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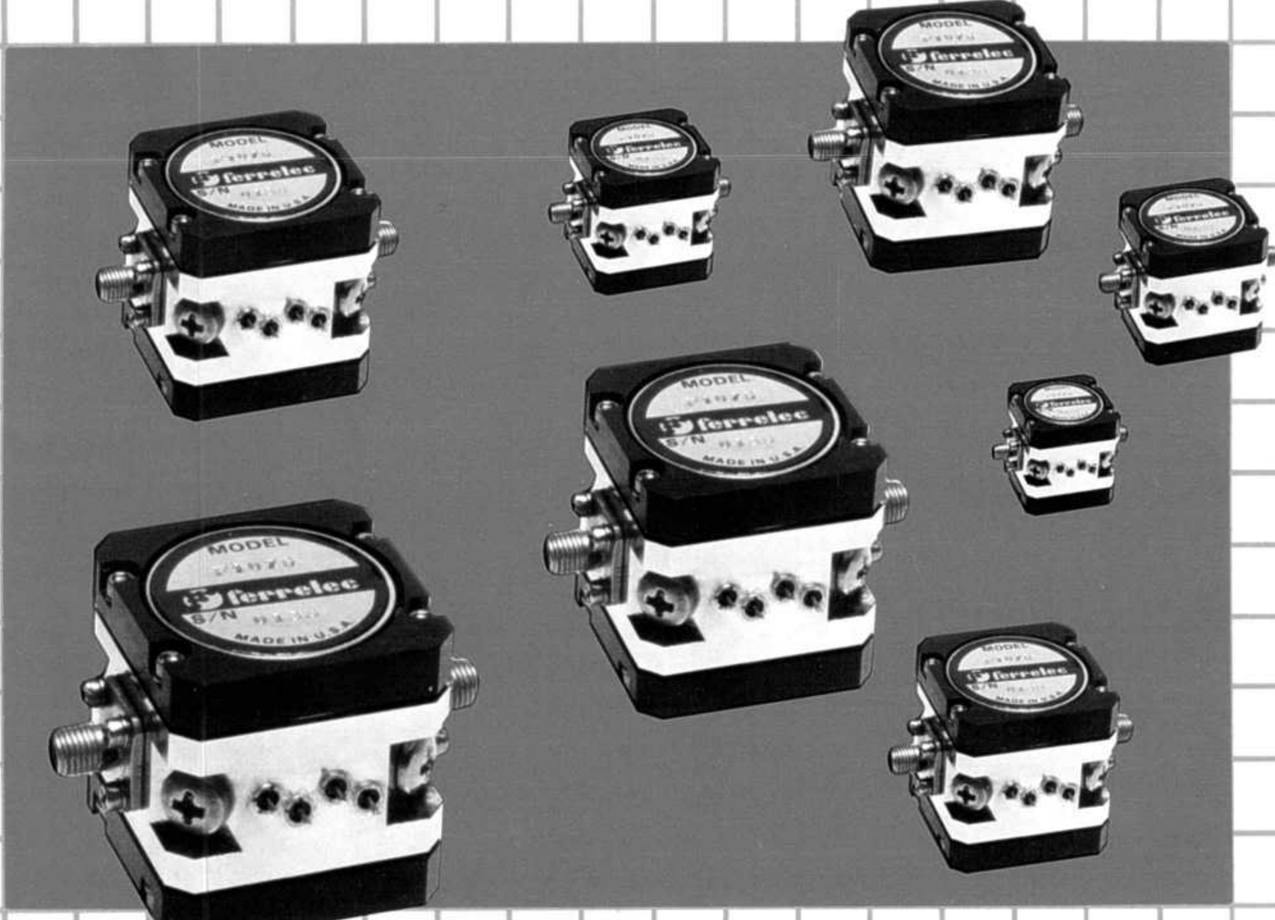

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TABLE OF CONTENTS

COLUMNS

ABOUT THE COVER

A YIG filter. The connector extruding from the left side of the device accepts the RF input, while the connector on the right is for the RF output. The four tiny circles on the front panel show the heater; this connection is also used for tuning.
(Photo courtesy of Ferretec, Inc)

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1) provide a medium for the exchange of ideas and information between Amateur Radio experimenters
2) document advanced technical work in the Amateur Radio Field
3) support efforts to advance the state of the Amateur Radio art.

All correspondence concerning *QEX* should be addressed to the American Radio Relay League, 225 Main Street, Newington, CT USA 06111. Envelopes containing manuscripts and correspondence for publication in *QEX* should be marked: Editor, *QEX*.

Both theoretical and practical technical articles are welcomed. Manuscripts should be typed and double spaced. Please use the standard ARRL abbreviations found in the 1985 and 1986 ARRL Handbooks and in the January 1984 issue of *QST*. Photos should be glossy, black-and-white positive prints of good definition and contrast, and should be the same size or larger than the size that is to appear in *QEX*.

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Empirically Speaking. . .

Automatic Control for Packet

On October 9, 1986, the Federal Communications Commission issued the following news release:

"FCC Authorizes Automatic Control for Certain Amateur Stations When Retransmitting Third-Party Traffic (PR Docket 85-105)

The Commission has amended Part 97 permitting network intermediate amateur stations, transmitting digital communications on VHF and above, using the American Radio Relay League, Inc (ARRL) AX.25 packet protocol, to be operated under automatic control while retransmitting third-party traffic.

Packet is a specialized form of digital communications, relatively new to Amateur Radio, consisting of numerous amateur stations using personal computers and associated circuitry retransmitting messages from originating stations to destination stations.

Although it acknowledged assurances of safeguards by the ARRL for the AX.25 packet protocol, the FCC noted that control operators capable of monitoring such transmissions must alert the control operator of any intermediate retransmitting station, under automatic control, of any stations misuse so that corrective action can be taken.

The Commission deferred action on requests for automatic control for digital communications on frequencies below VHF until its feasibility can be determined.

Action by the Commission October 6, 1986, by Memorandum Opinion and Order (FCC 86-427). Commissioners Fowler (Chairman), Quello, Dawson and Patrick, with Commissioner Dennis not participating."

We have seen the complete text as there is normally some delay before it appears in the *Federal Register*. Note that in the news release the authorization for transmitting third-party traffic applies only to VHF and above, not to "below VHF until its feasibility can be determined." That appears to open the door for the planned ARRL request to the FCC for a Special Temporary Authority (STA) to test the feasibility of automatic control of packet stations on MF and HF.

The announcement that ARRL would seek an STA was made in "It Seems to Us" in the May, 1986, edition of *QST*. A questionnaire was prepared and mailed to 50 stations that were known to be active or indicated interest in the STA. To date, 36 have responded. Staff work is now in progress to (a) consider frequency recommendations of the ARRL Ad Hoc Committee on Amateur Radio Digital Communication, (b) study propagational requirements, (c) prepare the STA request, and (d) develop a plan for general improvement of the HF packet-radio message-forwarding network. The purpose of the STA is to demonstrate whether packet stations can operate under automatic control at MF and HF, while handling third-party traffic, and without causing undue interference to other users. We will keep you advised as details fall into place.—W4RI

YIG Filters and Oscillators

By William Richardson, W3IMG
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Annapolis, MD 21403

The YIG device is commonly used as a filter or oscillator in electronic equipment that operates in a frequency range from 0.5 to 40 GHz. The device possesses remarkable characteristics: It has a wide frequency coverage from 2:1 to 18:1, offers electronic tuning with linearity of 0.2% or better, has a Q of 1000 or more and its size is typically 2 × 2 × 2 inches.

One drawback of the YIG device is its high cost (in the $500 to $2000 range). YIG filters were marketed in the early 1960s, followed closely by the YIG oscillator. Many of these devices are found on the surplus market in aged equipment such as microwave receivers, signal converters, signal generators and spectrum analyzers.

What is a YIG?

YIG is an acronym for Ytrrium-Iron-Garnet, a ferrite material. YIG crystals are grown and formed into spheres. When the sphere is placed in a magnetic field, it resonates, creating a condition where the resonant frequency is directly proportional to the strength of the magnetic field. If the magnetic field is generated by an electric current, the resonant frequency is directly proportional to this tuning current. There is a linear relationship, then, between the tuning current and resonant frequency.

A practical resonant circuit is created by placing a YIG sphere within a loop of wire having one turn or less. Fig 1 shows three configurations: an oscillator, a bandpass filter and a band-reject filter. YIG discriminators are available, but rare and of little use to the amateur. In each of the three cases, the YIG spheres are placed within a single magnetic field produced internally in the YIG device as shown in Fig 2. The sphere is glued to the tip of a beryllium-oxide rod which in turn is mounted to the case, rotated and aligned linearly to orient the sphere correctly in the magnetic field. The berryllium-oxide rod has excellent thermal conductivity and a self-regulating heater heats the rod to keep the YIG sphere at a constant temperature above ambient. Fig 3 shows the internal workings of a YIG device.

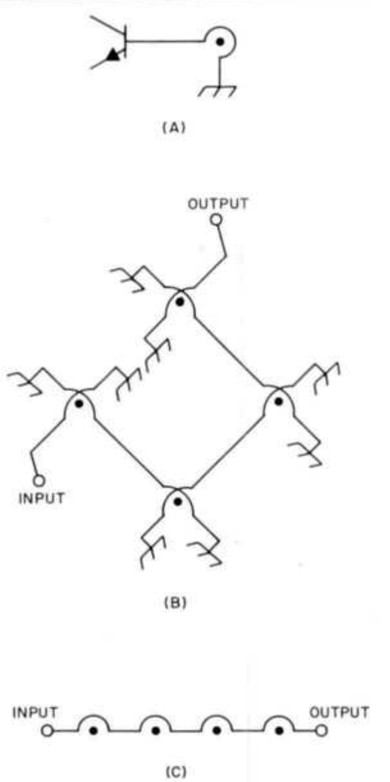

Fig 1—A YIG oscillator is shown at A, B shows a 4-pole bandpass filter and C illustrates a 4-pole band-reject filter.

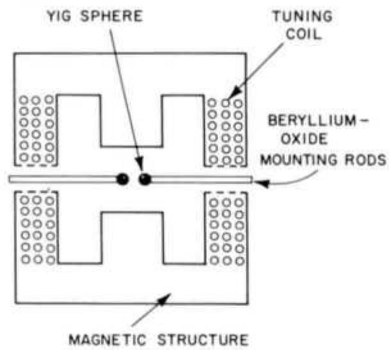

Fig 2—YIG spheres are placed within a single magnetic field. See the text for an explanation of how this is done.

Filters and Oscillators

As mentioned, YIG devices are expensive and the amateur will have to search for them on the surplus market. Older equipment will contain filters; oscillators were developed at a later date. The first YIG devices covered octave bandwidths. Later units covered wider ranges. Bandpass filters are available in 2, 3 or 4 stages. Some 4-stage filters have connectors to allow for an amplifier to be inserted between the second and third stage. Filter bandwidths of 15 to 50 MHz are commonly available with bandwidths up to 300 MHz. Oscillator power output is in the order of 10 to 50 mW. Older oscillators above 4 GHz used Gunn diodes instead of transistors; these require more power. A YIG oscillator is shown in Fig 4.

Never take a YIG device apart. The case is usually a part of the magnetic structure and it might not be reassembled correctly.

YIG Design Considerations

RF Connections

Designing equipment that uses YIG

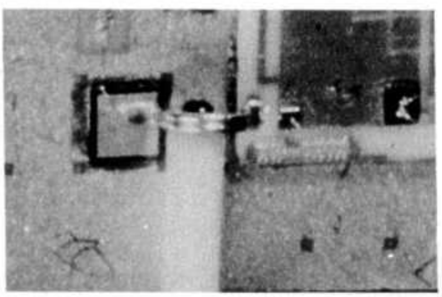

Fig 3—A close-up view of the internal parts of a YIG device. The YIG sphere is exposed at the top of the mounting rod (center). The metallic band is the coupling loop. An oscillator substrate is mounted in the upper right-hand corner.

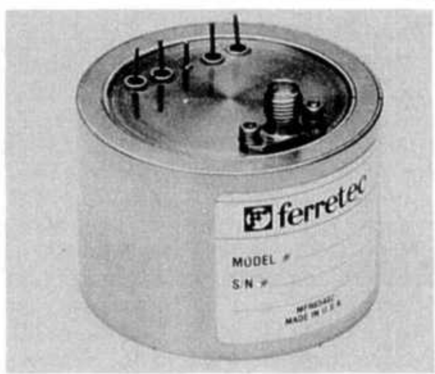

Fig 4—A cylindrical YIG oscillator. (Photo courtesy of Ferretec, Inc)

devices is easy, but three things must be considered when doing so: RF connections, device power and tuning current. RF connections are the simplest (see Fig 5). The coaxial connectors, usually type SMA, may be difficult to obtain. It is best to mount the filter and/or oscillator directly to the mixer using coaxial barrels and adaptors as necessary to reduce SWR effects. Any microwave mixer having a 50-ohm impedance and covering the desired frequency range is suitable; a doubly-balanced mixer is preferred. Fig 5 shows both a YIG filter and oscillator connection; either may be used with a variety of devices.

The usual IF for a YIG device is 160 to 250 MHz, but using a 144-MHz receiver to complete the microwave receiver is an easier design. Insertion loss of the YIG filter is about 6 dB. With the mixer and IF, the overall system noise figure (NF) is about 20 dB. A preamplier placed in front of the filter will give the best NF, but the preamplifier is susceptible to intermodulation from out-of-band signals. With the preamplifier placed after the filter, the mixer sees amplifier noise at both its normal and image response—the amplifier's NF is effectively increased by 3 dB. Dual 2-stage YIG filters have connections for inserting a preamplifier between the second and third stages and are specially designed for use with such a unit. This type of filter, however, is scarce on the surplus market.

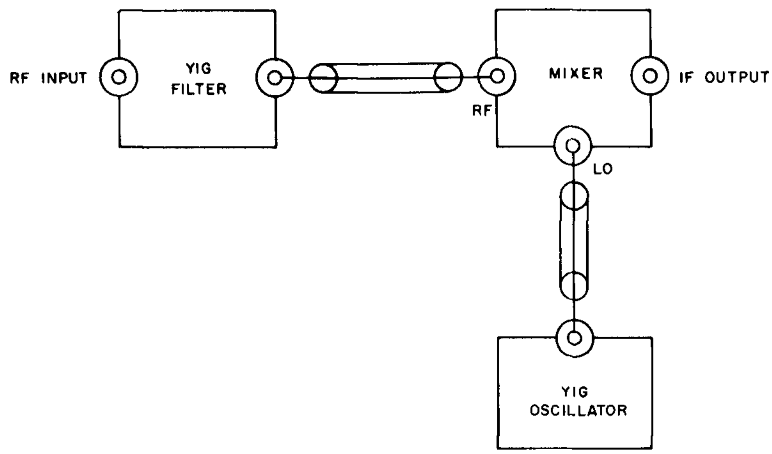

Fig 5—YIG tuner RF connections.

Device Power

YIG filters require power only for their heater. This power requirement is usually 20 to 28 volts at 5 watts or less. The initial surge may be higher. YIG oscillators have heaters and require power for the oscillator circuit. Sometimes two voltages are required for the oscillator circuit. Most older oscillators above 4 GHz use Gunn diodes that require currents up to 1.5 A. Other oscillators require that their voltage be programmed with frequency. Do not operate any YIG device without first making sure of its power requirements or the unit will fail.

Tuning Current

To design a tuning current generator (YIG controller) great care must be exercised because of its required current stability. A typical YIG device has a tuning sensitivity of 20 MHz/mA, ie, if the tuning current changes by 1 mA, the YIG resonant frequency changes by 20 MHz. Typical tuning currents vary from 100 to 1000 mA. Some fortunate experimenters ocassionally find a YIG device with an integral tuning generator. If you see a YIG in a unit, continue to look for the YIG controller circuitry as well.

Fig 6 shows a YIG controller. It is essentially a regulated, variable-voltage power supply. As the arm of the TUNE potentiometer is moved, the voltage across the sense resistor R_S follows and equals the voltage at the arm. The current through R_S and the YIG tuning coil varies in the same manner, with the current value dependent on the value of R_S. The sense resistor must be of sufficient wattage and stability so that there is no significant change in its resistance over different operating conditions. The supply voltage across the TUNE potentiometer must also be stable. A multi-turn potentiometer works best in this application. The YIG tuning current times the value of R_S must equal the range of the voltage at the arm of the TUNE potentiometer. Q1's supply voltage must exceed the sum of the voltage drops across R_S, the YIG tuning coil and Q1. The current capacity

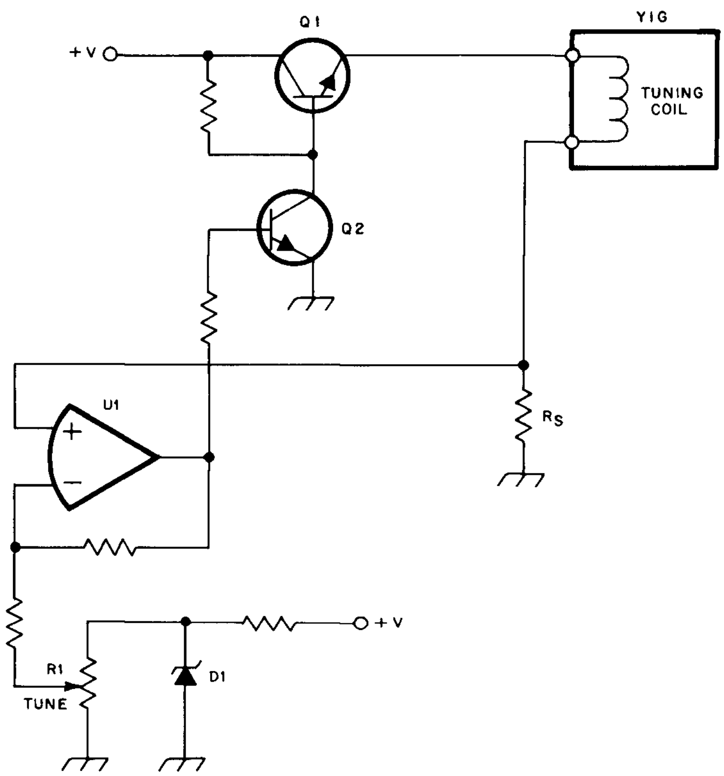

Fig 6—A typical YIG controller is essentially a regulated variable voltage power supply.

of the supply must exceed the maximum YIG tuning current. However, the supply need not be regulated.

YIG Device Operation

Most YIG oscillators have an auxiliary tuning coil often labeled FM COIL. It consists of a few turns around the YIG sphere itself and not the magnetic core material. This coil is used to frequency modulate the oscillator over small deviations up to 200 kHz. The inductance of the main tuning coil is so great that fast current changes through it generate excessive voltages across the coil because of the basic relationship E = L × di/dt.

YIG devices exhibit drawbacks when swept-tuned because the magnetic flux intensity requires a ferromagnetic core. Tuning speed is slow compared to a varactor. The maximum tuning rate is about 0.01 seconds across its entire range. Faster tuning is being developed by using laminated cores. Like all ferromagnetic devices, there is hysteresis; the tuning curve differs slightly when tuning up in frequency as compared to when tuning down. YIG devices are superior to varactor-tuned devices so far as stability and linearity are concerned.

Conclusion

Recent information disseminated from the manufacturing scene is about a small cube-shaped device called a Micro YIG.[1]

[1]C. Maker, "Cubic YIG Components Save Time and Space," *Microwaves & RF*, Apr 1986, vol 25, no 4, p 115.

Several varieties of the Micro YIG exist: a 1 cubic inch package to house components that operate at a frequency of 0.5 to 8 GHz and a 1.25 cubic inch package for applications up to 24 GHz. The device is designed to fit into tighter equipment spaces and to offer significant performance benefits in hysteresis and tuning speed. All internal connections are placed on a single surface to reduce production costs and simplify repairs. Because this development is relatively new to the marketplace, it is a matter of time before they will be available on the surplus market for a reasonable price. In the meantime, if you are considering experimentation and operation at the microwave frequencies, give serious thought to using a larger YIG device in your next project.

Bits

Antennas—A Four Day Short Course

On March 25-28, 1987, the Southeastern Center for Electrical Engineering Education at the Central Florida Facility in St Cloud, FL, will host a four-day study course on Antennas: Principles, Design and Measurements. The registration fee is $695 and this includes course materials and refreshment breaks. Early registration is encouraged. Contact SCEEE Central Florida Facility—Management Office, 1101 Massachusetts Ave, St Cloud, FL 32769, Attn: Ann Beekman, Registrar; tel 305-892-6146 for course details. —*KA1DYZ*

Call For Papers

The 1987 IEEE Vehicular Technology Conference will be held at the Holiday Inn Hotel and Convention Center in Tampa, FL during June 1-3. Papers are sought covering the full range of electronics in vehicular technology. Six copies of a 500-word summary should be submitted by December 15, 1986 to: Professor Gerard Lachs, VTC Technical Coordinator, Dept of Electrical Engineering, Univ of Southern Florida, Tampa, FL 33620. Authors will be notified of acceptance by January 30, 1987. Author's kits will be sent to the accepted authors with further instructions and deadlines. These papers will be published in the *37th Vehicular Technology Conference Record*, which will be available at the conference and from the IEEE Publications Office. Write to the above address for a list of topics to be covered.—*KA1DYZ*

Artech House Announces New Electronic Books

Each year the Artech House, Inc publishes a catalog of books related to the electronics and communication industry. During 1986, a number of new and inviting topics were covered in 10 new publications. A short sketch is offered on each:

- *Solid-State Radar Transmitters* by Edward D. Ostroff, et al; 272 pages about background and technical explanations to fully understand this technology. Practical design guidance and comprehensive theoretical discussions. Price: $60.
- *Shipboard Antennas* by Preston E. Law, Jr; 575 pages of information explaining the whats, whys and hows of over 250 individual naval and commercial antennas. Illustrations cover what is needed to integrate naval antennas into the complex electromagnetic environment of a modern ship. Price: $61.
- *Electric Filters* by Martin Hasler, PhD, and Jacques Neirynck, PhD; discover how to go beyond simple filter designs and understand the theoretical background of filters in this 355-page book that sells for $60.
- *Microwave Mixers* by Stephen A. Maas, PhD; this 500 page book deals with the theory, analysis, design and system applications of microwave and millimeter-wave mixers and mixer circuits. Price: $60.
- *Linear Active Circuits: Design and Analysis* by William Rynone, PhD; the newest and most comprehensive approach to linear circuit analysis is available in these 540 pages. Price: $66.
- *Microwave Tubes* by A. S. Gilmour, PhD; a comprehensive and balanced review of the operating principles of microwave tubes is covered in 600 pages. Price: $60.
- *Dielectric Resonators* by Darko Kaifez, PhD and Pierre Guillon, PhD; a 500-page compilation of the currently available information on dielectric resonantors and their applications in microwave circuits. Price: $60.
- *Distributed Processing and Database Systems, Vol I & II* by Wesley W. Chu, PhD; a two-volume book featuring an in-depth review of the latest advances in both distributed data processing and distributed database systems. The two-volume set sells for $112; vol I consists of 300 pages and vol II has 500 pages; each costs $56.
- *Signal Theory and Processing* by Frederic de Coulon; 550 pages worth of signal generation, detection and interpretation techniques. Price: $60.
- *Telecommunication Systems* by Pierre-Girard Fontolliet; these 450 pages provide a global, macroscopic view of telecommunication networks and systems. Detailed background of the practical aspects of transmission methods, modulation, system operation and network planning is included. Price: $60.

Prices are subject to change without notice. It is best to contact the Artech House, Inc, prior to purchase. Write to 685 Canton St, Norwood, MA 02062 for further information on the mentioned publications.—*KA1DYZ*

Error Detection and Correction Codes

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Background

Errors! Computers are not supposed to make errors, but they happen anyway. Any ham who has worked with 64 kbytes of dynamic RAM or another large data storage device knows that error detection and correction are a fact of life. If the error is not detected, the false data can result in serious consequences.

Several methods to detect and correct errors have been devised. One of the first methods used was to transmit the data twice. After transmission, the two sets of data were compared. If one set varied from the other, an error was detected. There was no way to tell which set of data was correct, thus a third set had to be transmitted. If any two sets of data agreed, those sets were assumed to be correct.

There are many problems with the data comparison method. It requires redundancy (three sets of data) and is far from foolproof. Modern error detection and correction has evolved into three basic methods:

- Parity checks
- Hamming codes
- Binary cyclic codes

Each method requires some degree of redundancy and neither are foolproof. They are widely used because they are the best available methods for most applications. Let's examine each category for an understanding of how these methods work.

Parity Checks

Parity checks (or parity bits) are error detection methods. This method will not correct errors; instead, it also requires retransmission of data. With this scheme, one bit is added to the end of a data word according to set rules:

To obtain *even parity*, the parity bit must make the total number of 1s in the word an even number. To be considered *odd parity*, the parity bit makes the total number of 1s in the word an odd number.

Even and odd parity bits for all possible four-bit words are shown in Table 1. Either type of parity will detect an error.

Table 1—Even and odd-parity bits for all possible four-bit words.

Data	*Even Parity*	*Odd Parity*
0000	0	1
0001	1	0
0010	1	0
0011	0	1
0100	1	0
0101	0	1
0110	0	1
0111	1	0
1000	1	0
1001	0	1
1010	0	1
1011	1	0
1100	0	1
1101	1	0
1110	1	0
1111	0	1

Encode and Decode Circuits

Most circuits used to generate parity checks are made from exclusive OR gates. Fig 1A shows the schematic symbol for the two-input gate device. It has an output of 1 when either input is 1. When both inputs are 1 or 0, the output is 0. The three-input gate shown in 1B can be made from a two-input gate. Fig 1C shows how this can be accomplished.

A circuit for the generation and detection of even parity on a set of four-bit data is shown in Fig 2. The circuit functions as follows:

- The four transmitted bits are tied to the input of an exclusive OR gate. The output is the even-parity bit.
- At the receiving end, the parity bit is generated again using the same method. This regenerated parity bit is compared to the transmitted parity bit through an exclusive OR gate.
- If the received parity bit is the same as the regenerated parity bit, the parity check will be 0 and no error has occurred. If they are different, the parity check will be 1. The check indicates that an error has occurred and the data must be retransmitted.

A close analysis of the circuit in Fig 2 reveals the following conditions:

- When an error is detected, it can occur in either the data bits or the parity bit.
- If two data bits are in error, the error will go undetected.

In most data systems, the probability of having a single bit error is very low. The probability of erroneously transmitting two or more bits is much lower than that.

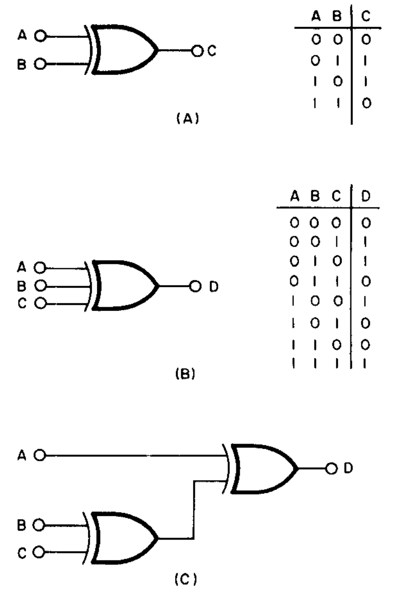


Fig 1—The schematic symbol for an exclusive OR gate. At A, the device is shown with a two-input gate. In B, the XOR has a three-input gate. C shows how a two-input gate can be converted to a three-input gate. The table next to each device lists the parity results when an even or odd bit is input to each gate of the XOR.

Hamming Codes

While parity checks are useful and commonly employed, it would be better if the error could be detected and corrected at the receiving end. Retransmission of the data would be unnecessary. There is such a technique that can both detect and correct single bit errors. It is called the *Hamming code*, named after its inventor R. W. Hamming.

The Hamming code for four-bit data is shown in Table 2. Three check bits have been added to each four-bit data work. The check bits have been chosen because on a bit position by bit position basis, any two of the seven-bit words differ in at least three positions. Here's an example:

Data word (A) and data word (B) differ

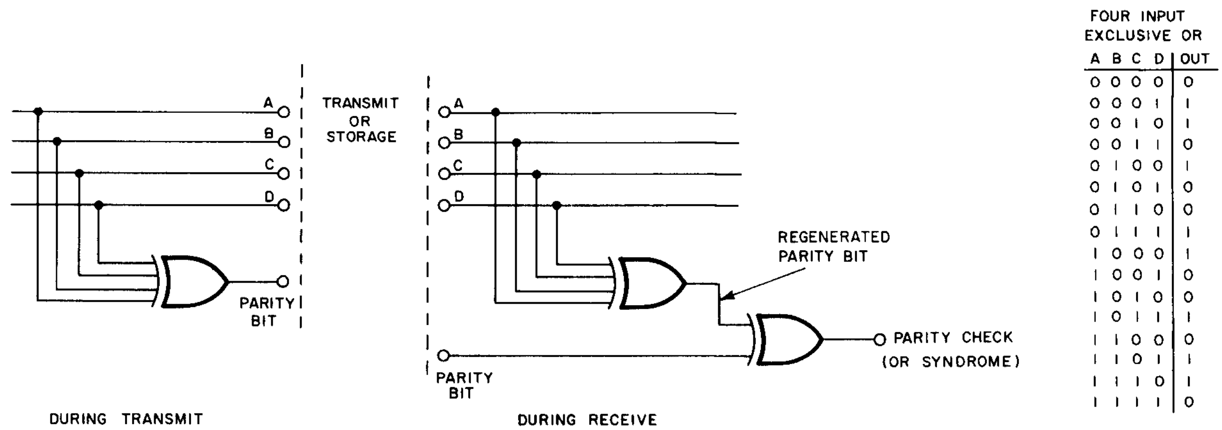


Fig 2—A complete circuit for generation and detection of even parity on a set of four-bit data.

Table 2—The Hamming code for four-bit data.

Word	*Data Bits*	*Check Bits*
A	0000	000
B	0001	011
C	0010	110
D	0011	101
E	0100	111
F	0101	100
G	0110	001
H	0111	010
I	1000	101
J	1001	110
K	1010	011
L	1011	000
M	1100	010
N	1101	001
O	1110	100
P	1111	111
Position	1234	567

in position 4, 6 and 7. Any two words chosen will differ in at least three places.

If one bit error occurs in a word, it is only one bit removed from the correct data and at least two bits removed from any other word in the data set. The error is then corrected by changing it back to the data word that it is closest to on a bit position by bit position comparison. Hamming codes are also known as *nearest neighbor* codes; correction occurs by changing the word to that of its nearest neighbor.

Other jargon often heard when working with error detection and correction material are:

Hamming Weight—the total number of 1s in a code word.

Hamming Distance—the number of bit positions that are different between two code words.

Minimum Distance—the minimum hamming distance between any two words in a set of data.

Operation of an Encode and Decode Circuit

A complete circuit for the use of the Hamming Code is shown in Fig 3. The code is generated by three exclusive OR gates. An examination of these gates show that they generate the three check bits of Table 2.

On the receiving end of the circuit, the check bits are regenerated. The transmitted check bits and the regenerated check bits are compared (or binary added) in exclusive OR gates XOR1, XOR2 and XOR3. The output of these gates is known as the *syndrome*. A zero syndrome indicates that no error has occurred, a nonzero syndrome raises the error flag.

For error correction, the syndrome is fed to a standard 3-of-8 decoder such as the 74S138. The output of the decoder is added back to the data through exclusive OR gates XOR4 to XOR7. To understand the complete action of this circuit, assume that an error has occurred. Let's go through the circuit, step-by-step, to see what happens.

1) The data word A, B, C, D = 1011 is transmitted.
2) From the circuit or from Table 2 the check bits are X1, X2, X3 = 000.
3) The error occurs in position A. The received data word is now received as A, B, C, D, X1, X2, X3 = 0011000.
4) The receiving circuit will generate check bits of X1, X2, X3 = 101 because it received the data A, B, C, D = 0011.
5) The outputs to the syndrome are XOR1 = 1, XOR2 = 0, XOR3 = 1. The error flag will be 1.
6) The input to the 3-of-8 decoder is 101. The output is Y5 = 0, Y7 = 1, Y6 = 1, Y3 = 1.
7) The input to XOR4 is 0,0, its output through the inverter is A = 1. The input to XOR 5 is 0,1, its output through the inverter is B = 0. The input to XOR 6 is 1,1, its output through the inverter is C = 1. The input to XOR7 is 1,1, its output through the inverter is D = 1.
8) The corrected output is A, B, C, D = 1011. The same as the transmitted data.

More Hamming Codes

Hamming codes exist for a wide range of data lengths. The general equation is:

$$N = \left[2^{(N-K)} - 1\right] \quad \text{(Eq 1)}$$

where

N = the total number of bits (data plus check)
K = the number of data bits
(N-K) = the number of check bits

N-K	N	
1	1	
2	3	
3	7	four-bit data, three check bits
4	15	
5	31	

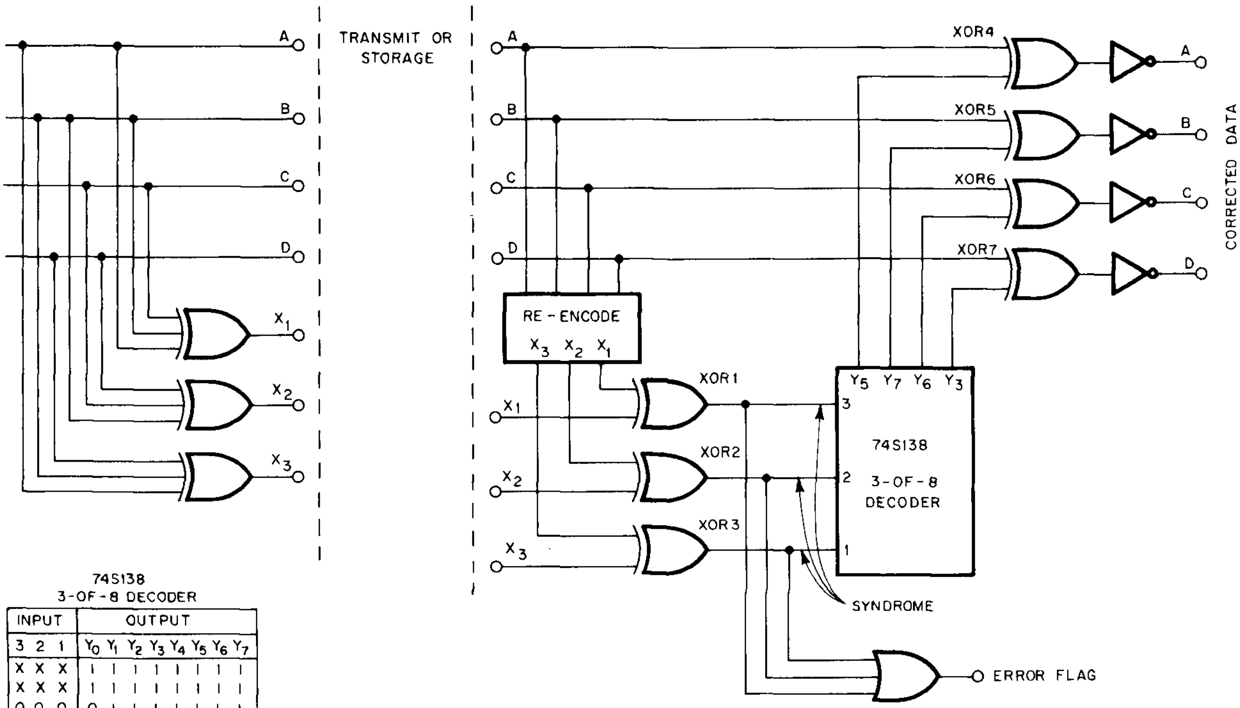
Four-bit data words fit a Hamming code exactly. It is called the *seven/four* or 7,4 *code*. Another type of Hamming code exists for data consisting of eleven data bits and four check bits. This is adapted to 8-bit data blocks by shortening the code. A circuit to generate check bits for 8-bit data is shown in Fig 4.

Binary Cyclic Codes

Another form of error detection and correction code is called the *binary cyclic codes*. Using cyclic codes, the binary data (Px) is divided by a binary number (Gx). This produces a quotient and a remainder.

Px/Gx = Quotient + Remainder (Eq 2)

The remainder is added to the end of the



74S138
3-OF-8 DECODER

INPUT			OUTPUT							
3	2	1	Y_0	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7
X	X	X	1	1	1	1	1	1	1	1
X	X	X	1	1	1	1	1	1	1	1
0	0	0	0	1	1	1	1	1	1	1
0	0	1	1	0	1	1	1	1	1	1
0	1	0	1	1	0	1	1	1	1	1
0	1	1	1	1	1	0	1	1	1	1
1	0	0	1	1	1	1	0	1	1	1
1	0	1	1	1	1	1	1	0	1	1
1	1	0	1	1	1	1	1	1	0	1
1	1	1	1	1	1	1	1	1	1	0

Fig 3—A complete encode/decode circuit for Hamming codes on four-bit data.

data in the form of check bits:

D1	D2	D3	D4	D5	D6	D7	Dn

C1	C2	C3	C4	Cn

When the data is received, this division is again performed by:

$$\frac{Px + Remainder}{Gx} \qquad \text{(Eq 3)}$$

If no errors occurred, the result of this second division is a remainder zero. If an error occurred, this second division will produce a nonzero remainder. The result of this second division is also called the syndrome, ie, a nonzero syndrome indicates an error.

In real circuits the binary division is performed by linear feedback shift registers (LFSR). These circuits consist of exclusive OR gates together with shift registers.

An example of this circuit is shown in Fig 5A. When the four-bit data word of 1101 is shifted through the register, the remainder is X3, X2, X1 = 001. If you shift all possible four-bit data words

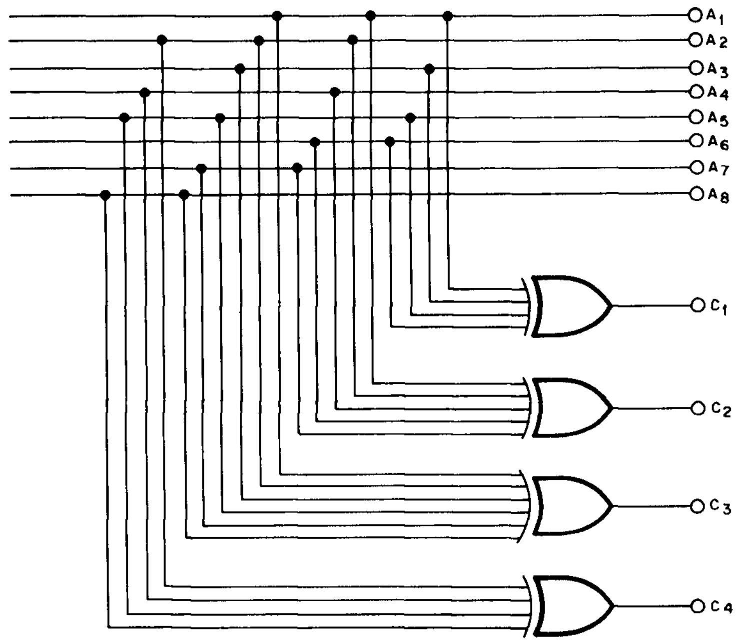


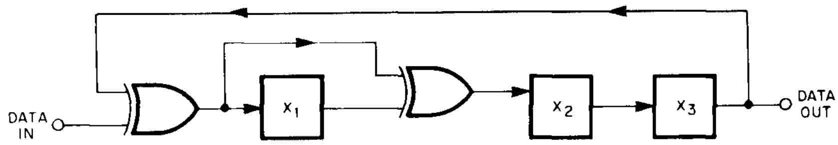
Fig 4—This circuit generates check bits for 8-bit data.

through this register, the remainders will turn out to be the same as the check bits of the Hamming code for four-bit data.

Fig 5B shows the seven-bit word 1101001 being shifted through the register. This data word is word "N" from Table 2. No error occurs, so the remainder left in the register is zero. Fig 5C shows a seven-bit data word that has an error. It is not one of the words in Table 2. The resulting nonzero register indicates that an error has occurred.

Conclusion

It is important to understand how detection and correction codes work. If errors in digital data transmission are to be reduced, then understanding and applying error detection and correction codes are a key element in the system.



DATA	SHIFT	$X_1\ X_2\ X_3$
		0 0 0
1	1	1 1 0
1	2	1 0 1
0	3	1 0 0
1	4	1 0 0

(A)

DATA	SHIFT	$X_1\ X_2\ X_3$
		0 0 0
1	1	1 1 0
1	2	1 0 1
0	3	1 0 0
1	4	1 0 0
0	5	0 1 0
0	6	0 0 0
1	7	0 0 0

(B)

DATA	SHIFT	$X_1\ X_2\ X_3$
		0 0 0
1	1	1 1 0
0	2	0 1 1
0	3	1 1 1
0	4	1 0 1
0	5	1 0 0
0	6	0 1 1
1	7	1 1 1

(C)

Fig 5—The binary cyclic codes are used to detect and correct errors. In A, exclusive OR gates and shift registers are connected to perform binary division. B shows the 7-bit data word 1101001 being shifted through the register. In C, the nonzero register indicates that an error has occurred.

Bits

Howard W. Sams & Co Offers Two New Books for the Electronics Enthusiast

IC Op-Amp Cookbook, authored by W. G. Jung, is written for hobbyists, technicians and design engineers. This third edition publication discusses the newest era of circuit design created by the introduction of the operational amplifier. The theory of the basic op amp is presented in detail. Over 200 practical circuit applications, material on instrumentation amps, information on the latest IC devices and manufacturer's data sheets are included. The *IC Op-Amp Cookbook* is a 600-page, softbound book retailing for $18.95. Contact Howard W. Sams & Co at the address listed below.

Progression into the modern technical telecommunications field is simplified with *Introduction to Digital Communication Switching*, written by J. R. Ronayne. This 200-page, softbound reference guide will expose readers to the concepts of digital communication switching—efficient channeling of incoming and outgoing telephone signals. Book discussions include pulse code modulation, error sources and prevention, digital exchanges and control and all-digital networks and the Open Systems Interconnection model. Price: $23.95. Contact Howard W. Sams & Co, 4300 W 62nd St, Indianapolis, IN 46268 or call 800-428-SAMS.—*KA1DYZ*

Siliconix Introduces the DG5240 Family of High-Speed CMOS Switching

Siliconix recently announced a new low-power, high-speed latched CMOS analog switch. The DG5240-DG5245 family of solid-state analog switches feature latched inputs, very fast switching action (t_{on} is less than 100 ns and t_{off} is less than 75 ns), an ON resistance of less than 30 ohms, ±15 V input range and ultra low power requirements (less than 1 μA). Benefits of using these devices include microprocessor compatibility, break-before-make switching action, low signal error, normally open or closed switches and battery operation. Applications for which these switches are used are high performance switching, sample and hold circuits and digital filters. Each switch is bidirectional and maintains almost constant ON resistance throughout their operating range. Package options include the 16-pin plastic and ceramic DIP. Performance grades range from 0 to 70°C and −55 to 125°C. For a DG5240 family data sheet, write to Siliconix, Inc, 2201 Laurelwood Rd, Santa Clara, CA 95054; tel 408-988-8000. —*KA1DYZ*

New Software for Digital Circuit Design

Logicware CADCD means software for Computer Aided Digital Circuit Design. This package performs minimization of Boolean functions into minimum sum of products and/or minimum product of sums form.

The software can handle up to eight input variables, up to eight output functions and "don't care" conditions. The program provides for easy design of sequential machines using up to eight JK and/or D flip flops, and minimized functions for the J, K and/or D flip-flop inputs are directly produced.

The program is menu driven to provide for a simple user interface. The Boolean functions are entered to the program in truth table format. The truth table can be edited, saved to disk, loaded from disk or printed. For sequential machine design, the truth table expresses the next state of each flip flop as a function of the current state and other inputs. The results of the minimization can also be displayed on screen, saved to disk or printed.

Cost of the program is $59 and is available for the IBM® PC, Apple® IIe and Apple IIc. Contact Logicware, 2346 W Estrella Dr, Chandler, AZ 85224; tel 602-821-2465.—*KA1DYZ*

A 100-MHz Universal Frequency Counter

By Dave Kunkee, KØDI
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Not long ago, I built a frequency counter useful from dc to 100 MHz. The counter uses the Intersil 7216 function counter chip in the basic circuit found in the *Intersil Data Book*.[1] Though the chip is only guaranteed to work up to 10 MHz, my unit tops out at 14.730 MHz.

Several modifications were made to the circuit to make the project more applicable to Amateur Radio. A preamplifier was included so that a frequency reading can be obtained from a pick-up loop placed close to the final amplifier of a transmitter. There is also a divide-by-ten frequency prescaler chip to allow operation to 100 MHz. Fig 1 is a block diagram of how the frequency counter works. Fig 2 is its schematic diagram.

The counter circuitry is contained on three printed circuit boards. These were made by cutting a pattern on ruby-lith and using photo-sensitive circuit boards (ultraviolet). The main circuitry is contained on a single-sided 3 × 4 inch board. The eight multiplexed displays are contained on a double-side 2 × 6 inch board that is mounted near the switches already soldered to the board. This process allows easy and neat construction of the displays.

The Intersil chip is more than just a frequency counter; it is a function counter. This chip can count frequency with 0.01,

[1]Notes appear on page 14.

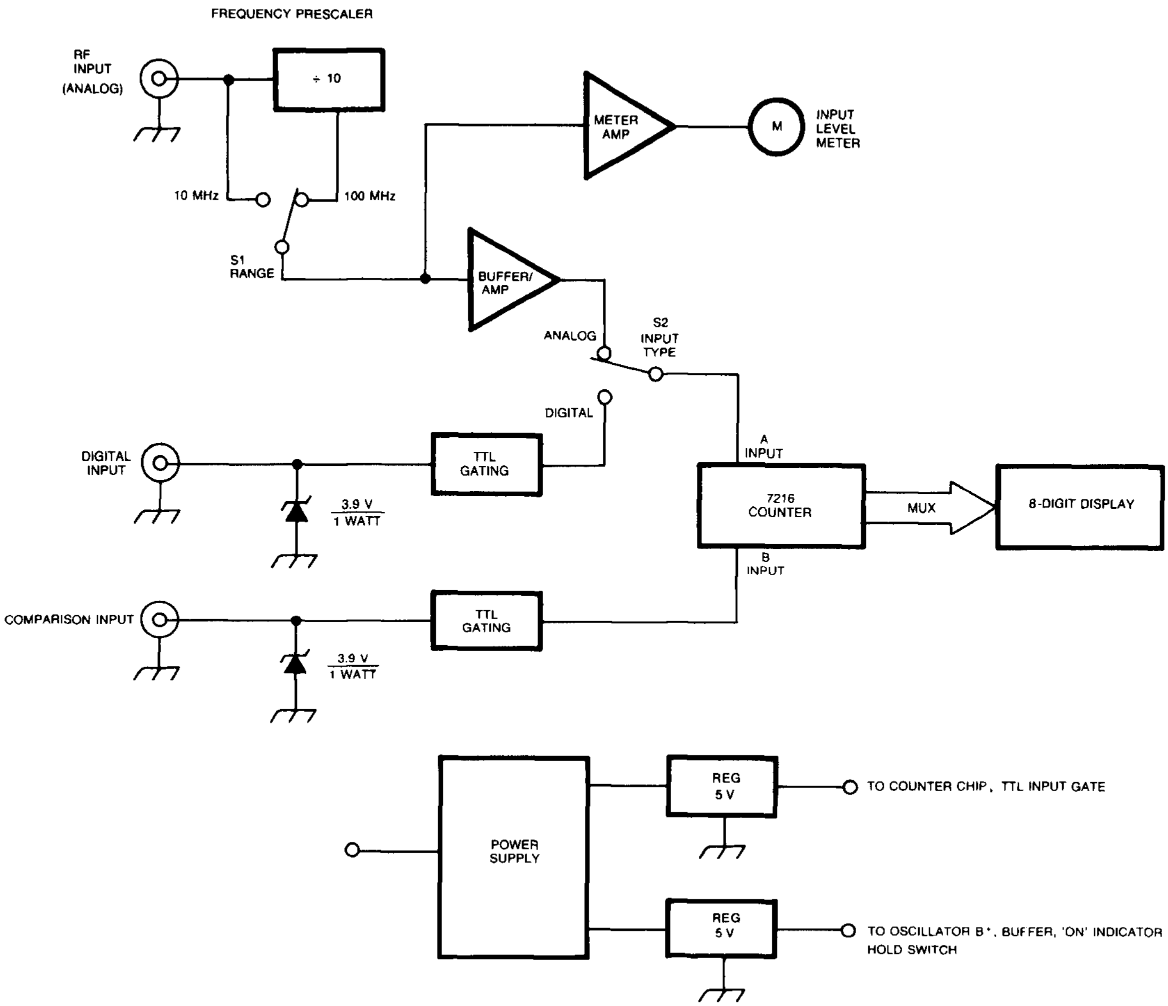

Fig 1—A block diagram of the 100-MHz Universal Frequency Counter. There are three inputs: RF, digital and comparison. The comparison input is for ratio and the distance start/stop mode only. The power source supplies 6.3 V at 3A. U3 and U4 are 5 V, 1.5 A voltage regulators.

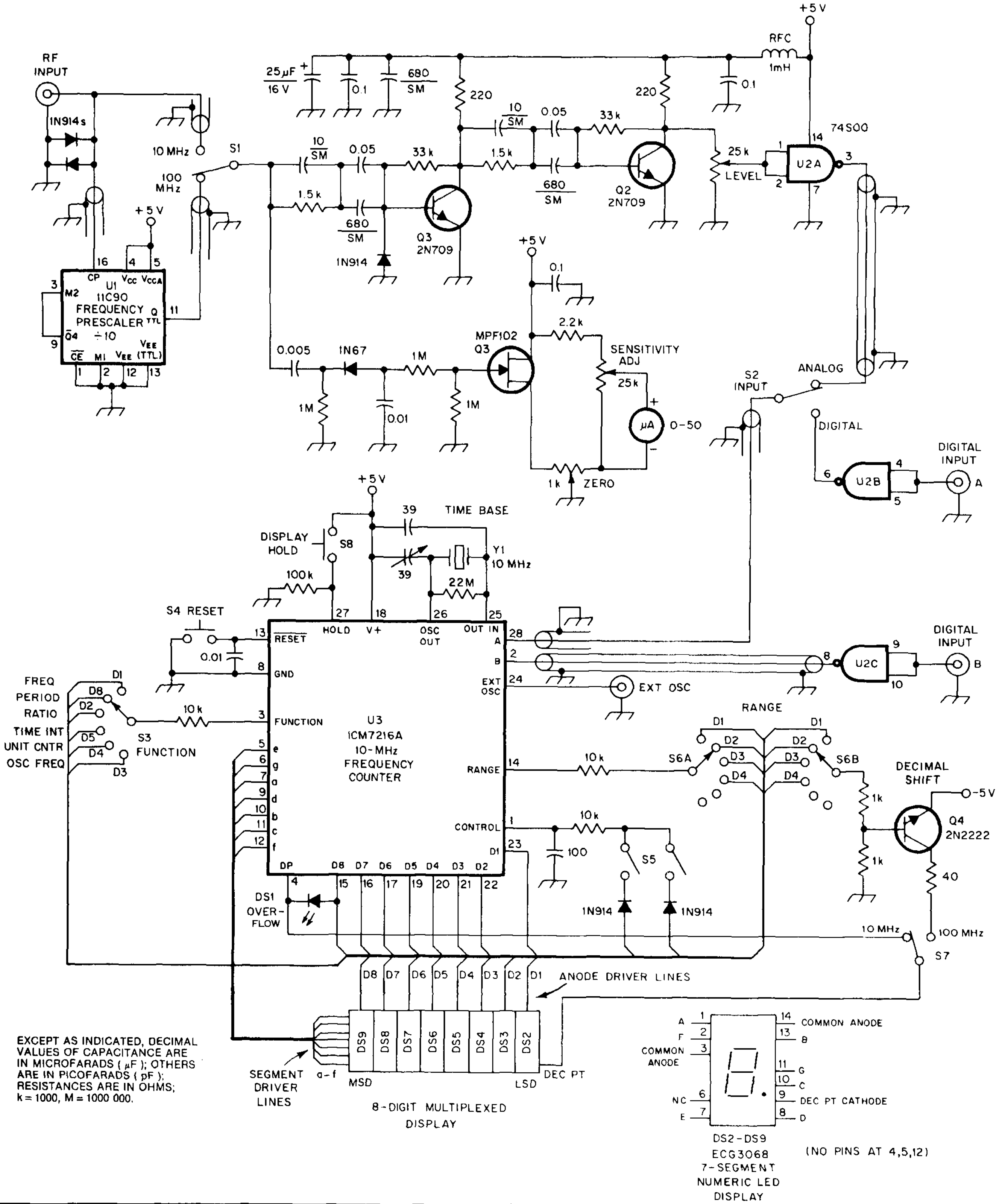

Fig 2—The schematic of the complete front-end circuit. The schematic first appeared in an article by Jim Pollock, WB2DFA, *Ham Radio*, Jan 1976.

DS2-DS9—Seven-segment numeric LED display, common anode (ECG3068-RED or equiv).
S1,S2,S7—SPST.
S3—Rotary wafer, one section, 6 positions, ceramic.
S4, S8—Push-button switch, SPST, normally open.
S5—SPDT.
S6—Rotary wafer, 2 sections, 6 positions, ceramic.
U1—Fairchild 11C90 frequency prescaler chip.
U2—74S00.
U3—7216A 10-MHz LSI frequency counter.

Continued on page 14.

By Bill Olson, W3HQT
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Noise Figure Measurement

Of all the homebrew projects an amateur builder can attempt, the low-noise preamplifier can probably make the biggest difference in performance with the smallest amount of effort. There are numerous published and proven designs. Only a few parts are required, and they are inexpensive. For this reason, the preamp is an excellent first project. It's also an excellent 1000th project because it seems like the devices available at reasonable prices just keep getting better and better.

For those of us who have built 20 or 30 preamps, having a means for testing our work becomes very desirable. After all, there isn't always a VHF conference with a noise measuring session occurring at the right time. Just because the manufacturer's data sheet for a low-noise device says it will have a 0.5-dB noise figure at 2 GHz doesn't mean the preamp will do that! For optimum noise performance, a device must be terminated with an impedance on the input that mismatches the device in the proper way. This input reflection coefficient is known as gamma opt and is not always specified by the manufacturer. The thing to remember here is that the input match to a device for low noise is not the same as for maximum gain. So, since we can't just tweak for maximum smoke, how do we tune up a preamp?

In the old days, before I could afford the proper equipment, tuning up on a weak signal was about the only way. Dave Mascaro, WA3JUF, used to have a 1296-MHz signal source sitting up in a tree a couple of hundred feet away from the 1296 antenna. When he wanted to check to see if his receiving system was working, or when he wanted to try out a new preamp, he just pointed the antenna at the weak-signal source. The signal could be attenuated by rotating the antenna away from the source. In this way he could always have a signal right at the noise to peak up on. This method is full of pitfalls, however. After listening to a receiver full of white noise and a barely perceptible signal for a couple of hours, I normally start hearing things like the New York Philharmonic Orchestra. Obviously there has to be a better way. The correct tool for the job is the automatic noise-figure meter.

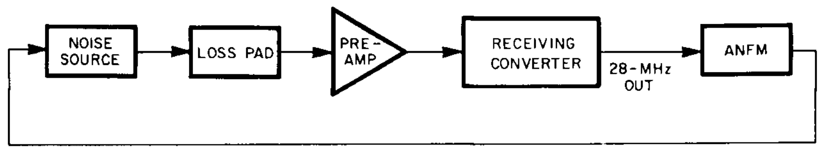

Fig 1—Here is a typical test setup for measuring the noise figure of a receiving converter. The loss pad is optional (see text). Most ANFMs use a 30-MHz input, so a converter must be used when testing higher-frequency preamps. Most noise-figure meters work fine with a 28-MHz input, so you can use an existing receiving converter.

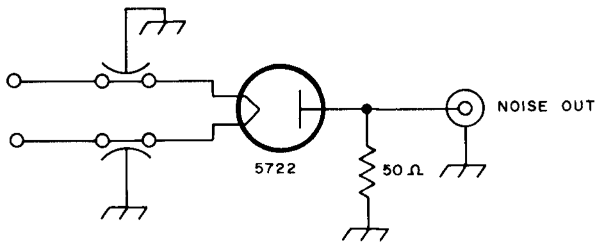

Fig 2—Thermionic diode noise sources such as this are normally usable up to 600 MHz. The ENR is about 6 dB.

Automatic Noise-Figure Meters

The automatic noise-figure meter (ANFM) is an instrument that measures the *noise figure (NF)* of a receiving system by monitoring the noise-power output of a receiver while the receiver input is switched between a 50-ohm resistive source and a 50-ohm noise source with a known amount of *excess noise*. Noise sources are specified as to their excess noise by the term *excess noise ratio (ENR)*. The ENR is the ratio in decibels of the noise output of the noise source versus the noise-power output of a resistor of the same resistive value at the same temperature. The following equation relates NF to ENR:

$$NF(dB) = ENR(dB) - 10\log(N2/N1 - 1) \quad \text{(Eq 1)}$$

where

N1 = output power with noise source off

N2 = output power with noise source on

Since N2 and N1 can be measured by the noise figure meter and the ENR is known, we can solve the equation. The ANFM does the math and displays the NF of the preamp or receiving system in dB. There are a number of articles in the amateur literature on automatic noise measurement theory and techniques, and readers are urged to consult these for a more in-depth treatment of the subject. See references 1-4 at the end of this column.

There are a number of different ANFMs available surplus and at flea markets these days, especially with the appearance of the HP8970A digital readout, microprocessor-controlled machine. Models to look for are the HP340A and B and 342A, as well as the AIL models 74 and 75. The older units show up for as little as $50 in working condition. When used with a suitable noise source, useful noise figure measurements can be made. See Fig 1.

Noise Sources

Noise sources come in three basic types: 1) the temperature-limited thermionic diode; 2) the argon gas tube; and 3) the solid-state diode noise source. The HP meters mentioned above and the AIL 74 have internal power supplies for both gas tubes and thermionic diode heads. The AIL 75 can also be used with a solid-state source. HP thermionic diode sources use a tube-type diode similar to a Sylvania 5722 and are usable up to around 600 MHz (see Fig 2). The most commonly used source is the HP 343A, which has an excess noise ratio of around 5 to 6 dB depending on frequency. There are a number of articles on homemade diode noise sources if you want to build your own. See references 5-8.

Gas-tube noise sources use an argon discharge tube coaxially mounted in a helical transmission line, as shown in Fig 3. The most common ones are the HP349A and AIL7010. Both are usable from around 200 MHz to over 3 GHz and have ENRs of around 15 dB. Both can be used with HP and AIL ANFMs with the appropriate interconnections. Since the gas-tube noise sources require an ionization pulse of a few thousand volts to light off the tube, a voltage spike of several volts appears in the output. This spike can wipe out many solid-state front ends (and who isn't using a solid-state front end these days?). Therefore it is recommended to use a 10-dB pad between the gas tube and receiver or preamp input to attenuate this pulse.

This pad has the additional advantage of making the meter readout more usable on the HP 340 series meters. Since these meters were designed long before low-noise solid-state front ends, the meter scale only goes down to 3 dB and meter calibration is best in the 10 to 20 dB NF range. With an accurate 10-dB pad added to the noise source, the '340 will read 0- to 10-dB NF in the center of the instrument meter.

A third advantage to using a loss pad between the noise source and preamp or receiving system applies to all types of noise sources. Since the noise figure of a transistor preamplifier depends upon the input reflection coefficient presented to the device as mentioned above, readings will only be accurate (and reproducible) if the noise source presents an accurate 50-ohm load to the input of the preamp. This must occur so that the preamp input matching network will in turn present the proper impedance to the device. One of the biggest contributors to measured differences from one NF setup to another is variations in load impedance from one noise source to another. The use of a good pad can minimize this variation.

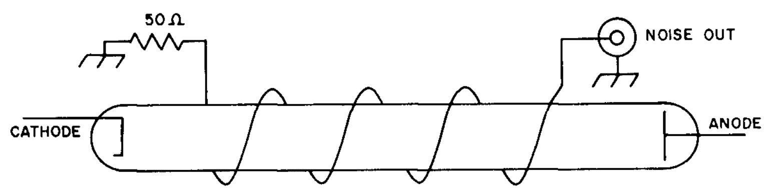

Fig 3—An argon gas-discharge tube noise source covers 200 to 3000 MHz with an ENR of about 15 dB.

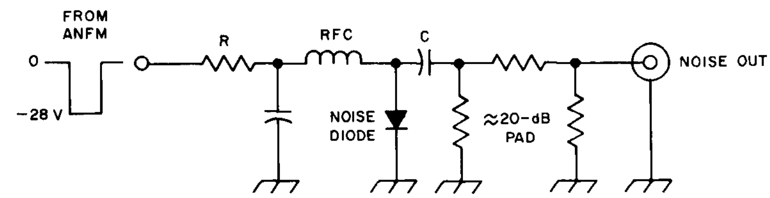

Fig 4—Commercially-manufactured solid-state diode noise sources use specifically designed noise diodes which are designed to give a constant noise output over a broad frequency range.

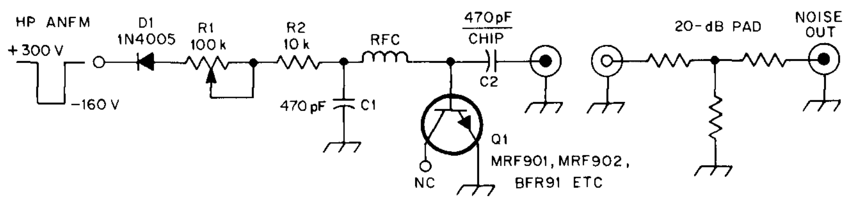

Fig 5—A homemade solid-state noise source is easy to build. This one is for use with HP340 and '342 noise-figure meters. R1 is adjusted for an ENR of 5.2 dB. This is accomplished by calibrating your test setup with a preamp of known performance. Accurate noise-figure test setups are available for use at most VHF conferences. D1 and R1 can be mounted in a box near the NF meter. The rest of the circuit mounts on the back of an SMA connector, as shown in Fig 6.

Solid-State Noise Sources

Modern noise-figure measuring systems use solid-state diode noise sources. This type of source is nothing but a microwave diode back-biased into avalanche, capacitively coupled to the output. An avalanching diode is *very* noisy. Since most high-frequency diodes are capable of providing up to 30 dB or more excess noise, a precision attenuator is usually built into the noise source to put the ENR in the 5- or 15-dB range for use with most ANFMs. See Fig 4.

While solid-state noise sources do not often turn up on the flea market circuit, a very usable one can be built using a reverse-biased emitter-base junction of an inexpensive microwave transistor. Excess noise will depend on the transistor chip, the transistor package, the coupling capacitor, the attenuator and the physical layout, so it's hard to know ahead of time exactly what the ENR will be. If the bias current is made adjustable, the source can be calibrated using a preamp of known performance.

The noise source I use is similar to one built by Paul Wade, N1BWT, a number of years ago. It uses an el-cheapo microwave device (I think I'm using a BFR91-type device in a ceramic package), and is built right on the back of an SMA male flange-mount connector. See Figs 5 and 6. All connections should be kept as short as possible, and the RF choke should be optimized for the frequency in use. A 1-kΩ, ¼-W resistor can be used as a broadband RF choke as an alternative. Since it only takes 4 or 5 V at a few mA to avalanche the emitter-base junction, and the diode output pulse on an HP340/342 goes from +300 to −160 V, a series diode and dropping resistor are used to provide a negative-going pulse of the proper level. For multi-band noise measurement, a multi-position switch can be used to switch in different dropping resistors for each band. Even without a preamp of known performance for calibration, this noise source can be used for preamp optimization.

To summarize, there is probably no part of an amateur station, especially in the UHF and SHF range that can be improved so much for as little investment as the receiving front end. GaAs FETs with noise figures in the tenths of a dB are

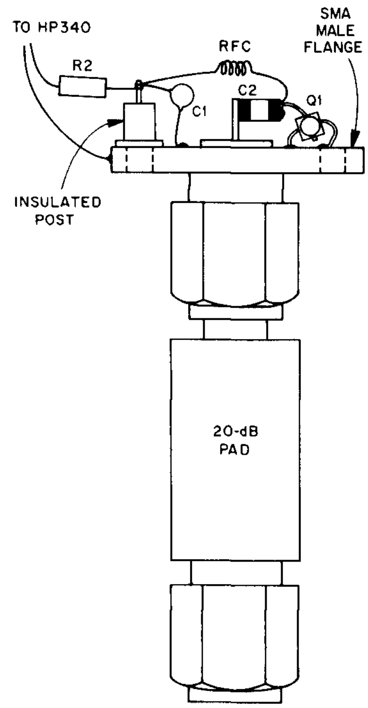

Fig 6—Construction details of the noise source shown in Fig 5.

available these days for under $10, and circuits abound. To get the most out of a preamp, however, it must be tuned for minimum noise. Once again, as technology rolls along, it leaves behind the tools with which we can perform these measurements at a reasonable cost!

Next month's column will be the final test equipment installment. In it I will discuss antenna gain measurement and show how to get reasonable backyard measurements (and how not to).

References

[1]B. Stein, "Automatic Noise Figure Measurements—Fact and Fancy," *Ham Radio*, Oct 1975, p 40.

[2]J. Fisk, "Receiver Noise Figure, Sensitivity and Dynamic Range—What the Numbers Mean," *Ham Radio*, Oct 1975, p 8.

[3]B. Lowe, "Hot and Cold Resistors as UHF Noise Sources," *QST*, Sept 1976, p 32.

[4]*Noise Figure Primer*, Application Note 57, Hewlett Packard, Palo Alto, CA, Jan 1965.

[5]B. Stein, "Diode Noise Source for Receiver Noise Measurements," *Ham Radio*, June 1979, p 32.

[6]J. Huie, "A VHF Noise Generator," *QST*, Feb 1964, p 23.

[7]R. Guentzler, "Noise Generators," *QST*, Mar 1972, p 44.

[8]L. Anciaux, "Accurate Noise Figure Measurements for VHF," *Ham Radio*, June 1972, p 36.

A 100-MHz Universal Frequency Counter

Continued from page 11.

0.1, 1 and 10-second gate times, as well as counting the period of a signal. This feature is useful when working with very low frequency signals. The chip can also display the ratio of two frequencies, count units (sequential) and display the time between two events. The last function could be used for model racing for instance. The finished project measures only 7 1/2 x 4 x 3 inches.

All parts are readily available through Radio Shack and Jameco[2], except for the prescaler chip. The price of the finished counter was under $100. I plan to experiment further with the counter to work out unfinished details. Table 1 lists the results of some tests I performed to learn how much signal is needed for an accurate count. The counter works well in the lower HF region and all of the functions work on my version.

Table 1

Required Signal Levels for Counter Frequencies

Freq (MHz)	*(in dBm)*	*Signal Level (in mV (RMS))*
2.5	−24.7	44.7
5.0	−19.7	23.2
10.0	−14.0	44.7
11.0	−15.1	39.4
12.0	−9.2	77.6
13.0	−4.3	136.0
14.0	−4.1	140.0

Notes

[1]*Intersil Component Data Catalog 1986*, Intersil, Inc, 10600 Ridgeview Court, Cupertino, CA 95014, p 7-36.

[2]Jameco Electronics, 1355 Shoreway Rd, Belmont, CA 94002; tel (415) 592-8097.

Bits

New Books From McGraw-Hill

A Comprehensive Guide to Artificial Intelligence And Expert Systems, written by R. Levine, D. Drang and B. Edelson, provides a solid grasp of AI terminology, clear diagrams and hands-on programming examples. Each program is written in BASIC and can be implemented on a personal computer.

Primary techniques used to create AI programs, types of expert systems that can be designed and implemented by the computer user and sophisticated programming applications are examined. An extensive section of the book deals with the design of three different truncated expert systems: for financial planning, for optimizing a sales effort and for the diagnosis of learning problems.

The 245-page edition of *A Comprehensive Guide to AI And Expert Systems* is available in paperback for $19.95. Contact McGraw-Hill Book Co at the address below.

Software Portability, written by O. Lecarme and M. Pellissier Gart, examines the science of software engineering, namely software reusability. Essential methods and techniques needed to understand and achieve successful data transport are reviewed. The authors tell how to develop a program that will not only meet current job requirements, but one that is capable of being transported to a different system for future projects. A special section is included that deals with language processors and with operating and programming systems that effectively demonstrate portability applications to actual situations. Other discussions investigate software property rights and protection, the portability of numeric software, macroprocessors, verifiers and filters, and much more.

For your copy of *Software Portability*, contact McGraw Hill Book Co, 1221 Avenue of the Americas, NY, NY 10020; tel 212-512-3493. The book contains 219 pages and sells for $49.95.—*KA1DYZ*

Word From Afar

Gregory Roberts, ZS1BI, of the South African Astronomical Observatory, has been publishing *The Journal of the Satellite Interest Group* for several years. *The Journal* focuses on receiving and tracking Amateur Radio satellites and other scientific and broadcast satellites. If your interest lies in this area, drop ZS1BI a note at c/o S. A. Astronomical Observatory, PO Box 9, Observatory 7935, South Africa. Because of the high cost of overseas subscriptions, rates will vary from country to country.—*KA1DYZ*

VHF+ Technology

By Geoff Krauss, WA2GFP
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New transistors with appealing performance characteristics continue to come to my attention. Some of the components remain in a high price range, but it is beneficial to consider what contributions they can add to a VHF+ project.

M/A-COM PHI, Inc (1742 Crenshaw Blvd, Torrance, CA 90501) manufactures a line of 1200-1400 MHz devices—the PH1214-XX series. (XX is 8, 30 or 60 W of power output with 9, 8 or 7 dB of gain, respectively.) These internally-matched devices use a 28-V dc power supply to operate in long-pulse/CW modes. With 1 W of drive fed to a -8 and cascaded to a -30 and a pair of -60s, the result is 100+ W out. With power triodes, the same stage and tube count are needed to obtain the same power levels. The data sheet curves for the PH1214-XX series look promising for linear operation, although someone will have to build a 1296-MHz amplifier and check it out. The price? Don't ask!

The SD-1506 and SD-1507, produced by Thomson Semiconductors (Commerce Dr, Montgomeryville, PA 18936-1002), are also rated for 1200-1400 MHz. Both devices are used for pulsed operation (300 μs, 10% duty cycle). Even with this design, a 300-W output from a dual, balanced device at 50 V dc and exhibiting 9 dB of gain is interesting. At least one VHF+er I know has already used pulse-rated transistors at good percentages of pulsed-output power, in solid-state 1296- and 2304-MHz CW power amplifiers. The same manufacturer also has a 500-W, 400- to 450-MHz device (SD-1565), at 40-V dc, in a 250 ms, 10% duty-cycle mode. Watch for this device during the next few years!

On the low-noise front, I am enthralled by components such as the Toshiba JS8830-AS GaAsFET, a 0.25 micron-gate-length chip with a rated typical noise figure/gain (NF) of 2.0/8 dB and 4.0/6 dB at 18 GHz and 30 GHz, respectively. The data sheet does not show operational data below 14 GHz! Time to start planning a forward-scatter station for 24 GHz!

The latest buzzword in low-noise devices is the high electron mobility transistor (HEMT). The HEMT is a commercially available device with a noise figure equal to 1.8 dB. It has a gain of 8 dB at 20 GHz and is available in sample lots costing from \$900-1200 each! (Remember that six to eight years ago a 1-micron gate GaAsFET was \$150+.)

Just what *is* a HEMT? Let us first review the diagram of Fig 1; note the GaAs MESFET shown in Fig 1A. A layer of N-doped GaAs sits atop the buffer layer. The source and drain electrodes extend into this doped layer only, through which the electrons are able to move. This movement, from source to drain, is modulated by the gate field, which is itself dependent on the input signal amplitude. The HEMT (shown in Fig 1B) has the same form of basic operation, but with one difference. The HEMT has a layer of *undoped* GaAs on top of the buffer layer, with a top layer of silicon-doped aluminum-gallium-arsenide (AlGaAs). The source and drain regions extend through both the AlGaAs layer and the undoped GaAs layer. Electrons are injected into the undoped (pure) GaAs layer from the source in the AlGaAs layer because the pure GaAs has a lower "work function" by about 0.3 eV. However, the injection of the negatively-charged electrons leaves the AlGaAs layer with a net positive charge, which in turn attracts the electrons back toward the heterojunction between the two layers. A very dense two-dimensional layer of an electron "gas" is formed, with a thickness of less than 100 Angstroms. This gas moves through the pure GaAs material and the speed of these electrons are not reduced by collisions with impurities; they have several times the mobility of electrons traveling through the doped layer in a normal GaAsFET—the faster the electrons go from source to drain, the less time for noise currents (ie, random electron movements) to have any interaction with them. Less noise current equals a lower noise figure, noise factor and temperature!

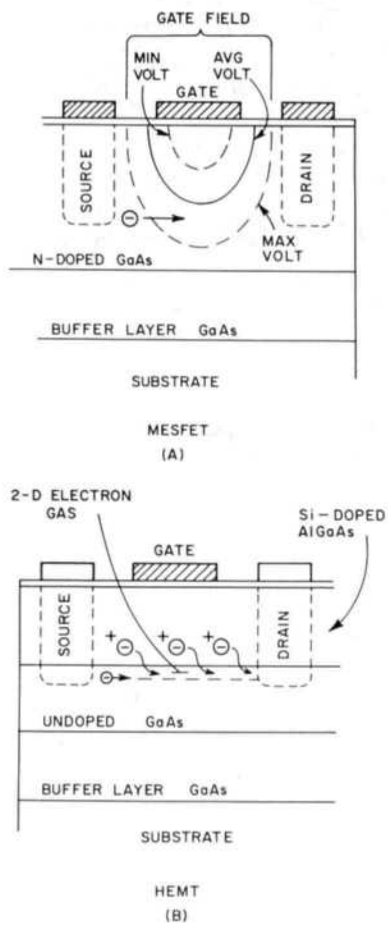

Fig 1—These two pictorials point out the differences in the chemical makeup of a MESFET (A) and HEMT (B). See text for an explanation of each device.