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engineering principles and practices

February 1997

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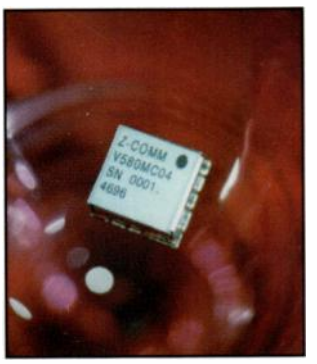
Model	Package	Frequency
V-0060	MINI	50-70MHz
V-0120P	Leaded	90-140MHz
V-0120S	S	90-140MHz
V-0140	MINI	110-170MHz
V-0180	MINI	150-210MHz
V-0250	MINI	200-300MHz
V-0350	MINI	300-400MHz
V-0450	MINI	400-500MHz

Model	Package	Frequency
V-0550	MINI	500-600MHz
V-0600	MINI	400-800MHz
V-0750	MINI	650-850MHz
V-0880	MINI	860-900MHz
V-0902	MINI	875-930MHz
V-1150	MINI	1075-1150MHz
V-2300A	MINI	2300-2400MHz

Minimum order = 5 pieces



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Model	Package	Frequency
SMV-1845	SUB	1815-1875MHz
SMV-2100L	SUB	2050-2150MHz
SMV-2200L	SUB	2150-2250MHz
SMV-2500L	SUB	2400-2485MHz
V-0800	MINI	750-850MHz
V-0965	MINI	950-980MHz
V-1000	MINI	600-1200MHz
V-1050	MINI	900-1200MHz
V-1075	MINI	1050-1100MHz
V-1100	MINI	700-1400MHz
V-1200	MINI	800-1600MHz

Model	Package	Frequency
V-1400	Leaded	900-1900MHz
V-1425P	Leaded	1350-1500MHz
V-1425S	S	1350-1500MHz
V-1800	MINI	1700-1900MHz
V-1950	MINI	1900-2000MHz
V-2000	S	1600-2200MHz
V-2250	MINI	2000-2500MHz
V-2300B	MINI	2200-2400MHz
V-2500	MINI	2400-2600MHz
V-3350	MINI	3100-3600MHz

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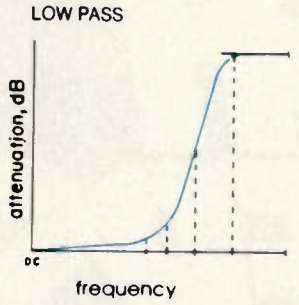
dc to 3GHz from $11.45



low pass, Plug-in, dc to 155MHz

Model No.	Passband MHz loss < 1dB	Stopband, MHz loss > 20dB	Stopband, MHz loss > 40dB
•★LP-1.9	DC-1.9	3.4-4.7	4.7-200
•★LP-2.5	DC-2.5	3.8-5.0	5.0-200
★LP-5	DC-5	8-10	10-200
★LP-10.7	DC-11	19-24	24-200
★LP-21.4	DC-22	32-41	41-200
★LP-30	DC-32	47-61	61-200
★LP-50	DC-48	70-90	90-200
★LP-70	DC-60	90-117	117-300
★LP-90	DC-81	121-157	157-400
★LP-100	DC-98	146-189	189-400
★LP-150	DC-140	210-300	300-600

dc to 1200MHz

Model No.	Passband MHz loss < 1dB	Stopband, MHz loss > 20dB	Stopband, MHz loss > 40dB
★LP-200	DC-190	290-390	390-800
★LP-250	DC-225	320-400	400-1200
★LP-300	DC-270	410-550	550-1200
★LP-450	DC-400	580-750	750-1800
★LP-550	DC-520	750-920	920-2000
★LP-600	DC-680	840-1120	1120-2000
★LP-750	DC-700	1000-1300	1300-2000
★LP-800	DC-720	1080-1400	1400-2000
★LP-850	DC-780	1100-1400	1400-2000
★LP-1000	DC-900	1340-1750	1750-2000
★LP-1200	DC-1000	1620-2100	2100-2500

All models priced qty. 1-9 ($ea.), Conn. Type P = 11.45, B = 32.95, S = 34.95, N = 35.95
• Exceptions: ★LP-1.9 P = 13.95, B = 34.95, ★LP-2.5 P = 14.95, B = 35.95
On both models, add following to B price: $3.00 for N, $2.00 for S
75 ohm versions available

Surface-mount

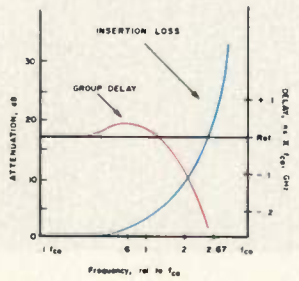
dc to 108MHz

SCLF-5	DC-5.0	8-10	10-200
SCLF-8	DC-8.0	12.5-16.5	16.5-200
SCLF-10.7	DC-11	19-24	24-200
SCLF-21.4	DC-22	32-41	41-200
SCLF-25	DC-25	36-47	47-200
SCLF-30	DC-30	47-61	61-200
SCLF-45	DC-45	70-90	90-200
SCLF-95	DC-95	146-189	189-400

dc to 1200MHz

SCLF-135	DC-135	210-300	300-600
SCLF-190	DC-190	290-390	390-800
SCLF-225	DC-225	340-440	440-1200
SCLF-380	DC-380	580-750	750-1800
SCLF-420	DC-420	750-920	920-2000
SCLF-550	DC-550	800-1050	1050-2000
SCLF-700	DC-700	1000-1300	1300-2000
SCLF-1000	DC-1000	1620-2100	2100-2500

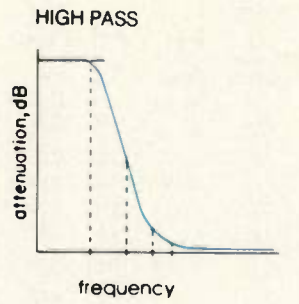
Price: SCLF 21.4–SCLF 420 $11.45 ea. SCLF-8, 10.7, 550, 700, 1000 $12.95 ea. SCLF-5 $14.95 Qty. (1-9)



Flat Time Delay, dc to 1870MHz

Model No.	Passband MHz loss < 1.2dB	Stopband MHz loss >10dB	Stopband MHz loss >20dB	VSWR Freq. Range, DC thru 0.2fco X	VSWR Freq. Range, DC thru 0.6fco X	Group Delay Variations, ns Freq. Range, DC thru fco X	Group Delay Variations, ns Freq. Range, DC thru 2fco X	Group Delay Variations, ns Freq. Range, DC thru 2.67fco X
★BLP-39	DC-23	78-117	117	1.3:1	2.3:1	0.70	4.0	5.00
★BLP-117	DC-65	234-312	312	1.3:1	2.4:1	0.35	1.4	1.90
★BLP-156	DC-94	312-416	416	1.3:1	1.1:1	0.30	1.1	1.50
★BLP-200	DC-120	400-534	534	1.6:1	1.9:1	0.40	1.3	1.60
★BLP-300	DC-180	600-801	801	1.25:1	2.2:1	0.20	0.6	0.80
★BLP-467	DC-280	934-1246	1246	1.25:1	2.2:1	0.15	0.4	0.55
▲BLP-933	DC-560	1866-2490	2490	1.3:1	2.2:1	0.09	0.2	0.28
▲BLP-1870	DC-850	3740-5000	5000	1.45:1	2.9:1	0.05	0.1	0.15

Price, (1-9 qty), all models: plug-in $19.95, BNC $36.95, SMA $38.95, Type N $39.95
NOTE: ▲ -933 and -1870 only with N and SMA connectors.



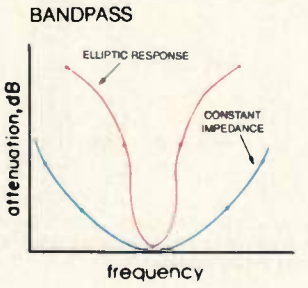
high pass, Plug-in, 13 to 1200MHz

Model No.	Stopband MHz loss > 40dB	Stopband MHz loss > 20dB	Passband, MHz loss < 1dB	VSWR Pass-band Typ.
★HP-25	DC-13	13-19	27.5-200	1.7:1
★HP-50	DC-20	20-26	41-200	1.5:1
★HP-100	DC-40	40-55	90-400	1.5:1
★HP-150	DC-70	70-95	133-600	1.8:1
★HP-175	DC-70	70-105	160-800	1.5:1
★HP-200	DC-90	90-116	185-800	1.6:1
★HP-250	DC-100	100-150	225-1200	1.3:1
★HP-300	DC-145	145-190	†290-1200	1.7:1

210 to 2200MHz

Model No.	Stopband MHz loss >40dB	Stopband MHz loss > 20dB	Passband, MHz loss < 1dB	VSWR Pass-band Typ.
★HP-400	DC-210	210-290	395-1600	1.7:1
★HP-500	DC-280	280-365	500-1600	1.9:1
★HP-600	DC-350	350-440	600-1600	2.0:1
★HP-700	DC-400	400-520	700-1800	1.6:1
★HP-800	DC-445	445-570	780-2000	2.1:1
★HP-900	DC-520	520-660	910-2100	1.8:1
★HP-1000	DC-550	550-720	1000-2200	1.9:1

Price, (1-9 qty), all models: plug-in $14.95, BNC $36.95, SMA $38.95, Type N $39.95. For ★HP-25, Add $2 ea. †Loss 1.5 dB max.



bandpass, Elliptic Response, 10.7 to 70MHz

Model No.	Center Freq. (MHz)	Passband I.L. 1.5 dB Max. (MHz)	3 dB Bandwidth Typ. (MHz)	Stopbands I.L. > 20dB at MHz	Stopbands I.L. > 35dB at MHz
★BP-10.7	10.7	9.5-11.5	8.9-12.7	7.5 & 15	0.6 & 50-1000
★BP-21.4	21.4	19.2-23.6	17.9-25.3	15.5 & 29	3.0 & 80-1000
★BP-30	30.0	27.0-33.0	25-35	22 & 40	3.2 & 99-1000
★BP-60	60.0	55.0-67.0	49.8-70.5	44 & 79	4.6 & 190-1000
★BP-70	70.0	63.0-77.0	58.0-82.0	51 & 94	6.0 &193-1000

Price, (1-9 qty), all models: plug-in $18.95,
BNC $40.95, SMA $42.95, Type N $43.95

Constant Impedance, 21.4 to 70MHz

Model No.	Center Freq. MHz	Passband MHz loss < 1dB	Stopband loss > 20dB at MHz	VSWR 1:3:1 Total Band MHz
★IF-21.4	21.4	18-25	1.3 & 150	DC-220
★IF-30	30.0	25-35	1.9 & 210	DC-330
★IF-40	42.0	35-49	2.6 & 300	DC-400
★IF-50	50.0	41-58	3.1 & 350	DC-440
★IF-60	60.0	50-70	3.8 & 400	DC-500
★IF-70	70.0	58-82	4.4 & 490	DC-550

Price, (1-9 qty), all models: plug-in $14.95,
BNC $36.95, SMA $38.95, Type N $39.95

NOTE: ★Add Prefix P, B, N, or S for Pin, BNC, N, or SMA connector requirement.

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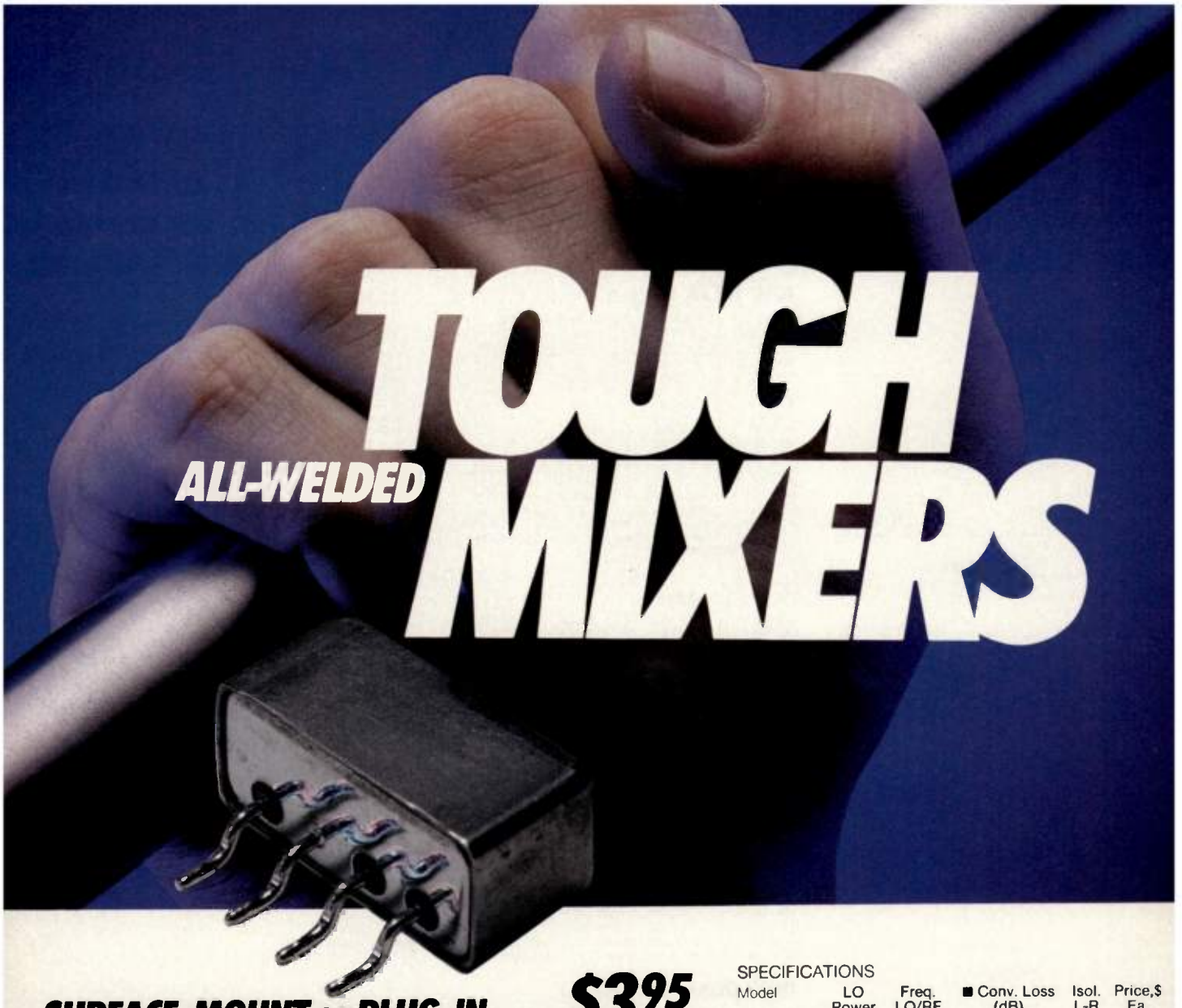

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actual size

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5-YR. GUARANTEE

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SPECIFICATIONS

Model	LO Power (dBm)	Freq. LO/RF (MHz)	■ Conv. Loss (dB) $\bar{X}$	δ	Isol. L-R (dB)	Price,$ Ea. 10 qty
TUF-3	7	0.15-400	4.98	0.34	46	5.95
TUF-3LH	10		4.8	0.37	51	7.95
TUF-3MH	13		5.0	0.33	46	8.95
TUF-3H	17		5.0	0.33	50	10.95
TUF-1	7	2-600	5.82	0.19	42	3.95
TUF-1LH	10		6.0	0.17	50	5.95
TUF-1MH	13		6.3	0.12	50	6.95
TUF-1H	17		5.9	0.18	50	8.95
TUF-2	7	50-1000	5.73	0.30	47	4.95
TUF-2LH	10		5.2	0.3	44	6.95
TUF-2MH	13		6.0	0.25	47	7.95
TUF-2H	17		6.2	0.22	47	9.95
TUF-5	7	20-1500	6.58	0.40	42	8.95
TUF-5LH	10		6.9	0.27	42	10.95
TUF-5MH	13		7.0	0.25	41	11.95
TUF-5H	17		7.5	0.17	50	13.95
TUF-860	7	860-1050	6.2	0.37	35	8.95
TUF-860LH	10		6.3	0.27	35	10.95
TUF-860MH	13		6.8	0.32	35	11.95
TUF-860H	17		6.8	0.31	38	13.95
TUF-11A	7	1400-1900	6.83	0.30	33	14.95
TUF-11ALH	10		7.0	0.20	36	16.95
TUF-11AMH	13		7.4	0.20	33	17.95
TUF-11AH	17		7.3	0.28	35	19.95

*To specify surface-mount models, add SM after P/N shown.

■ $\bar{X}$ = Average conversion loss at upper end of midband ($f_U/2$)

δ = Sigma or standard deviation

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- Product forum: Test/Measurement Equipment

RF editorial

Is digital all that it's supposed to be?

By Don Bishop
Editorial Director

Digital modulation holds the promise to solve all electronic communications problems, from telephone to television to computer networks and beyond. Or does it?

Support for digital comes in a shout; criticism of digital comes in a whisper.

The whispers say that early promises of a 64:1 capacity increase by moving from analog to spread-spectrum, digital cellular have been quietly revised to 32:1, to 16:1, to 8:1 or less.

They're saying that the field performance of narrowband digital radio communications networks doesn't meet the expectations raised by predicted performance. One of my long-time associates who prepares theoretical analyses of wireless systems with complex modulation schemes had what was for him a rare field assignment to troubleshoot a digital system. "You wouldn't believe the difference in the field," he told me. "In some respects, these system don't come close to predicted performance. It's been a real eye-opener."

Another engineer with a lot of experience in designing spectrum-efficient systems says that the benefits of digital modulation are readily apparent when bandwidth is virtually unlimited, as with a medium such as fiber optics. With limited bandwidth, such as radio spectrum allocated in frequency bands for over-the-air telecommunications, digital modulation can consume more spectrum than its analog counterparts, requiring either reduced range or reduced capacity to compensate.

Criticism seems to come in a whisper because enormous sums have been spent to develop digital wireless technology. A lot of people are depending on its success to sustain their jobs beyond the development phase. To say that it might not work as well as expected, or in some cases might not work well enough to meet requirements, could spell the end of some of those jobs.

Some of the claims for digital are just plain silly. I heard a representative of a cellular carrier say during a broadcast interview that the sound of digital cellular is better than analog. "It's like the difference between records and compact discs," he said. "Digital cellular is like CD sound." He vastly overstated the case. But the relative quality of the sound probably isn't the most important point.

Engineers experienced with analog modulation, and perhaps even forms of amplitude modulation vs. frequency modulation, quietly point out that the bandwidth requirement is less, interference is less and spectrum efficiency is greater than with digital.

Some extremely capable people are working on each side of the issue. It's likely that the performance results aren't exactly clear-cut. If you have some observations about the results obtained with digital vs. analog in working mobile communications systems, such as cellular, personal communications services (PCS) and enhanced specialized mobile radio (ESMR), I'd like to hear about them.

Call for papers

Be sure to come to the RF Design '97 Conference & Exposition scheduled for Sept. 10-12 at the Santa Clara Convention Center, Santa Clara, CA. All visitors are welcome, but you have an opportunity to take an active part, too. Look for our call for papers on page 19. Your colleagues will be there for the presentation of technical papers, and your paper can be among them. RF

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☐	ESMD-C1	Base Station	1-1000	6.5dB	40dB

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☐	ETC1.6-4-2-3	Wireless	500-2500	4:1	3 dB
☐	ETC4-1-2	Wireless	2-800	4:1	3 dB
☐	ETC9-1	Wireless	70-220	9:1	2.5 dB

COUPLERS

Send me more info	Part Number	Application	Frequency MHz	Ratio	Insertion Loss
☐	ESDC-7-2-75	CATV	5-800	7 ±1	2.8 dB
☐	EMDC-16-2-75	CATV	40-1000	16±1.1	1.0 dB
☐	ESDC-20-2-75	CATV	5-1000	20±1	1.1 dB

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☐	2	1510-1660	20	0.4	SOIC-8	DS52-0004
☐	3	824-960	18	0.6	SOIC-8	DS53-0001
☐	4	824-960	23	1.0	SOW-16	DS54-0001
☐	4	1200-1660	23	1.0	SOW-16	DS54-0003
☐	6	824-960	25	1.3	SOW 16	DS56-0001

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Editorial offices
5660 Greenwood Plaza Blvd., Suite 350
Englewood, CO 80111
303-793-0448; Fax 303-793-0454

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Gregg V. Miller, *Technical Editor*
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Intertec Publishing offices
9800 Metcalf Ave.
Overland Park, KS 66212-2215
913-341-1300; Fax 913-967-1898

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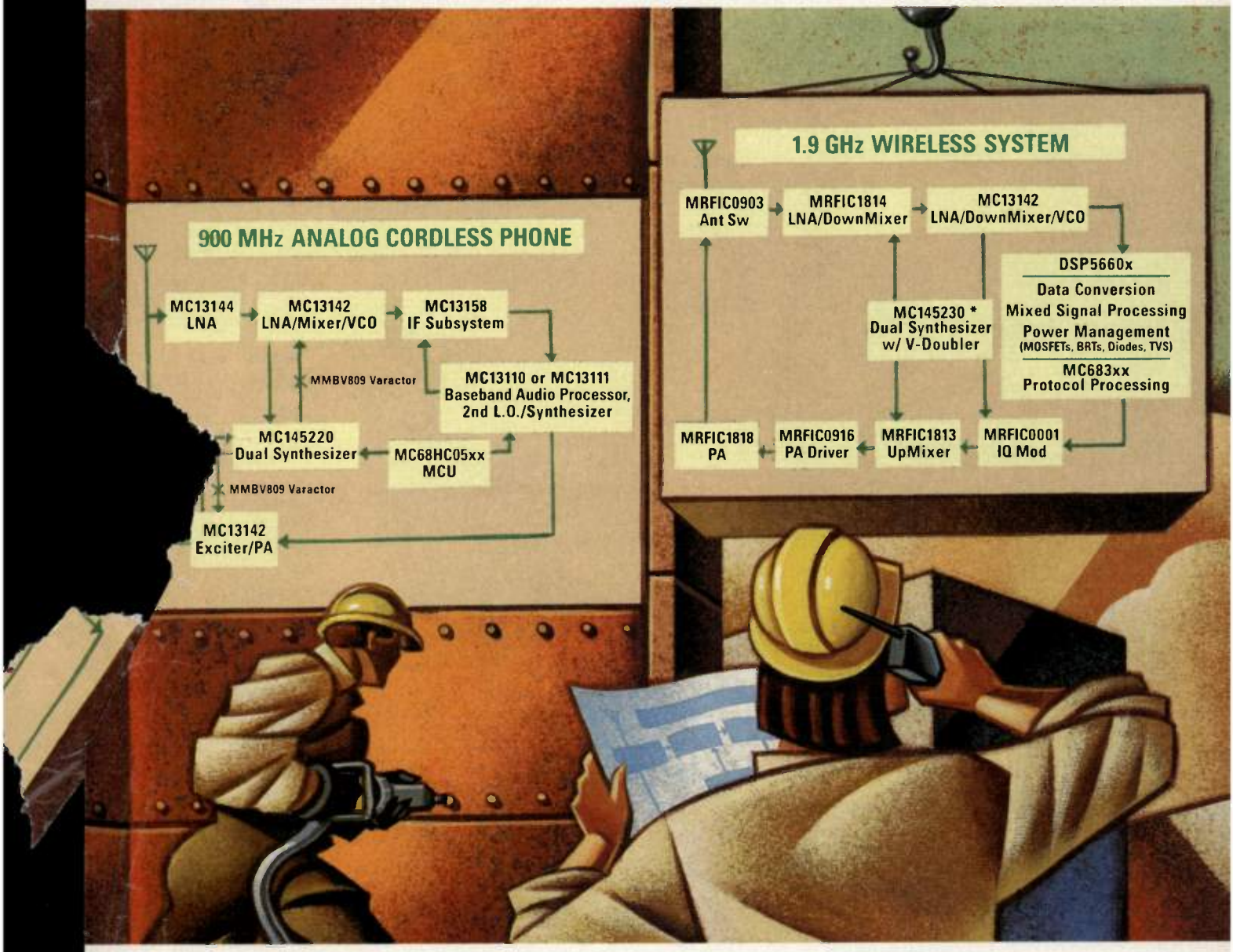

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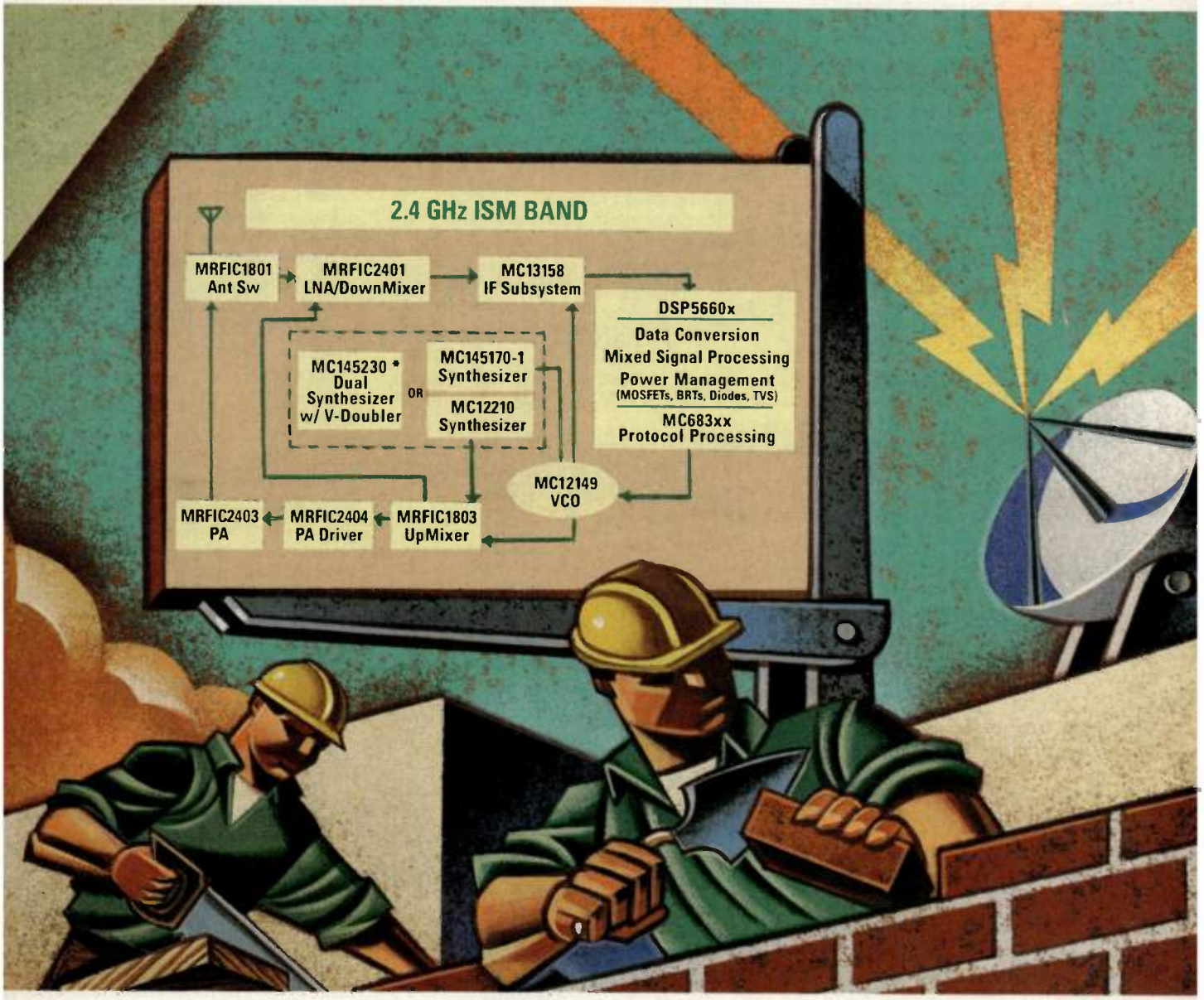

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Letters should be addressed to the Editor, RF Design, 5660 Greenwood Plaza Blvd., Suite 350, Englewood, CO 80111. Letters published may be edited for length or clarity.

Exposure standards

After reading Bob Schwaninger's article, "The FCC's RF Exposure Standards—the Newest Design Hurdle," in the November issue, I felt compelled to rebuff his closing remarks. Being involved in a small land mobile business, I can appreciate the work that Bob and his associates are accomplishing for us in Washington. Really though, "mandating foil-lined shoes" may appear to be typical Fed overkill, and attempting to follow the latest developments regarding RF exposure standards reveals a military maneuver appropriately labeled "Charlie Foxtrot." Between the industry-sponsored committees entrusted to guard the henhouse and the manufacturers' financially motivated downplaying of any related situations, there appears to be a lack of concern about the very people that make it possible for the counters to fiddle their beans.

By the nature of their employment, RF, two-way radio and now even telecommunications technicians are required on a daily basis to expose themselves to RF fields that often may exceed the proposed acceptable standards. If they read this, those individuals certainly will remember those many radiating mobile installations just a couple of feet from the standing wave ratio (SWR) meters they must read. Some of them routinely visit rooftop penthouses ringed by many radiating antennas clamped chest-high to handrails to save the cost of supporting structures. I often have wondered how much potentially harmful radiation my body is absorbing when the field strength anywhere on the rooftop measurably exceeds many times the antenna input burnout threshold of my service monitor. I think many others may have had the desire to know.

The FCC conveniently has skirted the issue by setting a double standard for technicians' exposure recommendations, separate from those of uninvolved laypersons. This opinion is based upon the premise that, because we are technically more aware that our fannies could be fried, we should know better and must be expected to expose ourselves more. Legally, this is called informed consent. Now, why should a government agency not agree with that?

Some industry authorities claim that telecommunications workers have given consent, and the public hasn't. I would like to hear from any worker related to my field who *actually has been asked* to agree to expose himself or herself to this danger that no one really can define. Please include the response from your employer after you have, in turn, asked whether you could obtain a copy of the ANSI and IEEE standard from your local job safety authority, or indicate whether you have requested that the employer purchase a radiation dosimeter to ensure your safety. Your employer's response probably will be "you'd better not get OSHA near here," at the same time he or she reaffirms the location of the front door. *Businesses just will not act until the law mandates them to.*

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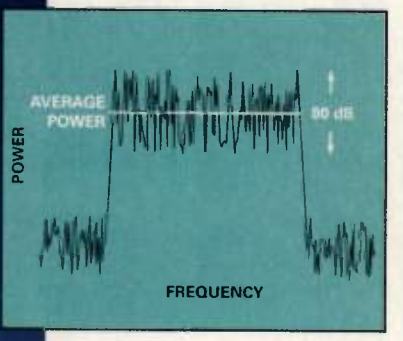

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interconnections of radio to phones, such workers have similar job titles whether we handle RF or not.

Manufacturers and the government will haggle over the price of liability avoidance and whose fault it will be for bringing this up in the first place. I am sure that some of you will suggest that I stop lamenting and enduring the unknown, just quit and sell stereos instead. Communications service technicians will continue to be the unnoticed minority, unless we speak up in collective individualism and insist to our few available authorities that our fates not be allowed to be the result of attention to other special interests. We must become visible as our own special interest lobby, so that physically, we do not become the "overkill." I suppose there always will be some lawyers who will insist that if you raise dogs, you should expect to get bitten.

Floyd H. Miltz, Licensed communications technician
Grand Rapids, MI

Schwaninger replies

In response to Mr. Floyd Miltz's letter regarding my article, "The FCC's RF Exposure Standards," in which Mr. Miltz takes issue with my flippancy regarding the FCC's attempt to articulate a bright line between safe vs. unsafe levels of exposure, I wish to offer the following observation: Mr. Miltz is correct. The federal government should demonstrate concern for telecommunications workers and their individual exposure to RF emissions. People who are made to come in close proximity to high levels of RF energy should be armed with sufficient knowledge regarding any alleged or proven health risks. And, given the paucity of information on this subject, to which the FCC's recent decision barely adds a jot of new data, Mr. Miltz's concerns are fully justifiable.

My conclusion took issue with the FCC's approach to the matter, which I feared might provide a false impression of concern with overall protection of workers' and the public's safety. As noted somewhat by Mr. Miltz, the FCC's focus was moreover on the RF emission levels from mobile, handheld equipment than on the type of exposure described by Mr. Miltz. Stated simply, the FCC concentrated more on the RF radiation from a cellphone than on the radiation from a powerful array of antennas co-located on the roof of a structure and the effect that the radiation might have on telecommunications workers. In fact, there is little in the FCC decision that attempts to define quantify or explain the existence of the risk to exposed workers. Instead, the workers are assumed to be informed and willing to accept the risk, at least at some level, and the FCC makes this assumption without even defining the assumed risk.

Having worked with numerous manufacturers and designers of RF equipment, particularly unlicensed devices, I have often been amused by the FCC's attempt to reduce the level of RF emissions from say, garage door openers while ignoring the greater levels of RF emissions and spectrum pollutants from brush motors, spark emitters light switches, home wiring, vehicular computers and the like. The unlicensed radio devices are within the agency's jurisdiction, but vacuum cleaners are not. The effect of the FCC's unbalanced treatment is that often the larger threat is ignored, while the smaller threat is handled with regulatory overkill.

Mr. Miltz also may note that while

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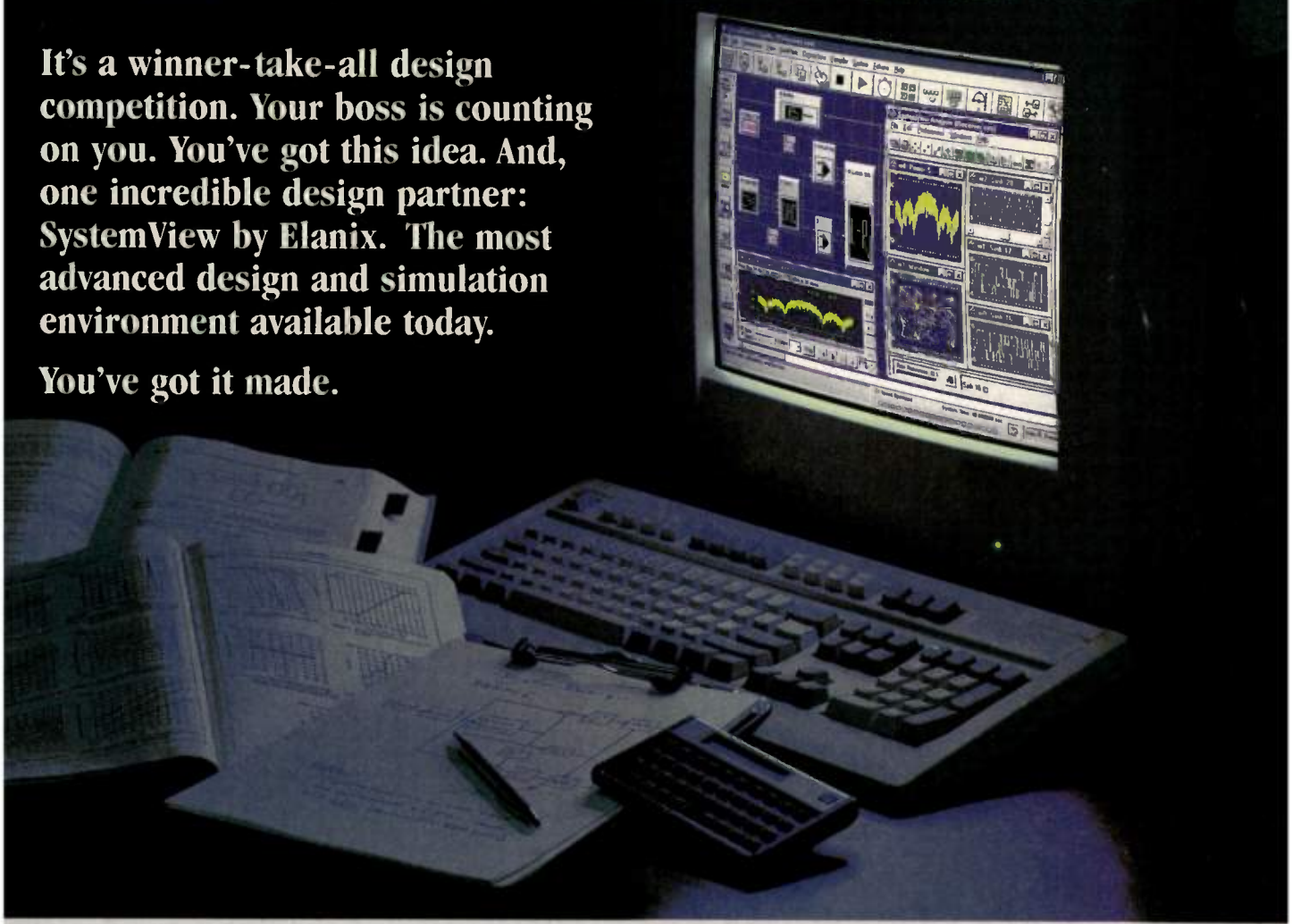

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the FCC was creating the RF emission thresholds described in my article, it was lowering the approval threshold for digital devices, changing the approval process from requiring certification to notification (the FCC form of allowing manufacturers to say, "trust me"). The agency also is licensing enhanced specialized mobile radio (ESMR) systems throughout the United States that allow operators to transmit upon more than 100 channels simultaneously, at higher than 800 MHz, thereby creating a collective high-powered, high-frequency RF emission risk, often at relatively low-level sites.

In conclusion, Mr. Miltz and I do not disagree on the greater threat from RF emission exposure and the need to continue to examine the area of worker safety. My fear is that we will see "foil-lined shoes" mandated before we see from the agency substantive progress that is designed rationally to confront the issue, rather than burying it under reluctantly created policy statements.

Robert Schwaninger
Washingon, DC

RF design 97 Conference & Expo

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CALL FOR PAPERS– CALL FOR SESSION MODERATORS

Do you have something to share? A unique solution to a common problem? A new technique or application? Whatever the topic, we would appreciate hearing from you. The RF Design '97 advisory board is seeking program suggestions and abstracts of fewer than 400 words on relevant RF topics. The deadline is March 31. Suggestions include:

Applications
- GPS
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Moderators are needed for sessions, or to help organize sessions on a subject of their special interest. All speakers and moderators receive free admission to the conference and a copy of the Proceedings (not including full-day short courses, travel or lodging).

All abstracts should be sent by March 31 to:

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RF calendar

February 23–27 **Nepcon West**—*Anaheim, CA*. Information: Reed Exhibition Company, 383 Main Ave., Norwalk, CT 06852-6059. Tel. 800-467-5656; Fax 203-840-9656; Web site: http://www.nepcon.reedexpo.com.

March 3–5 **CTIA Wireless**—*San Francisco*. Information: Dobson and Associates. Tel. 202-463-7905.

13–19 **CeBIT '97 World Business Center: Office, Information and Telecommunications**—*Hannover, Germany*. Information: Mette Fisker Peterson, Hannover Fairs USA, 103 Carnegie Center, Princeton, NJ 08540. Tel. 609-987-1202; Fax 609-987-0092.

17–20 **European Design and Test Conference**—*Paris*. Information: Conference Secretariat, CEP Consultants, 43 Manor Place, Edinburgh, EH3 7EB, United Kingdom. Tel. +44-131-300-3300; Fax +44-131-300-3400; E-mail edtc@cep.u-net.com.

25–27 **DSP World Spring Design Conference**—*Washington, DC*. Information: Dana Dowell, Miller Freeman. Tel. 415-278-5322; E-mail dsp@exporeg.com. Web site http://www.dspworld.com.

25–27 **Communication Design Engineering Conference**—*Washington, DC*. Information: Conference, 600 Harrison St. 4th Floor, San Francisco, CA. Tel. 617-821-9219; Fax 617-828-8198; E-mail cdec@exporeg.com.

April 2 **Surface Mount Technology Association Exhibition and Sessions**—*Atlanta*. Exhibiting information: Lynda Kelly, Tel. 770-518-9039; Fax 770-642-1288; Sessions information : SMTA National. Tel. 612-920-7682; Fax 612-926-1819; E-mail smta@smta.com; Web site http://www.smta.org.

14–17 **International Conference on Antennas and Propagation**—*Edinburgh*. Information: ICAP Secretariat, IEE Conference Services, Savoy Place, London WC2R 0BL, United Kingdom. Tel. +44 (0) 71-344-5467/5473; Fax +44 (0) 71-240-8830; E-mail lhudson@iee.org.uk or mswift@iee.orguk.

21–23 ***RF Design* Seminar Series**—*Las Vegas*. Information: Intertec Presentations, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111. Tel. 303-220-0600; Fax 303-770-0253.

22–24 **International Wireless Communications Expo**—*Las Vegas*. Information: Intertec Presentations, 6300 S. Syracuse Way, Denver, CO 80111. Tel. 800-288-8606 or 303-220-0600.
RF Pavilion—Manufacturers exhibits within IWCE. Components, test equipment, software and services for RF equipment manufacturing.

22–24 **Convergence Tech and IC Expo** for microelectronics, communications and computer professionals—*Dallas*. Information: Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, CA 90045. Tel. 800-877-2668, ext. 243; Fax 310-641-5117.

23–26 **Broadcast Technology**—*Jakarta, Indonesia*. Information: Eileen Lavine, Information Services, 4733 Bethesda Ave., Suite 700, Bethesda MD 20814. Tel. 301-656-2942; Fax 301-656-3179.

May 5–7 **Vehicular Technology Conference** for cellular and mobile wireless communications—*Phoenix*. Information: Wendy Rochelle, Registrar, IEEE Conference Service, 455 Hoes Lane, P.O. Box 1331 Piscataway, NJ 08855-1331. E-mail w.rochelle@ieee.org.

6–8 **Electronics Industries Forum of New England**—*Boston*. Information: Linda Hanson. Tel. 914-779-0696.

13–16 **Computer and Communication Electronics Design Exposition**—*Dallas*. Information: Reed Exhibition, 383 Main Avenue, Norwalk, CT 06851. Tel. 800-840-5614.

28–30 **IEEE International Frequency Control Symposium**—*Orlando, FL*. Information: Wendy Ortega Henderson, National Institute of Standards and Technology. Tel. 303-497-3593; Fax 303-497-6461; E-mail ortegaw@boulder.nist.gov.

June 1–5 **Supercomm**—*New Orleans*. Information: Telecommunications Industry Association. Tel. 202-326-7300.

9–14 **Asia Telecom**—*Singapore*. Information: Tom Dahl-Hansen, senior vice-president, Telecom. Tel. +41-22-730-5298; Fax +41-22-730-6444; E-mail. dahl-hansen@itu.ch.

10–12 **International Microwave Symposium and Exhibition**—*Denver*. Information: Horizon House. Tel. 617-769-9750.

11–13 **Virginia Tech Symposium on Wireless Personal Communications**—*Blacksburg, VA*. Information: Business Administrator, Jenny Frank, Mobile and Portable Radio Research Group, Virginia Polytechnic Institute, 840 University City Blvd., Pointe West Commons, Suite 1, Blacksburg, VA 24061-0350. Tel. 540-231-2958; Fax 540-231-2968; E-mail hilda@vt.edu; Web site: http://www.ee.vt.edu/mprg/home.html.

13 **Automatic RF Techniques Group** on characterization of broadband telecommunications components and systems—*Denver*. Information: Dr. Roger B. Marks, Conference Chair, NIST, 325 Broadway, Boulder, CO 80303. Tel. 303-497-3037; Fax 303-497-7828; E-mail r.b.marks@ieee.org. Web site http://www.boulder.nist.gov/ims/arftg.

August 20–22 **Piezoelectric Devices Conference and Exhibition**—*Kansas City*. Information: Pete Walsh, Electronic Industries Association. Tel. 703-907-7547; Fax 703-907-7501.

September 10–12 ***RF Design* Seminar Series**—*Santa Clara, CA*. Information: Intertec Presentations, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111. Tel. 303-220-0600; Fax 303-770-0253.

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PMB2333	T-SSOP-16	MIXER WITH DRIVER AMPLIFIER	-Integrated LNA/Driver Amplifier -Frequency range up to 3.0 GHz -Very highly isolated RF, IF and LO ports
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Besser Associates & Microwave Online Services—RF and Microwave courses are available on the World Wide Web exclusively through RF Globalnet. The courses will be given over a two-to-three week period. *Applied RF Techniques I: Linear Circuits*—begins in late February. Information: Larry Black, Microwave Online. Tel. 303-415-9233; E-mail larry@mosco.com; Web site http://www.rfmicrowave.com.

CKC Laboratories—*Core EMC Design*— March 11–12, Fremont, CA; June 17–18, Hillsboro, OR; *Immunity to ESD*—May 12, Orange County, CA; *CE Mark Design and Compliance Routes*—May 13–14, Orange County, CA; *EMC for Medical Electronics*—April 22–23. Information: Linda Grunow or Todd Robinson, CKC Laboratories, 5473-A Clouds Rest, Mariposa, CA 95338. Tel. 800-500-4362 or 209-966-5240; Fax 209-742-6133; E-mail Igrunow@ckc.com.

Georgia Tech Continuing Education—*Introduction to Radar Target Identification*– Feb. 25–28, Atlanta; *Infrared Countermeasures*—March 4–6, Atlanta; *Infrared Technology and Applications*—March 18–21, San Francisco; *Advanced Electronic Warfare Principles*—March 25–28, Atlanta; *Radar Cross Section Reduction*—March 25–28, Atlanta. Information: Department of Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332-0385. Tel. 404-894-2547; E-mail conted@gatech.edu; Web site http://www.conted.gatech.edu.

Learning Tree International—*Wireless Networks and Mobile Communications*—Feb. 18–21 Washington. Information: Learning Tree Int'l, 1805 Library St., Reston, VA. Tel. 800-850-9197 or 703-709-9119; E-mail uscourses@learningtree.com; Web site http://learningtree.com.

Mead Microelectronics—*Architectural and Circuit Design for Portable Electronics Systems* (3-days digital, plus 3-days analog)—March 31–April 5; *RF IC Design for Wireless Communication Systems*–May 12–16; *Data Communication ICs*–May 14–16. Information: Mead Microelectronics, 7100 Grandview Dr., Corvallis, OR 97330. Tel. 541-758-0828; Fax 541-752-1405. In Europe, contact Mead Microelectronics, Venoge 7, 1025 St. Sulpice, Switzerland. Tel. +41-21-691-0244; Fax +41-21-691-0245; E-mail mead@netgate.net or valence@mead.ch; Web site http://www.netgate.net/~mead.

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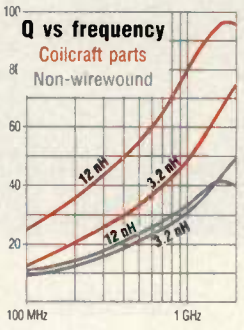

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University of Missouri-Rolla—*Grounding and Shielding Electronic Systems: How to Diagnose and Solve Electrical Noise Problems*—Feb. 19–21, Orlando, FL; March 10-12, Denver; May 19–21, Boston; June 25-27, Research Triangle Park, NC, August 13–15, Dallas; *Circuit Board Layout to Reduce Noise Emission and Susceptibility*—Feb. 21, Orlando, FL; March 12, Denver; May 21, Boston; June 27, Research Triangle Park, NC; August 15, Dallas; *Electromagnetic Compatibility Certificate Program*—Combination home study 40-hour video taped lecture and one-week on-campus laboratory course. Information: Continuing Education Coordinator, University of Missouri-Rolla, 103 ME Annex, Rolla, MO 65409-1560. Tel. 573-341-4132. Fax 573-341-4992; E-mail buddyp@shuttle.cc.umr.edu; Web site http://www.umr.edu/~conted.

Virginia Tech—*Antennas: Principles, Design and Measurements*—March 17–20, San Diego; May 19–22, St. Cloud, FL; *Principles of Electronic Counter-countermeasures*—April 8–10, Atlanta; *Infrared Technology and Applications*—April 15–18 Atlanta; *Phased-array Radar System Design*—April 29–May 2, Atlanta. Information: Kelly Brown, Northeast Consortium for Engineering Education, 1101 Massachusetts Ave., St. Cloud, FL 34769. Tel. 407-892-6146; Fax 407-892-0406.

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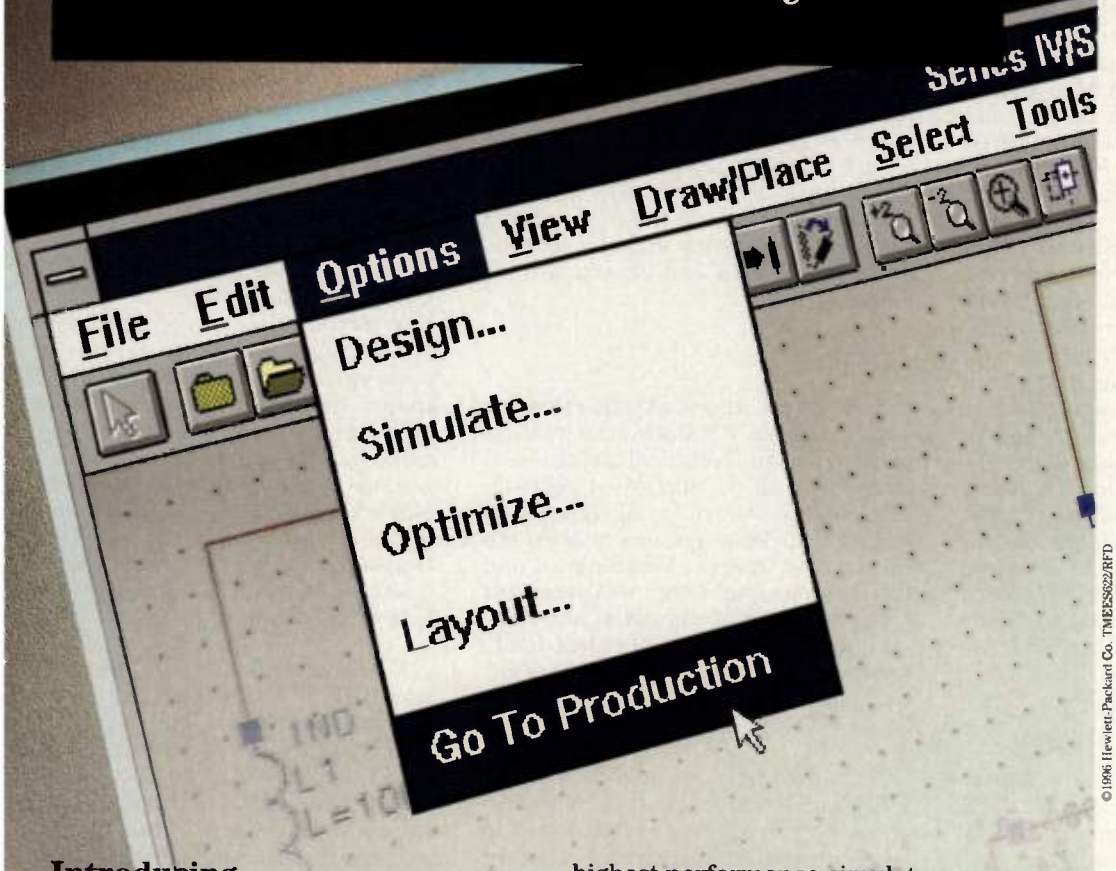

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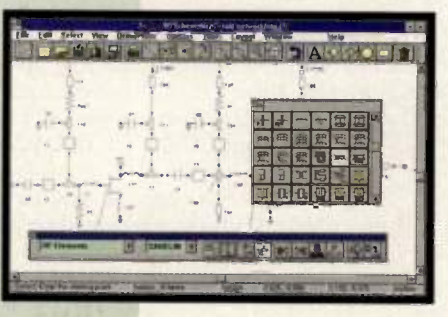

INFO/CARD 52

Western Wireless launches Portland PCS system

Western Wireless launched its VoiceStream wireless personal communications services (PCS) system in Portland, OR. Western Wireless was the first to win a PCS license in the Federal Communications Commission's spectrum auctions to launch commercial services. This is the fourth commercial PCS system the company has launched in less than six months, and is the sixth in the nation.

The VoiceStream PCS combines a wireless phone, pager and answering machine in one pocket-sized handset. Other features of VoiceStream's digital network include caller ID, call waiting, 24-hour text messaging, improved sound quality and digital encryption to prevent fraud and eavesdropping. VoiceStream's Portland-area network extends north to Woodland, WA, south to Salem, OR, east to Gresham, OR and west to Hillsboro, OR. It will reach central, coastal and southern areas of Oregon by the end of 1997. Western Wireless also plans to extend Voice Stream service to Boise, ID in 1997.

Ho Chi Minh City gets wireless loop technology

Ho Chi Minh City (formerly Saigon) Post and Telecommunications (HCM City P&T) has put Vietnam's first high-capacity, fixed-wireless telephone system into commercial operation, manufactured by Washington, D.C.-based Hughes Network Systems (HNS). The company's GMH 2000 system will provide 20,000 wireless telephone subscriber lines in Vietnam's largest city.

Kanematsu of Japan signed a contract with HCM City P&T for turnkey implementation on the first phase one year ago. The company's goal is 20 telephones per 100 inhabitants by the year 2000. The wireless loop technology is based on high-capacity digital advanced mobile phone systems (AMPS), with special fixed-cellular terminals capable of supporting digital voice, fax, data, pay phones and private branch exchange lines.

Contracts

Lindgren appoints northwest rep—Lindgren RF Enclosures has appointed Olson Technical Sales, Issaquah, WA, as its northwest regional sales representative for Lindgren EMI and RFI shielding systems in Northern California, Oregon, Washington and British Columbia. Olson will represent Lindgren's line of industrial shielding systems including double electrically isolated (DEI) screen and solid rooms, cell-type enclosures and anechoic chambers for EMC testing.

Agreement focuses on CDMA PCS handsets—Qualcomm has agreed with TriQuint Semiconductor to jointly develop RF integrated circuits for code-division, multiple-access (CDMA) handsets. The agreement addresses the radio frequency receive functions required in Qualcom's CDMA personal communications services (PCS) phones, including a focus on an RF receive component that provides critical radio performance required to achieve compliance with the North American IS-95 CDMA standard. The agreement combines Qualcomm's design engineering and CDMA technology expertise with TriQuint's high-quality semiconductor production capability and customer-owned tooling (COT) support.

Catalog distributor takes on M/A-COM products—M/A-COM, global provider of wireless components and sub-systems has an agreement with catalog distributor, Newark Electronics. M/A-COM will provide wireless products including RF integrated circuits, passive and control devices, antennas, cables and interconnects to Newark's distribution centers throughout the world, giving Newark Electronics' customers access to a broader selection of wireless component products within the catalog.

Cadence licenses product to support BIST—Cadence Design Systems has licensed LogicVision's Icrambist product to automate built-in, self-test (BIST) for embedded memories in integrated circuit (IC) designs. Icrambist shortens the process of inserting comprehensive at-speed embedded memory test. Under the agreement, Cadence

Business Briefs

Two power resistive products companies join forces—Skokie, IL-based Ohmite Manufacturing has acquired Memcor-Truohm, Huntington, IN. The company manufactures wirewound resistors and rheostats. Ohmite markets resistive and electro-mechanical components. For the time being, both companies will remain at their existing locations under present management. Ohmite has appointed Electronic Salesmasters, Beachwood, OH to represent the firm in Ohio and Western Pennsylvania.

Alltel Mobile holds CDMA digital field trial—Alltel Mobile Communications has begun a field trial of superconducting filters in a functional code-division, multiple-access (CDMA) cellular network. The test will be conducted at a functional CDMA site in Little Rock, AR.

Baystate Technologies acquires Cadkey product line—Baystate Technologies, developer and marketer of mechanical software for computer-aided design (CAD) systems has acquired the line of Cadkey PC-based mechanical design tools from Cadkey, Windsor, CT.

Mentor Graphics acquires Interconnectix—Mentor Graphics, Wilsonville, OR, has extended its position in high-speed printed circuit board (PCB) design by acquiring Interconnectix, Beaverton, OR, developer of interconnect synthesis software for designing high-speed, high-performance digital systems.

Philips acquires Polish magnetic components company—Philips Electronics, Netherlands, has acquired the Polish company, Ferpol, which manufactures components for use in electronics applications. Ferpol, located approximately 70 kilometers southwest of Warsaw, will be part of Philips Magnetic Products, which manufactures yoke rings, soft and hard ferrites and reed switches.

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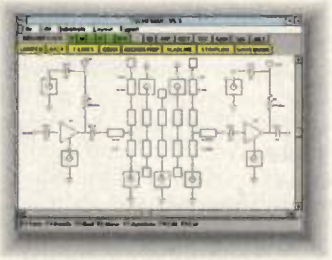

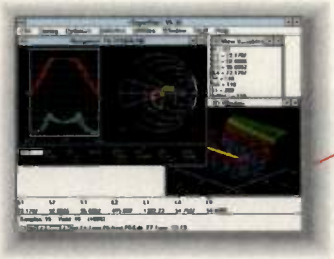

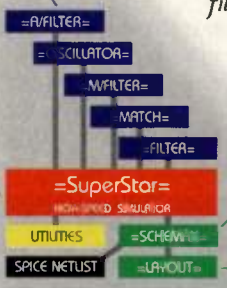

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INFO/CARD 16

can use Icrambist worldwide to satisfy design services agreements and will add the product to its multivendor portfolio of IC test products.

Andersen appoints reps—Andersen Laboratories has appointed new representatives to market their line of surface acoustic wave (SAW) products. The Thorson Company will market the products in Oklahoma, Arkansas and Louisiana. Krebill Components will market the products in Colorado, Utah, Idaho and Wyoming.

Silicon technology benefits digital cellular phones—Ericsson has specified VLSI Technology's higher-integration baseband silicon for its next generation of ultra-light, ultra-small cellular, personal communication networks (PCN) and personal communication services (PCS) handsets. Advances in VLSI's silicon technology contributed toward a 15% increase in talk time, an 83% improvement in standby time and a 12% reduction in weight compared to previous Ericsson global system for mobile communications (GSM) model handsets.

Cell processor provides building block—Newbridge Networks has selected Motorola Semiconductor's MC92500 ATMC controller chip for use in its 36170 Mainstreet ATMnet backbone switch. The 36170 Mainstreet ATMnet architecture offers service providers and large corporate users the high capacity and performance required to build broadband backbone networks.

Company makes appointments—Penny Technologies has appointed U.S. Technical Marketing, East Windsor, NJ, to market the company's Microwave and RF filters, diplexers, delay lines, time-delay modules, directional couplers and power splitters in Northern New Jersey and New York City Metropolitan area including Long Island, Westchester County and Fairfield County, CT.

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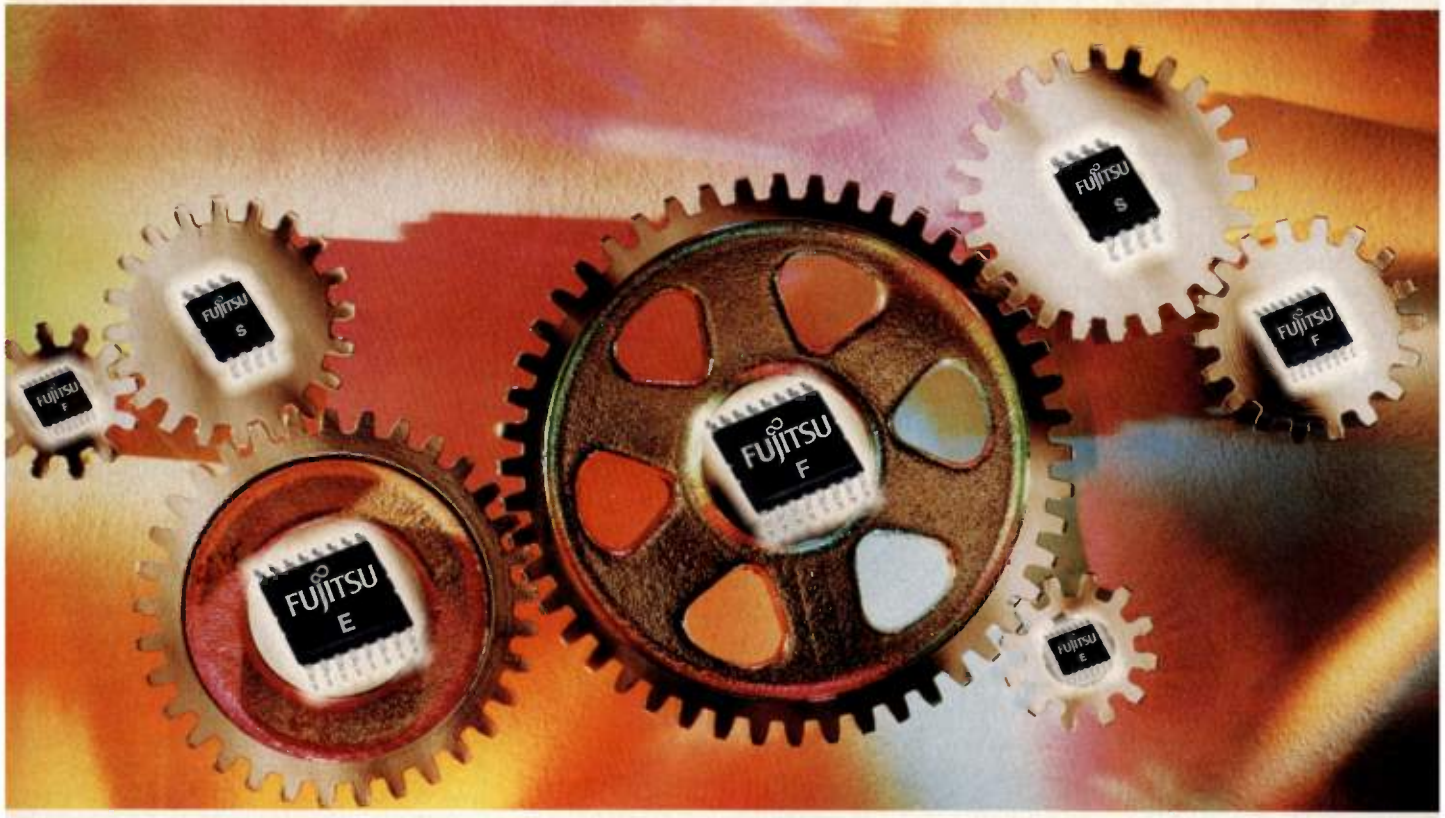

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INFO/CARD 30

RF directional couplers

By Michael G. Ellis, Ph.D.

The best theoretical performance available from a directional coupler, using ideal transformers, is a function of the turns ratio and the terminating impedances. Equations can be derived to describe the performance of transformer-based directional couplers. At VHF and UHF frequencies, wire gauge and core material can be chosen carefully to approximate the response based on the solution of these equations. A computer program can be used as a design aid.

Directional couplers separate signals based on the direction of signal propagation. These devices are used to split unequally the signal flowing in the main line and to pass unimpeded the signal flowing in the opposite direction. Ideally, some portion of the signal flowing into port A will appear at Port C. Similarly, any signal flowing into port C will be coupled to port A. Ports B and C are isolated from one another so that any signal flowing into port B will not appear at port C, yet it will feed through to port A.

The universal RF directional coupler symbol, shown in Figure 1(a), usually represents two transformers connected as shown in Figure 1(b). Directional couplers of this type have no characteristic impedance of their own. They become 50 Ω or 75 Ω directional couplers simply by matching all ports to either 50 Ω or 75 Ω, respectively.

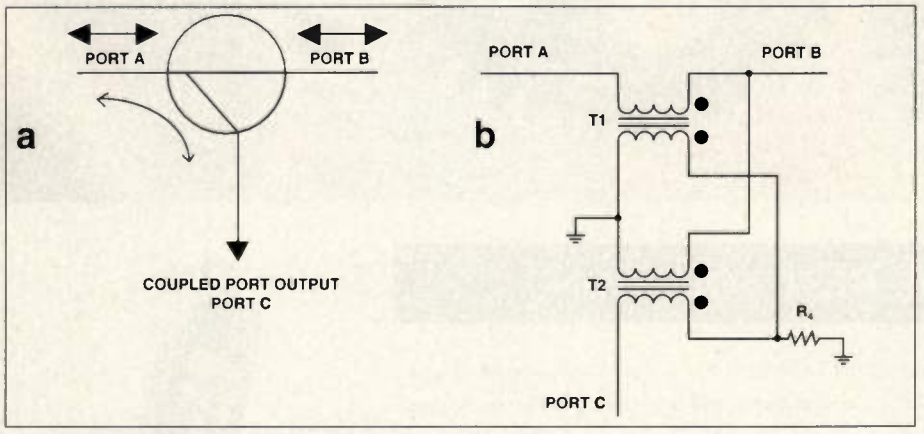

Figure 1. Directional coupler circuit configurations.

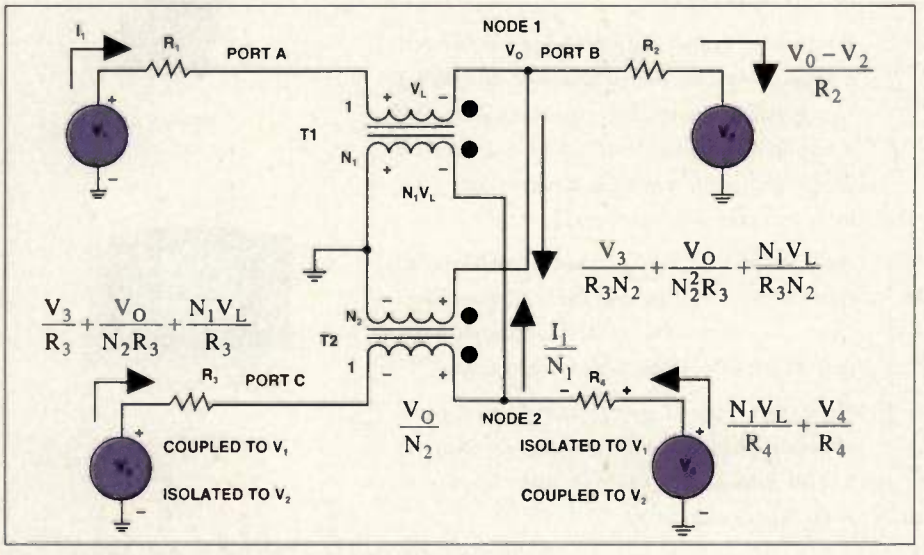

Figure 2. Nodal voltages and currents in a directional coupler.

Figure 2 is a universal model for analysis. In the forward mode of operation, V_1 is the applied input voltage with V_2, V_3 and V_4 replaced by shorts. V_o then becomes the output voltage. A portion of the output voltage, V_o, is coupled to R_3 and, ideally, no voltage appears across R_4. In the reverse mode of operation, V_2 is the applied input voltage with V_1, V_3 and V_4 replaced by shorts. The output voltage then becomes the voltage across R_1. A portion of the output voltage (voltage across R_1) is coupled to R_4 and, ideally, no voltage appears across R_3. The turns ratio of T1 is $1:N_1$, where N_1 is the secondary of the transformer T1. Similarly, the turns ratio of T2 is $1:N_2$, where N_2 is the secondary of the transformer T2. The location of the dots beside the transformers denotes that the voltage across the primary is in phase with the voltage across the secondary. Voltage sources are shown at all four ports because by shorting each of the three voltages sources to ground, the input impedance of the port with the non-zero voltage source can be found from the nodal equations.

The equations shown in Figure 2 can be written down by inspection using Ohm's law and Kirchhoff's voltage and current laws.

- I1 is defined to be the current through R_1.
- The voltage across the primary of T1 is defined to be V_L.
- The voltage at Node 1 is defined to be V_o.
- The current flowing through R_2 is, therefore, the voltage across R_2, divided by R_2, or $(V_o-V_2)/R_2$.
- The voltage across the secondary of T1 is N_1 times the voltage across the primary of T1, or N_1V_L.
- If the current through the primary of T1 is I_1, then the current through the secondary of T1 has to be I_1/N_1.
- The voltage across the secondary of T2 already has been denoted as V_o; therefore, the voltage across the primary of T2 has to be V_o/N_2.
- The current through R_3 has to be the sum of the voltages across R_3 divided by R_3. These three voltages are

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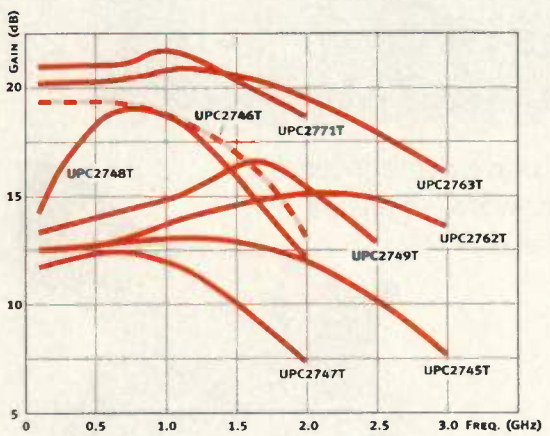

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UPC1678G	50MHz–1.9GHz	23	6	+15	49	500MHz
UPC1688G	50MHz–1.0GHz	21	4	0	19	500MHz
UPC2708T	50MHz–2.9GHz	15	6.5	+7.5	26	1.0GHz
UPC2709T	50MHz–2.3GHz	23	5	+7.5	25	1.0GHz
UPC2710T	50MHz–1.0GHz	33	3.5	+7.5	22	500MHz
UPC2711T	50MHz–2.9GHz	13	5	-3	12	1.0GHz
UPC2712T	50MHz–2.6GHz	20	4.5	-2.5	12	1.0GHz
UPC2713T	50MHz–1.2GHz	29	3.2	-4	12	500MHz

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UPC2745T	50MHz–2.7GHz	12	6	-3.7	7.5	500MHz
UPC2746T	50MHz–1.5GHz	19	4	-4.5	7.5	500MHz
UPC2747T	100MHz–1.8GHz	12	3.3	-11	5	900MHz
UPC2748T	200MHz–1.5GHz	19	2.8	-8	6	900MHz
UPC2749T	100MHz–2.9GHz	16	4	-12.5	6	1.9GHz
UPC2762T	100MHz–2.9GHz	14.5	7	7	27	1.9GHz
UPC2763T	100MHz–2.4GHz	19.5	5.5	6.5	27	1.9GHz
UPC2771T	100MHz–2.1GHz	21	6	11.5	36	900MHz

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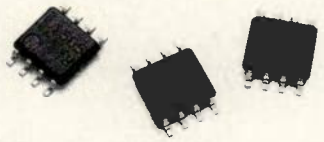

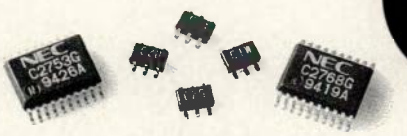

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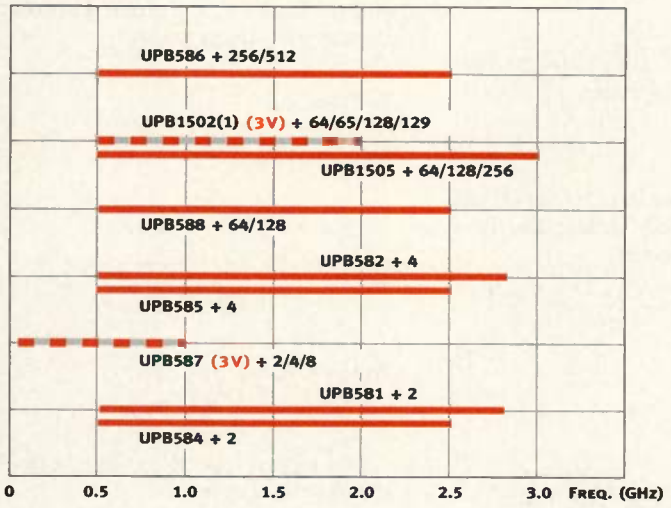

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UPC2757T[1]	100 - 2000	5.6	13	0
UPC2758T[1]	100 - 2000	11	17	+6
UPC2753GR[1]	DC - 400	6.9	79	-17
UPC2768GR[1]	10 - 450	7	80	-17
UPC8106T[2]	100 - 2000	9	9	+1
UPC8109T[2]	100 - 2000	5	4	-4

1. Downconverter
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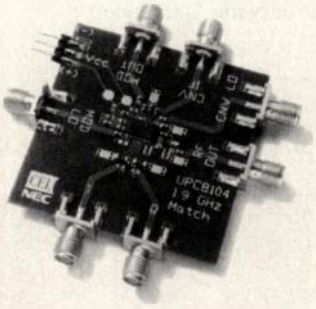

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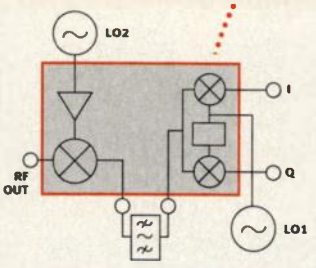

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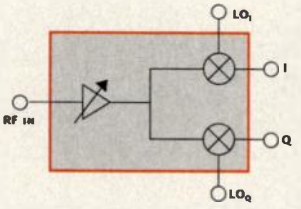

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V_3, V_o/N_2, and N_1V_L, and they add because they are all in phase. (If the solution to the equations shows otherwise, then one of the currents simply will be negative, indicating that actually it flows in the opposite direction than was initially assumed.) The current through R_3 becomes $V_3/R_3 + V_o/(N_2R_3) + N_1V_L/R_3$.

- The current through the secondary of T2 has to be equal to the current through R_3 divided by N_2, or $V_3/(R_3N_2) + V_o/(N_2N_2R_3) + N_1V_L/(R_3N_2)$.
- The current through R_4 is equal to the voltage across R_4, divided by R_4. The voltages to the left and right of R_4 are N_1V_L and V_4, respectively. They add because they are in phase; therefore, the current through R_4 is $N_1V_L/R_4 + V_4/R_4$.

Now the current flowing into Node 1 has to be equal to the currents flowing out of Node 1, therefore:

$$I_1 = \frac{V_3}{R_3N_2} + \frac{V_o}{N_2^2R_3} + \frac{N_1V_L}{R_3N_2} + \frac{V_o - V_2}{R_2} \quad (1)$$

Also, the currents flowing into Node 2 have to be equal to the current flowing out of Node 2, or:

$$\frac{I_1}{N_1} = \frac{V_3}{R_3} + \frac{V_o}{N_2R_3} + \frac{N_1V_L}{R_3} + \frac{N_1V_L}{R_4} + \frac{V_4}{R_4} \quad (2)$$

It is necessary to eliminate the variable, V_L, using the equation:

$$V_L = (V_1 - I_1R_1 - V_o) \quad (3)$$

Substituting equation (3) into (1) and (2) and rearranging terms, the final nodal equations become:

$$\frac{V_3}{R_3} + \frac{N_1V_1}{R_3} + \frac{N_1V_1}{R_4} + \frac{V_4}{R_4} + V_o\left(\frac{1}{N_2R_3} - \frac{N_1}{R_3} - \frac{N_1}{R_4}\right) = I_1\left(\frac{1}{N_1} + \frac{N_1R_1}{R_3} + \frac{N_1R_1}{R_4}\right) \quad (4)$$

and

$$\frac{V_3}{R_3N_2} + \frac{N_1V_1}{R_3N_2} - \frac{V_2}{R_2} + V_o\left(\frac{1}{N_2^2R_3} - \frac{N_1}{R_3N_2} + \frac{1}{R_2}\right) = I_1\left(1 + \frac{N_1R_1}{R_3N_2}\right) \quad (5)$$

Equations (4) and (5) easily are solved for V_o and I_1 because V_1, V_2, V_3 and V4 are known and only one is nonzero for a given analysis. From inspection of Figure 2, the input impedances at each port are given by:

$$\text{For } V_1 \neq 0,\ R_{in1} = \frac{V_L + V_o}{I_1}$$

$$\text{For } V_2 \neq 0,\ R_{in2} = \frac{-V_o}{\frac{V_o - V_2}{R_2}}$$

$$\text{For } V_3 \neq 0,\ R_{in3} = \left(\frac{V_3}{\frac{V_3}{R_3} + \frac{V_o}{N_2R_3} + \frac{N_1V_L}{R_3}}\right) - R_3 \quad (6)$$

$$\text{For } V_4 \neq 0,\ R_{in4} = \left(\frac{N_1V_L}{\frac{N_1V_L}{R_4} + \frac{V_4}{R_4}}\right)$$

The return loss, R_L, at port x (for x = 1, 2, 3 or 4) is given by:

$$RL_x = -20\log\left(\left|\frac{R_x - R_{inx}}{R_x + R_{inx}}\right|\right) \quad (7)$$

In the forward direction ($V_1 \neq 0$)

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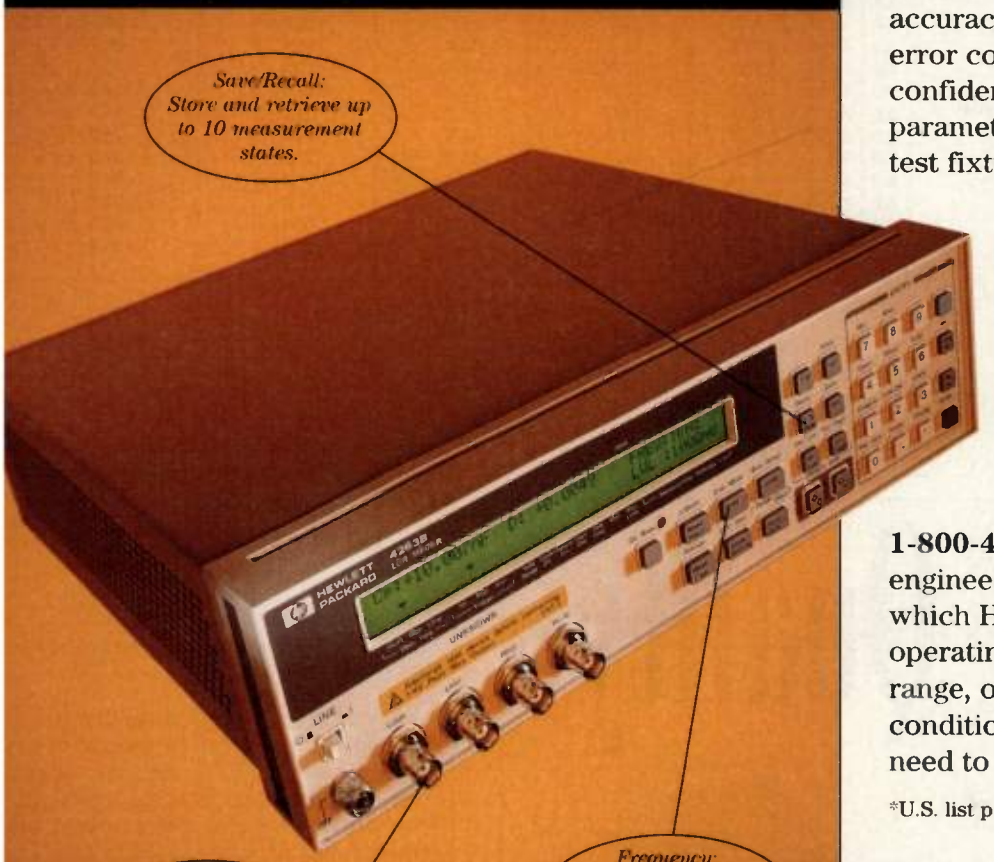

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from inspection of Figure 2, the loss at the various ports is given by:

$$\text{Forward insertion loss} = -20\log\left(\frac{\frac{V_o}{R_2}}{R_1 + R_2}\right) \quad (8)$$

$$\text{Forward coupled port loss} = -20\log\left(\frac{\frac{V_o}{N_2} + N_1 V_L}{\frac{R_2}{R_1 + R_2}}\right) \quad (9)$$

$$\text{Forward isolated port loss} = -20\log\left(\frac{N_1 V_L}{\frac{R_2}{R_1 + R_2}}\right) \quad (10)$$

In the reverse direction ($V_2 \neq 0$), the loss at the various ports is given by:

$$\text{Reverse insertion loss} = -20\log\left(\frac{I_1 R_1}{\frac{R_1}{R_1 + R_2}}\right) \quad (11)$$

$$\text{Reverse coupled port loss} = -20\log\left(\frac{N_1 V_L}{\frac{R_1}{R_1 + R_2}}\right) \quad (12)$$

$$\text{Reverse isolated port loss} = -20\log\left(\frac{\frac{V_o}{N_2} + N_1 V_L}{\frac{R_1}{R_1 + R_2}}\right) \quad (13)$$

N1	N2	INSERTION LOSS (dB)	COUPLED PORT LOSS (dB)	INPUT RETURN LOSS (dB)	OUTPUT RETURN LOSS (dB)	COUPLED PORT RETURN LOSS (dB)
1.0	1.0	7.96	1.94	14.0	14.0	14.0
1.5	1.5	2.60	3.94	15.7	15.7	15.7
2.0	2.0	1.29	6.15	19.4	19.4	19.4
2.5	2.5	0.78	8.01	22.7	22.7	22.7
2.5	3.0	0.65	8.76	26.1	22.6	22.6
3.0	2.5	0.65	8.76	22.6	26.1	26.1
3.0	3.0	0.52	9.57	25.6	25.6	25.6
3.0	3.5	0.45	10.2	28.4	25.6	25.6
3.5	3.0	0.44	10.2	25.6	28.4	28.4
3.5	3.5	0.38	10.9	28.2	28.2	28.2
3.5	4.0	0.33	11.5	30.6	28.2	28.2
4.0	3.5	0.33	11.5	28.2	30.6	30.6
4.0	4.0	0.28	12.1	30.4	30.4	30.4
4.0	5.0	0.23	13.0	34.6	30.5	30.5
5.0	4.0	0.23	13.0	30.5	34.6	34.6
5.0	5.0	0.18	14.0	34.2	34.2	34.2
5.0	6.0	0.15	14.7	37.5	34.2	34.2
6.0	5.0	0.15	14.7	34.2	37.5	37.5
6.0	6.0	0.12	15.6	37.3	37.3	37.3
6.0	7.0	0.11	16.2	40.1	37.3	37.3
7.0	6.0	0.11	16.2	37.3	40.1	40.1
7.0	7.0	0.09	16.9	39.9	39.9	39.9

Table 1. Directional coupler loss as a function of turns ratio.

Table 1 summarizes a portion of the design data that is available from the computer program based on the preceding equations. The return loss values in Table 1 are valid for any arbitrary characteristic impedance, Z_o; therefore, Table 1 can be used to design both 50 Ω and 75 Ω directional couplers. A turns ratio of 1.5 is achieved by two turns of wire on the primary, and three turns of wire on the secondary. Notice that the coupled port loss is approximated closely by the equation

$$\text{Coupled port loss} \approx 20\log(N), \quad \text{for } N = N_1 = N_2 \text{ and } N \geq 2 \quad (14)$$

The range of toroidal-based directional couplers can span two decades of frequency and commonly covers the frequency range of 5 MHz to 1 GHz.

As the turns ratio of T1 and T2 approach $N_1 = 1$ and $N_2 = 1$, the directional coupler does not degenerate into a 3 dB splitter. If a coupled port loss of 3.5–5 dB is desired, the splitter configuration shown in Figure 3 should be used. This basic splitter achieves 3.5 dB loss on each port. A resistive pi-pad on the output port defined as the coupled port can give an additional 0–1.5 dB or more of attenuation. The capacitor C typically is on the order of 1 pF

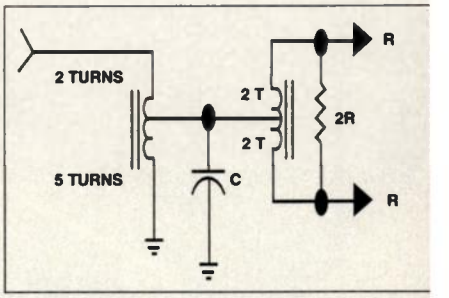

Figure 3. Transformer-type 3.5 dB power splitter. R = 75 for a 75 Ω system.

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and improves return loss.

The ferrite binocular in Figure 4 can be used to realize both the T1 and T2 transformers on a single twin-hole ferrite core. Low-frequency response is dictated by the ferrite material characteristics. High-frequency response partially is governed by total wire length, because the core effects no longer are dominant near the high-frequency end [2]. Interwinding capacitance, leakage inductance, copper losses and transformer coupling below unity ($k < 1$) also reduce high-end performance. Small shunt capacitances to ground at the coupler ports can be used to improve match and directivity at the expense of bandwidth. At higher frequencies, lead length must be kept to a minimum to limit parasitic inductance. To achieve broadband performance, ground connection lengths must be kept short.

Increasing the number of turns on the primary is limited by the number of wires that can fit through the core. For Figure 4, a turns ratio of 6:2, instead, or 3:1, can give superior results for a given frequency range. (The number of turns is determined by the number of times the wire is threaded through the center of the core, even though it may not make a complete 360° turn.) High-frequency response increases as core size and wire diameter decrease.

The response of the directional coupler can vary dramatically, depending on the interleaving of the primary and the secondary coils. If possible, intersperse the secondary windings with turns from the primary. Designers often will set the spacings of the primary and secondary coils to optimize certain design characteristics. The insertion loss at high frequencies can be decreased in the main path at the expense of high-frequency response on the coupled port by coupling loosely the primary and the secondary coils of T2, so that less high-frequency energy is fed to the coupled port. Changing the diameter of the primary wire relative to the secondary wire changes the coupling by tenths of a dB [3]. Using heavier-gauge magnet wire for the primaries reduces mainline insertion loss and improves power-handling capability. The isolated port

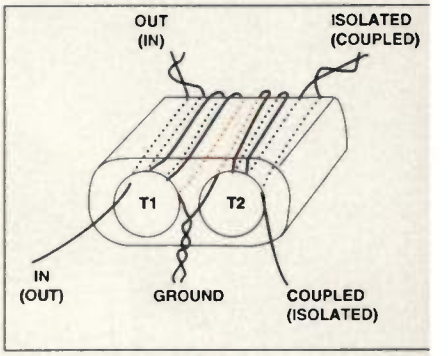

Figure 4. A 10 dB directional coupler.

should connect to a good Z_0 Ω load impedance, such as a small chip resistor.

A small capacitor in the range of 0.5–2 pF can be connected in parallel with this resistor to improve directivity.

A response typical for the coupled port is shown in Figure 5 using a Fair-Rite core and magnet wire. The coupled port frequency response is flat within ± 0.5 dB from less than 50 MHz to 900 MHz.

McWhorter provides other examples using different materials [2]. A 10 dB

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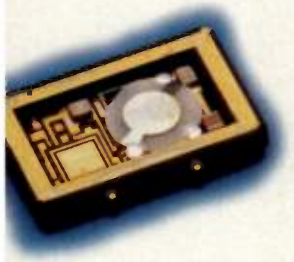

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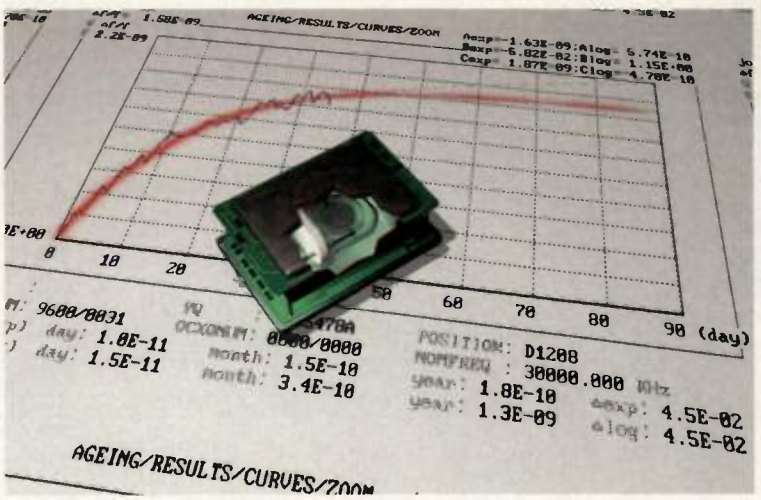

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2	TE5000	3	3.75	20	18.0	-	-	2	1.0	50	1800//+4
4	TE5010	3	3.75	30	14.0	-	-	3	2.0	60	1500//+3
6	TE5020	6	3.75	60	12.5	-	-	4	2.0	70	1500//+3
8	TE5030	6	3.75	60	10.0	90	12.5	5	2.0	80	1500//+3
2	TE5040	3	6.50	20	30.0	-	-	1	1.0	50	2700//0
4	TE5050	3	6.50	30	15.0	-	-	2	2.0	75	3100//0
6	TE5060	6	6.50	60	19.5	-	-	3	2.0	90	3100//0
8	TE5070	6	6.50	60	13.0	80	17.5	4	2.0	100	3100//0
2	TE5080	3	7.50	20	35.0	-	-	1	1.0	50	3000//0
4	TE5090	3	7.50	30	17.5	-	-	2	2.0	75	3300//0
6	TE5100	6	7.50	60	22.5	-	-	3	2.0	90	3300//0
8	TE5110	6	7.50	60	15.0	80	20.0	3	2.0	100	3300//0
2	TE5120	3	15.0	20	70.0	-	-	1	1.0	35	5000//-1
4	TE5130	3	15.0	30	35.0	-	-	2	2.0	60	5000//-1
6	TE5140	6	15.0	60	45.0	-	-	2	2.0	90	5000//-1
8	TE5150	6	15.0	60	30.0	80	40.0	3	2.0	100	5000//-1

21.4 MHz

NO. POLES	TEMEX P/N	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	LOSS dB	RIPPLE dB-MAX	ULT. REJ. dB-MIN.	TERM. Ω/PF
2	TE5180	3	3.75	15	12.5	-	-	2	1.0	50	850//+6
4	TE5190	3	3.75	30	12.5	-	-	3	2.0	70	850//+5
6	TE5200	6	3.75	60	12.5	-	-	4	2.0	90	850//+5
8	TE5210	6	3.75	60	10.0	80	12.5	5	2.0	100	850//+5
2	TE5220	3	6.50	15	20.0	-	-	2	1.0	50	1300//+2
4	TE5230	3	6.50	30	22.5	-	-	3	2.0	70	1400//0
6	TE5240	6	6.50	60	22.5	-	-	4	2.0	90	1400//0
8	TE5250	6	6.50	60	17.5	80	22.5	4	2.0	100	1400//0
2	TE5260	3	7.50	15	25.0	-	-	2	1.0	50	1500//0
4	TE5270	3	7.50	30	25.0	-	-	3	2.0	70	1600//0
6	TE5280	6	7.50	60	25.0	-	-	4	2.0	90	1600//0
8	TE5290	6	7.50	60	20.0	80	25.0	4	2.0	100	1600//0
2	TE5300	3	15.0	15	50.0	-	-	2	1.0	45	3000//0
4	TE5310	3	15.0	30	45.0	-	-	3	2.0	60	3000//-1
6	TE5320	6	15.0	60	45.0	-	-	3	2.0	90	3000//-1
8	TE5330	6	15.0	60	33.0	80	45.0	4	2.0	100	3000//-1

45.0 MHz

NO. POLES	TEMEX P/N	MODE	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	LOSS dB	RIPPLE dB-MAX	ULT. REJ. dB-MIN.	TERM. Ω/PF
2	TE9420	3-OT	3	3.75	18	16.0	3	1	40	2000//-1.0
4	TE9310	3-OT	3	3.75	30	12.5	3	1	70	2000//-1.0
2	TE7420	3-OT	3	7.50	18	28.0	2	1	40	3000//-1.0
4	TE7430	3-OT	3	7.50	40	30.0	3	1	70	3000//-1.0
2	TE7440	3-OT	3	15.0	15	47.0	2	1	40	8000//-1.5
4	TE7450	3-OT	3	15.0	30	50.0	3	1	70	8000//-1.5
2	TE7730	FUND	3	15.0	15	50.0	2	1	40	1100//+1.5
4	TE7740	FUND	3	15.0	40	60.0	3	1	70	800//+1.0

70.0 MHz

NO. POLES	TEMEX P/N	MODE	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	STOPBAND dB	STOPBAND KHz	LOSS dB	RIPPLE dB-MAX	TERM. Ω/PF
2	TE10400	3-OT	3	7.5	18	30	35	-910	2	1	2000//-1
4	TE10410	3-OT	3	7.5	35	25	80	-910	3	1	2000//-1
2	TE10420	3-OT	3	10	15	30	35	-910	2	1	2500//-1
4	TE10430	3-OT	3	10	35	40	80	-910	3	1	2500//-1

90.0 MHz

NO. POLES	TEMEX P/N	MODE	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	STOPBAND dB	STOPBAND KHz	LOSS dB	RIPPLE dB-MAX	TERM. Ω/PF
2	TE10440	3-OT	3	7.5	18	30	35	-910	2	1	2000//-1
4	TE10450	3-OT	3	7.5	35	25	80	-910	3	1	2000//-1
2	TE10460	3-OT	3	10	15	30	35	-910	2	1	2500//-1
4	TE10470	3-OT	3	10	35	40	80	-910	3	1	2500//-1
4	TE10480	3-OT	3	15	30	50	80	-910	3	1	4000//-1

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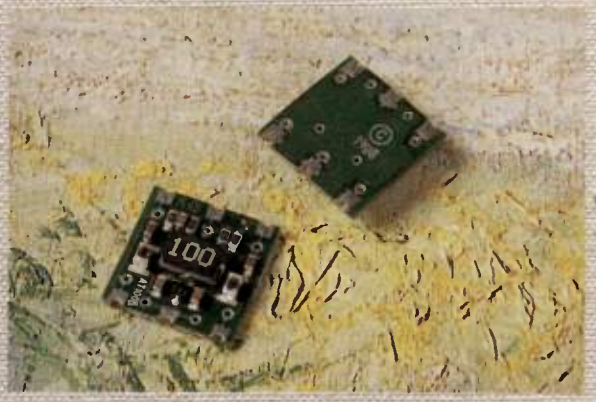
Virtual Wire® transceiver boards are designed for "embedded" low-power wireless data communications. They are available on 433.92 (DK1001B2-1) and 916.5 MHz (DK1002B2-1). Operation is from 3 Vdc. The transceivers feature receiver AGC for improved on-channel interference rejection, excellent out-of-band rejection, fast transmit/receive mode switching, and low current consumption. A Development Kit supports the transceivers, as detailed in the adjacent description. Single-unit pricing for the DK1001B2-1 is $100 each, and for the DK1002B2-1 is $120 each. INFO/CARD 46

New Virtual Wire® Development Kit

RFM's Virtual Wire® Development Kit is a powerful engineering tool for evaluating the feasibility of a low-power wireless data communications application. The Kit facilitates low-power wireless system development. It includes two RF transceivers, along with application development boards implementing a link-layer packet protocol. A demonstration terminal program and test antennas are also included. Each transceiver-protocol board set operates from two AAA batteries. The Kit is available on two frequencies, 433.92 and 916.5 MHz. Development Kit is priced at $350. INFO/CARD 47



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New ASH Receiver Chip Set

RFM now offers ASH (amplifier-sequenced hybrid) receiver technology in chip-set form for high-volume OEM applications. Each chip set includes two surface-mount SAW devices and a 20-pin SSOP (CUSTOM ASIC) IC. Chip sets are currently available on two frequencies. The CS1000 chip set operates on 433.92 MHz, and the CS1100 operates on 303.825 MHz. Additional frequencies will be introduced in the near future. RFM's proprietary ASH receiver technology offers -100 dBm sensitivity, excellent out-of-band rejection, and low-current operation (1.3 mA at 3 Vdc). The price of the chip set is $10.00 per 10,000 units. INFO/CARD 49

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coupler was fabricated on a Siemens B62152-A0008-X030 core. Each primary consisted of one turn of #33 magnet wire. Each secondary consisted of three turns of #38 magnet wire. This coupler was used in a continuous wave (CW) environment with excellent performance in the 10–1,000 MHz band.

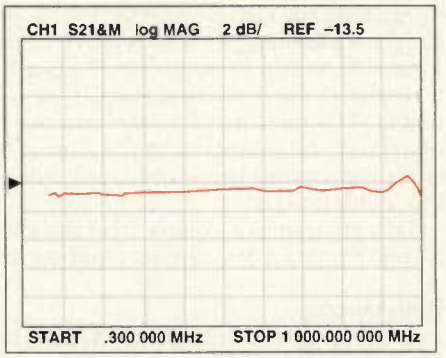

Figure 5. Typical coupled port response.

Two Micrometals T25-0 phenolic toroids were used to create a 20 dB coupler for use in the 500–2,200 MHz band. Each primary consisted of one turn of #32 silver-coated Teflon-insulated magnet wire. Each secondary consisted of 10 turns of #36 Formvar-coated magnet wire.

Conclusion

A computer program helps in designing transformer-based directional couplers. It was provided in a DOS BASIC version (with source), a DOS Visual Basic version and in a Windows Visual Basic version. The program solves the equations derived for arbitrary termination impedances and arbitrary turns ratios. A sample output screen is given in Figure 6 for a directional coupler terminated in 75 Ω on all ports and with a turns ratio of 5:1 for both T1 and T2.

R1 =[75] R2 =[75] R3 =[75] R4 =[75] N1 =[5] N2 =[5]

Rin =	[72.11765]	Input Return Loss =	[34.16703 dB]
Rout =	[77.99755]	Output Return Loss =	[34.16704 dB]
Rcoupled =	[72.11765]	Coupled Port Return Loss =	[34.16705 dB]
Risolated =	[77.99755]	Isolated Port Return Loss =	[34.16704 dB]

Output Voltage =	[.4898041	]Total Input Power =	[3.332054E–03]
Reverse Output Voltage =	[.4898041	]Total Output Power =	[3.332054E–03]
Coupled Voltage =	[9.995982E–02]		
Reverse Coupled Voltage =	[9.995996E–02]		
Isolated Voltage =	[1.998995E–03]		
Reverse Isolated Voltage =	[1.999256E–03]		

Insertion Loss =	[.1789969 dB]
Reverse Insertion Loss =	[.1789974 dB]
Coupled Port Loss =	[13.98644 dB]
Reverse Coupled Port Loss =	[13.98643 dB]
Isolated Port Loss =	[47.97535 dB]
Reverse Isolated Port Loss =	[47.97422 dB]

Calculate | Print | Information | Quit

Figure 6. Sample design output screen.

To conclude, the computer program accepts turns ratios for T1 and T2 that are greater than unity, less than unity or negative. A turns ratio of 0.5 would indicate two turns on the primary for

every turn of the secondary. A negative turns ratio would indicate that the user desires to reverse the polarity of the secondary of the transformer relative to the definition given in Figure 2. As can be seen from Figure 6, the return loss of a directional coupler theoretically never provides a perfect match. The total input power into the directional coupler is computed and compared to the sum of the power flowing out of the remaining three ports as a check on the accuracy of the computations.

This program is available from the author on a 3.5" PC compatible floppy for $15 to cover shipping and handling. *RF*

References

1. U.S. patent number 3,426,298, broadband directional coupler.

2. Mark McWhorter, "Broadband RF Transformer Directional Couplers," *RF Design*, July 1991, pp. 53–58.

3. Nic Hamilton, "RF Transformers Part 1: The Windings," *RF Design*, June 1995, pp. 36–44.

About the author

Michael Ellis received a B.S.E.E. from Vanderbilt University and a Ph.D. from Mississippi State University. He designs CATV-related products as a senior staff engineer for Electronic System Products (ESP), the research division of Antec. Previously, he worked at Hayes Microcomputer and Scientific-Atlanta. He can be reached at ESP, 5720 Peachtree Parkway, N.W., Norcross, GA 30092.

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A Smith chart custom-control software program for Visual Basic

By Viswanathan Iyer

The Smith chart probably is the graphical tool most commonly used by RF circuit designers. Its ability to condense a lot of information onto one chart and to interpret it graphically has made RF engineering tasks less tedious and less time-consuming. Various Smith chart computer programs are available; nevertheless, there is often a need for original software to perform some special task that may be otherwise unavailable with commercial software. These tasks could range from collecting and displaying data from a network analyzer to design automation and testing. The task becomes a lot easier if core software is available that easily can be reused and customized. The following information describes a Smith chart custom-control software program and demonstrates the ease of its use.

Visual Basic (VB) is probably one of the easiest programming tools developed for the PC. A custom control is a special form of dynamic link library (DLL) consisting of functions that can be called from VB. Custom controls are time-savers, allowing developers to produce specialized Windows applications by setting the desired properties either directly or during run time with VB statements. Controls have properties that define aspects of their appearance, such as size, shape, color and position.

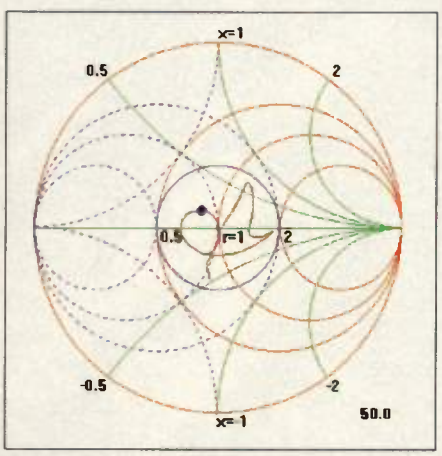

Figure 1. A typical Smith chart control display.

They can respond to events initiated by the user or triggered by the system. Additionally, it is possible to have multiple copies of a control in the same program.

By convention, custom control files have a .VBX extension. They are installed in the windows \system subdirectory and are loaded in VB by choosing "Add File" command from the "File" menu. After the file loads, the property box can be opened by choosing properties from the window menu (or by using the F4 key).

Smith chart custom control

The Smith chart custom-control program draws a Smith chart, plots reflection coefficient data and retains as many as 1,010 points in memory [1]. (See Figure 1.) Additionally, it can draw the voltage standing wave ratio (VSWR), quality factor (Q) and other noise and gain circles.

Properties and events

The Smith chart control program has 41 properties and 10 events. At design time, the properties can be found in the property box, and events can be accessed by double-clicking on the control. Figure 2 shows the Smith chart property box and events list. Custom properties and events (properties and events that apply only to this control) are marked with an asterisk (*). For information on standard properties or events, refer to VB books [2].

PROPERTIES

	Smith1 SMITH	
	Smith Chart Tool: Copr.1995,V.Iyer	
	About	Smith Chart Tool Cop
	BackColor	&H00FFFFFF&
*	CircleColor	&H000000000&
*	CircleIndex	0
*	CircleM	0
*	CircleQ	0
*	CircleR	0
*	DataQ	0
*	DataR	0
*	DataReset	False
	DragIcon	(none)
	DragMode	0 - Manual
*	DrawQ	0
*	DrawR	0
	FontBold	True
	FontItalic	False
	FontName	MS Sans Serif
	FontSize	7.8
	ForeColor	&H000000FF&
	Height	6132
	HelpContextID	0

	Smith1 SMITH	
	Index	
	Left	1008
*	MarkerQ	0
*	MarkerR	0
	MousePointer	0 - Default
	Name	Smith1
*	NumPoints	5
*	QCircle	0
*	Redraw	False
*	ResetAll	False
*	ShowAdmittance	False
*	ShowMarker	False
*	Sweep	False
	Tag	
*	ThisPoint	0
	Top	540
	Visible	True
*	VSWRCircle	0
	Width	6132
*	Z0	50

EVENTS

* ClickIn	* ClickOut	DragDrop
DragOver	GotFocus	KeyDown
KeyPress	KeyUp	LostFocus
* MouseMove		

Figure 2. Smith chart control property box and events.

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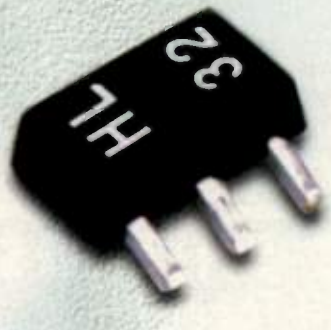

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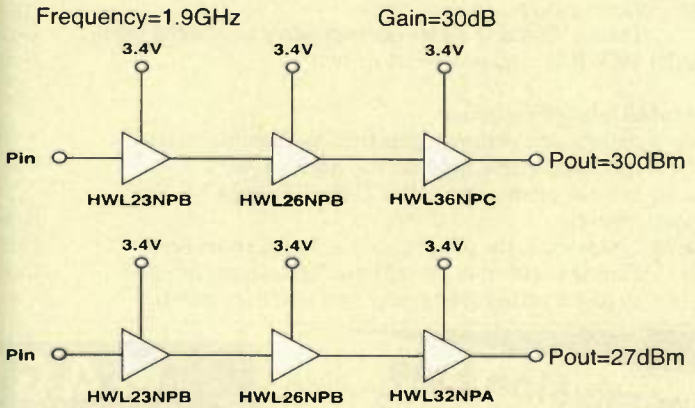

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Symbol	Parameters & Condition	Unit	Typical Data at f=1900MHz					
			HWL23NPB	HWL26NPB	HWL27NPB	HWL30NPA	HWL32NPA	HWL36NPC
I_{DSS}	Satuated current V_{DS}=5V, V_{GS}=0V	mA	110	220	400	600	1100	2000
P_{1dB}	Power Output at 1dB compression point							
	V_{DS}=3V, I_{DS}=1/2 I_{DSS}	dB	17.5	21.5	24.5	-	28.5	29.0
	V_{DS}=5V, I_{DS}=1/2 I_{DSS}	dB	21.0	24.5	-	28.5	-	32.5
G_{1dB}	Gain at 1dB compression point							
	V_{DS}=3V, I_{DS}=1/2 I_{DSS}	dB	13.0	10.0	8.0	-	8.5	10.0
	V_{DS}=5V, I_{DS}=1/2 I_{DSS}	dB	14.0	11.0	-	11.0	-	11.0

* All of above measurements made using CW RF source.

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Description and usage of custom properties and events

• ShowAdmittance Property

Purpose : Draws admittance circle on the Smith Chart
Syntax : [form.]smith.ShowAdmittance[= {True | False}]
Data type : Integer (Boolean)
Comments : The following table lists the ShowAdmittance property settings.

Setting	*Description*
True	Draws admittance circle on the chart
False (Default)	Admittance circles are not drawn

• VSWRCircle/QCircle Properties

Purpose : Draws VSWR/Q circles on the Smith Chart
Syntax : [form.]smith.VSWR{or Q}Circle[= data !]
Data type : Single
Comments : The following table lists the VSWR/Q property settings.

Setting	*Description*
>0	Draws VSWR/Q circles corresponding to entered value
0(Default)	VSWR/Q circles are not drawn

• DataM/DataQ Properties

Purpose : Plots and retains reflection coefficients magnitude and angle data on the Smith Chart.
Syntax : [form.]smith.DataM{or DataQ}[= data !]
Data type : Single
Comments : New data are plotted on the Smith chart after DataQ is entered. DataM and DataQ can be used to plot a series of as many as 1,010 data points by setting NumOfPoints and Sweep properties. The data entered are retained by the memory until the Reset property is set to True. The Color of the trace can be set by using ForeColor property.

Setting	*Range*	*Description*
DataM	= (0 - 1)	Sets reflection coefficient magnitude
DataQ	= (0 - 360)	Sets angle in reflection coefficients

• ThisPoint Property

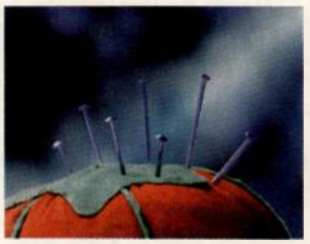
Purpose : Sets the current data point so that it can be identified.
Syntax : [form.]smith.ThisPoint[= point%]
Data type : Integer
Comments : The property setting for this point is from 0 to the number set by NumPoints property.

• NumPoints Property

Purpose : Specifies the number of data points.
Syntax : [form.]smith.NumPoints[= point%]
Data type : Integer
Comments : The minimum value of NumPoints is 2, and the maximum value is 1,010. The default value is 5.

• Sweep Property

Purpose : Draws trace on the Smith Chart corresponding to DataM/DataQ values.
Syntax : [form.]smith.Sweep[= {True | False}]
Data type : Integer (Boolean)
Comments : Sweep property allows DataM/DataQ values to be drawn as a trace by automatically incrementing



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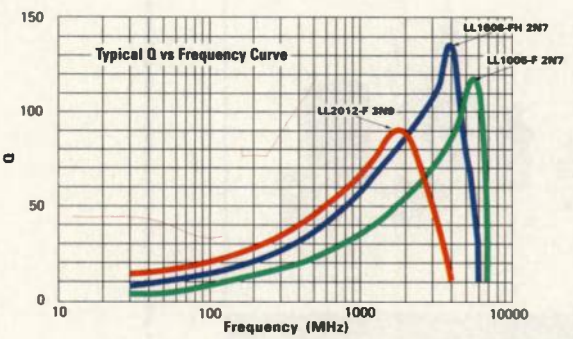

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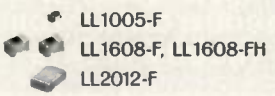

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ThisPoint from its current value to NumPoints.

Setting	*Description*
True	Off
False (Default)	On (Default)

• DrawM/DrawQ Properties

Similar to DataM and DataQ in sweep mode except the data are not retained by the memory, and there is no restriction on number of data points.

• Redraw Property

Purpose : Repaints the Smith Chart.
Syntax : [form.]smith.Redraw[= {True | False}]
Data type : Integer (Boolean)
Comments : The following table lists the Redraw property settings.

Setting	*Description*
True	Repaints Smith Chart and sets the value back to False.
False	Default

• DataReset Property

Purpose : Resets DataM/DataQ, ThisPoint, DrawM/DataQ and all Circles to 0.
Syntax : [form.]smith.DataReset[= {True | False}]
Data type : Integer (Boolean)
Comments : The following table lists the DataReset property settings.

Setting	*Description*
True	Resets data and sets the value back to false.
False	Default

• ResetAll Property

Purpose : Resets all properties to its default values.
Syntax : [form.]smith.ResetAll[= {True | False}]
Data type : Integer (Boolean)
Comments : The following table lists the ResetAll property settings.

Setting	*Description*
True	Resets all properties and sets the value back to False
False	Default

• MarkerM/MarkerQ Properties

Purpose : Places a marker corresponding to the MarkerM and MarkerQ input in terms of reflection coefficients.
Syntax : [form.]smith.MarkerM{or MarkerQ}[= data !]
Data type : Single
Comments : Marker can be turned on and off by using ShowMarker property. Marker property is useful to set up targets for impedance matching.

Setting	*Range*	*Description*
MarkerM	= (0 - 1)	Sets marker magnitude in reflection coefficients
MarkerQ	= (0 - 360)	Sets angle in reflection coefficients

• ShowMarker Property

Purpose : Turn marker on or off.
Syntax : [form.]smith.ShowMarker[= {True | False}]
Data Type : Integer (Boolean)
Comments : The following table lists the ShowMarker property settings.

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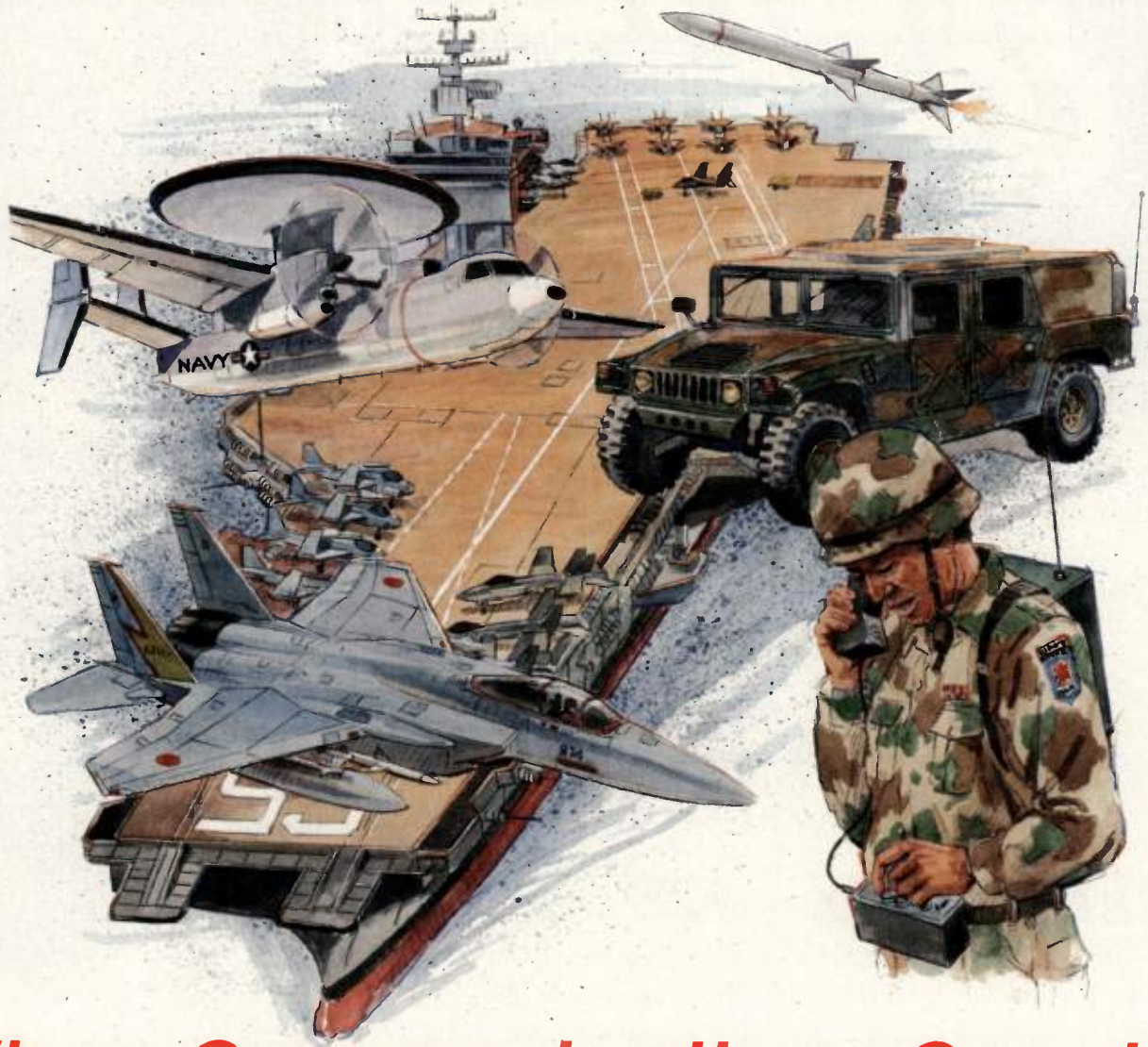

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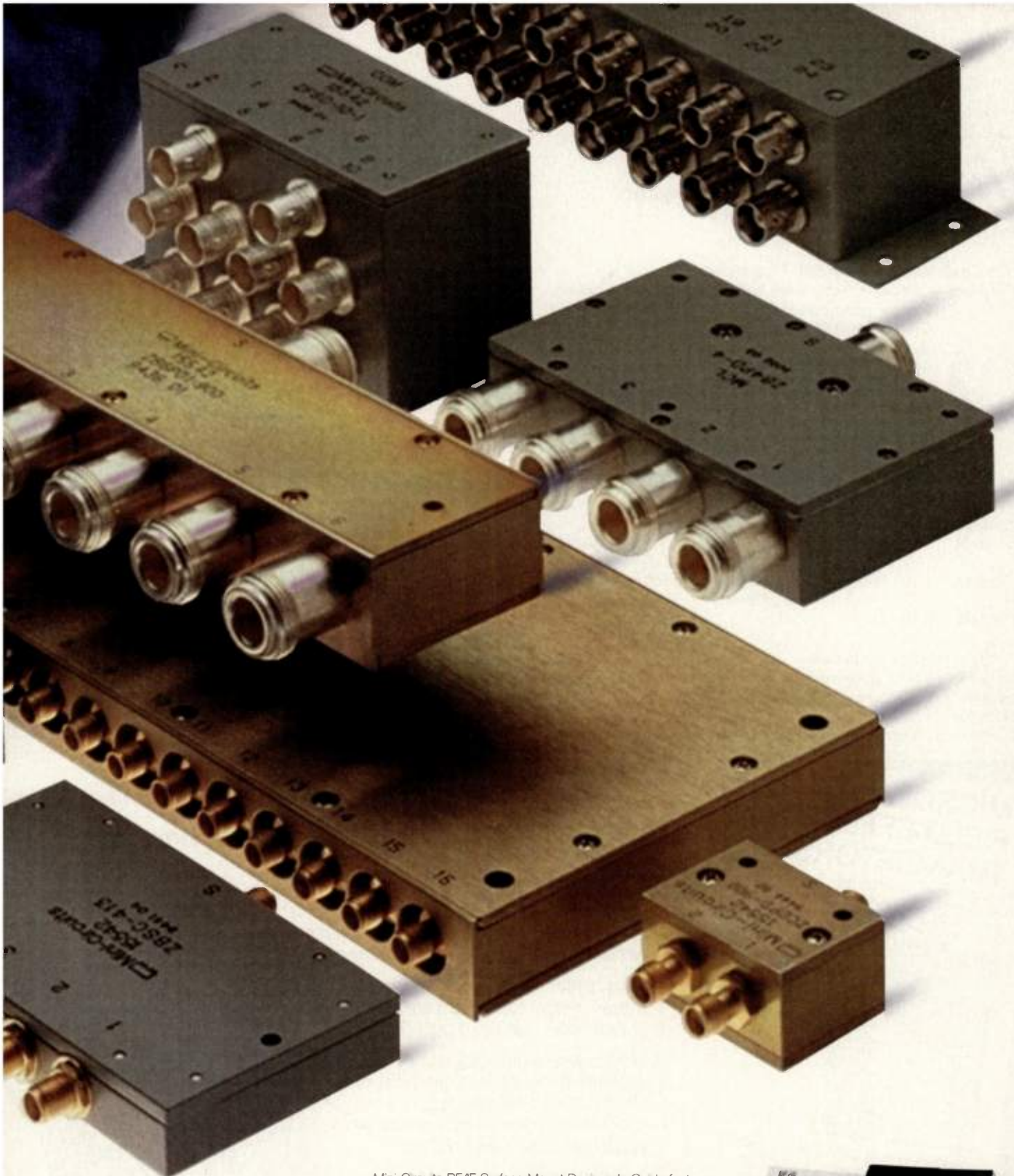

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Setting	*Description*
True	Displays marker corresponding to MarkerM/MarkerQ data
False (Default)	Hides maker

• CircleM/CircleQ/CircleR Properties

Purpose : Draws Circles with specified center and radius. Center point corresponds to reflection coefficient CircleM and CircleQ (magnitude and angle) and the radius equals to the CircleR data.

Syntax : [form.]smith.CircleM{or CircleQ or CircleR}[= data !]

Data type : Single

Comments : A maximum of 10 circles can be drawn by setting the CircleIndex property between 1 and 10. This property is useful for drawing constant gain or noise circles. CircleR property updates the new circle, hence it has to be entered last.

Setting	*Range*	*Description*
CircleM	= (0 - 1)	Reflection coefficient magnitude of center point
CircleQ	= (0 - 360)	Reflection coefficient angle of center point
CircleR	= (0 - 1)	Radius

• CircleIndex Property

Purpose : Sets circle numbers or hides the circles.

Syntax : [form.]smith.CircleIndex [= data %]

Data type : Integer

Comments : This property tracks the index of the circles and has to be increased manually before a new circle is drawn. Circle can be hidden by setting to 0 and issuing a redraw command.

Setting	*Range*	*Description*
CircleIndex =	(1 - 10)	Sets the current circle number for a particular data point
CircleIndex = 0		Hides the circle(s) after the next windows repaint or redraw

• CircleColor Property

Purpose : Sets circle color.

Syntax : [form.]smith.CircleColor [= color&]

Data type : long

Comments : This property sets the circle color corresponding to its index.

Setting	*Description*
CircleColor = &H00000000&	(Default) Black
CircleIColor = (Color)	Color specified using the color palette or RGB scheme

• Z0 Property

Purpose : Displays the characteristic impedance in ohms on the bottom right side of the chart.

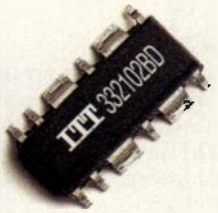
Syntax : [form.]smith.Z0 [= value!]

Data type : Single

Comments : This property is used to display current characteristic impedance of the chart. It also is used as a data storage for the host program, which may use this information to calculate impedance.

Setting	*Description*

Street Smarts.



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>0 Displays the value on the bottom right of the chart
50(Default) Default value is 50 Ω

• ClickIn Event

Purpose : To detect and retrieve coordinates of the point when the user double-clicks the left mouse button on the Smith chart.

Syntax : Sub Smith1_ClickIn (M As Single, Q As Single)
// program code here
End Sub

Data type : M As Single, Q As Single

Comments : When this event is triggered, a procedure is automatically invoked with arguments containing reflection coefficients (magnitude and angle) of the clicked point. This event is useful for displaying one or more interpretations of the same point on the Smith chart.

• ClickOut Event

Purpose : To detect when the user double-clicks the left mouse button outside the Smith chart's outermost circle, but inside the control (outside the Smith chart region).

Syntax : Sub Smith1_ClickOut ()
// program code here
End Sub

Data type : None

Comments : This event may be used to notify the user when a region outside the Smith chart is double-clicked.

• MouseMove Event

Purpose : To detect and retrieve the current coordinates of the mouse pointer when the user moves the mouse over the control.

Syntax : Sub Smith1_MouseMove (M As Single, Q As Single)
// program code here
End Sub

Data type : None

Comments : When this event is triggered, a procedure automatically is invoked with arguments containing reflection coefficients (magnitude and angle) of the mouse pointer. If the mouse pointer is outside the Smith chart region, then the arguments M and Q are set to 2 and 0, respectively. This event is useful for displaying Smith chart interpretations of the current mouse pointer location.

Examples on Smith Chart properties and events

The following section lists Smith Chart examples. To try these examples, start VB(3.0), load the Smith Chart control program and place it on the form. Open the Form_Load Subprocedure by double clicking on the form, enter the code and run it by using the "Run" command in the Menu. The following examples are performed during run time. Alternately, you can perform the same operation by using the property box during design time.

• Example 1—*The following code draws Admittance circles on the Smith chart.*

```
Sub Form_Load ()
```

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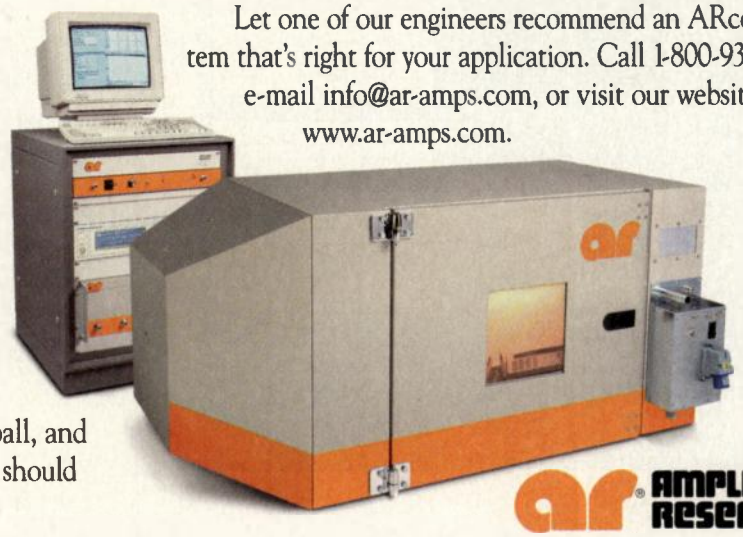

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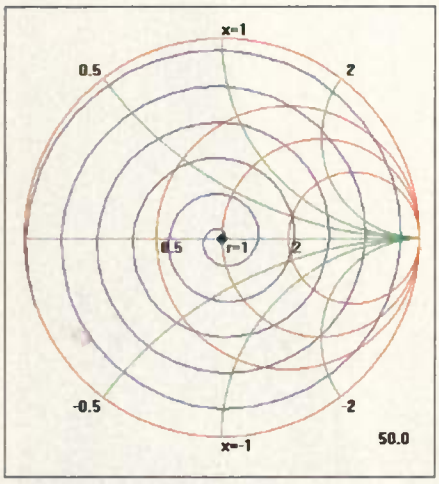

Figure 3. Output of Example 4.

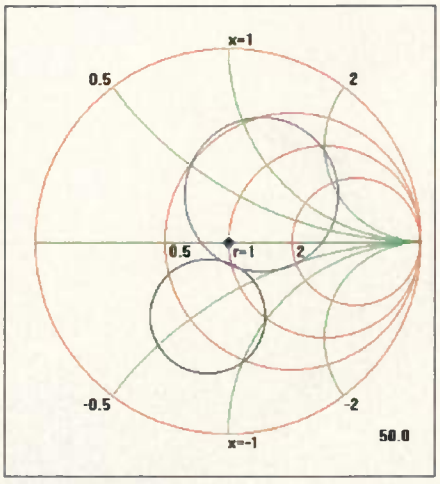

Figure 4. Output of Example 6.

•Example 3—*The following code plots a data point by moving the blue dot from the center to that point.*

```
Sub Form_Load ()
smith1.DataM = 0.5  'Magnitude of
                    'reflection coefficient = .5
smith1.DataQ = 48   'Angle of reflection
                    ' coefficient = 48°
End Sub
```

•Example 4—*The following code draws a trace of 200 data points on Smith chart. (See Figure 3.)*

```
Sub Form_Load ()
smith1.ForeColor = QBColor(1) ' Set
                    ' trace color to Blue
smith1.NumPoints = 201 ' Maximum
                    ' number of points set to 201
smith1.ThisPoint = 1 ' Current data
                    ' counter set to 1
smith1.ShowAdmittance = True
End Sub
```

•Example 2—*The following code draws constant VSWR and Q circles.*

```
Sub Form_Load ()
smith1.VSWRCircle = 1.5 ' Circle of Constant VSWR = 1.5
smith1.QCircle = 5 ' Circle of Constant Q = 5
End Sub
```

```
smith1.Sweep = True ' sweep mode on
For i% = 1 To 200 Step 1
smith1.DataM = i% / 200
smith1.DataQ = i% * 10
Next i%
End Sub
```

•Example 5—*The following code sets a marker on the Smith chart.*

```
Sub Form_Load ()
```

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```
Smith1.ShowMarker = True ' Turn marker on
Smith1.MarkerM = .5 'Magnitude of reflection coefficient = 0.5
Smith1.MarkerQ = 55 'Angle of reflection coefficient = 55°
End Sub
```

•Example 6—*The following code draws constant circles on the Smith chart. (See Figure 4.)*

```
Sub Form_Load ()
'Draw first circle
smith1.CircleIndex = 1 ' first circle
smith1.CircleColor = QBColor(0) ' Set color to Black
smith1.CircleM = .4 ' Magnitude = 0.4
smith1.CircleQ = 255 ' Angle = 255°
smith1.CircleR = .3  ' Radius = 0.3

'Draw second circle
smith1.CircleIndex = 2 ' second circle
smith1.CircleColor = QBColor(1) 'Set color to Blue
smith1.CircleM = .3 ' Magnitude = 0.3
smith1.CircleQ = 55 ' Angle = 55°
smith1.CircleR = .4 ' Radius = 0.4
End Sub
```

•Example 7—*The following example uses ClickIn event to display reflection coefficients. Enter this code in Smith1_ClickIn sub-procedure, which can be opened by double-clicking on Smith chart control during the design time.*

```
Sub Smith1_ClickIn (M As Single, Q As Single)
MsgBox ("Gamma [Mag]: " & Format(M, "#0.000") &
Chr$(13) & "Gamma [Ang]: " & Format(Q, "###.00")), ,
"Smith.vbx"
End Sub
```

Conclusion

With the advancement of state-of-the-art programming, software is treated as components, allowing a novice programmer to build applications quickly. With a Smith chart custom-control software program, you can write your own custom Visual Basic applications by setting its properties and events. *RF*

Acknowledgments

The author thanks Kevin Deibler and Suzana Otano-Lata for proofreading the document and testing the software.

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2. Microsoft Visual Basic Version 3.0, Professional Features Book 1, Microsoft.

About the author

Viswanathan Iyer graduated from Florida Atlantic University, Boca Raton, FL, in 1994 with an M.S.E.E. For the past three years, he has been working for Electropharmacology, Pompano Beach, FL, as a research and development engineer, where he is involved in design and development of RF therapeutic equipment. He can be contacted via E-mail at iyer@emi.net.

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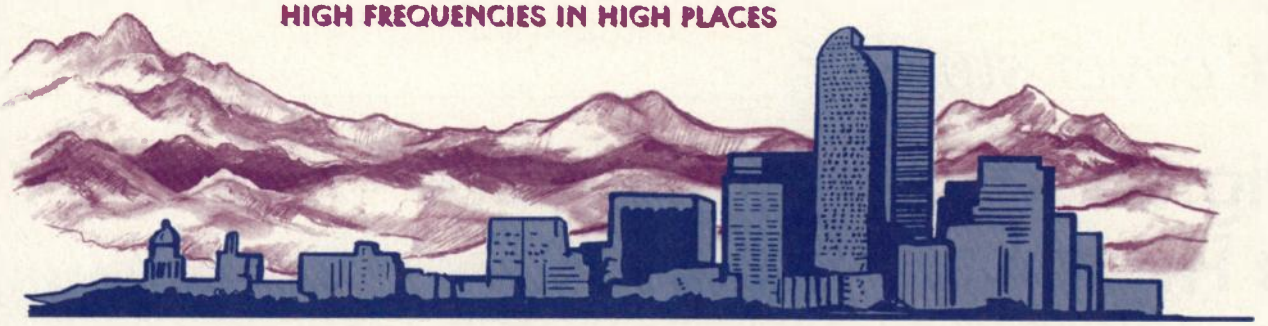

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Digital signal processors in RF systems

By Cesar Benavente and Fernando Cruz

In the past few years, the use of digital signal processors (DSPs) in the telecommunications industry has increased. The constant advances of DSPs have improved performance, increased speed and diminished cost for a number of devices. Processes that previously used only analog technology now use microprocessors or microcontrollers. On the other hand, digital applications may be expensive and may not always be competitive with analog technology. The following information evaluates the usefulness of digital technology vs. analog technology and compares performance, quality and cost.

DSPs are optimized microprocessors and microcomputers for applications that require high-speed data processing, numerical handling or mathematical operations in which involved operations require intensive multiplication and accumulation. As such, DSPs offer numerous advantages over analog circuits, general-purpose microprocessors and bit-slice devices. Although microprocessors are well-known in electronics because they are the "heart" of any computer, the literature and theory about DSPs has been scarce. But now the development of DSPs is on the increase.

Many products have evolved their designs by integrating general-purpose DSPs. DSP technology and custom designs will improve the functionality and characteristics of a system and will minimize the form factor, power dissipation, board volume and system price.

DSPs are becoming more specific. Examples are those designed to code and decode video signals using JPEG, MPEG and H.261 algorithms. Such outlines of coding and decoding can be implemented by general-purpose DSPs, but the problem encountered is the sub-use of the device possibilities. Sometimes it is more profitable to design specific elements that are well-adapted to concrete applications and that may be thought to offer the best performance possible.

Figure 1 shows the general block diagram of the Texas Instrument TMS320xx DSP family and its hardware configuration.

Analog vs. DSP

The trend from analog toward digita communications standards has bee the result of numerous activities. On significant reason is that analog sys tems have been victims of themselves and in certain areas are oversaturate [1]. Although a digital signal initiall requires a larger bandwidth than a analog one for the same quality, digiti zation offers to designers several ad vantages, including incremenal effi ciency improvements due to com pression and discontinuous transmis sion.

In the global system for mobile com munications (GSM, formerly Group Speciale Mobile) digital system, th processor has to carry out coding an decoding, compression and expansion

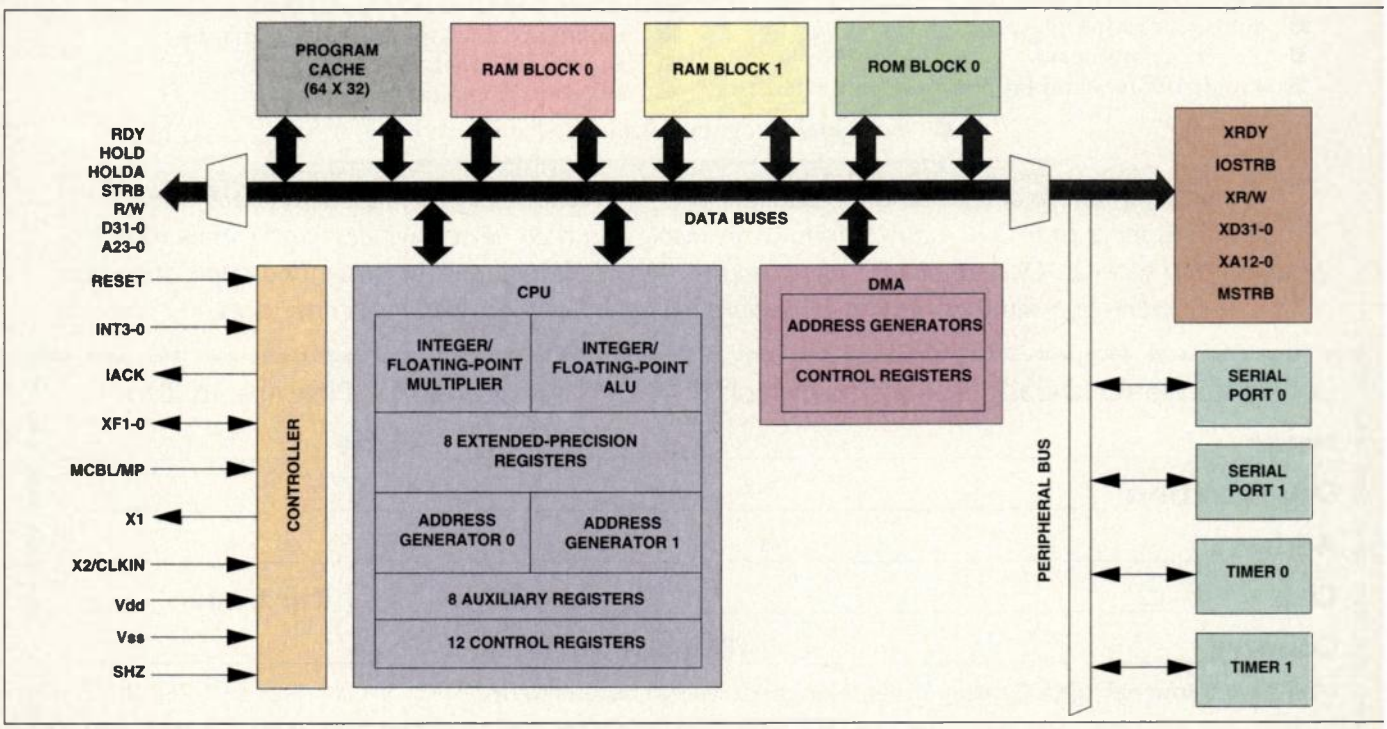

Figure 1. Texas Instruments' TMS320xx DSP's family general block digaram.

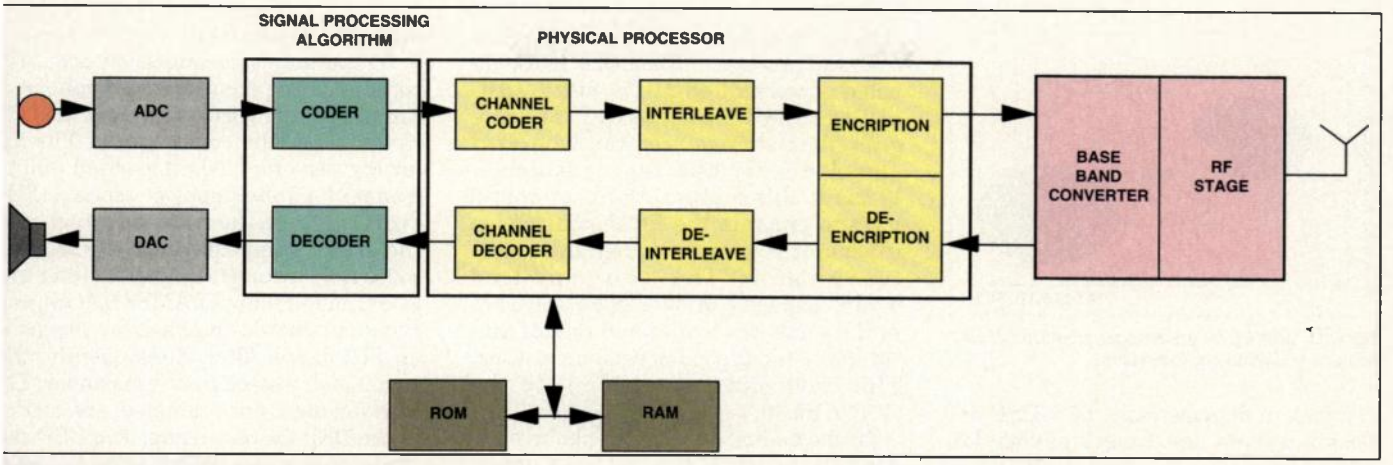

Figure 2. A GSM front-end where DSP functions are integrated.

rror correction and 20 millisecond dis-ontinued transmission. These require-ients help to explain why mobile dig-:al radio has come into use only in the ast few years. (See Figure 2).

An indispensable requirement for a SM system is the availability of fast SPs. One estimation is that each hannel-coding function requires more an 10 million instructions per second MIPS) of processing capacity. The DSP lso could be used for tone generation nd echo cancellation.

To analyze whether an architecture at is not based on a DSP is suitable r digital signal processing, it is elpful to see how it responds to a se-ies of basic features such as the fol-wing.

- Fast and accurate arithmetic. In e majority of systems, it is desirable at the DSPs respond in real time, aking use of the computing speed and e availability of special data formats.
- Fast and constant data flow. The mputing units should be used to the ighest potential. It will be useful to ly on special addressing modes such s bit inversion or circular buffers. It lso would be desirable for two perands to operate on a single cycle.
- Zero overload in curls. A program r a digital signal processing applica-on occasionally is a repetitive algo-ithm with a considerable amount of ata to handle. Discharging the central rocessing unit (CPU) jumps control-ng work and decreases pointers, assing this function to other units. aking the algorithm in hardware if ecessary will increase the system roughput.

Some companies believe that DSPs nd analog circuits are complementary. It often is possible to take advantage of each. For example, if a DSP circuit is available, it is possible to diminish the non-linearity of an amplifier by analyzing the intermodulation products and, based on some specifications, to make it work the best way.

On the other hand, it is appropriate to emphasize that the cellular-telephone market growth has exceeded the most optimistic forecasts. Technology has continued to improve, and the equipment costs have gone down. Cost reduction and performance improvement are a result of the advance in component technology. An example is the realization of whole-voice and data processing by means of a DSP. The earliest cellular telephones used discrete analog circuitry and digital processing for voice and data.

The introduction of DSPs in the cellular telephone environment opens a new age for this technology because of the processor's inherent high functionality and flexibility, requiring a reduced number of components. Besides, DSP-based products have stable characteristics that perform in a wide range of temperatures. They eliminate the necessity of tuning in the factory and minimize the problem of weak components, thereby ensuring more reliable products.

Alternative architectures

It could be supposed that other architectures, such as a reduced instruction set computer (RISC) or the paralleling use of processors, execute instructions fast. A big inconvenience of RISC processors is that their designers consider the multiplying instruction to be redundant because the operation would be accomplished by means of successive sums. In a general-purpose computer, this operation is not often introduced, but in a digital signal treatment application, this basic operation appears in numerous occasions. Older RISC models do not have a multiplying instruction, though the latest do introduce it. Digital signal processors integrate multipliers to carry out single-cycle calculations.

It is possible that no specific architecture's speed is superior to that of a DSP, but one must keep in mind the type of operations carried out. The millions of instructions per second that a RISC or a parallel architecture could carry out is not the same as what a DSP could carry out. Even so, it is not definitive to analyze the millions of operations per second on a floating point that these other architectures could carry out.

When data-handling is considered, the scale begins to incline in favor of DSPs. For example, calculating the fast fourier transforms (FFTs) with 1,024 points (radix 2), the RISC i860 from Intel would spend 1.024 milliseconds (at 50 MIPS & 80 MFLOPS), and the ADSP21020 would spend only 0.853 milliseconds (at 33.3 MIPS & 66 MFLOPS). The DSP is faster than the RISC, and better data handling allows the DSP to get a better result. This improvement is caused by the capacity of the 21020 to do addressing with bit inversion, to the presence of units dedicated to address calculation, and to the fact that jumps are controlled by hardware. Addressing operations and jumps to the CPU of any general purpose-computer spend extra time when the system is not based on DSPs.

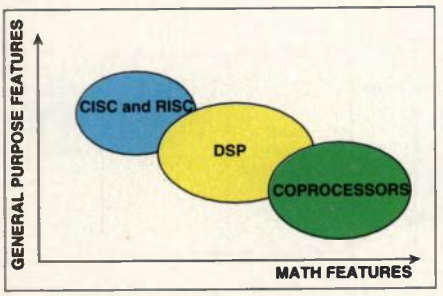

Figure 3. DSP's joint advantages from CISC/RISC devices and math coprocessors.

Figure 3 demonstrates how DSP devices integrate advantages of complex instruction set computer (CISC) and RISC devices and mathematical coprocessors. The graphs of Figure 4 compare the evolution that RISC, CISC and DSP devices have undergone in the last few years.

Devices and typical applications

Some of the latest novelties show the repercussion that DSP use has had in the sector. Some typical applications have been in use for a while.

The TMS320C57 from Texas Instruments, developed for telecommunications, includes a C5x series DSP memory to implement digital-cellular telephone standards and two intelligent peripherals (a serial port with buffers and an interface for the host processor). The use of 3V technology permits the device to work with a sustained throughput of 40 MIPS. The device consumes 5 µA in its standby state, and has a 32-kbyte read-only memory (ROM) and a 7-kbyte random-access memory (RAM). The serial port has a 2-kwords buffer.

AT&T Microelectronics has introduced a family of digital signal processors with flash memory. Many digital-cellular telephone makers already use the new processor, FlashDSP1616, capable of work at 50 MIPS with 5V DC and at 30 MIPS with 3V DC. The program data storage area can be erased electronically and reprogrammed. Without this feature, the user would have to program the ROM and change it when it is time to change the execution program. The "store and load again" capacity of developed software in the same DSP chip could reduce considerably the typical development time. This device is compatible with the DSP1616x30.

In the analog cellular telephone field, the DSP G5001/D chip set uses digital processing techniques to carry out all audio signal and data processing functions required in a subscriber unit. The basic functions carried out by the chip sets are dedicated to the following cellular standards: advanced mobile phone system (AMPS) (USA), TACS (Europe and Japan) and nordic mobile telephone (NMT) (Northern Europe). These functions include voice companding, filtering and limiting, joined to the signal processing. The chip set consists of a first-generation DSP of the TMS320 family, two codecs and an application-specific integrated circuit (ASIC) that includes most of the glue logic and hardware extensions.

Microelectronics has implemented two types of modems for data transmission in different formats. This allows free-hand use of integrated and dual-tone, multiple-frequency (DTMF) generation.

The audio processor of the subscriber unit manages signals coming from the handset to the transceiver and vice versa. Two coding standards are used to sample audio signals and to characterize the analog-to-digital (A-to-D) and digital-to-analog (D-to-A) converters.

In the audio transmission area, th signal coming from the microphone i sampled in the user codec, then the DS carryies out the compression. The fol lowing pre-emphasis is carried out b means of a finite impulse response (FIR digital filter. In the audio reception area the signal sampled by the transceive codec is fed through a low-pass filter an is decimated (only in AMPS/TACS), ca rying out the de-emphasis by means c an FIR digital filter. Subsequently, thi signal is processed by the expandor. Th received data, once sampled, are carrie to the DSP for processing. The DSP ca ries out the non-return to zero (NRZ data extraction, maintaining the syn chronisity of early and late improve techniques.

Advanced digital signal processin techniques have been used to imple ment an audio processor, data pro cessing and supervision functions i analog telephone designs. This is a rel able and efficient approach to task that conventionally are supported b large amounts of analog and digital ci cuitry. The design is flexible enough t allow for improvements such as ech cancellation, full-duplex, hands-fre functioning and voice recognition fo automatic dialing.

By means of a set of five circuits AT&T [2] carries out the Persona Computer Memory Card Internationa Association (PCMCIA) functions on single board. These five devices for the Spectre architecture of AT&' Microelectronics, and they integrate a the functions of a GSM front end, in cluding the RF signal processing, an allow the construction of a portabl front end on a PCMCIA board. This is low-cost and low-power-consumptio application. It allows all GSM tele

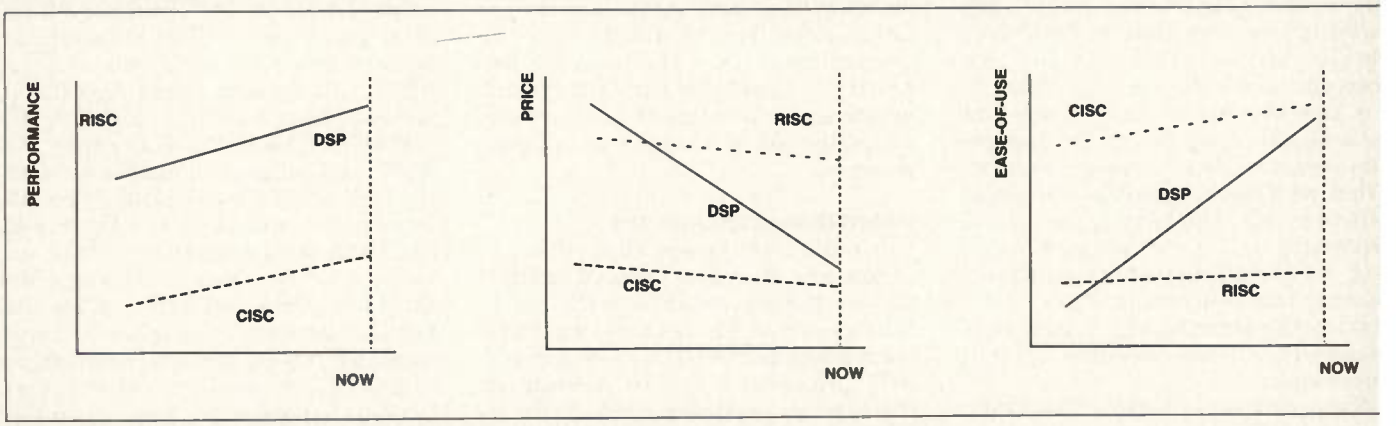

Figure 4. The graphs represent the RISC, CISC and DSP evolution in the last few years in the features listed.

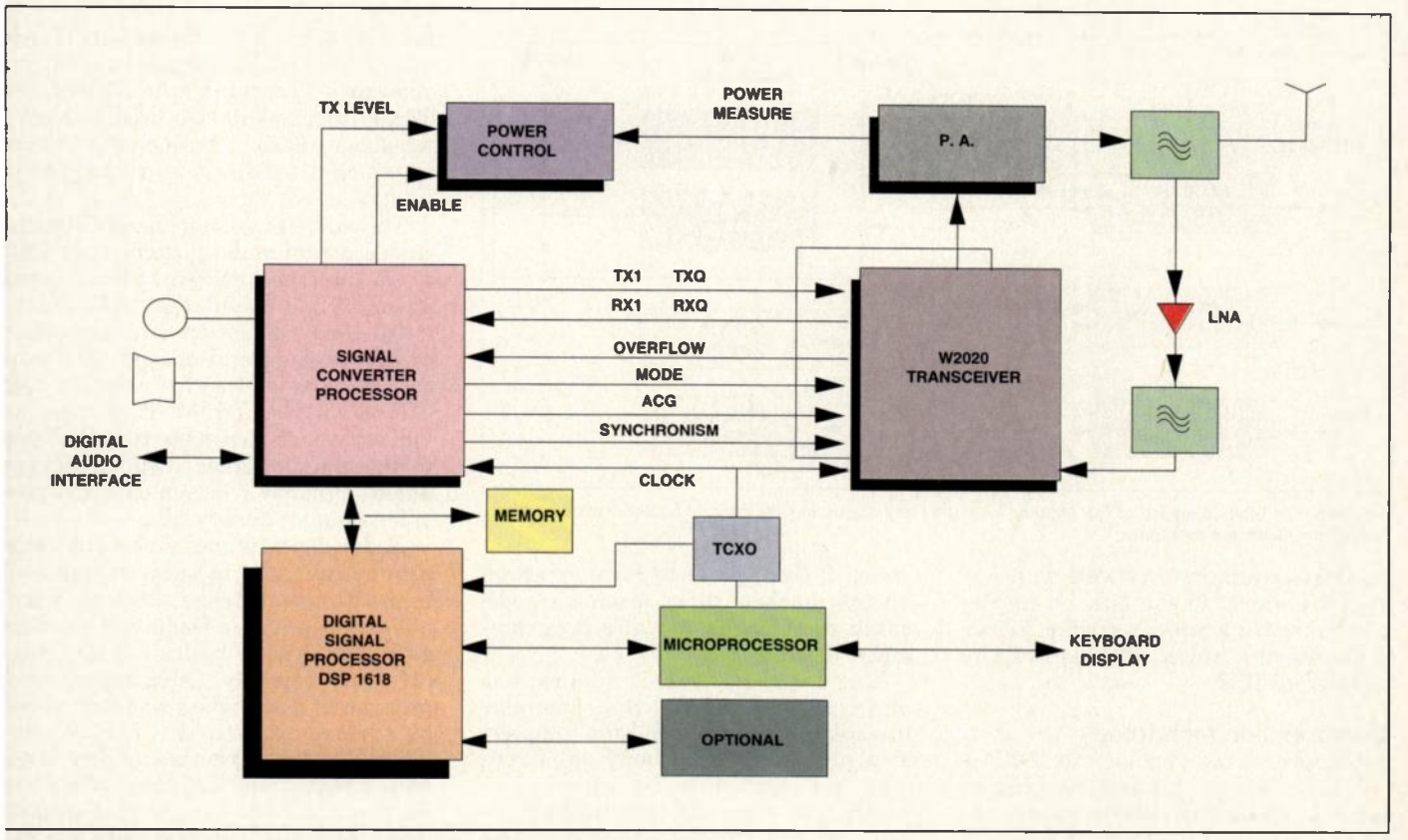

Figure 5. The block diagram of the AT&T chip set for GSM functions.

phone functions, by means of the inclusion of some filters, low-noise amplifiers (LNAs), a microcontroller and a memory to store data service comparative parameters. The new family consists of a baseband signal processor, signal converter, radio transceiver, power gain stage and power amplifier controller. The DSP is a 26 MIPS device with an internally shared memory architecture that facilitates the communication between both processors with minimal overload. Figure 5 shows the interconnection blocks diagram of the devices set developed by AT&T for GSM functions.

The ST18932 DSP application-specific integrated circuit (ASIC)-core from SGS-Thomson has been designed to offer a versatile and low-cost product to consumers who require a dedicated DSP. The ST18932 offers all the specifications required to carry out a voice coder (vocoder) GSM 06.10 in real time for a digital-cellular telephone. Initially, hardware and software are designed to help users in the development or to create a customized software vocoder for GSM. It could be used in any other design based on the ST18932, with minimal software adaptations.

The TCM320AC39 is a voice band processor that requires a minimum number of additional components [3]. The device design is optimized for GSM system requirements, offering a linear conversion mode, fitting the filtering characteristics to the necessities specified by the system. In a typical design, a microphone and a headphone are connected to a DSP through A-to-D and D-to-A converters. Usually, discrete components are used to connect the microphone and the headphone, and a standard codec is used to connect with the DSP. Control could be carried out by means of external components or additional software in the DSP.

An emerging application is a checking system for telecommunication by means of a universal adapter [4]. The digital signal processing universal adapter is used mainly as a general tool to solve generic telecommunications problems. The adapter could be connected to a general-purpose computer by means of an IEC625 bus or to the measurement system controller, using it for single or series measurement. It is based on a programmable DSP (TMS32010) and high-resolution A-to-D and D-to-A converters that allow an almost completely digital implementation for voice-band measurement that conventionally is carried out by means of analog circuitry. With the suitable code, it could measure several magnitudes, such as frequency spectrum, distortion, voice and noise levels, or it could simulate transmission channels and a low-speed voice codec. It could be programmed to make pulse code modulation (PCM) measurements between analog ports and between analog-digital, digital-analog and digital-digital interfaces. It also could carry out signal processing, send it, take measurements and tasks to evaluate and meet the quality requirements.

In general, tests require signal generation, measurement and results evaluation. When carrying out these functions in digital form, the wave-shape digital representations are generated and measured by a DSP, and the interface to input and output ports are realized by A-to-D and D-to-A converters. Conventionally, all the devices' functions required several pieces of general-

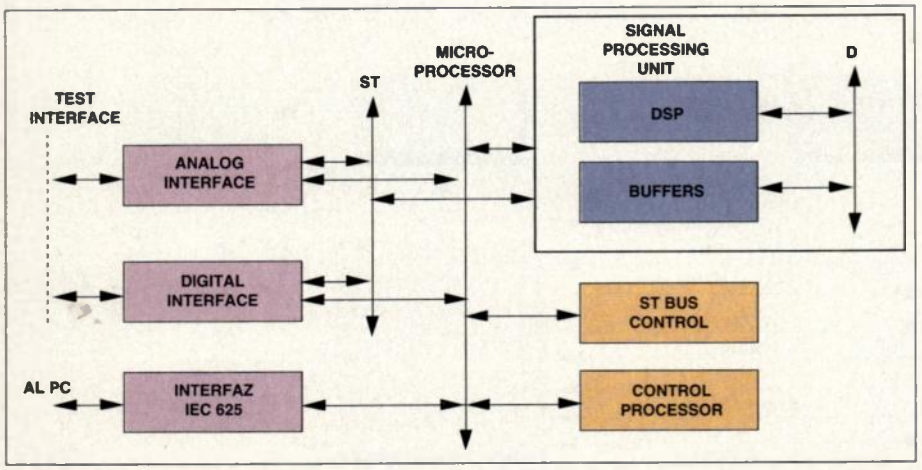

Figure 6. The block diagram of the adapter for digital signal processing thought to solve telecommunication measurement problems.

purpose equipment as well as a few specific ones. These can be implemented by the adapter software. Figure 6 shows the block diagram of the adapter for DSP.

Compression technology

Compression technology for DSP is still in its infancy. It has a great importance in audio and video systems, and the hardware for these systems is based on DSP technology [3]. Two categories of these products have appeared on the market: those products dedicated to compression and programmable devices.

Because of its specific applications and cost restrictions, the consumer market will require dedicated compression processors that carry out fixed-standard algorithms. The greater versatility of the telecommunications products requires devices that can be configured or programmed so that they are able to support different standards used in different applications, often via software. Programmable DSPs from Texas Instruments are used in audio, telephone, video and other applications in which a compression technique is used.

The audio consumer market has included digital audio systems with DSP as the latest technology. DSPs are used in amplitude modulation (AM) stereo C-QUAM receivers for auditory effect creation, reverberation and echo cancellation, as well as for compact disc (CD) quality sound [5]. These specific applications demonstrate that DSP use in digital radio signal reception reduces analog circuitry requirements and provides a higher-quality sound.

Radar digital signal processing techniques involved in large-range and high-resolution target detection frequently use linear frequency varying signals (chirp) or biphase modulation [4]. Until recently, chirp signal compression in most radars was carried out by surface acoustic wave (SAW) devices. The last advances in very large scale integration (VLSI) technology has resulted in the development of specialized DSPs with enough computing capacity to implement adaptive digital filters that could make real-time radar signal compression possible.

Figure 7 is a block diagram of a digital pulse compression system that could be integrated in radar systems.

There are two techniques for implementing an adaptive filter digitally. One method is to use an FIR filter to carry out cross-correlation. The most important advantage of this technique is the theoretical simplicity of the hardware design. The difficulty is in imple-

TOOLS	TMS32OC30	DSP32C	PD77230	ADSP21020	DSP96002
ASSEMBLER	YES	YES	YES	YES	YES
LINKER	YES	YES	YES	YES	YES
C COMPILER	YES	YES	NO	YES	YES
SIMULATOR	YES	YES	YES	YES	YES
EMULATOR	YES	YES	YES	YES	NO
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SEMINARIES	YES	NO	NO	YES	YES

TABLE 1. Tools and services available for different DSPs.

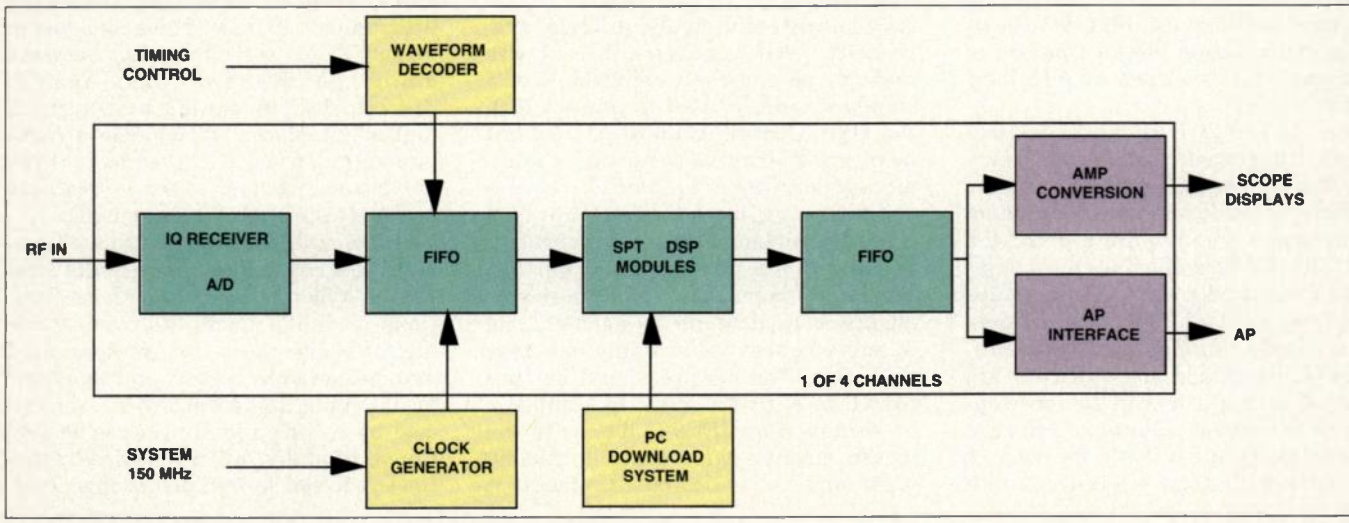

Figure 7. The block diagram of the digital pulse compression system used in radar.

mentation. The other technique consists of the use of the convolutional sum in the frequency domain. Because time-domain convolution is equivalent to multiplying in the frequency domain, taking the discrete fourier transform (DFT) of the sampled signal and multiplying it by the conjugated transmitted signal and then multiplying by the conjugated transmitted signal in the frequency domain, the spectrum of the correlations is formed. The output signal could be recovered by the inverse discrete fourier transform (IDFT).

The DFT can be implemented efficiently by the FFT. The great availability of DSP chips that carry out FFTs allows this method to be implemented in hardware. Several factors related to the application should be considered when determining the hardware used: word length, arithmetic type, windowing, scaling, FFT structure, aliasing size and complexity.

The digital signal processing theory and the necessary hardware to implement a digital pulse compression system have been available for years. Some of the advantages of their use are guaranteed accuracy; flexibility and predictability through simulation; and a simple calibration process. The disadvantages have been complexity, available speed and cost. But the latest advances in high-speed circuits have reduced or eliminated these inconveniences, opening a wide field of applications.

Using digital pulse compressing systems for wideband signals has been possible because of the use of advanced DSP chips. In the past, cost and complexity were substantial enough to outweigh advantages. These inconveniences have been eliminated by time bandwidth products and have been reduced drastically in other products, resulting in the practical use of digital pulse compression, a viable technology for several real-time applications.

Tools

One of the important facts to consider when choosing a device is the selection of development tools that allow the designer to save considerable time. A deep knowledge of the instruction set is not necessary to program the device with the corresponding code. Tools are available to facilitate this work, including algorithms already designed that can be incorporated into the application for the device.

Other tools include all those elements that, although not part of the processor, have been created with the purpose of coordinating the internal and external operation. These tools will not influence the characteristics of the DSPs, but they do obtain better results. It is important to consider them because they constitute the link between the DSP and the user, the user being the method of interchanging data and information. The more potent the tools, the simpler the processor handling at programming level and the simpler hardware circuitry, allowing the user to take advantage of the complete performance. Table 1 shows a comparative summary of tool aids available for dif-

ferent processors [6], [7], [8], [9], [10].

Many icon-based design tools allow designers graphically to choose and place blocks that represent the functions of the application. The system compiles the functions to assemble them to the DSP code.

A good C compiler largely facilitates the programming. This is important if the algorithm is complicated, because using an assembler language does not have the same complexity as using a high-level language to program. The C language is a usual way of implanting algorithms guided to digital signal processing, but one need not become a programmer. Tools exist in the market that are suitable, so the designer does not have to program "by hand" using machine code.

Simulation software uses blocks abl to generate the C code needed to pro gram a DSP. Operations are simulate by means of the blocks. Subsequentl the C code will be translated to th code of the corresponding DSP. Two ex amples of this type of software ar Hypersignal for Windows an Simulink.

Sets of software tools make the jo easier for the designer and reduce th design time. An example is the develop ment kit for multimedia application for Microsoft Windows for the 24-bi DSP56000 DSP µP, that includes voice data and high-quality audio communi cations with the personal compute (PC) media system. The software li braries include routines for the voic synthesis, fax and data modems MPEG algorithms, voice compressio and text-to-voice conversion.

Another example is DSP Lib, a li brary of signal-processing routines fo the devices TMS320C3x an TMS320C40 from Texas Instruments The designer proportions the nexus i C code to tie these routines to the DS program. Some functions that the li braries include are: FFT, FIR and infi nite impulse response (IIR) filters, con volution, correlation, windowing Gaussian noise generation and matri multiplication. The library can imple ment an FIR filter with 100 coefficient in 548 µs on the DSP TMS320C40 at 4 MHz.

In most development software tools it is not necessary to write the cod (because one could use the previousl programmed algorithm). Texa Instruments' TMS320 software cooper ative offers a collection of data sheet with algorithms. The desired algo rithm can be selected from the packet.

Other devices that facilitate desig are those that incorporate analog RI functions as typical DSP functions thus decreasing the design time. Wher RF circuits and DSPs were not previ ously together, designers require prod ucts that can interconnect then without big restrictions.

Expectations in radio communications

Digital signal processing is crucial i many RF markets. The infrastructure for satellite personal communications cellular communications and persona communications service (PCS) all re quire some type of digital signal pro cessing [11].

The digital signal processing ca pacity has reached the height o

emerging wireless communications market expectations. Modern DSPs are faster, more self-contained and frequently are compounded for specific applications such as cellular telephones, wireless local area networks (WLANs) and video transmission.

DSPs (for example, the AT&T DSP1617) operate around 50 MIPS, and devices are available in 16–32 bits, with both fixed-point and floating-point arithmetic. The specification will depend on the application for which it is needed, so some devices will be more adequate for specific applications than others.

Where a single processor cannot perform the work alone, parallel processing offers an alternative. Radar signal processing or video processing frequently require parallel processing for greater capacity than is needed in cellular base stations. These have to manage a multitude of information channels simultaneously.

Diverse devices are designed to be connected in parallel (for example, the TMS320C40). However, computational overhead is produced proportionally to the connection of more devices in parallel. There is a point at which it is more expensive to compute the way in which the division of tasks will be carried out, than to do the actual work in the first place. Even so, that point is far above the level of a single DSP performance.

The increase in DSP use in portable systems has guided the demand for low-consumption devices. Many DSPs get "wait and stop" states, and among the devices soon to be introduced will be the 3V technology. A clear example of this tendency is the ADSP2171 DSP µP with 33 MIPS, designed for applications in which low power is one of the requirements [7]. This device is characterized by three energy-consumption optimization modes that can reduce required power to a minimum of 0.5 mW. The device requires a maximum of only 28 mW and 3.3 MIPS to execute the voice-coding algorithm used in GSM. It contains ADSP2171 forms, and its code is compatible with the ADSP-21xx family of 16-bit fixed-point devices. It has an improved architecture that includes bit-handling instructions and an Xop-squared instruction. The memory included in the chip is 2 Kwords of 24 bits for program data and an optional block of ROM program (8K × 24 bits).

Sector companies

One of the tendencies that has been observed is the formation of alliances between companies producing subsystems. This is often the result of the necessity of making products competitive. In turn, alliances may require specialized groups devoted to research and development, or agreements between companies with prestige in digital systems development.

Analog Devices formed a work group with the objective of continuing the development of devices for wireless applications, starting with the analog signal processing line. The new group will combine RF functions with DSP, audio band functions and baseband to address all the communication issues in RF.

The company has announced an organization plan for the recently formed

communications division [12]. The division will consist of five groups devoted to different areas of the market, including GSM, the emerging wireless communications, wireless infrastructure, telecommunications and RF. Each group will be supported by an engineering team and a systems development team.

Analog Devices and IBM are working together in the design of circuits composed of RF and signal mixing for wireless communications applications. Initial efforts have resulted in the fabrication of a D-to-A converter of 12 bits at 1 GHz.

Cadence and Siemens reached an agreement to undertake digital logic design, analog signal mixers, circuit design, simulation, physical design of integrated circuits, verification and engineering services support. Siemens also collaborates with Cadence in the development of checking advanced applications.

Texas Instruments and Teknekron Communications Systems (TCSI) have reached an agreement with the objective of developing a set of high integration level, next-generation devices for cellular telephone [13]. The agreement combines Texas Instruments DSP technology and its range of linear products, including RF Codecs and audio-band, A-to-D and D-to-A converters with TCSI's experience in DSP based communication systems. Texas Instruments provides products to cellular telephone markets, from components to chips sets, that allow the design of a complete system and single-chip applications.

Siemens offers optimized DSP macros for analog and digital technology [14]. The company offers a large number of Si and GaAs devices for voice, text, data and image applications. These are self-contained blocks that form common parts of modern telecommunication equipment. The company's involvement in mobile communications includes VLSI applications and low-power-consumption device sets made for GSM 1900 and digital European cordless telephone (DECT) standards.

The Sony Electronics consumer products group has started a wireless digital communications division [9]. The division will market products to support all cellular-digital transmission standards.

Conclusion

New devices in the market offer advantages including low-power consumption; faster computing speed memory integration; and A-to-D and D-to-A converters to shorten design time. Device programmability is important too. Development support is best when it requires a short learning curve. The change to a new method should result in as little time lost as possible.

The integration of DSPs in different systems has encouraged custom system design. A growing number of designers use DSP technology to improve existing systems. The most suitable way of getting high differentiation, optimization and integration is by using low-cost custom-made devices. To facilitate that

ntegration, a DSP could be used as a ıost, joined to RAM and ROM modules, ›eripherals and ASIC logic, depending ›n the need of the particular applica- ion.

Many companies work in general- ›urpose DSP development, offering de- ›ices with architectures and sets of in- tructions that offer the designer a arge number of possibilities. Designers nust decide which of the algorithms ınd processes that will be carried out n the system will be integrated. *RF*

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About the authors

Cesar Benavente is an engineer in telecommunications at the Universidad Politecnica de Madrid. He has been a professor in the circuit and systems department of engineering at the Universidad Politecnica de Madrid since 1991. He is working on the application of DSPs and signal processing algorithm applications in communications systems.

Fernando Cruz is a telecommunications engineer at Universidad Politecnica de Madrid. He has worked in the department of development engineering in Telettra, Spain. He has been a professor in the circuit and systems department of engineering at Universidad Politecnica de Madrid since 1990. His work centers on the study and application of DSP algorithms in architectures of specific processors.

The analogy of quartz and coaxial resonators in an oscillator circuit

By Wai-Tak P. Lee

Many people have designed crystal oscillator circuits without having a good understanding of the piezoelectric devices. Similarly, many designers are comfortable with the transmission line as an electrical component or device without understanding it as a resonator—nor do they recognize the LC equivalence of the transmission line. Some have expressed an interest in using the transmission line as a resonator at a frequency of about 2.3 GHz [1]. The following information discusses the similarity of the electrical behavior of piezoelectric resonators to that of transmission line resonators, connects the two devices and demonstrates their equivalency.

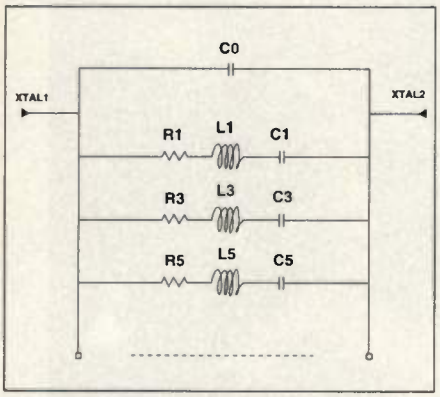

Figure 1. Crystal LC equivalent model.

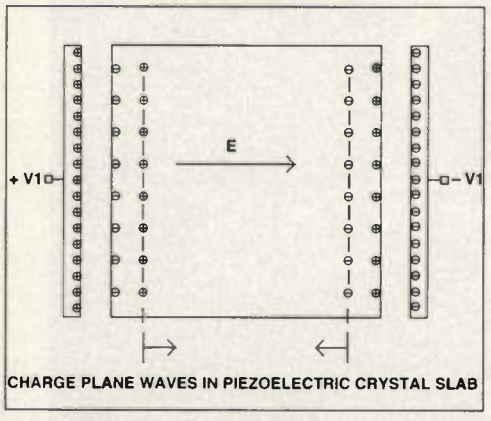

Figure 2. Dynamic electrical behavior of a piezoelectric crystal.

Common piezoelectric devices, known as *crystals* or *ceramic resonators*, are constructed like a simple capacitor. When a DC electric field is applied to a typical crystal, the electric field strains the crystal. The strained crystal produces surface charges that generate an induced electric field. Because the induced electric charges depend on the voltage applied and on the structure and material of the capacitor, the total capacitance of the piezoelectric crystal has two capacitance components [2]:

$$C = C_o\left(1 + K^2\right) = C_o + C_oK^2 \qquad (1)$$

where:

C is the total capacitance;

C_o is the regular dielectric capacitance of the crystal, or the shunt capacitance;

K^2 is the coupling constant of a piezoelectric material;

C_oK^2 is the piezoelectric capacitance.

The piezoelectric capacitance is proportional to C_o, which automatically takes into account the capacitor structure of the crystal. This capacitance can be compared with the commonly known LC crystal equivalent circuit model shown in Figure 1. The total capacitance, C, of a piezoelectric device is given by:

$$C = C_o + C_oK^2$$

From the crystal equivalent circuit model, it also is equal to:

$$= C_o + C_1 + C_3 + C_5 + C_7 + \ldots + C_n \qquad (2a)$$

for n = odd

Therefore,

$$C_oK^2 = C_o + C_1 + C_3 + C_5 + C_7 + \ldots + C_n = \sum C_n \qquad (2b)$$

Because C_n is inversely proportional to n^2, the different overtone capacitance is related or can be expressed in terms of C_1. Therefore:

$$C_n = \frac{C_1}{n^2} \qquad (3)$$

Thus, the sum of C_n for all n = odd integers is

$$\sum C_n = \sum \frac{C_1}{n^2} = C_1 \sum \frac{1}{n^2} = C_1 \frac{\pi^2}{8} \qquad (4)$$

The sum is the total piezoelectric capacitance and, by Equation 2b, is equal to

$$\sum C_n = C_oK^2 = C_1 \frac{\pi^2}{8} \qquad (5)$$

or from Equation 3

$$C_n = \frac{C_1}{n^2} = \frac{8C_oK^2}{\pi^2 n^2} \qquad (6)$$

or

$$C_1 = \frac{8C_oK^2}{\pi^2} \qquad (7)$$

The above derivation directly has tied the piezoelectric properties of the crystal to the model's electrical parameters under the static condition. Because $C_n = C_1/n^2$, the model has $L_n = L$, a constant. Figure 1 helps to explain the crystals equivalent circuit model completely. The model consists of a shunt capacitance, C_o, in parallel with each overtone frequency resonator. The overtone frequency resonators consist of L_n and C_n in series. All L_n are the same and equal to L. With an understanding the equivalent circuit model, C_n easily can be measured with an impedance analyzer [3].

The induced charges contribute to the piezoelectric capacitance, C_oK^2. Because of the strain of the crystal, the induced charges are in two forms. One part is the *static surface charges* and the other is the *moving charge plane waves*. The plane waves are not stationary when a DC field first is applied.

The plane waves eventually diminish, leaving only the static surface charges. A positive charge plane wave front and a negative charge plane wave front move toward each other. (See Figure 2.) This movement generates a constant positive current from one end

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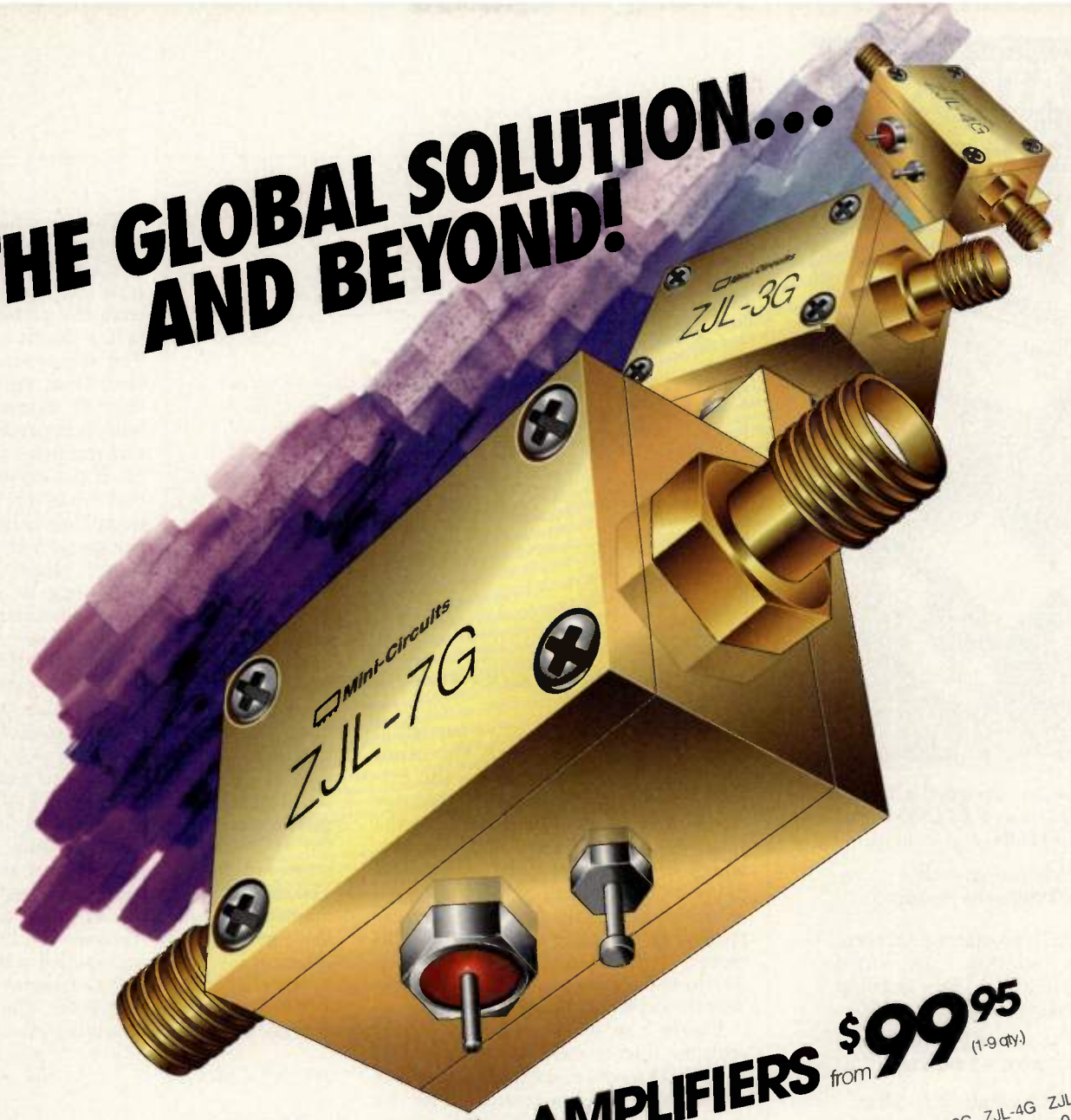

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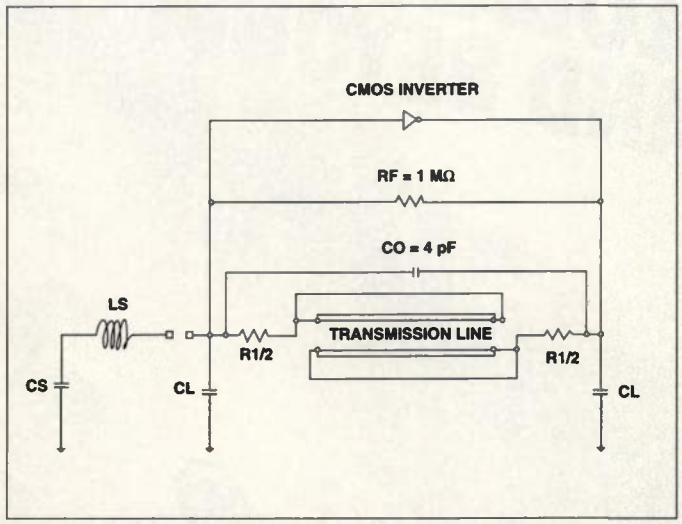

Figure 3. Transmit line oscillator circuit for simulations.

of the crystal and a negative current of the same magnitude from the other end. The net current seen by the outside observer is the sum of these two currents. A designer quickly can model this behavior with a transmission line, which will give the same current and delay as the crystal, by adjusting the characteristic impedance, Z_o, and by specifying the delay time, Δt. To complete the model, add an external capacitor to the transmission line to represent the crystal's shunt capacitance.

Figure 3 shows the oscillator circuit with the transmission line model of the crystal. External resistors are added to the transmission line to account for the crystal's loss.

Ceramic material has large piezoelectric coupling constants. Assume $K^2 = 0.16$ for a ceramic material. For a typical crystal of this material with a shunt capacitance, C_o, of 4 pF, the crystal's piezoelectric capacitance is $C_oK^2 = 0.64$ pF. Equation 6 can be used to calculate all the different C_n for the L-C equivalent circuit model parameters. For example, using the calculation results in:

$C_1 = 0.5187$ pF and $L_1 = L_3 = L_n = 0.48828$ mh, a constant. The L-C equivalent circuit model parameters can be calculated as shown. The model parameters then can be used in the circuit simulation (or transient analysis) of a crystal oscillator. In the simulations, only L_n and C_n as high as n = 5 are included in the simulations. Because n goes to infinity, the number of resonators in the model must be limited for simulation purposes.

The parameters for the transmission line model can now be derived from the piezoelectric capacitance. For any transmission line, specify only its characteristic impedance, Z_o, and the delay time, Δt. If the crystal is for 10 MHz, the delay time is half of the period or 100 nsec; thus, the delay time, Δt, is 50 nsec. The impedance can be calculated as follows. The total capacitance of this transmission line, which is to model the crystal's piezoelectric effect, is $C_oK^2 = 0.64$ pF. The transmission line has the fixed delay Δt. The charging of the piezoelectric capacitor does not follow the resistive-capacitive (RC) time constant for charge and discharge times. The total charge stored, if a voltage V is applied, is equal to $Q = VC_oK^2$. Because the current, I, of a transmission line is constant for a constant applied voltage, V, the charge stored in a capacitor also can be calculated by $Q = \Delta tI$. The two charges are equated resulting in:

$$VC_oK^2 = \Delta T \cdot I \qquad (8)$$

Therefore,

$$\frac{V}{I} = \frac{\Delta t}{C_oK^2} = Z_o \qquad (9)$$

Equation 9 is the formula for calculating the characteristic impedance, Z_o, from the piezoelectric capacitance, C_oK^2, and the delay time. If the capacitance value, 0.64 pF, and the delay time 50 nsec is substituted, $Z_o = 78{,}125\ \Omega$; thus, the derivation of the parameters of the transmission model for a crystal has been demonstrated. The transmission line represents the piezoelectric capacitance only. It is necessary to add a capacitor in parallel with the transmission line to model the shunt capcitance. A resistance to represent the crystal losses, as shown in Figure 3, also can be added.

Transient circuit analyses [4] with both models described above in any oscillator circuit can be run. The equivalency of these two models can be

lemonstrated. In circuit theory, if two ircuits produce the same impulse or tep responses, they are considered to e equivalent. Because both models ave the same shunt capacitance, the hunt capacitance can be ignored. For he purposes of this model, crystal loss an be ignored, too. What remains are he LC resonators in one model and the ransmission line in the other. Both epresent only the piezoelectric capaciance being modeled. The LC model inludes only three LC resonators, n = 1, and 5. A voltage step is applied to oth models. Judging from the transnision line's behavior, the current reponse should be a square wave. The urrent responses of the two models are hown in Figure 4. Note how closely natched the two responses are for the irst half-cycle. The transmission line esponse is more ideal because the nodel contains the resnators for all overtone frequencies.

The LC model includes nly the three lowest-requency resonators. Because of the rounding-off rrors, the various C_n are ot exact multiples of C_1. his difference implies that he various frequencies calulated with L_n and C_n are ot exact harmonics of the undamental frequency. As ime progresses, various frequencies cannot lock in hase with the fundamental requency; thus, the current esponse of the LC model annot maintain the square ave response in the subsequent cycles. This phenomenon demonstrates the equivlency of the two models and alidates the calculations of hese two models' parameers.

Either model can be laced in an oscillator circuit or simulations. The resnators initially are charged o excite the oscillator circuit. The simulation results or both models in the same ircuit are in Figure 5. Both undamental oscillations at 10 MHz build up similarly. Figure 6 shows the close-up iew of the oscillations. Different materials or different cut crystals have different piezoelectric capacitance. With circuit simulation, the effect of the piezoelectric capacitance on the oscillation can be tested by varying the model parameters. One will find the larger the coupling constant K^2, the easier the circuit will be able to oscillate. This translates into either faster oscillation build-up or a lower gain requirement on the amplifier. K^2 can be interpreted

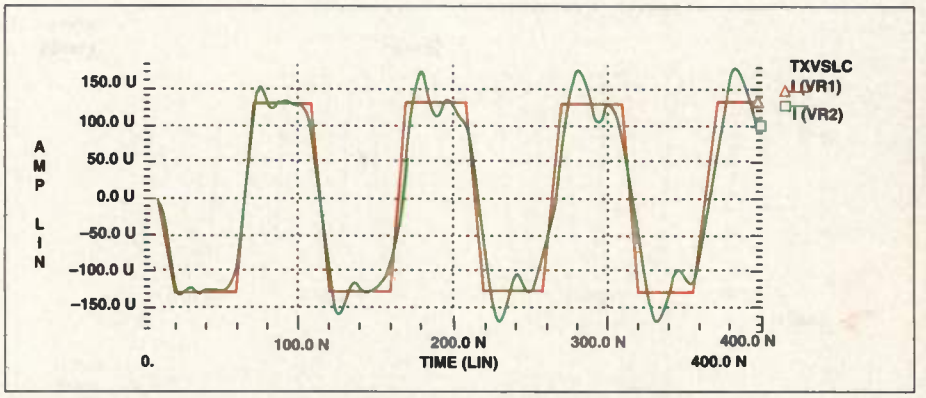

Figure 4. Step responses of the LC circuit model and the transmission line circuit model.

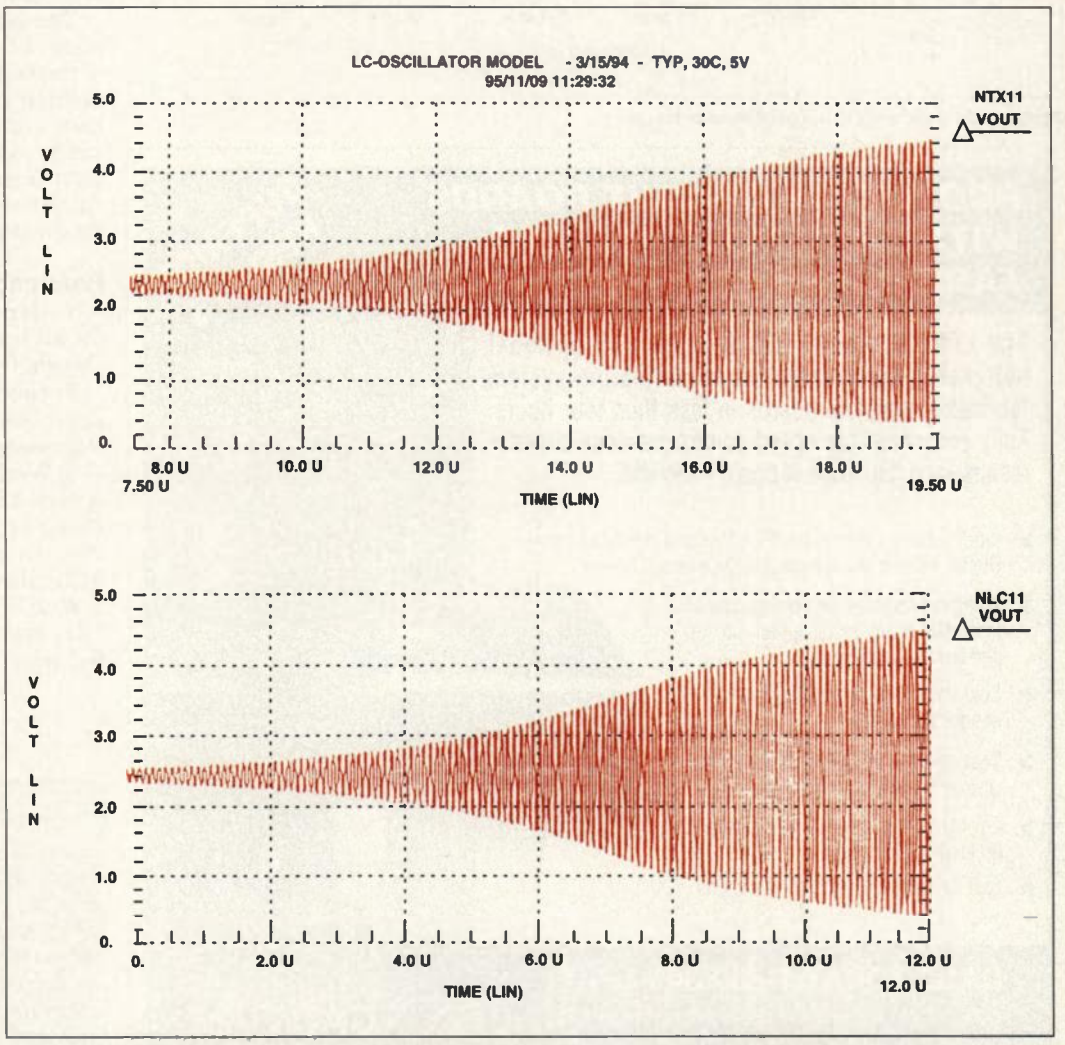

Figure 5. Oscillation build-up of both models. The top one is the transmission model and the bottom is the LC model.

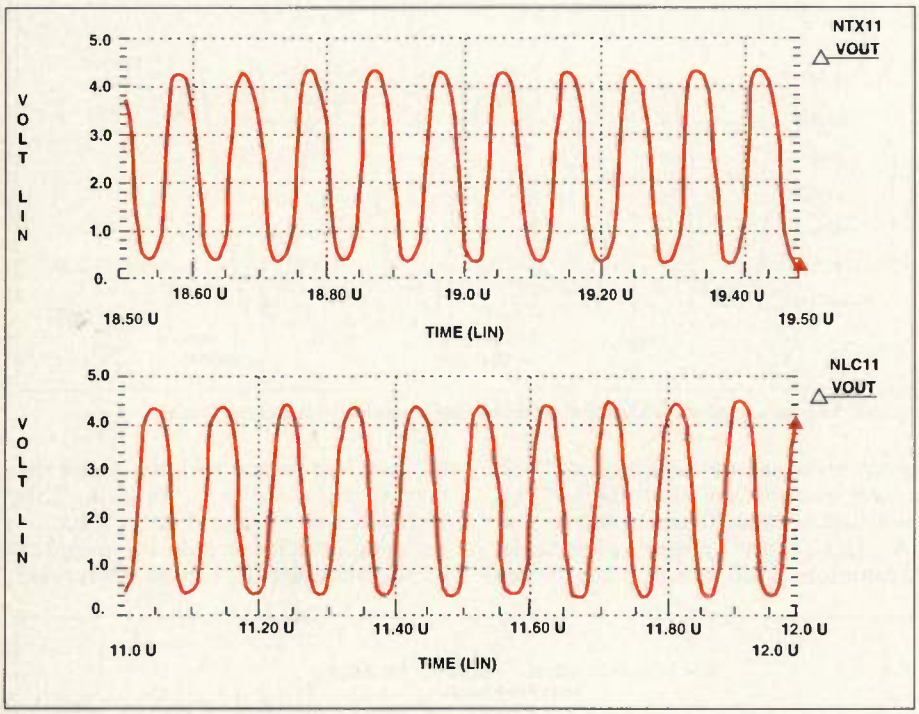

Figure 6. Enlarged view of the oscillation build-up.

as the ratio between the regular *dielectric capacitance* and the *piezoelectric capacitance* of the crystal, intuitively recognizing that the piezoelectric effect is the cause for oscillator behavior. Similarly, the larger the piezoelectric effect, the better the oscillator circuit operates. If the simulations include the trap tank circuit for the fundamental oscillation, both the L-C model and the transmission line model will oscillate at the third overtone frequency [3].

Conclusion

The piezoelectric resonator can be modeled either by an LC equivalent circuit or by a transmission line in parallel with a capacitor. They are equivalent circuits. Through the derivation and calculation of model parameters, a better understanding of the piezoelectric behavior of the crystal can be achieved.

The larger the ratio or coupling constant, K^2, the lower the gain required of the oscillator circuit; or the faster the oscillation build-up. By knowing how a transmission line or coaxial resonator can be used as a resonator in an oscillator circuit, a designer can see that the transmission line is a more exact model for the crystal. *RF*

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About the author

WaiTak P. Lee received a B.S.E.E. from MIT, and a M.S.E.E. and a Ph.D.E.E. from Carnegie Mellon University. He is a principal ASIC engineer designing various systems in chips. He has been with Rockwell Semiconductor systems divisions for 23 years. He has the responsibility for crystal oscillator circuit designs.

Oscillator manufacturers look to smaller packaging to keep up with current design trends

/ectron Laboratories

It is well known that the use of a 'acuum-sealed enclosure that contains he crystal and oscillator circuitry can e of significant value in enhancing the erformance of oven-controlled crystal scillators (OCXOs). These devices, owever, often require custom packag- ng and are relatively complex to man- facture.

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The EMXOs ruggedized construction nd superior frequency stability make he unit the ideal choice for high relia- ility, fast warm-up and low power pplications. The unit can also be pace-qualified.

nternational Crystal Manufacturing

International Crystal Manufacturing nakes more than crystals. The compa- y has been manufacturing standard nd custom oscillators for more than 40 ears. It currently manufactures a full ine of TCXO, VCXO and TCVCXO vith frequencies from 250 kHz to 125 MHz and temperature stabilities up to .5 ppm over varying temperature anges. International Crystal Manufacturing also has a full line of lock oscillator in the standard 14 and pin packaging with a choice of TTL or HCMOS output. A new line of oscilla- ors with an output pin configuration hat is compatible with the standard 14 PIN DIP oscillator, but are available vith up to 1 ppm temperature stability

over various temperatures, will be available from 4–30 MHz. The company also offers engineering assistance to those who need custom specifications and packaging. It specializes in custom frequencies, custom packaging and quick delivery of both small quantities in standard and custom frequencies.

M-tron Industries

One of the fastest and ever-changing devices in the arena of electronic components has been the crystal clock oscillator. M-tron has been a manufacturer of frequency control devices since 1965 and continues to look at better ways and new products to serve the growing clock oscillator market.

M-tron is meeting the challenge of the '90s with the development of a small ceramic package surface mount oscillator. This oscillator, measuring 5 × 7 × 1.75 mm, will be available at frequencies up to 160 MHz and be ACMOS/HCMOS/TTL compatible with tri-state option. Tight stability over an extended temperature range will be available. This oscillator is targeted for telecommunications and PCMCIA applications where small size, high performance and reliability are critical. M-tron provides the engineering support that is often needed with today's higher technology applications.

Oak Frequency Control Group

Tomorrow's electronic communication infrastructure will cause the demand for better functionality, package design and lower-cost frequency control devices to increase. Advancements in oscillator capabilities depend on improvements in quartz crystal technology. At Oak Frequency Control Group (OFC), major growth is expected for compact 1" square OCXOs using miniaturized SC cut crystal resonators. Also, system size reduction needs are providing steady growth for DIP OCXOs utilized in wireless PCS applications. In 1997, new SC cut resonators, under development, will make the popular DIP OCXO available with SC cut performance. A current trend is conversion to user preferred, surface mount type OCXOs, as evidenced by demand for OFC's surface mount OCXO product line. Tape and reeled, reflowable packaging format will see explosive growth over the next two years as hand installed OCXO designs are phased out. Future frequency spectrum crowding and data throughput demands will increase the need for ultra high stability OCXOs which approach atomic oscillator accuracies for wireless infrastructure using CDMA and GSM formats. *RF*

RF products

Spectrum analyzers offer improved performance and ease of use

The MS2653A spectrum analyzer covers the 9 kHz to 8.1 GHz frequency range. It features a dynamic frequency range of 105 dB over the entire spectrum, sweep times of 12.5 µs, an average noise level is less than –110 dBm and noise sidebands at 10 kHz offset are less than –90 dBc/Hz. Designed for maintenance of wireless communications equipment and devices, built-in functions automatically measure burst power, adjacent channel power, occupied bandwidth and channel power. Available options include a 1 Hz resolution frequency counter, high-speed time domain sweep, internal and external trigger with gating function, AM/FM demodulator and an FM demodulation waveform display. A Personal Computer Memory Card International Association (PCMCIA) memory card interface for downloading software to the analyzer to provide fully automated measurements is also available. The MS2653A is priced at $17,500.

Anritsu Wiltron
INFO/CARD 164

Dual-channel synthesizer

The PTS D310 is a broadband dual-channel synthesizer configured in a single rack-mount cabinet. Each instrument contains two fully independent low-phase noise, low spurious output and fast switching frequency synthesizers. The PTS D310 features two channels, each covering 100 kHz to 310

MHz with 0.1 Hz resolution, a frequency switching speed of 20 µs, phase noise of –115 dBc/Hz at 310 MHz with a 1 kHz offset and an output power as high as 13 dBm. Each output channel is controlled through a separate 50-pin parallel interface.

Programmed Test Sources
INFO/CARD 165

Wireless data control product

Skyline RF modems, one of the wireless data communications products, consist of an integrated 2 W UHF synthesized transceiver, data modem and I/O interfaces. Designed for a variety of applications from point-to-point RF links to complex multipoint wireless data acquisition and control applications, features include the use of advanced error correction, addressing up to 65,000 units and and a built-in store-and-forward repeater capability.

Sonik Technologies
INFO/CARD 166

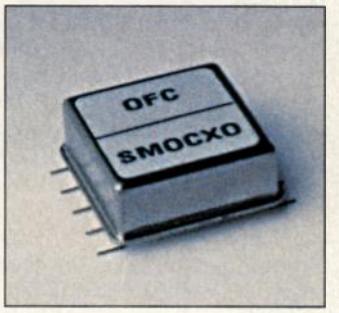
Ceramic capacitor has high capacitance

The Mini-switchmode ceramic capacitor series combines the advantages of high capacitance found in tantalum capacitors with the ESR performance of ceramic capacitors. The J and L lead configurations provide mechanical stress relief to prevent cracking of large surface mounted ceramic capacitors due to thermal cycling. The capacitors are supplied in SMT ready and are priced at $2–$3 each in quantities of 10,000 pieces.

Johanson Dielectrics
INFO/CARD 167

OCXO designed for PCS, base stations

The SMOCXO is a reflowable surface-mount, oven-controlled crystal oscillator (OCXO) designed for personal communications services (PCS), cellular base stations, test equipment and synthesizers. The SMOCXO features a frequency range of 10–25 MHZ, meets a temperature stability specification of $\pm 5 \times 10^{-8}$ over a 0°C to 70°C range with, aging of ±0.5 ppm/year, operates from a 5 V supply with steady state power of 1.0 W and has a phase noise of –130 dBc/Hz. The SMOCXO measures 1″ × 1″ × 0.5″.



Oak Frequency Control
INFO/CARD 168

AMPLIFIERS

CDMA AGC amplifier for dual-mode cellular

The RF2609, a complete automatic gain control (AGC) intermediate frequency (IF) signal amplifier, is designed for the transmit section of dual-mode, code-division, multiple-access frequency modulation (CDMA/FM) cellular applications. The RF2609 features a gain control range from –48 dB to 42 dB and operates from DC to 200 MHz. The circuit's noise figure, IP3 and other specifications are compatible with the IS-95 interim standard for CDMA cellular communications. The RF2609 is designed as part of a chip set that includes a receive IF AGC amplifier, a transmit upconverter and a receive mixer.
RF Micro Devices
INFO/CARD 169

Low-noise, high-power, MOSFET amplifiers

Designed for Cosite communication systems, this series of low-noise, high-power metal oxide semiconductor field effect transistor (MOSFET) technology amplifiers amplifies high-level signals without saturation. The amplifiers feature noise figures as low as 1.6 dB with output power in the 5–20 W range. The series includes a UHF satcom amplifier that operates from 200–400 MHz and higher power versions that operates from 30–400 MHz in three bands. All ampifiers have a maximum voltage standing wave ratio (VSWR) of 1.2:1. Prices for the amplifiers start at $850 for a single unit.
Pole/Zero
INFO/CARD 170

Class A/AB power amplifier operates from 1–30 MHz

A 100 W class A/AB power amplifier, model 30-100-35-A3, is a high-power module that operates from 1–30 MHz. The amplifier features a gain of 40 dB typical with a 35 dB gain minimum, 65% typical efficiency and measures 4.84″ × 2″ × 1″. The 30-100-35-A3 is designed for airborne communications, aircraft, radar, missiles and mobile communications and is priced at $2,595.
LCF Enterprises
INFO/CARD 171

LNA operates from 1–2 GHz

A low-noise amplifier (LNA), model AM-1477, features a nominal gain of 40 dB, output power of 17 dBm and noise figures of 2.1 dB at 2 GHz and 1.4 dB at 1 GHz. It requires 15 VDC at 130 mA. The unit is priced at $375 and comes equipped with SMA.
Miteq
INFO/CARD 172

TOOLS, MATERIALS & PROCESSES

Fast-curing adhesives for wire assembly

Light-weld UV and ultra light-weld UV and visible adhesives cure in seconds and provide a cost-effective assembly for wire and coil assembly, unitizing, strain relief, coating and terminating. These adhesives provide structural adhesion to all types of wire and have better durability than tapes, cyanoacrylates, solvent-activated adhesives, hot melts or epoxies.
Dymax
INFO/CARD 173

Polyolefin shrink tubing slides over connectors

Insul-Grip HS-101-3X polyolefin tubing is a flexible, single-wall, polyolefin heat-shrinkable tubing that slides over connectors or irregularly shaped components that are larger than the wire bundle, fitting snugly over everything. The tubing features a 3:1 shrink ratio and is available in sizes ranging from 1/16″ to 1.5″.
Insultab
INFO/CARD 174

Adhesive films eliminate messy application

Ablefilm supported and unsupported adhesive films provide electrical conductivity, electrical insulation or thermal conductivity to meet the needs of a variety of bonding applications. Convenient, die-cut adhesive preforms eliminate messy paste application. The 550-series is designed for difficult-to-bond metals and retains bond strength after exposure to moisture. The 561 series is designed for bonding materials with severely mismatched coefficients of thermal expansion. The 5025E provides excellent thermal conductivity.
Ablestik
INFO/CARD 175

TEST & MEASUREMENT EQUIPMENT

AWGN generator for CATV and cable modem

The UFX-BER-CATV additive white gaussian noise (AWGN) generator covers the frequency band from 5–85 MHz. Designed for testing CATV systems and cable modems by injecting noise in the upstream and downstream paths, the generator features a typical crest factor of 18 dB and automatic setting of accurate C/N ratios. Direct setting of Eb/No, C/N, C/No and C/I also is available.
Noise/Com
INFO/CARD 176

RF amplifier covers range from 1–1,000 MHz

Model 100W1000, an all-solid-state RF amplifier, delivers a minimum of 100 W of CW power over a frequency range of 1–1,000 MHz. The minimum linear output power measured at the 1 dB gain compression point is 60 W over the same bandwidth. Minimum gain at maximum setting is 50 dB. The amplifier will provide full-rated output power without foldback into loads with a voltage standing wave ratio (VSWR) as high as 6.0:1. The unit is priced at $28,000.
Amplifier Research
INFO/CARD 177

Television demodulators offer high performance

The DS1000 family of television demodulators, designed for cable television and network operators and installa

tion and maintenance service providers, assesses the quality of analog-television-modulated RF transmission systems. The DS1000 family offers the precision needed to make accurate, repeatable measurements of RF signals from 47.25–860.25 MHz modulated with PAL or NTSC analog video. The DS1000 family also features a qaudrature output for the measurement of incidental carrier phase modulation (ICPM), sensitivity from –20 to 30 dBmV and is priced at less than $5,000.
Tektronix
INFO/CARD 178

SUBSYSTEMS

High-level sub-assembly for PCS applications

A multiple-function subassembly featuring active and passive components is a cost-effective system for personal communications services (PCS) and cellular frequency base stations. It integrates directional couplers, power dividers, mixers, filters, amplifiers and frequency synthesizers in a multilayer printed circuit board (PCB) with logic, alarm, monitor and control circuitry. The subassembly will transmit or receive at either the 800 MHz or the 1.8 GHz band.
KDI/triangle electronics
INFO/CARD 179

High-performance synthesized digital receiver

The DCL-VHF-DX, a high-performance synthesized digital receiver operating in the VHF band (153–173 MHz), supports digital data and has excellent audio output that outperforms many high-end commercial radios. The receiver features a 10 MHz band spread and can be tuned to any frequency in the selected band.
RF Neulink
INFO/CARD 180

SIGNAL PROCESSING COMPONENTS

Miniature cellular diplexer

The Model IC853D is a low-cost, high-performance miniature cellular diplexer covering the standard AMPS, ETACS and TACS cellular bands. It features an insertion loss of 1.5 dB nominal, a ripple < 0.2 dB, transmit-to-

receive isolation typically 60 dB and return loss typically better than 16 dB on all ports. Designed to be used in micro, pico and nano cells, the unit measures 3″ × 1″ × 6″ and is priced less than $140 in production volume.
Indutec
INFO/CARD 181

GPS filter

Model 8158, a GPS filter with a center frequency of 1,401 MHz, features a 0.8 dB bandwidth of 40 MHz minimum. The insertion loss is less than 4.0 dB and rejection points are 30 dB at 1,227 and 1,575 MHz, and 50 dB at 1,050 MHz. The unit measures 0.75″ × 0.44″ × 0.32″.
Piezo Technology
INFO/CARD 182

SIGNAL SOURCES

VCOs have low phase noise

The 180S series of low phase noise VCOs features a power output of 13 dBm typical, a tuning voltage of 0–12 V, harmonics of greater than 15 dBc and an input power of 15 VDC at 50 mA for a frequency range of 800–2,800 MHz. The VCOs are available in commercial and military versions.
EMF Systems
INFO/CARD 183

Universal surface-mount crystal packages

In response to market demands for low-cost, high-performance surface-mount crystals, The 49SUB series features frequencies ranging from 3.5–66.67 MHz and a standard frequency tolerance of ±50 ppm. They are priced from 80 cents to $1.50 each in quantities of 1,000.
Saronix
INFO/CARD 184

Voltage-controlled oscillator for UHF radio

The V385ME01 surface-mount, voltage-controlled oscillator (VCO) for ultra-high frequency (UHF) radio applications generates 360–410 MHz within a control voltage range of 0.5–4.5 VDC. The VCO features an output power level of 7.25 ± 2.75 dB into a 50 Ω load, and draws only 15 mA from a nominal 5 VDC bias. The device pulls less than 2 MHz with a 14 dB return loss and covers the 50 MHz frequency range with an average tuning sensitivity of 40 MHz/V. The V385ME01 measures 0.5″ × 0.5″ × 0.22″ and is priced around $15 in quantities of 1,000.
Z-Communications
INFO/CARD 185

Quartz oscillators operate at 100 MHz

The Model FE-102A-100 crystal oscillator features an operating frequency of 100 MHz at a profile of 1″. Designed for low-frequency synthesis, doppler radar, low-noise phase lock loop (PLL) systems and phase-noise reference, the crystal oscillator's typical phase noise is –135 dBc at 100 Hz from the carrier, –163 dBc at 1 kHz from the carrier and –173 dBc at 10 kHz from the carrier.
Frequency Electronics
INFO/CARD 186

OCXO has high stability and reliability

The 260-0536 10 MHz model oven-controlled crystal oscillator (OCXO) uses an SC-cut resonator to offer a thermal stability of ±1.0 x 10–9 from –30°C to 70°C. Aging is specified at 3.0 x 10–10 per day with a phase noise offset of –125 dBc/Hz at 10 Hz. The device measures 2″ × 2″ × 1.5″. Designed for paging and cellular base stations, instrumentation and telecommunications, they are priced at $480 each in quantities of fewer than 100.
Milliren Technologies
INFO/CARD 187

Layout editor, verification software

Tanner Research has released version 6.0 of L-Edit and L-Edit Pro mask layout editor and chip verification system. This version offers 45° layout and verification needed in complementary metal oxide semiconductor (CMOS) and bipolar designs. All angle rotation of instances in L-Edit is now supported, and a replace instance capability has been added. Arc and torus drawing primitives are included, and L-Edit's cross-section viewer provides variable etch and implant angle and undercut offset capability for simulating fabrication steps. Windows 95 and NT support is provided, along with support for Windows 3.1 and DOS operating systems. A subcircuit recognition capability permits layout at lower levels in the hierarchy to be defined and extracted as a subcircuit, reducing verification time. Device perimeter and source and drain area also are included in the extraction. Other new features include easy entry and editing of technology setups and design rules by importing a text file from a word processor or text editor. L-Edit version 6.0 is available for PCs, SunSpark, HP-9000 and Macintosh systems. Pricing starts at $1,495 in the United States for PC and Macintosh platforms, and at $2,995 for Unix systems.

Tanner Research
INFO/CARD 153

Software determines electromagnetic behavior

Microwavelab is a 3D electromagnetic fields simulation software program for designing high-frequency devices such as antennas, microstrip and waveguide components and resonators. Microwavelab is available on Unix-based workstations, multiprocessing super computers and Windows NT.

Microwavelab is used to determine both the electromagnetic behavior of new designs before a prototype has been built and as a verification tool for existing designs to predict network and antenna specifications. Besides the insight from being able to see the fields, Microwavelab calculates scattering (S), admittance (Y) and impedance (Z) matrices; characteristic impedance; propagation constants; and a range of antenna metrics, such as efficiency, polarization ratios, sidelobe levels, gain and directivity.

The results can be displayed in formats including Smith charts, omega-beta diagrams, polar plots, X-Y graphs, tabular matrices and field contours. Results can be converted into formats for use in complementary tools such as Supercompact and Touchstone.

Microwavelab's graphical user interface uses industry standard application specific integrated circuit (ASIC) solids geometry for both modeling precision and transfer to design systems. Automated meshing features include mesh refinements based upon the accuracy needs of the user. Precision geometry, coupled with push-button meshing, facilitates the analysis of complicated devices and features.

MacNeal-Schwendler
INFO/CARD 154

Software guides SMD placement

Cognex has a machine vision software used in the assembly of printed circuit boards. Users will integrate Cognex machine vision engines and surface-mount device placement guidance package (SMDPGP) software with high-speed electronics assembly machines that automatically pick up surface mount devices and place them on printed circuit boards. The Cognex vision system locates fiducials on printed circuit boards for alignment, inspects the quality of each SMD device and then guides placement of those devices onto the printed circuit boards.

The software enables each placement equipment manufacturer to tailor the system to specific needs. Working in conjunction with any Cognex 4000 series VMEbus or 5000 series PC plug-in vision processor, the Cognex SMDPGP package includes Cognex's location technology for locating fiducials within complex printed-circuit-board images. The software uses advanced inspection strategies to determine the correct series of high-speed, edge-finding algorithms for locating and examining each lead on an SMD device. This enables repeatable placement even for devices that are front-lit or that have slightly bent leads. For ball grid arrays (BGAs), odd-formed devices and large devices with many hundreds of leads, the vision system can capture an image of the device using multiple fields of view (MFOV and can piece together the data fo accurate device inspection.

When coupled with one of the Cog nex 4000 or 5000 vision processors, th package sells for between $7,500 an $15,000, depending upon quantity an configuration.

Cognex
INFO/CARD 155

Scanning system maps electromagnetic emissions

Designed to locate and quantify elec tromagnetic activity on powered an functioning printed circuit boards an other equipment, Emscan has bee integrated with a high-performance P to enhance storage and data manage ment of broadband and frequency specific emission scans.

Emscan incorporates scanner, per sonal computer and monitor in on desktop unit. The scanning surface cor sists of a 9″ × 12″ grid containing 1,28 current probes spaced 0.3″ (0.76 cer timeters) apart. The probes detect an transmit local magnetic-field-level in formation to a user-supplied spectrur analyzer, which then feeds location level and frequency data to the PC Frequency response of the scannin grid is 10 MHz to 1 GHz.

Emscan software, operating unde Windows 3.1, performs scans and dis plays results in color on-screen. Spike in spectral scans identify frequencies a which high emissions have been detec ed. Spatial scans at these frequencie identify levels and locations of emissio sources on the board. Spatial scan overlaid by on-screen board layout permit users to identify problem com ponents and connections.

Broadband spectral scans can ident fy problem emisisons during any user determined state of board activity Spatial scans can document and ma emission characteristics during user determined board functions as wel Both spectral and spatial scans can b stored and compared with real-tim scans to check results of emissior affecting board changes.

The software is used in combinatio with a receiver or spectrum analyzer, color monitor, keyboard, mouse and color printer for hard copies of scan (optional). The price is $33,000.

Amplifier Research
INFO/CARD 156

Interim standards published

The Telecommunications Industry Association (TIA) has published several interim standards.

TIA/EIA/IS-684, "Public Mobile and Personal Communications Systems–Time Division Multiple Access (TDMA) Radio Interface–Radio Link Protocol 2," specifies a radio link protocol (RLP2) that layer-3 entities may use to isochronously transport data across a TDMA radio interface. This protocol maintains bit-count integrity by delivering cumulative nibble counts to layer 3.

TIA/EIA/IS-129, "Interworking and Interoperability between DCS 1900 and IS-41-based MAPs for 1800 MHz Personal Communications Systems–Phase I," addresses functions that require interworking and interoperability to ensure nationwide and global availability of personal communications services (PCS) in the 1800 MHz broadband frequences for mobile users. To ensure seamless operation of services across dissimilar PCS systems, it is critical that specific interoperability, interconnection and Internet-working standards be developed nationally and internationally.

TIA
INFO/CARD 157

Inductor, transformer products detailed

Vanguard Electronics' inductor and transformer products are detailed in several catalogs. Products fall into two broad categories—RF components and power magnetics. Each category is offered in both through-hole and surface mount packages, depending on the required performance characteristics.

The RF components primarily are designed for applications at frequencies from 100 kHz to 1 GHz and power ratings as high as 1 W. Surface-mount RF components are suitable for a variety of mounting methods including infrared belt furnace and vapor phase soldering.

Vanguard Electronics
INFO/CARD 158

Catalog contains technical tutorials

The free, 696-page 1997 Instrumentation Reference and Catalog from National Instruments describes the company's more than 500 software and hardware products that engineers and scientists use to develop integrated, PC-base instrumentation systems for test and measurement and industrial automation. The catalog includes tutorials on data acquisition, GPIB, VXI and industrial automation; product line overviews; and selection guides.

The first section of the catalog introduces the concept of virtual instrumentation and helps users choose components suited to their individual applications. The five product sections feature tutorials with application examples to help readers learn about using plug-in data acquisition (DAQ) systems, signal conditioning, IEEE-488.2, VXI and MXI instrumentation, serial instrumentation and fieldbus.

National Instruments
INFO/CARD 159

Crystal, oscillator catalog released

Micro Crystal has released a 12-page brochure detailing crystals and oscillators. Crystals include metal can (SMD) and through-hole 30–200 kHz, 32.768 kHz clock crystals (SMD and through-hole) and ceramic package SMD 10 kHz to 2.1 MHz and 8–30 MHz. Oscillators featured include OCXO (as high as 24 MHz), 14-pin clock oscillators (as high as 160 MHz), tight stability VCXO (as high as 45 MHz) and SMD clock oscillators (as high as 160 MHz).

The company's products are known for their micro size, low-power dissipation and environmental characteristics.

Micro Crystal
INFO/CARD 160

Book covers theory for antennas, transmission line

Antennas and Transmission Lines is a reference with diagrams and graphics included, adaptable to home study. The first third of the book covers basic antenna theory, including point array sources, wave interference, standing waves, collimators, lenses, apertures and simple radiators.

The second third of the book deals with transmission lines, discussing such subjects as line impedance matching, Smith and immitance charts, lumped circuits, waveguides, directional couplers, hybrid junctions, reactive elements, resonant circuits and quality factor (Q).

The final third of the book consists of selected antenna topics such as self-impedance, balance, short and antifade antennas, frequency- and ground-independent antennas, half-space, noise and radio-range protection. The price is $19.95.

MJF Enterprises
INFO/CARD 161

Filtering products eliminate EMI, RFI

A 44-page catalog details a line of power products designed to eliminate EMI and RFI. This line of products includes high-current, single-line filters, power arrays, power entry filters, power-line filters, multi-section filters, custom assemblies and power distribution systems.

The catalog provides features, applications, catalog numbers, performance specifications, temperature characteristics, insertion loss curves, circuit diagrams and line drawings for each of the product lines. Also explained in the brochure is the company's overall EMI filtering experience and EMC testing services, application guidelines for using EMI filters, EMI measurement guidelins and a design inquiry form.

These EMI filtering power products are designed for use in a variety of applications where a power source is involved, such as logic and telephone rack bus systems, cellular base stations, power supplies, DC charging systems, telecommunications switching networks, radar and transmission systems, computers and peripherals, digital equipment, medical devices, military and secure equipment.

Spectrum Control
INFO/CARD 162

Crystal specifications, terminology detailed

A technical reference and catalog from Oak Frequency Control (OFC) Crystals provides an in-depth look at critical areas of crystal resonator design and fabrication. Key crystal performance specifications and terminology are discussed in detail, and the range of the company's products and capabilities is presented. Products include surface-mount devices and high-frequency fundamental crystals.

Croven Crystals
INFO/CARD 163

RF website directory

The following pages contain website addresses and descriptions of advertisers in this issue. The information is provided by the advertisers. For more information, refer to the ad index on page 102 for the page reference to the company's advertisement.

Amplifier Research
Power amps, interference generators, test cells
http://www.ar-amps.com

Anritsu Wiltron
Test and measurement solutions
http://www.anritsuwiltron.com

California Eastern Labs
Providing product solutions for RF & microwave devices
http://www.rell.com

Cinox Corporation
Maunfacturer of quartz AT and SC cut crystals
http://www.horandata.net/cinox

Coilcraft
RF inductors, EMI/RFI filters, RF transformers, LC filters
http://www.coilcraft.com

Delphi Components
Precision DRO's and CRO's
http://www.delphidro.com

Eagleware
Synthesis and simulation tools for RF & microwave designers
http://www.eagleware.com

Ecliptek Corporation
Quartz crystals, crystal oscillators and inductors
http://www.ecliptek.com

Elanix
Supplier of Windows-based CAE/EDA software
http://www.elanix.com

Fujitsu Microelectronics
RF ICs, PLL, versi-TILE custom RF macro array, SAW filters
http://www.fujitsumicro.com

Hewlett-Packard EEsof
High-frequency PC software
http://www.hp.com/go/hpeesof

Hexawave
Medium power GaAs FETs, MOSFETS and MMIC switches
http://www.hw.com.tw/~newone

Huber & Suhner
Antennas, tower mount amps, repeaters, EMF protectors
http://www.hubersuhnerinc.com

II Morrow
Contract manufacturing specializing in RF
http://www.iimorrow.com/contract.htm

Indutec
Filters, diplexers and tower mounted products
http://www.indutec.com

International Crystal Manufacturing
Custom crystals, oscillators and filters
http://www.icmfg.com

Johanson Dielectrics/Technology
Ceramic chip capacitors for wireless appilcations
http://www.johanson-caps.com

Lap-tech
Frequency control products
http://www.laptech.com

Locus
OEM product development
http://www.locusinc.com

LPKF CAD/CAM Systems
Systems for fabricating prototype circuit boards
http://www.lpkfcadcam.com

Microwave Solutions
Solid state microwave amplifiers
http://www.mwsolns.com

Milliren Technologies
dUltra stable OCXO's
http://www.mti-milliren.com

Mini-Circuits®

Mini Circuits
Mixers, amplifiers, bias-tees, power splitters/combiners
http://www.minicircuits.com

Monitor Products
High performance oscillators
http://eemonline.com/monpro

MOTOROLA
Semiconductor Products Sector

Motorola SPS
RF semiconductor supplier
http://design-net.sps.mot.com

M-tron Industries
Quartz crystals and hybrid oscillators
http://www.mtron.com

National Semiconductor
Moving and shaping the future.™

National Semiconductor
Low-power frequency synthesizers
http://www.national.com

Nearson
RF/microwave connectors, cable assemblies
http://www.nearson.com

Noble Publishing
Books, videos and software for RF & microwave designers
http://www.noblepub.com

NOISE/COM

Noise-Com
Noise testing products
http://www.noisecom.com

Oscillatek
Manufacturers of precision crystal oscillators
http://www.otek.com

PENSTOCK

Penstock, An Avnet Company
RF/microwave components supplier
http://www.penstock.avnet.com

Raltron Electronics
Crystal units, oscillators, filters and ceramic resonators
http://www.raltron.com

RF Monolithics
SAW-based RF components and modules
http://www.rfm.com

Richardson Electronics
Product soltuions for RF & microwave devices
http://www.rell.com

Rockwell Semiconductor Systems–Filter Products
Electrical bandpass filters in the 3–600 kHz CF range
http://www.rockwell.com/products/domestic/semicond2.html

Saronix
Frequency control products: crystals, oscillators and filters
http://www.saronix.com

Sawtek
SAW filters
http://www.sawtek.com

Tecdia
Single layer chip capacitors, DC power boards, bias-T
http://www.tecdia.com

Temex Electronics
Crystal filters, crystals, oscillators, capacitors
http://www.tekelec-temex.com

Trompeter Electronics
Manufacturer of RF interconnects for telecom, broadcast
http://www.trompeter.electronics.industry.net

T-Tech
Circuit board prototyping systems
http://www.t-tech.com

US CAD Software
Design programs for use with AutoCAD
http://www.uscad.com

Vectron Laboratories
Crystal oscillator manufacturers
http://www.vectronlabs.com

Voltronics
Suppliers of variable trimmer capacitors
http://www.voltronicscorp.com

Z-communications
Supplier of VCO's from 20–7,000 MHz
http://www.zcomm.com

The Aerospace Corporation is a private, non-profit company whose central mission is to assist the government in applying the full potential of science and technology to the advancement of space systems vital to national security. We are currently seeking exceptional Engineers who want to be involved in all phases of professionally challenging projects. You will analyze military communication systems in support of concept definition, tradeoff studies, proposal evaluations, and contractor monitoring. Current SBI required. If you are up to the challenge, then we have the following opportunities for you:

Communications

Communications Systems Hardware/Analysis (East Coast)

Requires MSEE or Ph.D. in Communications Systems Engineering. Successful candidate will be able to perform in-depth, detailed analytical systems analysis; and analysis/design of RF microwave hardware from baseband through mmwave. Familiarity with the design and operation of oscillators, synthesizers, amplifiers, fitters, mixers, and other microwave components is required. Proficiency with EEsof Omnisys, and Libra is highly desirable. Prior design experience, both analytical and on the bench, is required.

Communications Systems Analysis (East Coast)

Requires MSEE or Ph.D. in Communications Systems Engineering. Successful candidate will have the ability to formulate analytical and simulation models for system performance evaluation; and a strong background in communications systems engineering, math and computer science that includes modulation, demodulation, coding, detection, synchronization, and digital communications theory. Prior work experience with EEsof Omnisys or Cadence SPW required.

Electronic Circuit Designer (East Coast)

Requires BSEE of MSEE. A strong background in electrical networks (both passive and active) and digital design is required. Successful candidate will have the ability to design/analyze both analog and digital circuitry (ADCs, DDS, FIR & IIR filters) PLLs, filters, amplifiers, switching power supplies, and general baseboard circuitry. Prior experience in the actual breadboarding and hardware implementation of these circuits is highly desirable. Strong background in device characteristics which impose inherent limitations on electrical designs is desired. Prior work experience with EEsof Libra or PSPICE is also desired.

Reliability Analysis (East Coast)

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ERA-1 ERA-1SM
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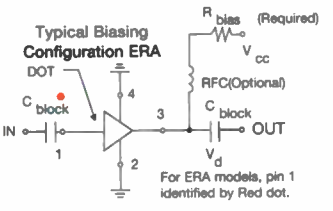

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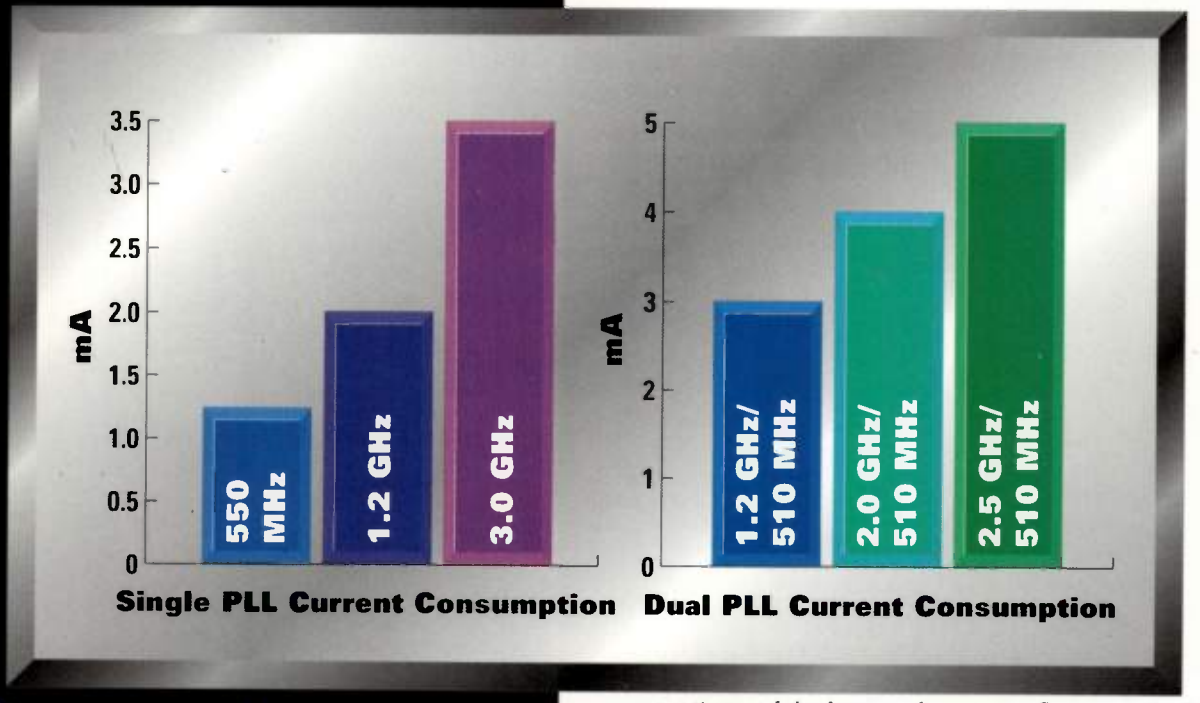

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