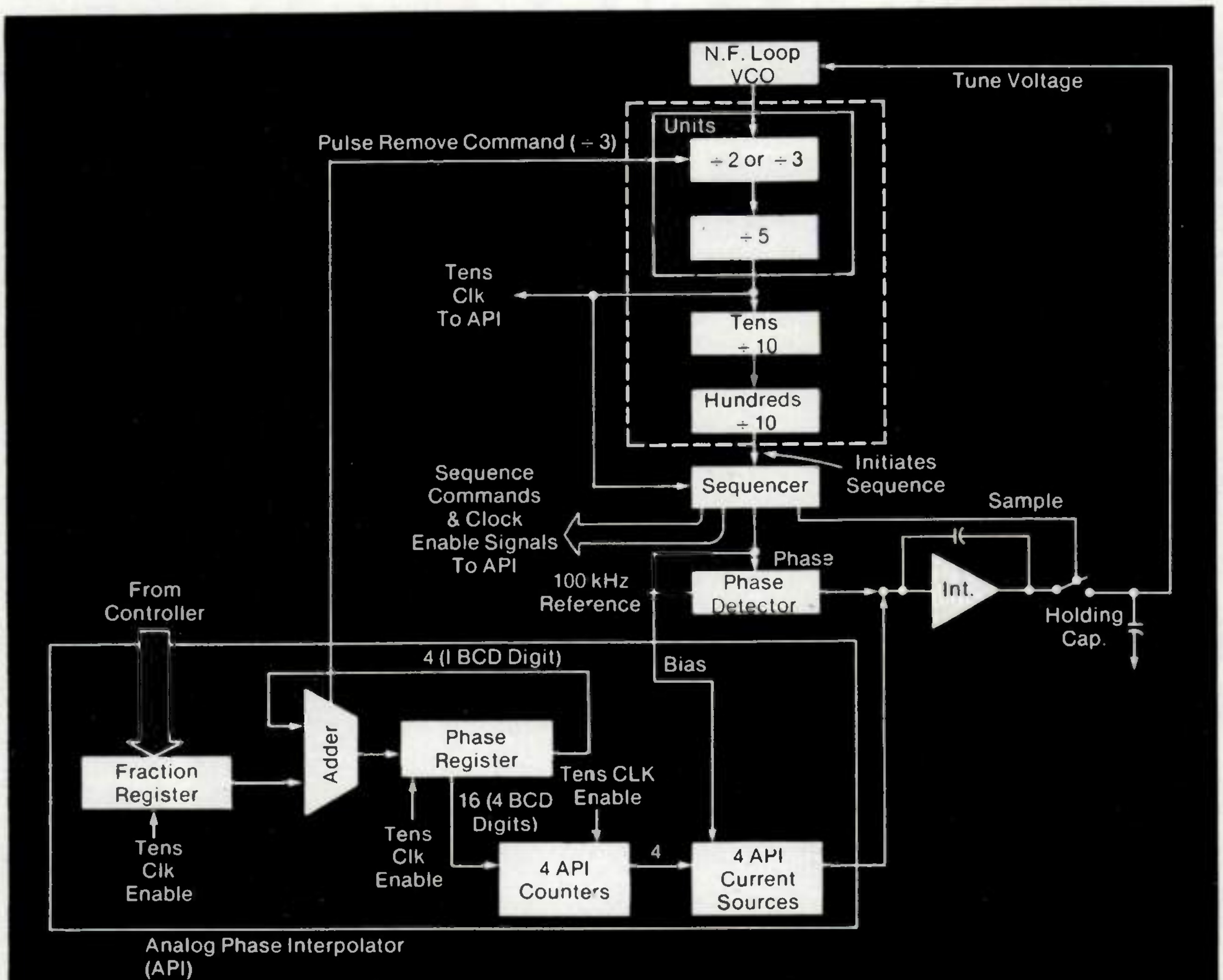

Figure 1. N.F. Loop, Basic Block Diagram.

Low-Noise Frequency Synthesizers Using Fractional N Phase-Locked Loops

A detailed discussion of a high-resolution synthesizer presented on a theoretical and operational basis.

Ulrich Rohde, Ph.D.
Rohde & Schwarz
Fairfield, NJ

In frequency synthesizers, the resolution or step size is equal to the reference frequencies applied to the phase detector over one period. The lock-up time under ideal conditions then is between 8 and 30 times the sample period.

As the resolution increases, the reference frequency decreases and the lock-up time further increases. To eliminate this problem, multi-loop synthesizers have been developed. However, with these synthesizers the incidences of spurious responses increases and due to the large number of loops and the shielding required their cost increases.

In most applications, like signal generators and communication receivers or systems, the sideband performance of the synthesizer determines the overall performance.

Fractional N Loop

A new method is described which is currently used in a number of

Hewlett-Packard instruments and in at least one shortwave receiver (RA6790) — the fractional N loop.* Its advantages and drawbacks will be discussed. It may appear, at first glance, that the fractional N loop has unlimited advantages. However in reality it is a compromise between resolution, spurious responses and lock-up time. Information on the technique also called "the digiphase system" may be found in a number of papers.[1,2,3]

In reality the expression fractional N is not quite correct. Figure 1 shows the basic block diagram of a fractional division loop. The loop in reality does not supply a fractional division ratio but rather changes the division ratio periodically over a certain period by the help of an adder driven by the fraction register.

Synthesizer Block Diagram

Figure 1 shows the block diagram of such a synthesizer as used in the Hewlett-Packard model 3335 synthesizer (reproduced with Hewlett-Packard's permission).

We find a number of familiar components in the block diagram. At the top, we recognize the voltage-controlled oscillator (VCO), which is divided by 2 or 3 and then by 5 for the unit counter and then by 10 and another 10.

A sequencer is required for the sequence commands and clock enable signals to the analog phase interpolator where an adder is used on an alternating basis to obtain high resolution. The output from the sequencer is introduced into the phase detector which is also driven by the 100 kHz reference.

The output of the phase detector is integrated and cleaned up by a sample and hold discriminator from the sequencer. The frequency setting can be supplied to the synthesizer either in parallel or serial form depending upon the chip used. The fraction register in Figure 1 makes the necessary transfer into the adder and the following phase register.

We will learn that this principle of deleting certain pulses through the pulse remover generates sidebands, which is the basic drawback of this principle. The analog phase interpolator (API) counters and current sources comprises a D to A

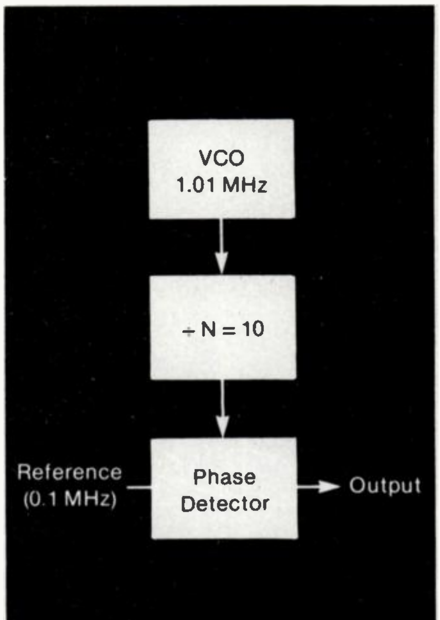

Figure 2. Basic Diagram, Open Loop N Step Loop.

converter that produces a voltage 180° out of phase relative to the voltage that generates the sidebands. It, therefore, removes the unwanted sidebands and cleans up the system.

Sideband suppression, in this case, is limited to 50-60 dB below the carrier.

The pulse removing circuit (divide by 3) can also be used as a variable modulus divider depending upon the reset command and, therefore, forms a high-frequency pre-scaler which can be made synchronous with the other dividers. As a result of this, one can build a very fast pre-scaler. (A technique that does not reduce the resolution of the synthesizer).[4,5,6] In some applications, these dividers can have values of 2/3, 5/6, 10/11, 20/21, 40/41 to as high as 100/101. The advantage is to reduce the requirements for the following dividers to a fairly low speed so that CMOS dividers can be used.

Fractional N PLL Concept

Consider an N step loop under an open loop condition. Assume a reference frequency of 100 kHz, N = 404 and a VCO frequency of 40.455 MHz (N = 40; F = 0.455). The VCO operates at a fractional multiple (404.55) of the reference signal (404.55 x 0.1 MHz = 40.455 MHz). This case is shown in Figure 2.

The phase detector compares the low-to-high transition of the reference and divide-by-N signals. Since the VCO does not operate at N times the reference but operates at a fractional component (F = 0.055 MHz), the signal from the divide-by-N block advances on the reference signal. Each time the divide-by-N signal makes a low-to-high transition, the phase detector compares it to that of the reference. The phase detector generates an output proportional to the *period* between the two low-to-high transitions. In the phase-locked condition of an N-step loop, this period remains constant. In this open loop example with the VCO containing a fractional component, the period between low-to-high transitions is continuously increasing. Therefore, the phase detector output voltage consequently is also increasing.

When analyzing the open loop, it is of interest to view the operation in terms of reference periods. A reference period is defined as the time required for the reference signal to complete one cycle. In each reference period the reference signal goes through one cycle while the VCO, operating 404.55 times as fast, goes through 404.55 cycles. The VCO has advanced 1/55 of a cycle of phase on the integer part N times f_{ref} in one reference period. In two reference periods, the VCO has gone through 809.1 cycles or advanced two-tenths of a cycle of phase.

When the VCO operates with a fractional offset (F), it continually advances in phase of N x f_{ref} each reference period. From the example of Figure 2 in 55 reference periods, the VCO will have gone through 40455 cycles or advanced one cycle of phase ($2\pi = 360°$) with respect to N times f_{ref}.

In an N-step loop the VCO is phase-locked to a reference signal. With the introduction of the divide-by-N block, the VCO operates at a multiple N of the reference frequency.

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*Part of this material will appear in the new book, "Digital Frequency Synthesizers" to be published by Prentice-Hall in 1981.

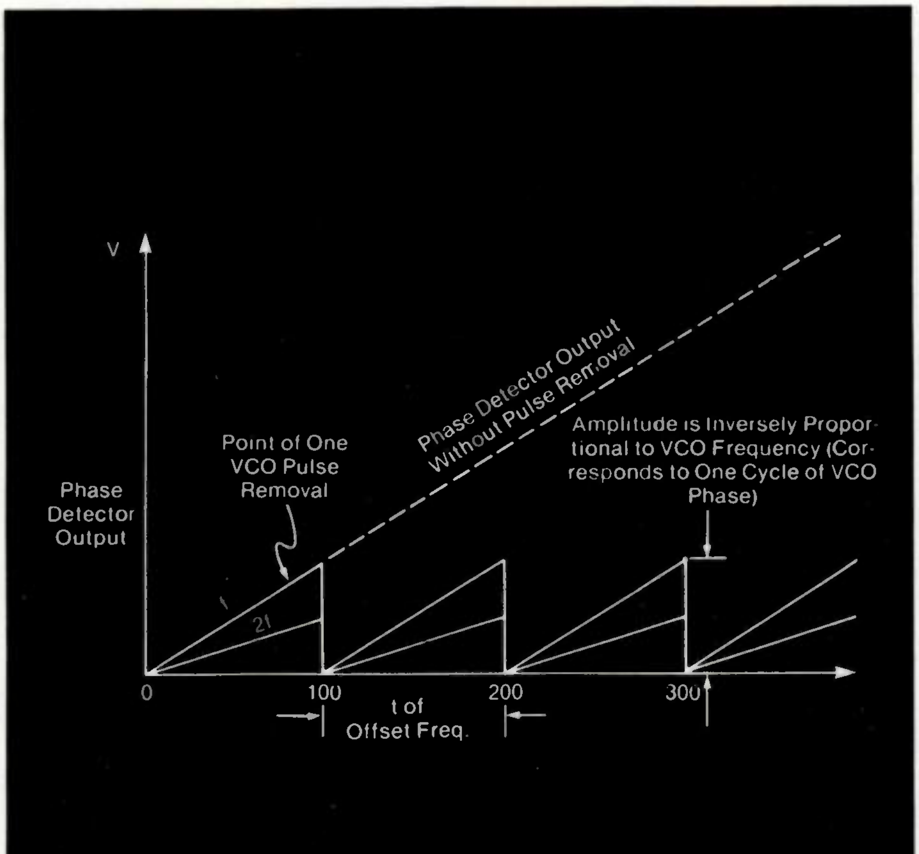

Figure 3. Phase Detector Sawtooth Output.

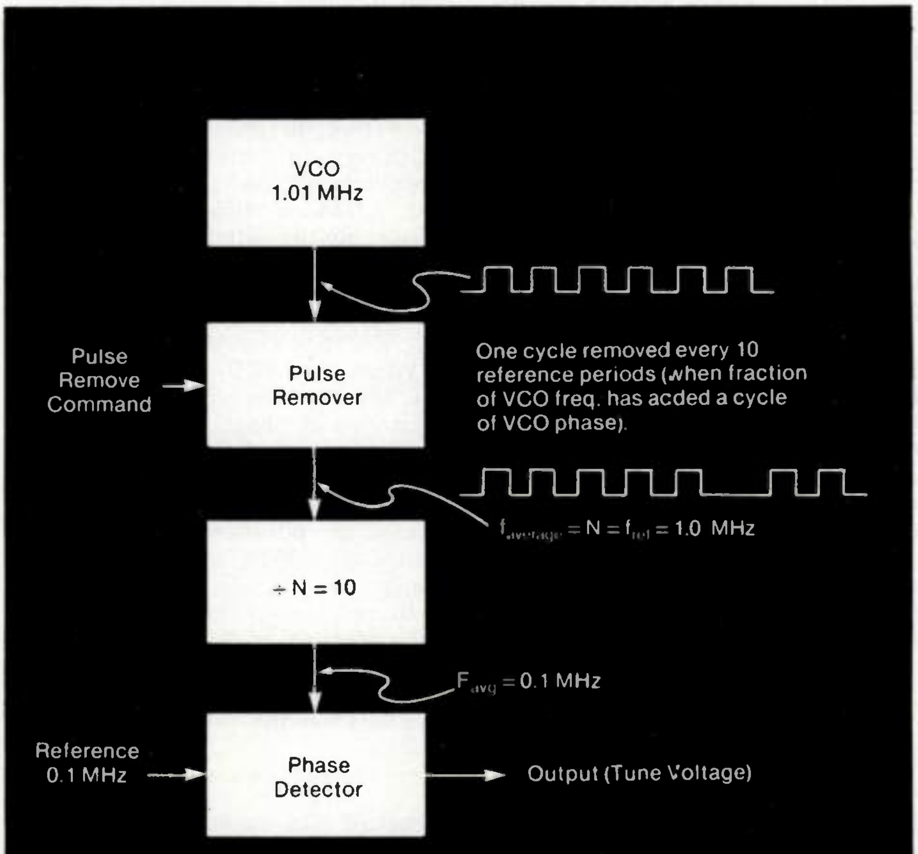

Figure 4. N Step Loop with Pulse Remover Block.

In the fractional loop (N.F loop) the VCO operates at an integer-plus-fractional multiple of the reference frequency: $F_O = f_{ref}(N + 1/N)$.

As previously illustrated in Figure 2, assume, the VCO operates at 40.455 MHz, a reference of 0.1 MHz, and N equals 404. Each time the reference signal goes through one cycle, the VCO goes through 404.55 cycles. After 55 reference cycles, the VCO has gone through 40455 cycles and the VCO has advanced one full cycle of phase. If 55 VCO cycles are removed from the VCO pulse train applied to the divide-by-N block at the time a full VCO cycle has advanced, the phase advancement on the average is cancelled and the average frequency applied to the divide-by-N block is N x f_{ref} or in this example: 40.4 MHz.

As a result of the continual removal of the 55 VCO cycles (removal of one cycle of phase); the VCO advances one cycle of N x f_{ref} and the phase detector output becomes a sawtooth waveform as seen in Figure 3. The waveform increases linearly due to the advancing phase of the VCO until the VCO has advanced one cycle of VCO phase (360°). At this point, 55 cycles are removed from the VCO pulse train cancelling the previous advancement of a cycle of phase. The phase detector responds to this sudden one cycle phase loss by returning to its initial output. The sequence is repetitive, generating a sawtooth waveform. The maximum amplitude reached represents one cycle of VCO phase. As the VCO frequency is increased, the time interval for the VCO to go through one cycle of phase is less. Therefore, the maximum phase detector amplitude is decreased. (The phase detector maximum amplitude is inversely proportional to the VCO frequency.)

The necessity to remove 55 VCO cycles from the VCO output each time the output advances one cycle of phase of N x f_{ref} requires that we use a pulse remover block as shown in Figure 1. In Figure 3 the case is shown for a VCO operating at 1.01 MHz and a reference frequency of 0.1 MHz. The pulse remover, therefore, is switched on every ten reference periods. In the case of the 40.455 MHz operation one cycle has to be removed every 55 reference periods. A method of determining when the VCO has advanced one cycle of phase is required. Such information can then be used to trigger the pulse remover block and the VCO cycle removed at the appropriate time.

Accumulator

The fractional part of the VCO frequency determines the time required for the VCO to advance one cycle of phase of N x f_{ref}. The time required is the period of the fractional offset frequency and corresponds to a certain number of reference periods. If the fractional part of the VCO is stored in a fraction register as shown in Figure 1 and that quantity added to a second register each reference period, the second register will contain a running total of the fraction. This is the fraction of a VCO cycle of phase advancement at any point in time. For this reason, the second register is called the phase register, and the entire configuration is called an *accumulator.* The accumulator, therefore, consists of the fraction register, the adder, and the phase register. The phase register will reach unity the same reference period the VCO has advanced one full cycle of phase. When unity is reached, the phase register overflows and transmits an overflow signal. The overflow signal corresponds to the point in time the VCO has advanced one cycle of phase of N x f_{ref}. The overflow signal can now be applied to the pulse remover block as a pulse remover signal.

In the 40.455 MHz VCO example the VCO operates with an offset frequency not evenly divisible into 1. A fractional overflow can result when the phase register reaches unity. In our example the VCO operating at 40.455 MHz after one reference period has advanced 404.55 cycles, 809.1 after two, and 1213.65 after three reference cycles. Prior to the second reference period, the phase register has accumulated 0.55 cycles and a second reference period 0.55 is added and the sum is 1.1. This causes an overflow as the pulse remove signal and the fractional overflow of 0.1 is loaded into the phase register and the next sequence phase begins to accumulate from 0.1 instead of 0.

Pulse Remover Command Section

Up to this point, the pulse remover command section hasn't been considered. Figure 4 is a block diagram which includes the pulse remover command section. This structure provides a means of automatically removing VCO cycles whenever the VCO advances one full cycle of phase of the frequency N x f_{ref}.

The open loop phase detector output of Figure 4 is a sawtooth waveform superimposed on a DC voltage. Only the DC voltage of this output is of interest. A VCO requires a DC-tuned voltage in order to maintain a stable output signal. A sawtooth AC signal superimposed on the DC VCO signal would cause frequency modulation of the VCO signal. The AC sawtooth waveform of the phase detector output must be cancelled or removed leaving the DC component to tune the VCO to the proper frequency. We know that the VCO output advances a fraction of a cycle of phase of N x f_{ref} each reference period. The fraction of a cycle of phase that the VCO is advanced at any one reference period is represented by the fractional sum in the phase register. For the example of Figure 4, the contents of the phase register when viewed with respect to time is a staircase resetting to zero once unity is reached as shown in Figure 5. The staircase approximates a sawtooth waveform. The leading edge of each step represents the phase detector output for that reference period. The phase detector does not generate a ramp but samples the VCO with respect

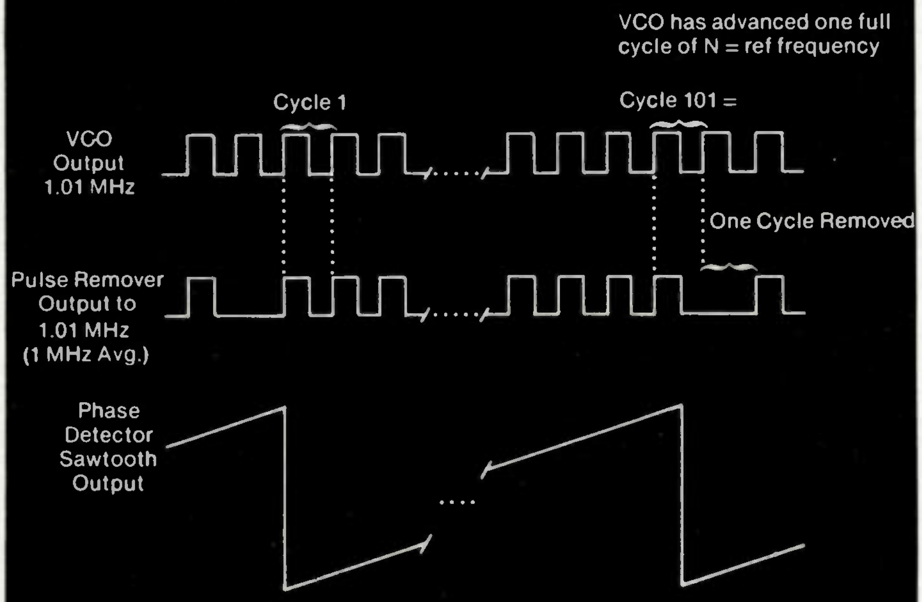

Figure 5. Phase Detector Sawtooth Output with Respect to Pulse Remover Output.

to the reference each reference period generating the staircase output.

If the contents of the summing register are applied to a digital-to-analog converter (DAC), the DAC output will follow the steps of the summing register and approximate a sawtooth output. Applying the DAC output through an inverter and summing it with the phase detector output essentially cancels the AC component (sawtooth) of the phase detector output. This leaves the DC component. (Required as a VCO control signal.)

Two requirements of the waveform generated by the DAC, such that it will approximate the phase detector sawtooth output, are:

a. It must have a variable amplitude.
b. It must have a variable period.

The amplitude is inversely proportional to the frequency of the VCO and changes whenever the VCO frequency is changed. To demonstrate the amplitude dependence on VCO frequency, look at Figure 6. If a reference of 0.1 MHz is used, and a VCO frequency of 1.01 and 2.01 MHz are used, different voltages are obtained. Note that each VCO frequency example contains a 0.01 MHz offset or fractional frequency. In terms of reference periods (10 μs), the duration of the 0.01 MHz offset is

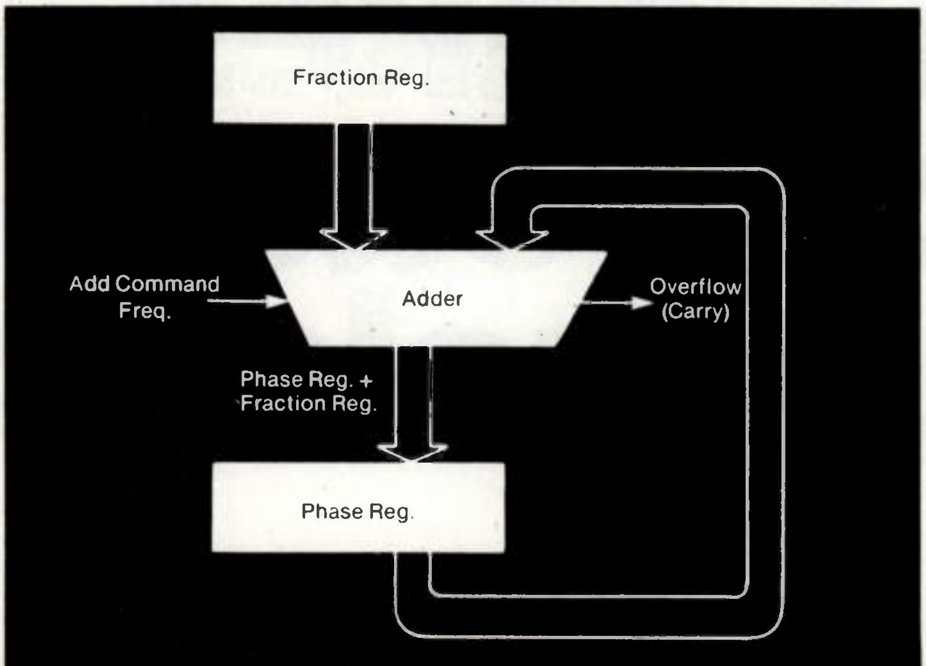

Figure 6. Accumulator.

ten reference periods. At this point, the offset frequency has completed one cycle and added a cycle of phase to the VCO signal. Since the period of 2 MHz is half the interval of 1 MHz, the phase detector output representing one cycle of phase at 2 MHz is half the amplitude of the output representing one cycle of 1 MHz phase. When the VCO cycle is removed, a 360° phase loss is

(Continued on page 28.)

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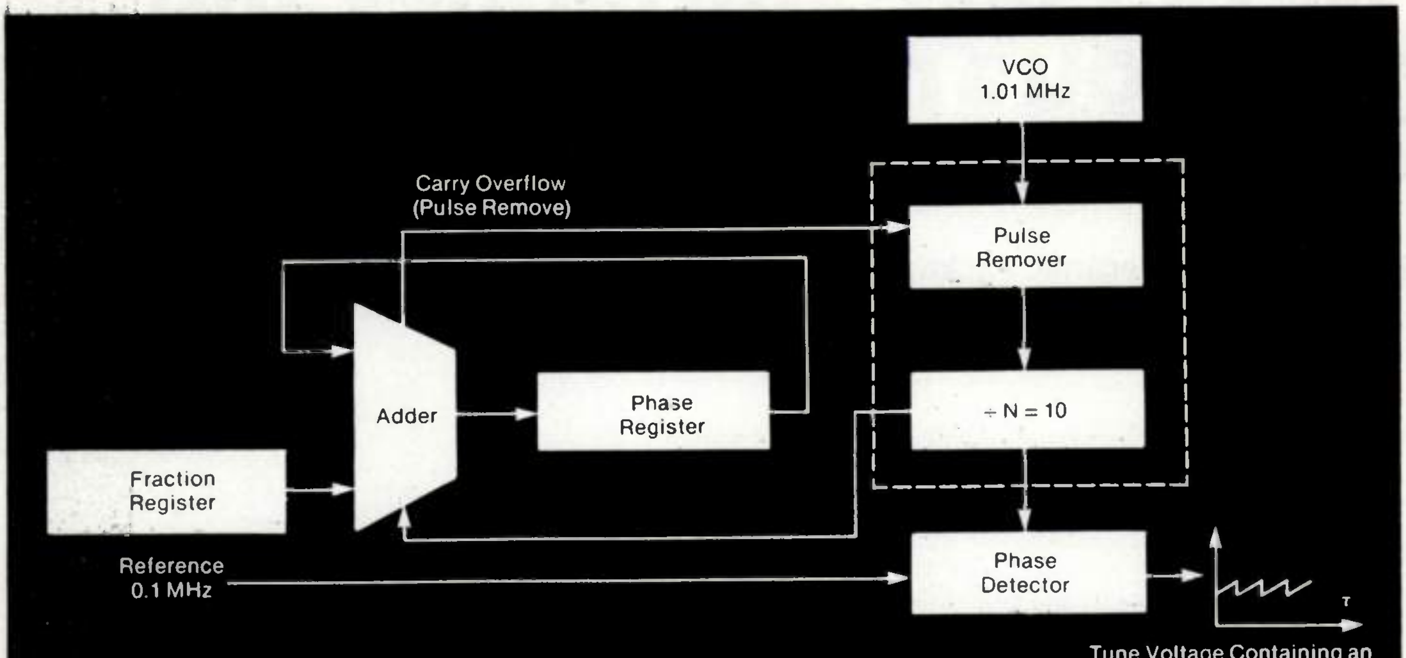

Figure 7. N.F. Loop with Pulse Removed Command Section.

(Continued from page 25.)

detected by the phase detector and it responds by returning to its initial output causing the high-to-low transition of the sawtooth. If the offset or fractional part of the VCO frequency is changed, the duration of the sawtooth change for these two periods is the same. The sawtooth generated by the DAC must change amplitude and period as the phase detector output changes and must be superimposed on zero volts DC. It can then be inverted and summed with the phase detector output to remove the sawtooth from the tune voltage applied to the VCO. (Figures 7, 8, 9.)

NF Loop Block Diagram

A general block diagram of an NF loop is shown in Figure 10. The basic elements of an N step loop are present; the VCO, divide-by-N counter, phase detector and low-pass filter. In addition to these, a fraction register, adder and phase register provide the "bookkeeping system" to keep a record of the phase advancement from reference period to reference period. This system is known as a phase interpolator and in conjunction with a digital-to-analog converter (DAC), the system is referred to as an analog phase interpolator (API). Each reference period it generates an analog voltage equal and opposite in polarity to the phase advancement voltage generated by the phase detector. The voltage applied to the LPF is then a DC voltage constituting the VCO tune voltage. Since the "bookkeeping system" must update each reference period (the phase detector output changes each reference period after the VCO/N and reference signal comparison), the system receives its add command (update command) at a VCO/N rate.

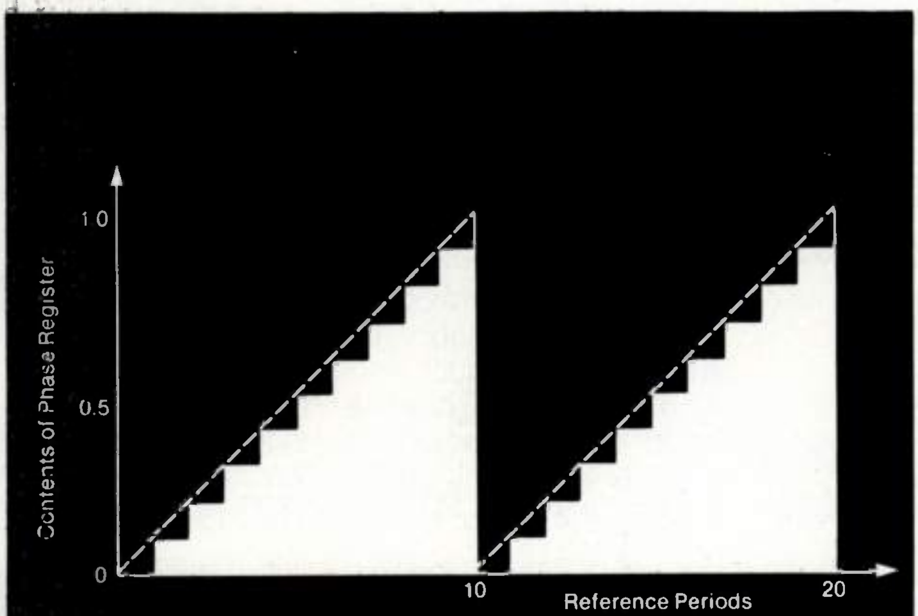

Figure 8. Phase Register Contents.

Operation

The previous discussion was based on a synthesizer which is controlled by a microprocessor which performs a number of arithmetic and control functions. The controller receives the data information from a keyboard or a bus like the RS232 serial or IEEE parallel bus and drives the input decoder. This data includes loop frequency data and instructions which set up the operating modes of the data register in the phase interpolator. Data register operation is controlled by a steering section. The data register is responsible for the bookkeeping scheme of the phase interpolator. There are three data registers.

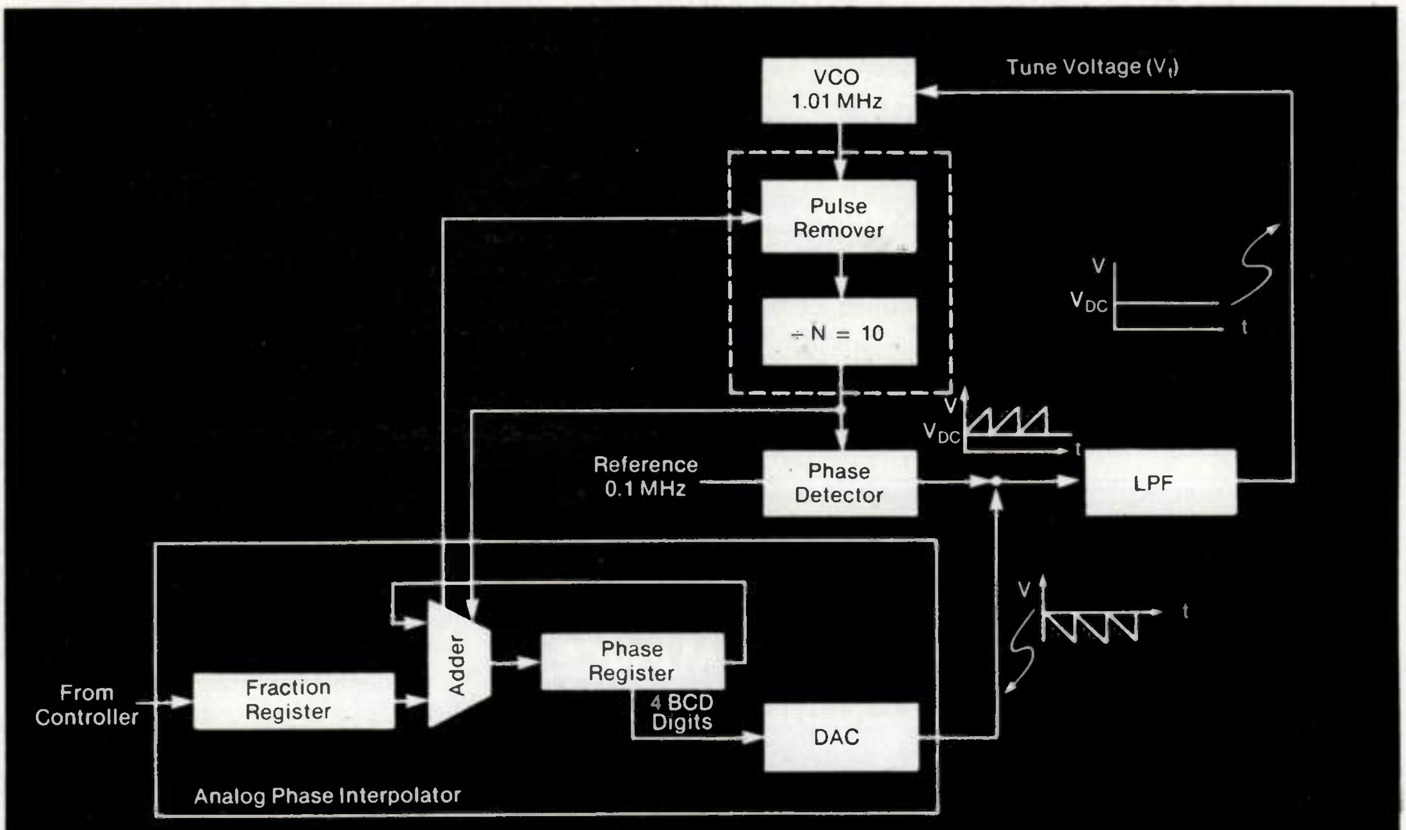

Figure 10. General Block Diagram, N.F. Loop.

a. f_1 frequency register
b. f_2 frequency register
c. Phase register.

Frequency Register

Only one of the frequency registers is active at a time. The frequency register will always contain the current frequency of operation and this data will be circulated (output connected to input and the data shifted until the starting state is reached) once each reference period. The other frequency register will contain the previous frequency of operation and be sitting idle but enabled to accept

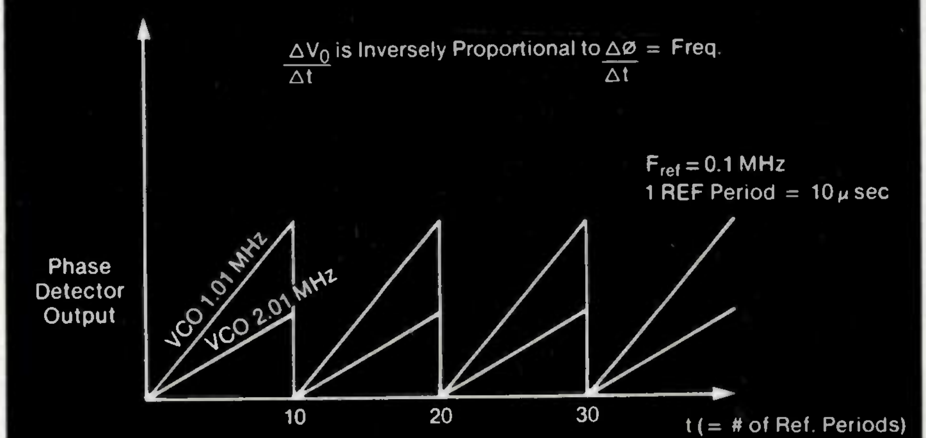

Figure 9. Phase Detector Output for Two VCO Frequencies with the Same Offset.

new data when a new output is programmed.

The data steering logic controls the operating modes of the f_1 and f_2 frequency registers. The LOAD DATA command enables the idle frequency register to be clocked by the controller line (LDC (LOAD DATA CLOCK) to enter a new frequency. During this time the operation of the loop is not interrupted because the circulating frequency register continues operation while data is being loaded. Once the data is entered, the SET FREQ command interchanges the functions of the f_1 and f_2 registers and the new data now circulates to operate the loop at the new frequency.

Frequency data in the f_1 or f_2 register consists of 16 BCD digits which are loaded least significant digit first. The twelve least significant digits represent the fractional portion of the frequency while the next three digits contain the integer or N portion of the frequency. This accounts for fifteen of the sixteen digits in the f_1 or f_2 register. The sixteenth digit, which is the last digit loaded, is not required and therefore is always loaded as a zero. During circulation of the data in the f_1 or f_2 register, this digit is truncated and therefore does not affect the operation of the loop.

Each reference period the divide-by-N counter initiates a sequence of events by triggering the sequencer. Part of the sequence is the enabling of the f_1 or f_2 register clock, the phase register clock and the N register clock. The phase register is clocked for the first twelve digits circulated by the f_1 or f_2 register, the N register for the next three. When the sixteenth digit is circulated by the f_1 or f_2 register, neither phase register nor N register is clocked. Therefore, this digit has no affect on the loop operation. As a result of the sequence of clocking the registers and N register, the phase register quantity has been increased by the fractional component of the f_1 or f_2 register. The N register contains the three N number digits used to preset the divide-by-N counter.

Phase Register

The phase register serves two purposes:

a. Records the total phase advancement of the VCO with respect to each reference period.

b. Causes the adder to overflow in the reference period the VCO has advanced a full cycle of phase.

The record of total phase advancement is used each reference period to drive the API section. The four most significant digits of the twelve digits in the phase register are used to preset four API counters. When these counters are clocked by the API clock, they generate an output pulse inversely proportional to the preset number. These four counter outputs drive the API section which develops a signal that counteracts the changing phase detector signal resulting in an unchanging tune voltage. The overflow of the adder indicates the reference period the N.F. loop VCO has advanced a full cycle of VCO phase. The overflow decode triggers the units counter during the pulse remove enable interval of the loop sequence to divide by three for one output pulse of the first stage. Since this stage has been providing an output for every two pulses input (divide-by-two) it effectively has removed a VCO cycle by dividing by three for one output pulse. The cycle of phase the N.F. loop VCO has advanced has been removed and the phase relationship of the N.F. loop VCO and N times the reference is reset.

The API section consists of two parts:

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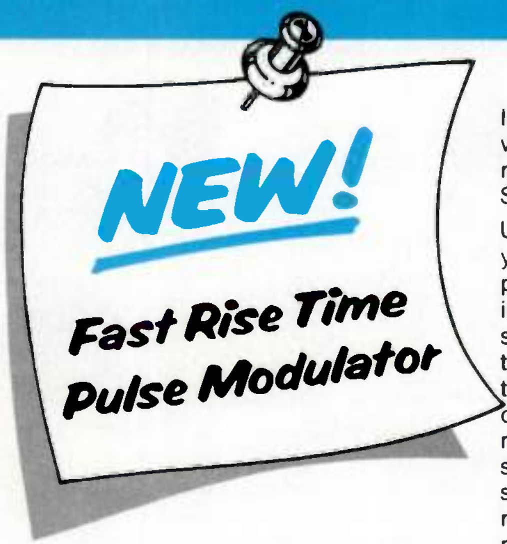

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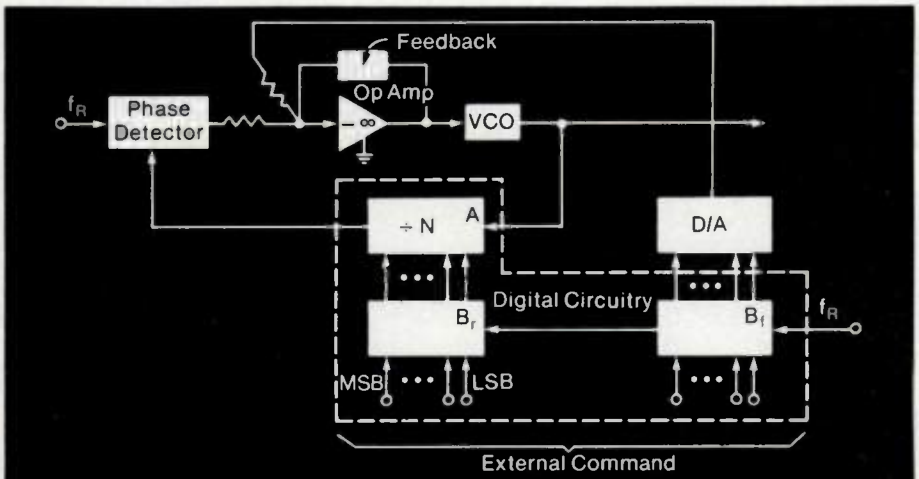

Figure 11. Simplified Block Diagram of the Digiphase System.

a. The API counters
b. The API current sources.

All API current sources are turned on by the BIAS command each reference period. The four most significant digits of the phase register preset the API counters which control when each of the four API current sources turn off. The smaller the phase register digits, the longer the API current sources are on.

The phase detector compares the sequencer output "BIAS" with a 100 kHz reference signal. The BIAS signal is first reclocked to TENS CLOCK VCO/10) and then to the N.F. loop VCO signal itself. If the N.F loop VCO is operating with a fractional component, the reclocked BIAS signal applied to the phase detector gains phase each reference period with respect to the reference signal. The output applied to the integrator is an increasing voltage. The purpose of the API section is to negate the effects of the increase in the phase detector output.

The method used to generate the N.F loop VCO tune voltage is similar to that used in an N step loop. Currents are integrated and the integrated voltage is transferred to a holding capacitor.

The digiphase system or fractional N phase-locked-loop allows extreme high resolution depending upon the resolution of the fraction register and the phase register. Figure 11 again shows a simplified version of this system. As mentioned previously, the resolution is determined by the f_1 or f_2 register which has 16 digits. Three of these digits are being used for the N division which leaves 13 available digits. Of the 13 digits, the last one is always set to zero. The 12 digits are used for the fractional division and would allow an ultimate resolution of 100 kHz (reference) divided by 10^{12} or a resolution of 0.1 μHz. The synthesizer, so to speak, consists of two loops, one being a 100 kHz loop with a lock-up time probably 8 to 20 cycles or 800 μs to 2 ms. The fractional

The fractional portion of the loop (Accumulator, Pulse Remover and D/A) resolution most likely will lock up within one cycle where one cycle is 1/reference or 10μs.

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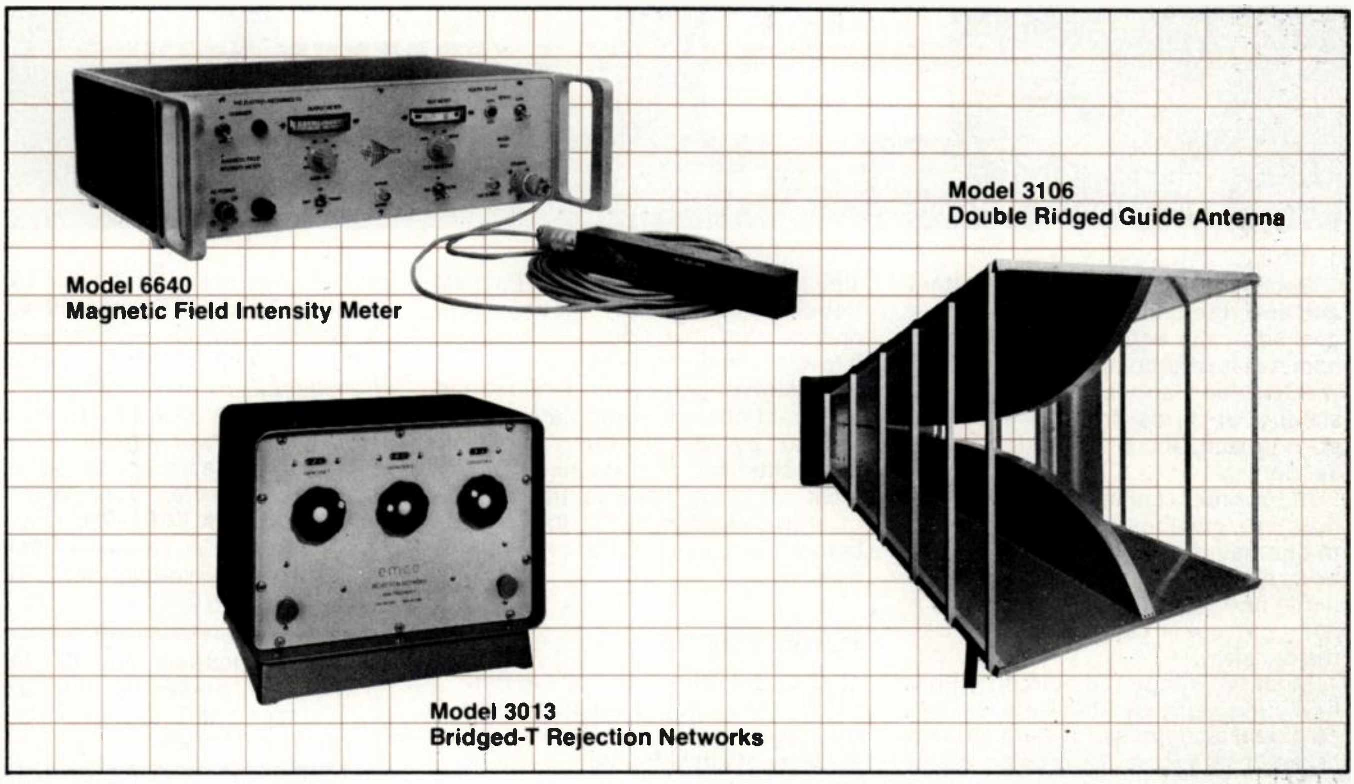

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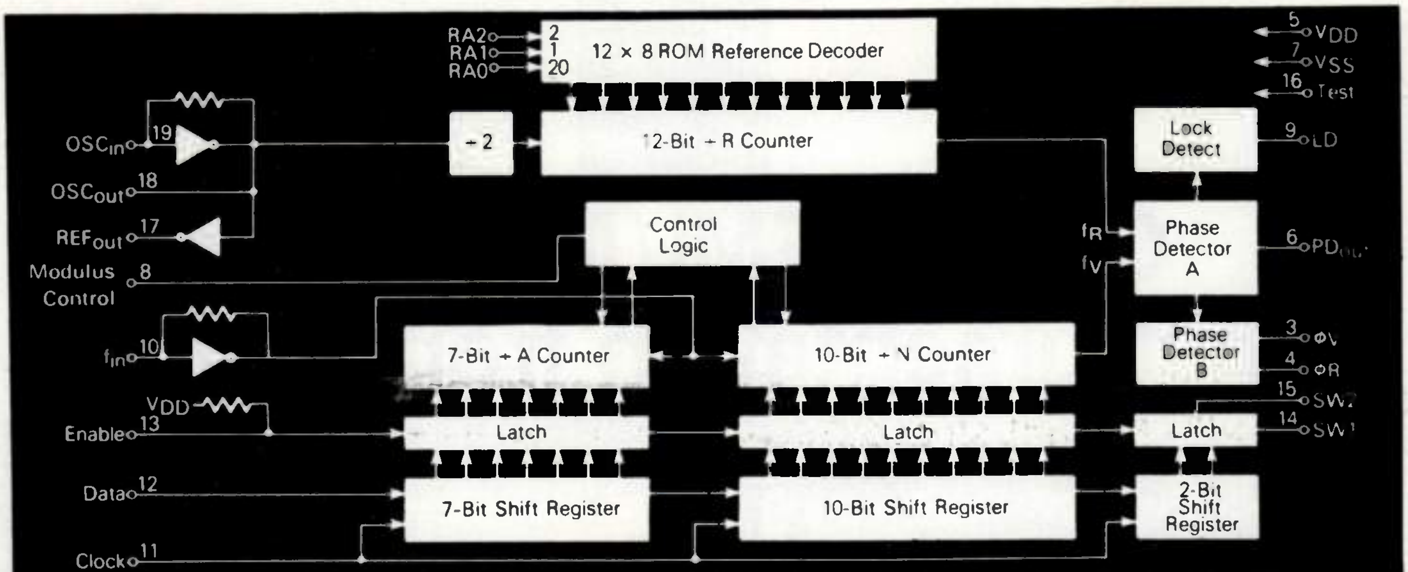

Figure 12. Block Diagram of the Motorola MC145156 Synthesizer IC reproduced with permission of Motorola.

Because of active low pass filters and speed requirements of the D to A converter, the actual lock-up time is somewhat of a compromise between these values and should be in the vicinity of 1 ms for the fractional portion and about 2 ms for the N section.

It becomes immediately apparent from the previous mathematics that if one requires the 0.1 μHz resolution, it would take a million cycles until one pulse gets removed. A microprocessor can keep track of all the data flow.

Modern integrated circuits that have frequency synthesizers on one chip and accept serial data stream as seen in Figure 12 provide major simplifications. The Hewlett-Packard frequency synthesizer model 8962A operates on this principle. However it is a fairly expensive solution.

In signal generator applications, the fractional N loops are always divided by 20 in order to get a noise sideband performance improvement of 26 dB. Due to the number of active circuits in the loop, it can barely meet 120 DB/Hz over a wide bandwidth.

References

1. G.C. Gillette — "Digiphase Principle," *Frequency Technology*, August, 1969.
2. Jerzy Gorski-Popiel — "Frequency Synthesis: Techniques and Applications," IEEE Press, 1975.
3. Hewlett-Packard — "Synthesizer/Level Generator 3335A," *Instruction Manual*, page 816-836.
4. Racal — "RA6790 Receiver," *Instruction/Repair Manual*, 1978.
5. Vadim Manassewitsch — "Frequency Synthesis," John Wiley & Sons, New York, 1976/1980.
6. U.L. Rohde — "Modern Design of Frequency Synthesizers," *Ham Radio*, July, 1976.

By publication time Dr. Rohde will have presented this article at a technical session at Southcon '81 in Atlanta.

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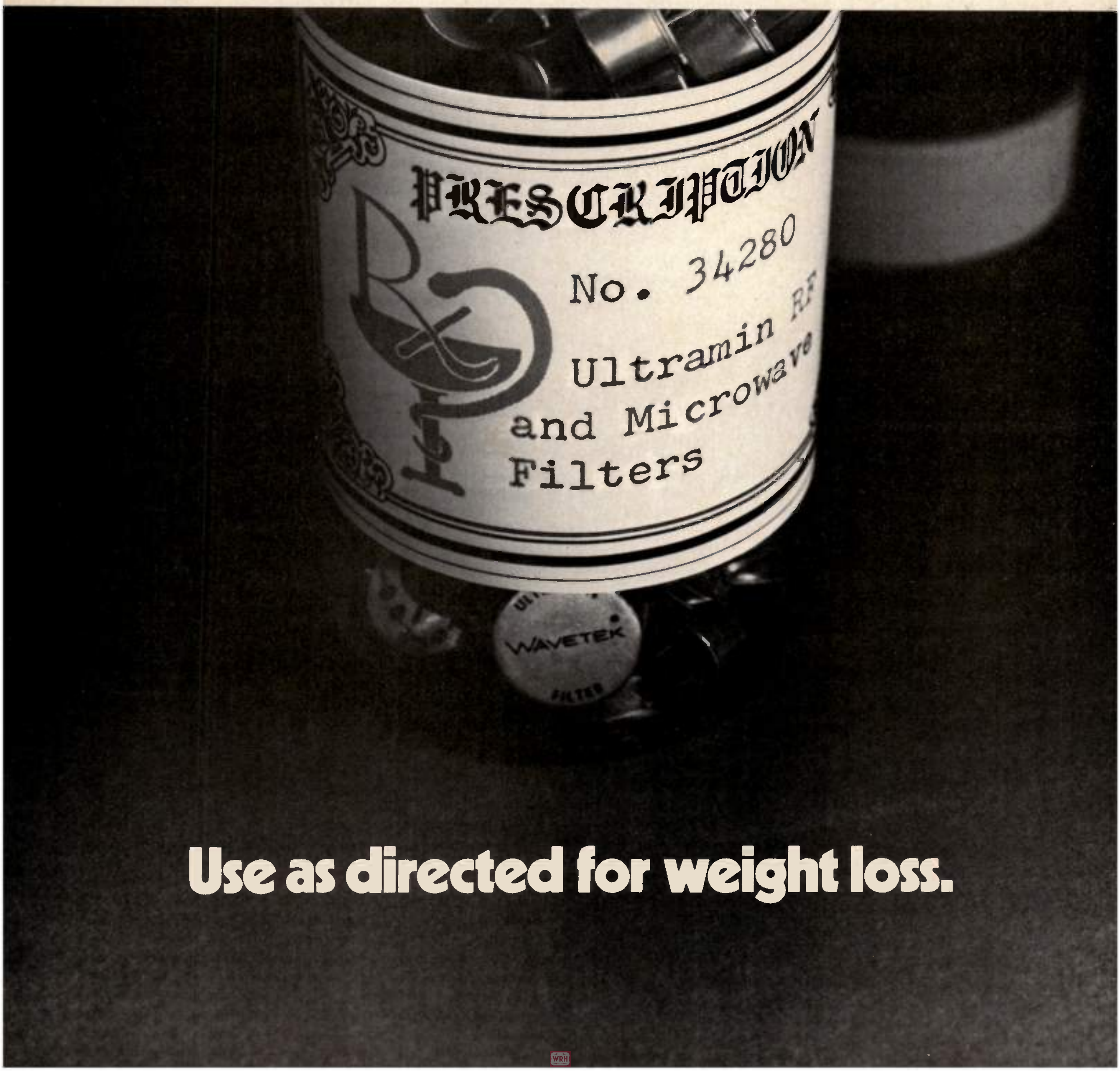

Part I

Wideband Monofilar Autotransformers

This articles takes the mystery out of autotransformer design. It is a comprehensive, practical discussion replete with useful charts.

Alex J. Burwasser
Consulting Engineer
Fair-Rite Products Corp.
Wallkill, NY

What do most engineers do when they need a wideband autotransformer? If this engineer's observations are representative, the design and construction of such a transformer is, more often than not, a very tedious matter of trial and error. Typically, the engineer selects a core that happens to be handy, twists up some wires, winds the transformer, and installs it in his circuit. If performance is unsatisfactory, he then begins the tedious process of adding or removing turns, trying a different core size, a different core material, or using a different wire gauge. The problem here is that there are quite a number of variables, and the engineer seldom has time to design a truly optimum transformer.

This article presents detailed design, construction, and performance information for a number of high-performance wideband autotransformers covering impedance transformation ratios that should satisfy nearly any low-power level application. These versatile auto-transformers offer superb performance, are small in size, low in cost, highly repeatable, and can be easily manufactured with readily obtainable parts by assembly personnel of ordinary skill and experience. Armed with the information presented in this application note, the engineer can easily, rapidly, and confidently design autotransformers with specified performance characteristics into his circuits, bypassing most of the laborious tasks this normally entails.

Specifying An Autotransformer

If we endeavor to construct an autotransformer with superior performance characteristics, the question naturally arises as to which characteristics are to be improved. This question is best addressed by considering the desirable qualities of an autotransformer.

Most manufacturers specify their RF transformers in terms of transmission characteristics. That is, transmission loss is specified as a function of frequency. The bandwidth of the transformer is that frequency range over which the transmission loss is contained within some specified limit. Figure 1 is a graphical illustration of the possible transmission characteristics of a transformer, where the bandwidth is f_2-f_1.

It is evident that the "bandwidth" of this transformer is somewhat arbitrarily determined, particularly if the roll-off is gradual. If more transmission loss can be tolerated, the bandwidth will, by definition, be extended. Conversely, if less transmission loss can be tolerated, the bandwidth will be diminished. Consequently, any meaningful bandwidth specification *must* be accompanied by the corresponding transmission loss limitation. One manufacturer rates his transformers at the 1 dB, 2 dB, and 3 dB bandwidths. Even complete knowledge of the transmission characteristics of a transformer does not provide the designer with sufficient information. A transformer must also be specified in terms of its *reflection* characteristics. Although manufacturers often do not specify RF transformers in terms of reflection characteristics, this specification is

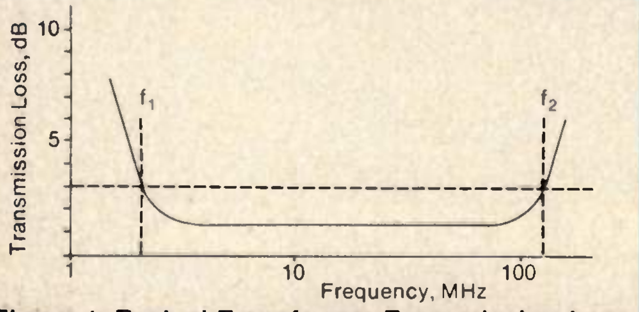

Figure 1. Typical Transformer Transmission Loss Vs. Frequency.

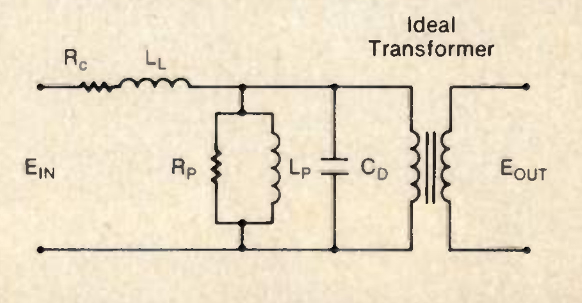

Figure 2. Transformer Lumped Element Equivalent Circuit.

nonetheless very important, as it defines the *quality* of the impedance transformation over the frequency range of interest.

At this point, it might be helpful to model a transformer into its lumped element equivalent circuit as illustrated in Figure 2. This equivalent circuit separates a practical transformer into an ideal transformer and the equivalent parasitic resistances and reactances that account for the less-than-ideal performance invariably encountered.

As Martin[1] points out in his application note, the equivalent parallel inductance (L_p) and resistance (R_p) primarily establish the low frequency roll-off of the transformer, since they tend to diminish in value at lower frequencies. Of these two elements, L_p usually predominates. Martin also cites the winding capacitance (C_d) and the leakage inductance (L_1) as being responsible for the high frequency roll-off, since the reactance of L_1 increases and the reactance of C_d decreases with frequency. In the autotransformers presented in this application note, C_d has the predominant influence on high frequency roll-off.

Over the majority of the frequency range (where the effects of the transformer parasitic reactances are less pronounced), the coil winding resistance (R_c) and R_p are primarily responsible for the residual insertion loss. In the autotransformers presented in this article, R_p is the predominant factor influencing the magnitude of this residual insertion loss.

Unfortunately, these parasitic elements do more than merely cause losses. They also affect the value of the impedance reflected from the secondary to the primary. Consider the ideal 1:4 autotransformer depicted in Figure 3. If we terminate the secondary with 200 ohms as shown and measure the impedance at the primary terminals, we should measure 50 ohms. Now, if we model this practical autotransformer as an ideal one in conjunction with a parasitic RLC network as shown in Figure 4, we can expect that the parasitic lumped elements will cause perturbations in the impedance reflected from the secondary to the primary. Thus, instead of seeing a resistive impedance of 50 ohms at the input terminals, we will probably measure a resistance of something other than 50 ohms, as well as reactance. In other words, the input impedance will be complex. Another way of looking at this is to consider the impedance scaling factor of the autotransformer to no longer be 4, but instead to be some complex quantity a + jb. If the autotransformer is to be useful, *a* should be near 4 and *b* near zero.

Reflection Characteristics

Now, we all recognize that no autotransformer can be perfect, and we therefore are willing to forgive a certain amount of insertion loss and variation in the impedance scaling factor. But, for the same reason that we require information regarding an autotransformers's transmission characteristics, we also require information concerning the autotransformer's *reflection* characteristics (a broader term used to describe variations in the autotransformer's impedance scaling factor). Unfortunately, as mentioned earlier, many manufacturers do not provide this information.

We could specify the reflection characteristics of an autotransformer by measuring the complex impedance at various frequencies and then plot the results on a Smith Chart. The solid line on Figure 5 illustrates how such a plot might appear. Using a sophisticated RF network analyzer, this plot could be easily and rapidly made. Network analyzers of this class, however, are quite expensive.

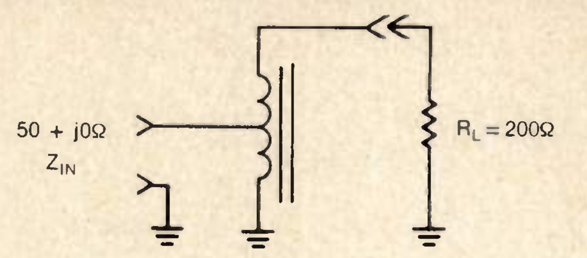

Figure 3. Ideal 1:4 Autotransformer.

An easier and more practical method of specifying the reflection characteristics of an autotransformer is to measure and plot VSWR as a function of frequency. The ideal autotransformer of Figure 3 would present a VSWR of 1.0 at the primary terminals. If this autotransformer was less than ideal and exhibited a VSWR of, say, 1.5 at a particular frequency, we could then define the locus of points on the Smith Chart on which the complex impedance must lie (i.e., on the 1.5 VSWR circle as illustrated by the dotted line on Figure 5). But, we would have no way of knowing which exact point on that VSWR circle represented

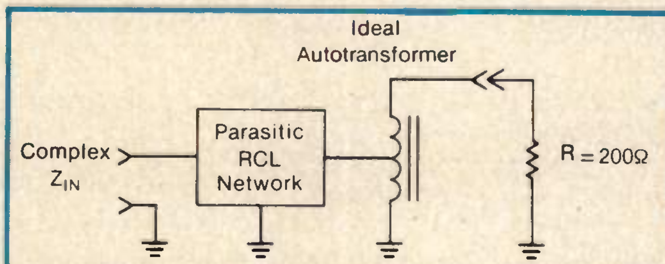

Figure 4. Simplified Equivalent Circuit of Practical 1:4 Autotransformer.

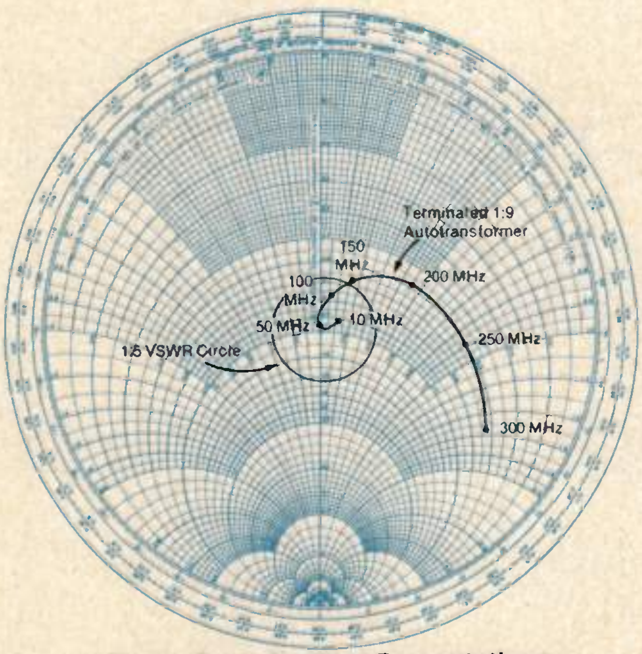

Figure 5. Smith Chart Presentations.

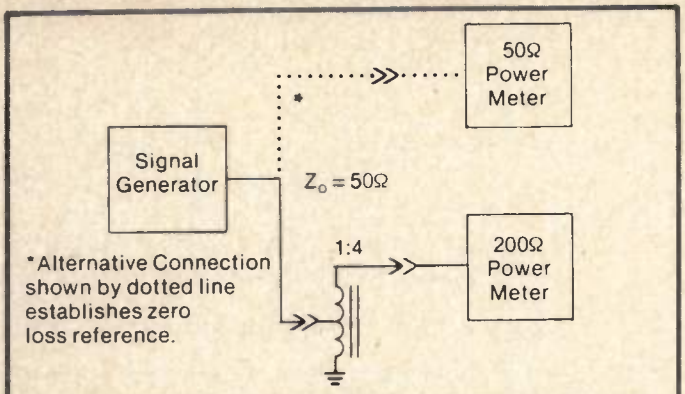

Figure 6. "Direct" Transmission Loss Test Setup.

the particular complex impedance we would be measur ng. In order to determine that exact point, we would need to know the phase angle of the voltage with respect to the current.

Thus, the reflection characteristics of an autotransformer have the dimensions of magnitude and phase angle. From transmission line theory[2], we can express this complex quantity as ρ (rho), the voltage reflection coefficient:

$$\rho = \frac{Z_r - Z_o}{Z_r + Z_o} \qquad (1)$$

Where Z_r = the input impedance of the autotransformer
Z_o = the driving source (reference) impedance

When Z_r is a complex quantity, ρ will likewise be complex. Z_o is assumed to be real.

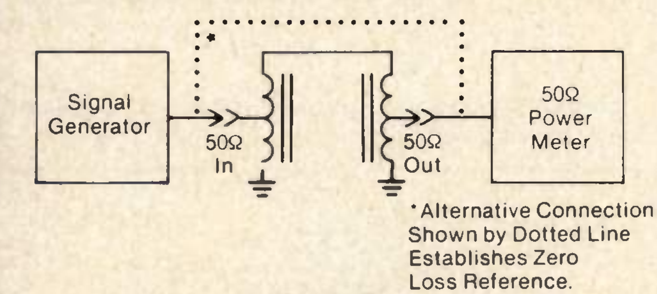

Figure 7.
"Back-To-Back" Transmission Loss Test Setup.

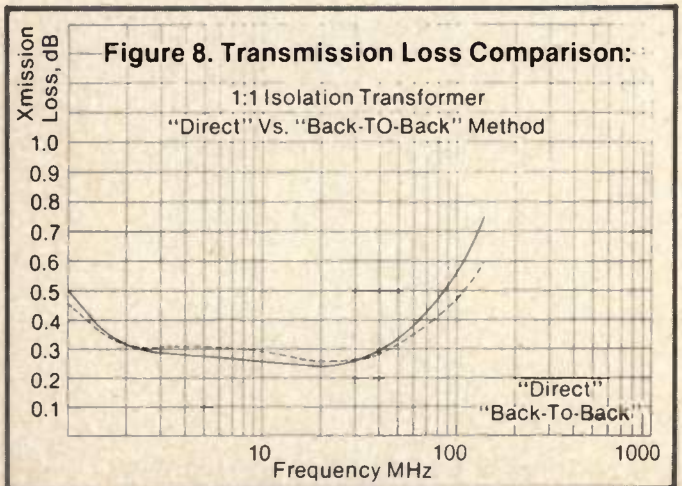

Figure 8. Transmission Loss Comparison:

The magnitude of the reflection coefficient, expressed as $|\rho|$, is related to VSWR by Equation 2:

$$|\rho| = \frac{r - 1}{r + 1} \qquad (2)$$

Where r = VSWR

Another useful quantity to consider is return loss, given by the relationship:

$$\text{return loss (dB)} = 20 \log_{10} \frac{1}{|\rho|} \qquad (3)$$

Thus, VSWR, the magnitude of the voltage reflection coefficient, and return loss are simply different expressions of the same quantity. Any of these quantities may be satisfactorily employed to specify the reflection characteristics of an autotransformer. Although neither of these expressions provide phase information as does ρ in Equation (1), they all provide a very succinct manner of specifying reflection characteristics. Furthermore, the required instrumentation for measuring VSWR, ρ and return loss is relatively simple and inexpensive.

Transmission Measurements

Figure 6 illustrates one possible method for measuring the transmission loss of an autotransformer. The signal source is first connected to the 50 ohm power meter, and the power level (P1) is noted. The signal source is then connected to the autotransformer primary, and the power level as indicated on the 200 ohm power meter (P2) is noted. (The 200 ohm power meter could be a standard 50 ohm power meter with a minimum-loss resistive matching pad.) The autotransformer transmission loss is then P1-P2.

Although this direct method is conceptually correct, it would require power measuring equipment and matching pads of exceptional precision to be able to accurately measure insertion losses on the order of a few tenths of a dB. With the instrumentation normally employed for this purpose, these measurements would be unreliable. Another problem is that the instrumentation would have to change to accommodate autotransformers of different impedance transformation ratios.

A more satisfactory (if somewhat less "pure") method is the back-to-back technique as illustrated in Figure 7. With this method, the signal generator is first connected to the power meter to establish the zero loss reference power level, P1. The signal generator and power meter are then connected to the back-to-back autotransformers, and power level P2 is noted. The total insertion loss is then P1-P2, half of which is attributed to each autotransformer.

Now, it can be argued that the back-to-back technique introduces some error terms when the VSWR is greater than 1.0. To empirically obtain some idea of how accuracy is affected, two 1:1 isolation transformers were constructed and their transmission loss measured in the back-to-back configuration as described in the previous paragraph. Next, the transmission loss of just one of the transformers alone was measured directly in the same fixture (since there is no nominal impedance level shift in a 1:1 transformer). The results of both measurement techniques as presented in Figure 8 indicate good agreement between the two methods, especially below 70 MHz where the VSWR is low.

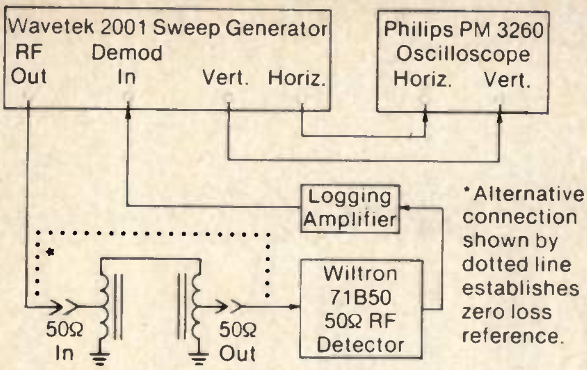

Figure 9. Swept Transmission Loss Test Setup.

Thus, despite the fact that the back-to-back method is less than pure in theory, its accuracy appears to be quite acceptable in practice. It also affords the powerful advantage that all transmission measurements can be made in a 50 ohm line regardless of the impedance transformation ratio of the transformers under test. Figure 9 is the actual swept transmission loss test setup used to measure the transmission loss of the autotransformers presented in this article. All lead lengths are made as short as absolutely possible to minimize fixture — induced errors at high frequencies.

Reflection Measurements

Swept reflection measurements are conducted using the test setup of Figure 10. The key element here is the "VSWR autotester" (rho bridge), a device that produces a DC output voltage proportional to ρ, the magnitude of the voltage reflection coefficient of the network being measured. See reference (3) for more detailed information about this versatile and inexpensive instrument. The logging amplifier results in an oscilloscope display of return loss (in dB) as function of frequency. The autotransformer secondary is terminated in a 50 x n ohm 1/8 watt carbon film resistor, where n is the nominal autotransformer impedance transformation ratio. As in the transmission test fixture, leads are kept very short.

Autotransformer Construction

Most RF autotransformers are constructed with multifilar windings connected series-aiding, with taps placed

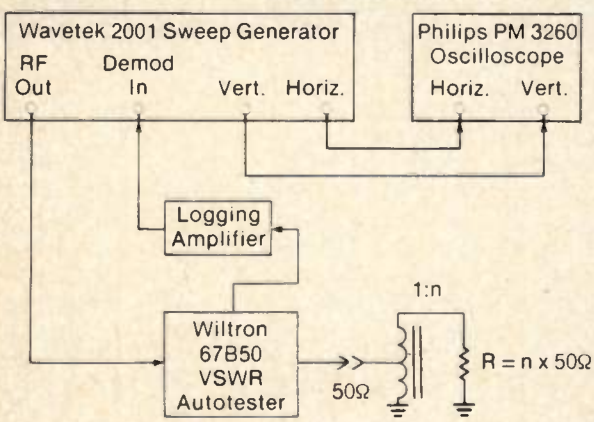

Figure 10. Swept VSWR Test Setup.

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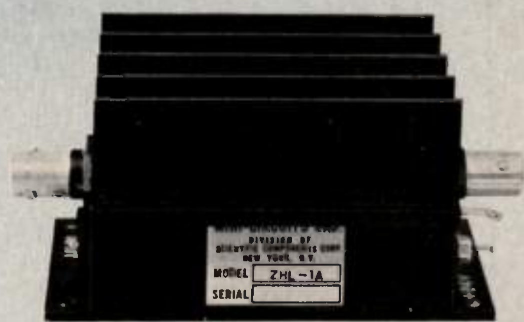
- Broadband ... each model multi-octave (see table)
- High linear output ... up to 30 dBm (1 W)
- Gain ... available from 16 dB to 27 dB
- Very flat gain response ... ±1 dB
- Connectors ... BNC Std; SMA, TNC, N available
- Compact ... 3.75" × 2.60" × 1.92" (ZHL-A Models)
  4.75" × 2.60" × 2.22" (ZHL Models)
- Self-contained heat sink
- One-week delivery

ZHL-2-8

If your application requires up to 1 watt for intermodulation testing of components ... broadband isolation ... flat gain over a wide bandwidth ... or much higher output from your frequency synthesizer or signal/sweep generator ... MiniCircuits' ZHL power amplifiers will meet your needs, at surprisingly low prices. Five models are available, offering a selection of bandwidth and gain.

Using an ultra-linear Class A design, the ZHL is unconditionally stable and can be connected to any load impedance without amplifier damage or oscillation. The ZHL is housed in a rugged 1/8 inch thick aluminum case, with a self-contained hefty heat sink. BNC connectors are supplied; however, SMA, TNC and Type N connectors are also available. Of course, our one-year guarantee applies to each amplifier.

So from the table below, select the ZHL model for your particular application now ... we'll ship within one week!



ZHL-1A

MODEL NO.	FREQ. MHz	GAIN dB	GAIN FLATNESS dB	MAX. POWER OUTPUT dBm 1-dB COMPRESSION	NOISE FIGURE dB	INTERCEPT POINT 3rd ORDER dBm	DC POWER VOLTAGE	DC POWER CURRENT	PRICE $ EA.	PRICE QTY.
ZHL-32A	0.05-130	25 Min.	±1.0 Max.	+29 Min.	10 Typ.	+38 Typ.	+24V	0.6A	199.00	(1-9)
ZHL-3A	0.4-150	24 Min.	±1.0 Max.	+29.5 Min.	11 Typ.	+38 Typ.	+24V	0.6A	199.00	(1-9)
ZHL-1A	2-500	16 Min.	±1.0 Max.	+28 Min.	11 Typ.	+38 Typ.	+24V	0.6A	199.00	(1-9)
ZHL-2	10-1000	15 Min.	± 1.0Max.	+29 Min.	18 Typ.	+38 Typ.	+24V	0.6A	349.00	(1-9)
ZHL-2-8	10-1000	27 Min.	±1.0 Max.	+29 Min.	10 Typ.	+38 Typ.	+24V	0.65A	449.00	(1-9)
ZHL-2-12	10-1200	24 Min.	±1.0 Max.	+29 Min.*	10 Typ.	+38 Typ.	+24V	0.75A	524.00	(1-9)

Total safe input power +20 dBm, operating temperature 0° C to +60° C, storage temperature −55° C to +100° C, 50 ohm impedance, input and output VSWR 2.1 max
*+28.5 dBm from 1000-1200 MHz
For detailed specs and curves, refer to 1980/81 MicroWaves Product Data Directory, Gold Book, or EEM.

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at the appropriate winding junctions. Figure 11 shows schematic representations of bifilar and trifilar wound autotransformers. This multifilar winding technique imposes limitations on the impedance transformation ratios obtainable if awkward taps between the winding junctions are to be avoided. For example, the bifilar wound autotransformer may only be used for a 1:4 impedance transformation (where the impedance transformation ratio is the square of the turns ratio). Similarly, the trifilar wound autotransformer may only be used for a 1:9 or a 1:9/4 impedance transformation. Other ratios may be obtained by placing additional taps on the windings, but tapping a multifilar winding at any point other than the winding junctions is very difficult from a manufacturing standpoint. Nagle[4] describes in his article a straightforward technique to determine if a suitable n-filar autotransformer can be constructed to satisfy a particular impedance transformation requirement. He goes on to provide an example whereby a 50 to 72 ohm autotransformer is designed around a hexfilar winding.

Another problem here is that multifilar windings in themselves pose manufacturing difficulties. In the case of the hexfilar wound autotransformer, for example, each of the six wires would need to be color-coded so that the assembler could twist together the correct

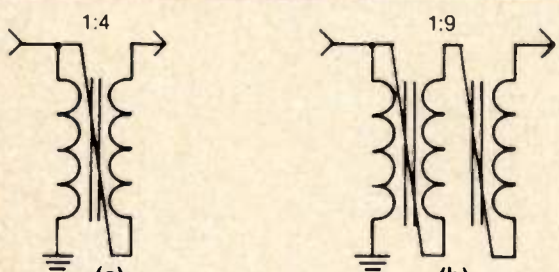

Figure 11. (a) Bifilar and (b) Trifilar Wound Autotransformer Schematic Diagrams.

wires at each junction. Next, all of the five twisted wires and the two ends would have to be tinned and trimmed. The resulting taps would then have to be carefully placed in order so that all but the desired one could be clipped off. Care would have to be exercised to prevent possible shorts. This transformer obviously would be difficult and expensive to manufacture.

Although apparently not widely recognized, it is not always necessary to employ multifilar windings in autotransformers. If the core is small enough, adequate interturn winding "intimacy" is usually assured, thus relaxing the requirement for multifilar windings. In fact, under these circumstances, the conventional single-tapped winding can result in autotransformer performance superior to that of one that has been multifilar wound as will be clearly demonstrated later in this article.

Employing this "monofilar" winding technique permits much greater flexibility in terms of being able to establish a desired impedance transformation ratio. From a manufacturing standpoint, the monofilar winding technique greatly simplifies construction, since only a single wire is required. The tap is created by simply "pigtailing" and twisting the wire at the appropriate turn. All three protruding wires may then be tinned simultaneously in a solder pot. Figure 12 is a drawing of a 1:4 monofilar wound autotransformer. Figure 13 is a photograph of the completed unit.

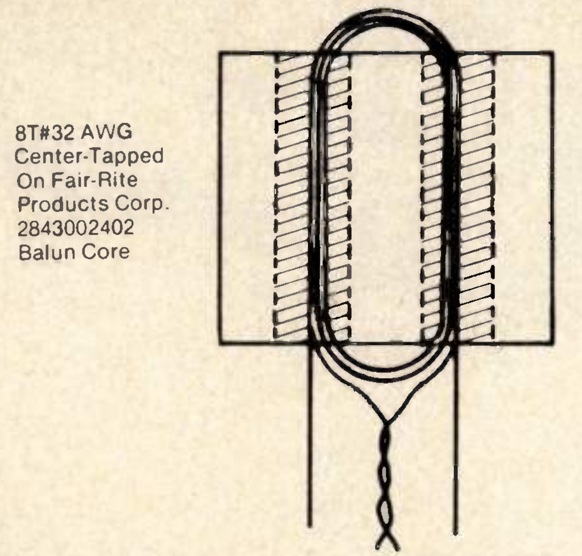

Figure 12. Cutaway Drawing of 1:4 Monofilar Autotransformer.

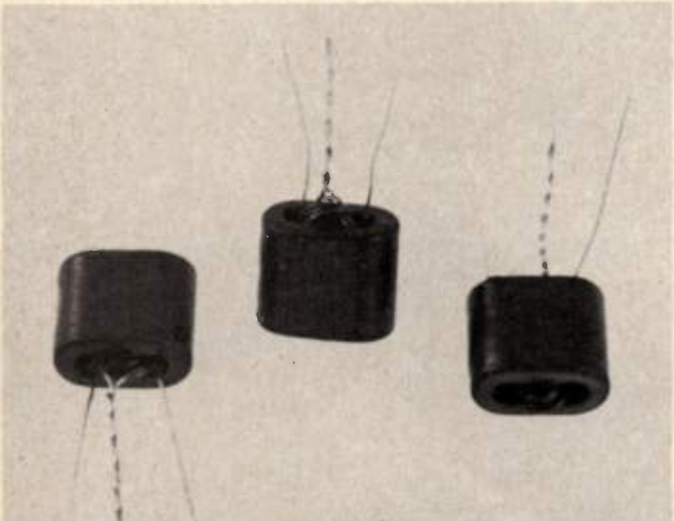

Figure 13. Photograph of 1:4 Monofilar Autotransformer.

Table 1. Autotransformer Winding Data

Nominal Z Ratio	"Primary" Turns	"Secondary" Turns
1 to 1.5	4	5
1 to 2	5	7
1 to 3	4	7
1 to 4	4	8
1 to 5	4	9
1 to 6.25	4	10
1 to 7.5	4	11
1 to 9	4	12
1 to 16	4	16

Note: "Primary" refers to number of turns from tap to ground. "Secondary' refers to number of turns on entire winding.

The core employed is a two-hole ferrite balun core.* This core is very well suited for wideband autotransformer applications. Its form factor (a figure of merit applied to ferrite cores as a measure of suitability for wideband operation) is much lower (better) than that of the more commonly used toroid. Its small size and low cost are also factors that make this core very attractive. Referring to Figure 12, note how all three leads protrude from the same side of the core. The wire employed in this, as well as all other autotransformers described in this article, is #32 magnet wire with single polyurethane insulation. This compact autotransformer mounts upright and solders directly to the circuit board, occupying a bare minimum of board "real estate".

To obtain different impedance transformation ratios, it is necessary only to establish the correct number of turns and select the appropriate tap position. In other words, we are not limited to a narrow range of impedance transformation ratios as would be the case for multifilar wound autotransformers. Table 1 provides monofilar autotransformer winding data for a variety of impedance transformation ratios. All these autotransformers employ inexpensive, readily-obtainable two-hole ferrite balun cores* and #32 single polyurethane insulated magnet wire, and are wound as shown in Figure 12 (with the appropriate number of turns and tap position).

The impedance transformation ratio is related to the turns ratio by:

$$Z_t = \left(\frac{N_s}{N_p}\right)^2 \qquad (4)$$

Where Z_t = *impedance transformation ratio*
N_s = *number of secondary turns (the total number of turns on the entire winding)*
N_p = *number of primary turns (the number of turns from the tap to ground)*

For example, the 1:2 (nominal) autotransformer has a total winding of 7 turns, tapped 5 turns from ground. The impedance transformation ratio is:

$$Z_t = \left(\frac{7}{5}\right)^2 = 1.96$$

The best is yet to come — Part 2 of wideband monofilar autotransformers appearing in the next issue contains actual measured autotransformer performance data. Twenty charts help to illustrate the test results.

*Fair Rite Products Corp. # 2843002402

References

(1) Martin, W.A., "Use of Ferrites for Wide Band Transformers." Application Note published by Fair-Rite Products Corp., Wallkill, N.Y. 12589.
(2) Anzac, "Transmission Line Equations," Application Note, 1978 Anzac RF and Microwave Components Catalog, p. 245.
(3) Wiltron, 'Present-Day Simplicity in Broadband SWR Measurements," Technical Information, 1976 Wiltron Catalog, p. 14.
(4) Nagle, J.J. "Wideband RF Autotransformers," Electronic Design 3, February 2, 1976.

A LIFETIME GUARANTEE AND 11 OTHER REASONS TO BUY AN "OPTOELECTRONICS" FREQUENCY COUNTER

1. SENSITIVITY: Superb amplifier circuitry with performance that can't be matched at twice the price. Average sensitivity of better than 15 mV from 10 Hz to 500 MHz on every model and better than 30 mV from 500 MHz to 1.1 GHz on the Series 8010A and 8013.

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7. PORTABILITY: All models are delivered with a 115 VAC adapter, a 12 VDC cord with plug and may be equipped with an optional ni-cad rechargeable battery pack installed within its case. The optional Ni-Cad pack may be recharged with 12 VDC or the AC adapter provided.

8. COMPACT SIZES: State-of-the-Art circuitry and external AC adapters allowed design of compact easy to use and transport instruments.
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Series 7010: 1-3/4" H x 4-1/4" W x 5-1/4" D

9. MADE IN U.S.A.: All models are designed and manufactured at our modern 13,000 square foot facility at Ft. Lauderdale, Florida.

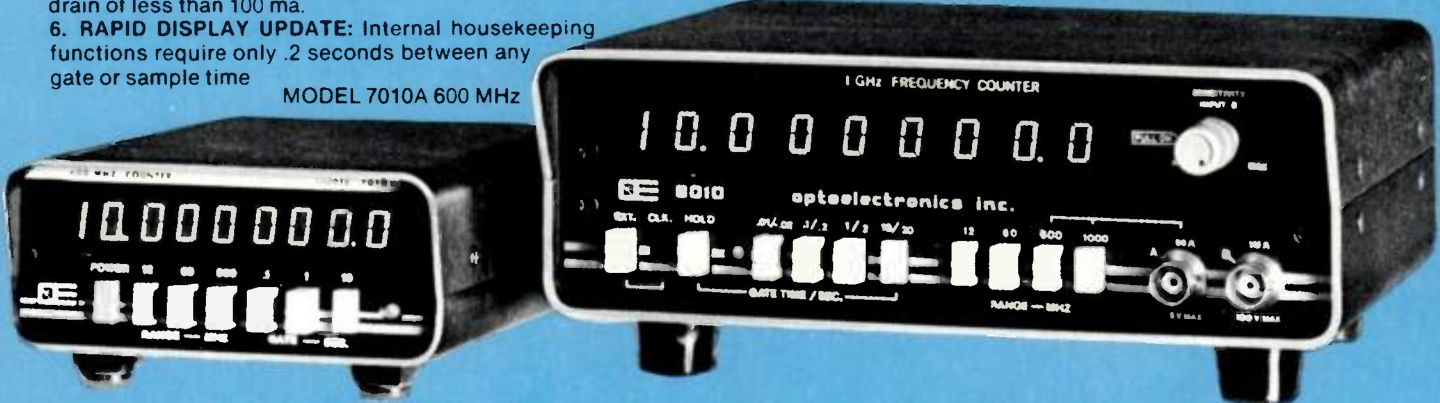
10. CERTIFIED CALIBRATION: All models meet FCC specs for frequency measurement and provided with each model is a certificate of NBS traceable calibration.

11. LIFE TIME GUARANTEE: Using the latest State-of-the-Art LSI circuitry, parts count is kept to a minimum and internal case temperature is only a few degrees above ambient resulting in long component life and reliable operation. (No custom IC's are used.) To demonstrate our confidence in these designs, all parts (excluding batteries) and service labor are 100% guaranteed for life to the original purchaser. (Transportation expense not covered).

12. PRICE: Whether you choose a series 7010 600 MHz counter or a series 8013 1.3 GHz instrument it will compete at twice its price for comparable quality and performance.

MODEL 8010A/8013 1.1 GHz/1.3 GHz

MODEL 7010A 600 MHz



MODEL	RANGE (From 10 Hz)	10 MHz TIME BASE			AVG. SENSITIVITY		GATE TIMES	RESOLUTION			EXT. CLOCK INPUT/OUTPUT	SENSITIVITY CONTROL	NI-CAD BATTERY PACK
		STABILITY	AGING	DESIGN	10 Hz to 500 MHz	500 MHz to 1.1 GHz		12 MHz	60 MHz	Max. Freq.			
7010A	600 MHz	± 1 PPM	< 1 PPM/YR	TCXO*	15 mV	N/A	(3) 1. 1. 10 sec	1 Hz	1 Hz	10 Hz (600 MHz)	YES OPTIONAL	NO	YES OPTIONAL
7010.1A		± 0.1 PPM											
8010A	1.1 GHz	± 1 PPM	< 1 PPM/YR	TCXO*	15 mV	30 mV	(4) 01. 1. 1. 10 sec	1 Hz	1 Hz	10 Hz (1.1 GHz)	YES STANDARD	YES	YES OPTIONAL
8010.1A		± 0.1 PPM											
8010.05A		± .05 PPM		OCXO**									
8013.1	1.3 GHz	± 0.1 PPM	< 1 PPM/YR	TCXO*	15 mV	30 mV	(4) 01. .1. 1. 10 sec.	1 Hz	1 Hz	10 Hz (1.3 GHz)	YES STANDARD	YES	YES OPTIONAL
8013.05		± .05 PPM		OCXO**									

*TCXO = Temperature Compensated Xtal Oscillator **OCXO = Proportional Oven Controlled Xtal Oscillator

SERIES 7010A

#7010A	600 MHz Counter - 1 PPM TCXO	$199.95
#7010.1A	600 MHz Counter - 0.1 PPM TCXO	$249.95

OPTIONS:

#70-H	Handle/Tilt Bail (not shown)	$2.95
#Ni-Cad-701	Ni-Cad Battery Pack & Charging Circuitry Installed Inside Unit	$19.95
#EC-70	External Clock Input/Output	$35.00
#CC-70	Carry Case - Padded Black Vinyl	$9.95

SERIES 8010A/8013

#8010A	1.1 GHz Counter - 1 PPM TCXO	$399.00
#8010.1A	1.1 GHz Counter - 0.1 PPM TCXO	$450.00
#8010.05A	1.3 GHz Counter - .05 PPM Oven	$499.00
#8013.1	1.3 GHz Counter - 0.1 PPM TCXO	$550.00
#8013.05	1.3 GHz Counter - .05 PPM Oven	$599.00

OPTIONS

#Ni-Cad 801	Ni-Cad Battery Pack & Charging Circuitry Installed Inside Unit	$49.95
#CC-80	Carry Case - Padded Black Vinyl	$ 9.95

ACCESSORIES

#TA-100	Telescope antenna with right angle BNC	$ 9.95
#P-100	Probe, 50 Ohm, 1X	$13.95
#P-101	Probe, Lo-Pass Audio Usage	$16.95
#P-102	Probe, Hi Z General Purpose	$16.95
#LFM 1110	Low Frequency Multiplier X 10, X 100, X 1000 For High Resolution of Audio Freq	$119.95

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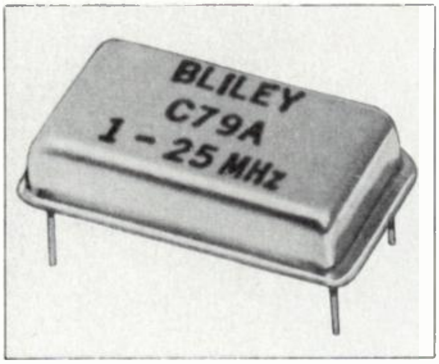
Clock Hybrid Oscillator

Bliley Electric Company is marketing an improved clock hybrid oscillator whose frequency ranges from 1 to 25 MHz with custom options available for complementary and dual frequency outputs.

Designated C79A, the oscillator is supplied in a proven reliable all metal,

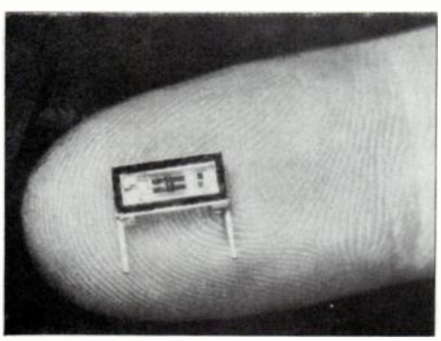


resistance-weld enclosure measuring .810 x .510 x .200 inches and is DIP compatible. Standard performance specifications of the Bliley device offer plus-or-minus .01 percent from 0 to 70 degrees centigrade. ±5 volts DC voltage and TTL logic output is generated from standard 7400 series devices. Custom high speed TTL logic is also available.

Contact: Bliley Electric Company, 2545 West Grandview Boulevard, P.O. Box 3428, Erie, PA 16508. INFO/CARD #137

Ultra-Miniature Tuning Fork Quartz Crystals

A series of ultra-miniature quartz tuning-fork crystals tuned to any desired frequency in the range 350-600 kHz has been introduced by Statek Corporation. They are designed specifically for microprocessor clock circuits, mobile radios, pagers and various telecommunications applications. A 500 kHz crystal is stocked for 4-bit microprocessors.



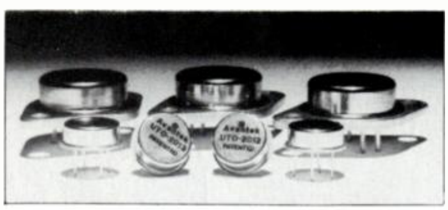
Two versions of the new crystals are offered: the CX-1H for series-resonant oscillator applications and the CX-1V for parallel resonant (Pierce) oscillator applications. The crystals are contained in a hermetically-sealed ceramic package with leads compatible with DIP spacing or without leads for use in hybrids. Calibration tolerance is ±0.2 pecent at 25°C. Frequency variation is 0 to −0.02 percent from 0°C to 70°C. Stock resistance is considerably better than 1000g, 1 mS, half sine wave.

Contact Statek Corporation, 512 N. Main, Orange, CA 92668. INFO/CARD #136.

VMOS and GaAs FET Amplifiers

Avantek, Inc. Santa Clara, CA has introduced three new TO-8 and TO-3 packaged thin-film cascadable amplifier modules, specifically designed for the extremely wide dynamic-range I.F. amplifier requirements of today's state-of-the-art super-heterodyne receiving systems. They are also suitable for signal distribution and driver applications.

The UTO-161, a TO-3 packaged module, incorporates a VMOS FET transistor to produce a minimum output power of +32 dBm (+20V input)



and +30 dBm (+15V input) over the −54° to +71°C temperature range and frequencies from 10-100 MHz. Its performance specifications also include 8 dB minimum gain, 6 dB maximum noise figure and a remarkable +43 dBm intercept point for third order intermodulation products.

Using GaAs FET transistors, the TO-8 packaged UTO-2012 and UTO-2013 offer 500-2000 MHz frequency coverage with up to +18 dBm output power, 8.5 dB gain and noise figures as low as 5.0 dB over the −54° to +71°C temperature range.

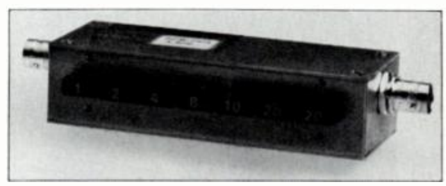
These FET amplifier modules include matching and feedback circuitry that assures an excellent 50-ohm impedance match at both input and output and virtually eliminates interaction between cascaded modules. In addition, both the VMOS and GaAs FET modules include temperature-compensated active biasing, using an associated low-frequency silicon bipolar transistor to maintain an optimum quiescent current over a wide operating temperature range.

All that's required to use these FET amplifiers is to install the modules in a conventional 50-ohm microstrip environment, assure that the case is properly contacting the ground plane and apply the 15 or 20 VDC bias. There is no need for the complicated matching networks typically required for low-frequency GaAs FET amplifiers, bias networks or temperature stabilization. Each module incorporates built-in power supply decoupling capacitors.

Contact Avantek, Inc., 3175 Bowers Ave., Santa Clara, CA 95051. INFO/CARD #138.

Pushbutton Attenuators Models 50B and 75B

Frequency range D.C.-750 MHz 50 and 75 ohm available. Flat frequency



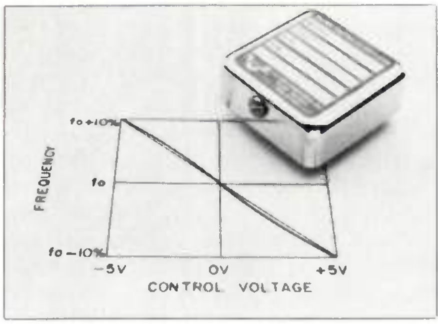
response. Special steps available.

Contact JFW Industries, Inc., P.O. Box 226, Beech Grove, IN 46107. Circle INFO/CARD #134.

Wide Deviation VCO

Vectron has complimented its line of voltage controlled crystal oscillators with the VC-371 and VC-381 series of non-crystal controlled VCOs, available at center frequencies ranging from 50 kHz to 500 MHz.

Deviation of the standard model is ±10 percent, optionally extendable to a full octave. Stability over 0 to +50°C is ±1 percent with −55°C to +85°C operation available. Output

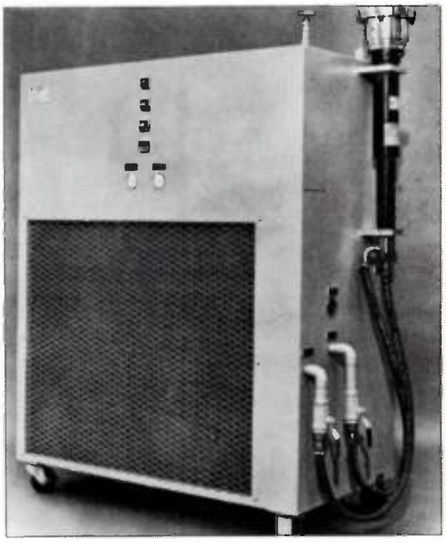


of +7 dBm into 50 ohms is standard, with TTL, CMOS, and ECL outputs available.

Contact Vectron Lab, Inc., 166 Glover Avenue, Norwalk, CT 06850. Circle INFO/CARD #133.

Self-Cooled 80KW Coaxial Load

First introduced by Bird over a decade ago, the concept of compact high-power self-contained RF Terminating Systems has now led to extending the upper limit of the series from 50KW to 80KW. The entire series of 10, 25, 50 and now 80KW Moduload® RF Load Resistors is designed for terminating a 50-ohm line with negligible VSWR during off-line or off-the-air



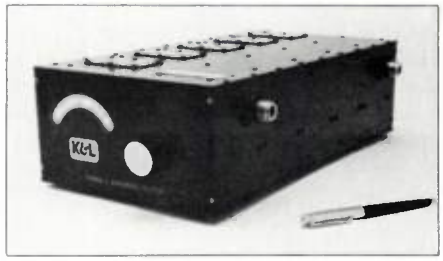
tests and maintenance of transmitters, in locations where water supply is unreliable, expensive or simply not available.

The new model 8690 is capable of 80,000 watts continuous dissipation in ambient temperatures from a low of −20°C to +35°C. The flexibility of mounting the Load Resistor up to 20 feet from the heat exchanger permits venting the 270,000 BTU/hour (enough to heat two houses) at a more convenient location away from the transmitter room or test lab. VSWR is less than 1.1 over the entire range of 1 kHz to 800 MHz.

Contact Bird Electronic Corporation, 30303 Aurora Road, Cleveland (Solon) OH 44139. INFO/CARD #131.

Tunable BPF

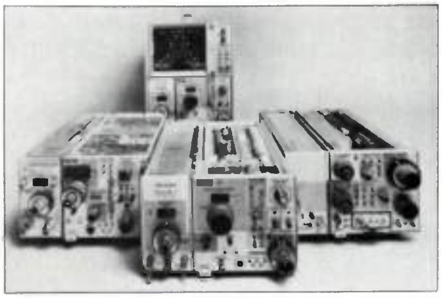
K & L Microwave, Inc. has just announced the release of a new VHF Tunable Bandpass Filter. The new filter covers a greater than octave band from 30 to 76 MHz and has a power handling capability of 50 Watts Peak or CW when terminated in a load as poor as 3 to 1. Designated Model HP5BT-30/76-N, it has a passband of only 3 percent of the tuned frequency.



The 40 dB Rejection Bandwidth is limited to 6 percent maximum. This selectivity is achieved by the use of 5 High Q gang tuned resonators which are tracked together and tuned by merely dialing in the desired frequency with a single knob. The frequency is read directly from an engraved calibrated dial which has an accuracy of better than 1 percent. Operated in a 50 ohm system, the VSWR is typically less than 1.3/1 at the center frequency, with a specification of 1.5/1 maximum.

Contact: K & L Microwave, Inc., 408 Coles Circle, Salisbury, MD 21801. INFO/CARD #132.

Digital Storage RF Spectrum Analyzer



Bringing digital storage capabilities to the most widely used frequency ranges in the RF spectrum, Tektronix is introducing the 7L14 Spectrum Analyzer. The 7L14 will be of special importance to operators using the HF, VHF and low UHF bands.

The 7L14 Spectrum Analyzer has been designed to meet the needs of the following primary user groups: broadcast stations (AM, FM, TV), military communications, CATV companies, and utility companies (specifically firms and agencies that use two-way radio). Measurements sought by these customers include power level; distortion; depth of modulation; modulation rate, deviation and index; spurious signals; gain; attenuation; frequency response (with a tracking generator); and noise levels.

The 7L14 features a built-in limiter which protects the first mixer. The limiter does not degrade the distortion (harmonic and intermod) measurement capabilities of the 7L14. As a result, signal levels up to one watt can be connected to the input for any setting of the RF attenuator without damage to the first mixer. The limiter has a built-in DC block which, in addition to preventing damage from a DC level on the signal, will protect the mixer from large (up to 50V) line frequency (50/60 Hz) signals which may be present along with the wanted signal.

The 7L14 provides frequency coverage from 10 kHz to 1800 MHz. Other features include: 70 dB on screen dynamic range, spurious free; minus 130 dBm sensitivity, with 30 Hz resolution; CRT readout of control settings, four-to-one shape factor resolution filters; tracking generator and counter options; and a display mainframe compatible with more than 25 different 7000 Series plug-ins.

Contact Tektronix Marketing Communications Department, D.S. 76/260, P.O. Box 1700, Beaverton, OR 97075. Circle INFO/CARD #138.

LF Impedance Analyzer And Network Analyzer

This new model HP 4192A is a low frequency impedance analyzer and network analyzer. In a frequency range of 5 Hz to 13 MHz, the HP 4192A measures 11 impedance parameters as well as gain, phase and group delay. Both one-port and two-port devices can be tested and the devices can be either floating or grounded.

The HP 4192A offers 4-1/2 digit readings with 0.3 percent basic measurement accuracy. Options include ±35 VDC bias (10 mV resolution), and analog output. Two special test fixtures and an accessory kit are also available.

An internal frequency synthesizer provides excellent resolution from 5.000 Hz to 13.000000 MHz. Frequency can be swept linearly or logarithmically or can

be set to a spot frequency.

Output level is continuously adjustable from 5mV to 1.1Vrms into an open circuit. Standard output impedance is 50 ohms with 75 ohms optional. Useful accessories for the telecommunications industry are the HP Model 11473A-11476A transformers which convert the HP 4292A output to various impedances and connectors.

These features make the HP 4192A well suited for characterizing individual components such as inductors and capacitors as well as testing complete circuits including filters and amplifiers. Also, because of its flexibility, the HP 4192A can provide test conditions for most devices which are the same as actual operating conditions.

Impedance parameters measured by the HP 4192A include L, C, R, Z, Y, phase angle, X, G, B, D and Q. Changes in the parameters can be displayed as delta or delta percent. The HP 4192A's sensitivity and wide measuring range are typified by the range of Z from 0.1 milliohm to 1.3 Megohm and Y from 1 nanoSiemen to 1 Siemen. These capabilities make the HP 4192A suitable for use in a wide spectrum of applications including: 1) materials testing, 2) evaluation of PC mounted inductive and capacitive devices, 3) semiconductor evaluations and 4) Crystal testing.

Contact Inquiries Manager, Hewlett-Packard Company, 1507 Page Mill Road, Palo Alto, CA 94304. Circle INFO/CARD #127.

First 2 GHz Log I.F. Amplifier

The industry's first logarithmic I.F. amplifier operational to 2 GHz is now available from the Beverly Division of Varian Associates.

Ideal for use in electronic-warfare and radar systems, as well as monopulse tracing receivers, the new I.F.-to-log video amplifiers — called the ICL-5 Series — are based on a hybrid integrated-circuit design, and cover the frequency range from 600 to 2000 MHz. Features include exceptionally stable log linearity and stability over

Errata

In the "Narrowband Butterworth or Chebyshev Filter Design using the T1-59 Calculator" article that appeared in the November/December 1980 issue of *r.f. design* the following chart was accidently omitted.

Alphanumeric Codes	Storage Register Location
64210100.	25
64151333.	26
64243116.	27
64353600.	28
64352700.	29
64323516.	30
64353327.	31
64144300.	32
4200000037.	33
1445362317.	34
152317.	35
4533170000.	36
3537230037.	37
3717354332.	38
144137.	39

an operational temperature range to 85°C.

The accuracy of a log amplifier is measured by determining the maximum deviation of the actual log curve from an ideal log plot. Users of the ICL-5 can expect a deviation of less than ± 1 dB.

Because Varian log amplifiers are designed to be broadband, they can be used with the full intrinsic I.F. bandwidth in many applications. As a result, a system designer can expect highly accurate amplitude measurements instantaneously over extremely broad bandwidths.

Varian Associates, Beverly Division, Salem Road, Beverly, MA 01915. Circle INFO/CARD #130.

Precision Automatic Noise Figure Indicator

Eaton Corporation's Electronic Instrumentation Division has developed a new precision automatic noise figure indicator (PANFI) called Ailtech 7514 as part of its noise figure measurement line of instruments.

The Ailtech 7514 simply and accurately measures the noise figure of an amplifier or receiver. Its rapid, direct-reading capability allows im-

mediate evaluation of the effects of circuit adjustments on noise performance. The Ailtech 7514 with option 09, provides for six preselected, front-panel switchec input frequencies — 21.4. 36, 45, 60, 70, 160 MHz — in addition to 30 MHz. The same option, when used with an external local oscillator, permits noise figure measurements on devices with output frequencies from 10 to 1000 MHz.

In conjunction with the Ailtech 76 Series solid-state noise generators, the Ailtech 7514 is a valuable tool for the evaluation of the noise performance of amplifiers and receivers over the range from 10 MHz to 18 GHz.

The Ailtech 7514 is basically a bench-top instrument; however, it is offered with optional rack mount brackets as Option 11.

Contact Ailtech, 2070 5th Ave., Ronkonkoma, NY 11729. INFO/CARD #129.

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