RF design™

July 1994

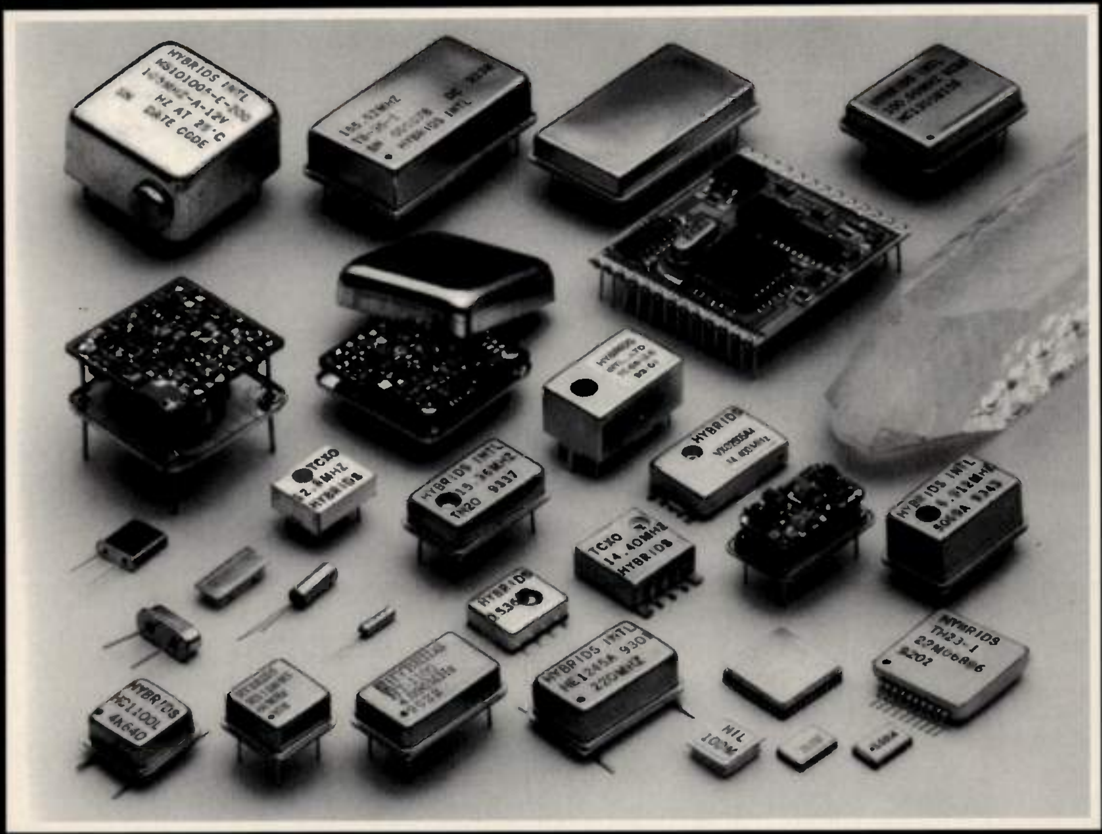
July Special Section: Product Data Sheets

Featuring Products from:

MFJ Enterprises/Ameritron
Hybrids International
Temex Electronics
Oscillatek
LCF Enterprises
Q-bit Corporation
Stanford Microdevices

WIRELESS 15 YRS LEADERSHIP

CRYSTAL OSCILLATORS
AND THICK FILM HYBRID CUSTOMIZATION



- FREQUENCY RANGE 1Hz TO 1GHz.
- ECL, XO, VCXO, ECL, PECL, MECL, ECL IN PS, 10K, 100K DIFFERENTIAL OUTS FOR SONET, LAN, ATM, DDS, AND OTHER DATA RECOVERY APPLICATIONS.
- HIGHER LIMIT (HIGH FREQUENCY CLOCK OSCILLATORS) CMOS, HCMOS, TTL, SINEWAVE TYPE OUTPUTS, UP TO 230MHz (VARY WITH OUTPUT LOGIC).
- TCXO'S, VCXO'S, TCVCXO'S ALL LOGIC OUTPUTS INCLUDING SINEWAVE IN DIP (.8" X .5" X .4") AND (1" X 1" X .5") PACKAGES.
- CLIPPED SINEWAVE TCXO, VCXO, TCVCXO FOR CELLULAR RADIO COMMUNICATION.
- CUSTOMIZATION TO YOUR REQUIREMENTS.

HYBRIDS INTERNATIONAL, LTD.

311 N. LINDENWOOD DRIVE / OLATHE, KANSAS 66062
PHONE: (913) 764-6400 • FAX (913) 764-6409

LCF ENTERPRISES RF POWER AMPLIFIERS

(Standard or Custom)

1 MHz - 2 GHz • 1 W - 1 kW

Part No.	Output Power	Gain	MODULES DC Supply	MODULES PKG
2 MHz - 30 MHz				
30-2-5-35	5W	35dB	24/28V	E3
30-2-50-35	50W	35dB	24/28V	E3
30-2-100-35	100W	35dB	28V	E3
30-2-200-35	200W	35dB	28V	E3
30 MHz - 100 MHz				
100-30-5-35	5W	35dB	24/28V	E3
100-30-100-35	100W	35dB	28V	E3
50 MHz - 150 MHz				
150-50-2-40	2W	40dB	12/15V	C3
150-50-100-35	100W	35dB	28V	A3
150 MHz - 200 MHz				
200-150-100-10	100W	10dB	28V	A1
200-150-100-18	100W	18dB	28V	A2
200-150-100-35	100W	35dB	28V	A3
200-150-200-35	200W	35dB	28V	A3
50 MHz - 250 MHz				
250-50-200-10	160W	10dB	28V	A1
250-50-200-18	160W	18dB	28V	A2
250-50-200-35	160W	35dB	28V	A3
50 MHz - 400 MHz				
400-50-1-30	1W	30dB	12/15V	C3
225 MHz - 400 MHz				
400-225-1-35	1W	35dB	12/15V	C3
400-225-10-35	10W	35dB	24/28V	A3
400-225-30-10	30W	10dB	24/28V	A1
400-225-30-18	30W	18dB	24/28V	A2
400-225-30-35	30W	35dB	24/28V	A3, B3
400-225-50-10	50W	10dB	24/28V	A1
400-225-50-18	50W	18dB	24/28V	A2
400-225-50-35	50W	35dB	24/28V	A3
400-225-100-10	100W	10dB	28V	A1
400-225-100-18	100W	18dB	28V	A2
400-225-100-35	100W	35dB	28V	A3
225 MHz - 600 MHz				
600-225-30-10	30W	10dB	24/28V	A1
600-225-30-18	30W	18dB	24/28V	A2
600-225-30-30	30W	30dB	24/28V	A3, B3
400 MHz - 600 MHz				
600-400-30-10	30W	10dB	24/28V	A1
600-400-30-18	30W	18dB	24/28V	A2
600-400-30-30	30W	30dB	24/28V	A3, B3
925 MHz				
925-1-8	1W	8dB	12/15V	D1
100 MHz - 500 MHz				
500-100-5-30	5W	30dB	24/28V	A3
500-100-10-30	10W	30dB	24/28V	A3
500-100-100-30	100W	30dB	28V	A3
500 MHz - 1000 MHz				
1000-500-10-8	10W	8dB	24/28V	A1
1000-500-10-16	10W	16dB	24/28V	A2
1000-500-10-30	10W	30dB	24/28V	A3
10 MHz - 1200 MHz				
1200-10-10-30	10W	30dB	24/28V	A3

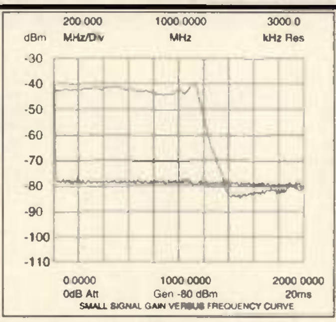
* Test Fixture (Option "B") includes heat sink, fan, thermal shutdown, and electrical fuse protection
** Rack-mount amplifiers: 120 Vac - 60 Hz / 240 Vac - 50 Hz

MODULES - SMALL SIZE • HIGH EFFICIENCY

- 200 watts
- 150 - 200 MHz
- 55% overall efficiency
- 35 dB gain
- 4.84" x 2.0" x 1.0"

- 100 watts
- 225 - 400 MHz
- 45% overall efficiency
- 10 dB gain
- 3.0" x 2.0" x 1.0"

SYSTEMS - LOW COST • RUGGED PROTECTION



SMALL SIGNAL GAIN VERSUS FREQUENCY CURVE

- 10 MHz - 1200 MHz
- 10 watts CW
- 40 dB
- 19" x 7" x 18"
- 35 lbs maximum

LCF ENTERPRISES • 651 Via Alondra, # 712 • Camarillo 93012 USA • Phone: 805-388-8454 • FAX: 805-389-5393

INFO/CARD 41

TEMEX STANDARD 10.7MHZ MONOLITHIC CRYSTAL FILTERS CHANNEL SPACING FOR 12.5 • 20 • 25 AND 50KHZ

ELECTRONICS, INC.

CRYSTALS • CRYSTAL FILTERS • L/C FILTERS

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. (Rp//Cp) OHM/PF
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	6.5	20	30.0	–	—	1	1.0	50	2700//0
4	TE5050	3	6.5	30	15.0	–	—	2	2.0	75	3100//0
6	TE5060	6	6.5	60	19.5	–	—	3	2.0	90	3100//0
8	TE5070	6	6.5	60	13.0	80	17.5	4	2.0	100	3100//0
2	TE5080	3	7.5	20	35.0	–	—	1	1.0	50	3000//0
4	TE5090	3	7.5	30	17.5	–	—	2	2.0	75	3300//0
6	TE5100	6	7.5	60	22.5	–	—	3	2.0	90	3300//0
8	TE5110	6	7.5	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

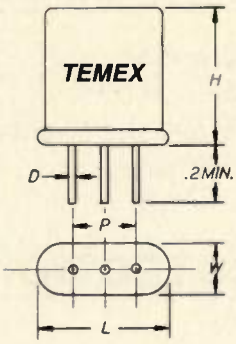
NOTES:

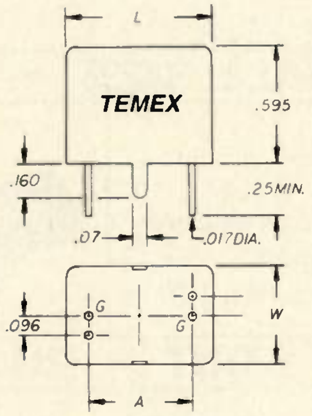
1. Maximum inband ripple over temp. range -20°C to 70°C.
2. Parallel termination capacity is adjusted for optimum filter response. Nominal parallel capacity, Cp: ±3pf. Impedance, Rp specified above.
3. A tandem set is a combination of matched 2 pole filter units making up multipole filters [example: 4 pole response; (2) 2 pole units-matches.]
4. These models available in other packages not shown below.

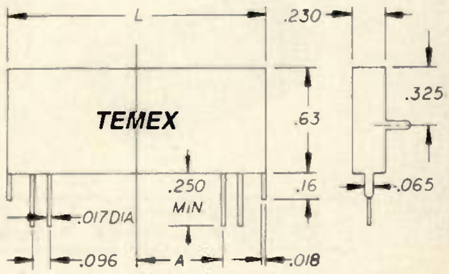
TO ORDER: TEMEX P/N and PACKAGE TYPE: Example: TE5100M5.

# POLES	PACKAGE SELECTION
2	M3 or 4
4	M3 or 4(x2)M5, 6, 7, 8 or 9
6	M3 or 4(x3)M5, 6, 8 or 9
8	M3 or 4(x4)M6 or 9

(x2)=2 cases (x3)=3 cases (x4)=4 cases







PKG	L	W	H	P	D
M3	.435	.185	.45/.53	.192	.017
M4	.750	.350	.750	.486	.030

HC-18/3:M3 HC-6/3: M4
HC-49/3:M3

PKG	L	W	A
M5	.590	.470	.354
M6	.745	.496	.528

PKG	L	A
M7	.89	.216
M8	1.32	.435
M9	1.75	.645

All specifications subject to change without notice.

*Consult **TEMEX** for your custom crystal and filter requirements.*

3030 W. Deer Valley Rd. • Phoenix, AZ 85027 • 602-780-1995 • (FAX) 602-780-2431

TEMEX STANDARD 21.4 MHZ MONOLITHIC CRYSTAL FILTERS CHANNEL SPACING FOR 12.5 • 20 • 25 AND 50KHZ

ELECTRONICS, INC.

CRYSTALS • CRYSTAL FILTERS • L/C FILTERS

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. (Rp//Cp) OHM/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	6.5	15	20.0	–	—	2	1.0	50	1300// + 2
4	TE5230	3	6.5	30	22.5	–	—	3	2.0	70	1400//0
6	TE5240	6	6.5	60	22.5	–	—	4	2.0	90	1400//0
8	TE5250	6	6.5	60	17.5	80	22.5	4	2.0	100	1400//0
2	TE5260	3	7.5	15	25.0	–	—	2	1.0	50	1500//0
4	TE5270	3	7.5	30	25.0	–	—	3	2.0	70	1600//0
6	TE5280	6	7.5	60	25.0	–	—	4	2.0	90	1600//0
8	TE5290	6	7.5	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

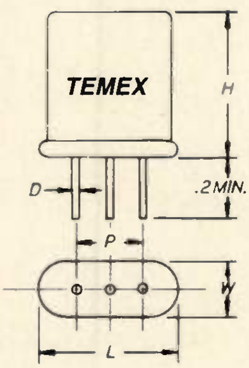
NOTES:

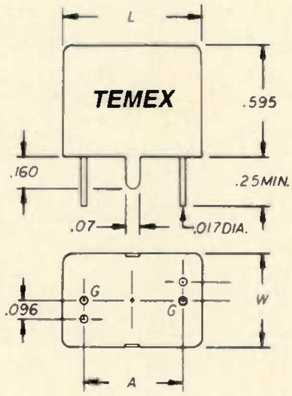
1. Maximum inband ripple over temp. range -20°C to 70°C.
2. Parallel termination capacity is adjusted for optimum filter response. Nominal parallel capacity, Cp: ±3pf. Impedance, Rp specified above.
3. A tandem set is a combination of matched 2 pole filter units making up multipole filters [example: 4 pole response; (2) 2 pole units-matched.]
4. These models available in other packages not shown below.

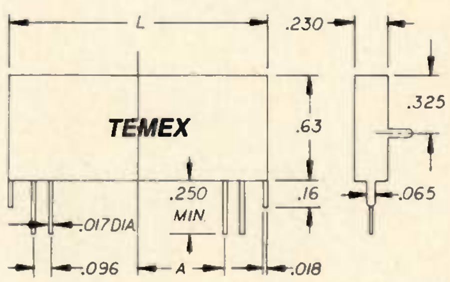
TO ORDER: TEMEX P/N and PACKAGE TYPE: Example TE5280M3

# POLES	PACKAGE SELECTION
2	M1, 2 or 3
4	M1, 2 or 3(x2)M5, 6, 7, 8 or 9
6	M1, 2 or 3(x3)M5, 6, 8 or 9
8	M1, 2 or 3(x4)M6 or 9

(x2) = 2 cases (x3) = 3 cases (x4) = 4 cases







PKG	L	W	H	P	D
M1	.300	.100	.310	.114	.017
M2	.310	.125	.320/.345	.148	.017
M3	.435	.185	.45/.53	.192	.017

HC-44/3:M1 HC-45/3:M2 HC-18/3:M3 HC49/3:M3

PKG	L	W	A
M5	.590	.470	.354
M6	.745	.496	.528

PKG	L	A
M7	.89	.216
M8	1.32	.435
M9	1.75	.645

*Consult **TEMEX** for your custom crystal and filter requirements.*

3030 W. Deer Valley Rd. • Phoenix, AZ 85027 • 602-780-1995 • (FAX) 602-780-2431

TEMEX STANDARD 45.0 MHZ MONOLITHIC CRYSTAL FILTERS

ELECTRONICS, INC.

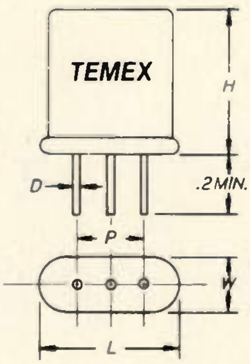
CRYSTALS • CRYSTAL FILTERS • L/C FILTERS

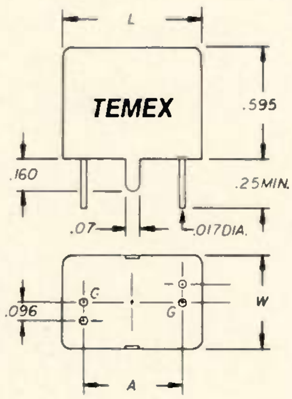
45 MHz MONOLITHIC CRYSTAL FILTERS										
NUMBER OF POLES	MODE	TEMEX P/N	PASSBAND		STOPBAND		LOSS	RIPPLE	ULT. REJ.	TERMINATION
			dB	±KHz	dB	±KHz	dB	dB-MAX	dB-MIN	Ohms/pF
2	30T	TE7420	3	7.5	18	28	2	1	40	3000//-1.0
4	30T	TE7430	3	7.5	40	30	3	1	70	3000//-1.0
2	30T	TE7440	3	15	15	47	2	1	40	8000//-1.5
4	30T	TE7450	3	15	30	50	3	1	70	8000//-1.5
2	FUND	TE7730	3	15	15	50	2	1	40	1100//+1.5
4	FUND	TE7740	3	15	40	60	3	1	70	800//+1.0

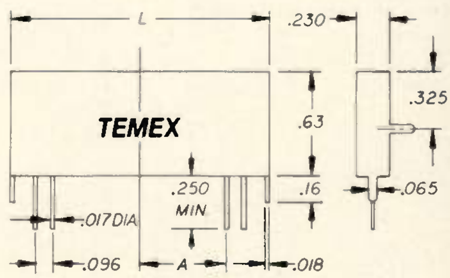
NOTES:
1. Maximum inband ripple over temp. range -20° C to 70° C.
2. Parallel termination capacity is adjusted for optimum filter response. Nominal parallel capacity, Cp: ±3pf. Impedance, Rp specified above.
3. A tandem set is a combination of matched 2 pole filter units making up multipole filters [example: 4 pole response; (2) 2 pole units-matched.]
4. These models available in other packages not shown below.
5. Standard package = M2.
6. 50 Ohms Z I/0 available in our M5 or larger packages.
7. 30T = Third overtone crystals.
   Fund = Fundamental crystals.
8. Other models available, consult factory.

# POLES	PACKAGE SELECTION
2	M1, 2 or 3
4	M1, 2 or 3(x2)M5, 6, 7, 8 or 9

(x2) = 2 cases







PKG	L	W	H	P	D
M1	.300	.100	.310	.114	.017
M2	.310	.125	.32/.345	.148	.017
M3	.435	.185	.45/.53	.192	.017

HC-44/3:M1 HC-45/3:M2 HC-18/3:M3 HC-49/3:M3

PKG	L	W	A
M5	.590	.470	.354
M6	.745	.496	.528

PKG	L	A
M7	.89	.216
M8	1.32	.435
M9	1.75	.645

All specifications subject to change without notice.

*Consult **TEMEX** for your custom crystal and filter requirements.*

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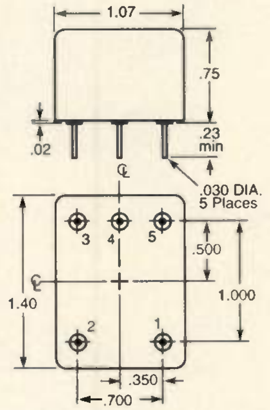
OSCILLATEK
A DOVER TECHNOLOGIES COMPANY
620 N. Lindenwood Drive • Olathe, Kansas 66062
FAX (913) 829-3505 • Phone (913) 829-1777

Solder Seal OCXO Small Package



RD Package

Output Options:

TD	= TTL	=	DC	to	50 MHz
HC	= HCMOS	=	DC	to	50 MHz
RC	= +7 dBm 50Ω	=	DC	to	50 MHz

Stability Options

A18	=	±1 x 10^{-8}	0° to +50°C
B28	=	±2 x 10^{-8}	0° to +70°C
D27	=	±2 x 10^{-7}	-40° to +85°C
S38	=	±5 x 10^{-8}	-40° to +85°C

Screening Options:

C = Standard Commercial
S = Class "B" per MIL-O-55310

Typical P/N:

HC RD K1 A 4 D27 C 10.000 MHz

- C — Screening
- D27 — Stability
- 4 — Aging
- A — Supply
- K1 — Predetermined
- RD — Package
- HC — Output

Supply Options:

A	= +5.0 VDC	3 Watts
B	= +12.0 VDC	3 Watts
C	= +15.0 VDC	3 Watts
D	= +24.0 VDC	3 Watts

Aging Options:

2	= 1 x 10^{-8}/day	2 x 10^{-6}/year
3	= 5 x 10^{-9}/day	1 x 10^{-6}/year
4	= 3 x 10^{-9}/day	5 x 10^{-7}/year
5	= 1 x 10^{-9}/day	2 x 10^{-7}/year

Phase Noise (10 MHz Sinewave)

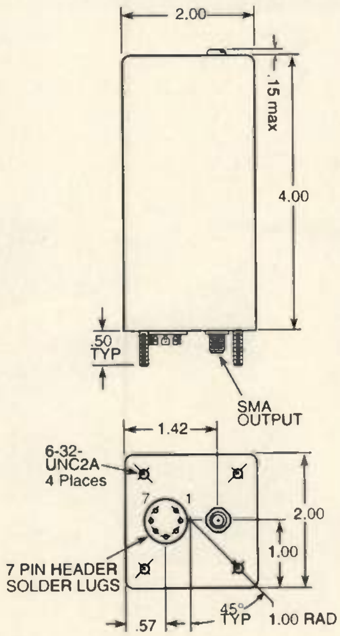
At	10 Hz	= -100 dBc
	100 Hz	= -127 dBc
	1.0 KHz	= -148 dBc
	>10.0 KHz	= -155 dBc

Pinouts:

Pin 1 = Output
Pin 2 = Gnd, Case
Pin 3 = VCO Input*
Pin 4 = VCO Reference*
Pin 5 = Supply

*When specified

High Stability HF OCXO



V1 Package

Output Options:

RC = +7 dBm 50Ω
RE = +13 dBm 50Ω

Stability Options

A50	=	±5 x 10^{-10}	0° to +50°C
A30	=	±3 x 10^{-10}	0° to +50°C
B70	=	±7 x 10^{-10}	0° to +70°C
C29	=	±2 x 10^{-9}	-20° to +70°C
C19	=	±1 x 10^{-9}	-20° to +70°C
S29	=	±2 x 10^{-9}	-40° to +70°C

Screening Options:

C = Standard Commercial
S = Class "B" per MIL-O-55310

Supply Options:

B	= +12.0 VDC	12 Watts
C	= +15.0 VDC	12 Watts
D	= +24.0 VDC	12 Watts

Aging Options:

6	= 5 x 10^{-10}/day	1 x 10^{-7}/year
7	= 3 x 10^{-10}/day	5 x 10^{-8}/year
8	= 1 x 10^{-10}/day	2 x 10^{-8}/year
9	= 7 x 10^{-11}/day	1 x 10^{-8}/year

Phase Noise (5 MHz)

At	10 Hz	= -120 dBc
	100 Hz	= -140 dBc
	1.0 KHz	= -155 dBc
	>10.0 KHz	= -157 dBc

Typical P/N:

RC V1 M1 C 7 C29 C

- C — Screening
- C29 — Stability
- 7 — Aging
- C — Supply
- M1 — Predetermined
- V1 — Package
- RC — Output

Frequency Options:

1 MHz	5 MHz	10 MHz
20 MHz	50 MHz	100 MHz

Pinouts:

Pin 1 = Supply
Pin 2 = Gnd, Case
Pin 3 = No connect
Pin 4 = Supply
Pin 5 = VCO Reference*
Pin 6 = VCO Input*
Pin 7 = VCO Return*

*When specified

CALL FOR OUR 100 PAGE CATALOG FOR MORE OPTIONS

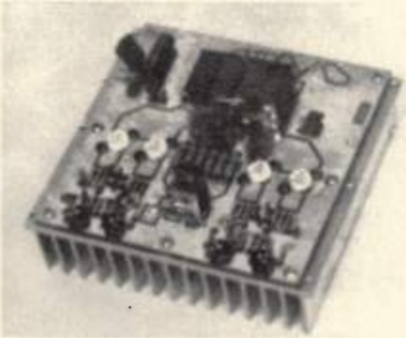
High Power RF Amplifiers,
Power Generators, Transmitters . . .

Ameritron can deliver high power amplifiers from stock, custom build your design or design a product to your specs from 1 to 250 MHz at power levels up to 5000 watts.

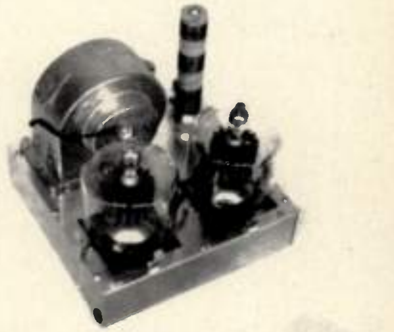
We manufacture from start to finish using modern CAD tools and CNC machinery.

Whether you need one or OEM quantities, you'll get the lowest prices and the fastest delivery in the industry.

Here's how . . .



1 **Ameritron's** 200 Watt FET Linear Amplfier Module is ready-to-use. Can be combined to produce several kilowatts. Modules available for 2-30 MHz; 30-120 MHz; 120-250 MHz.



2 **Ameritron's** chief engineer gives you 20 years of experience with high power vacuum tubes. Plus you get the field experience of thousands of high powered amplifiers in use all over the world.

6 **CAD** workstations are used for product mechanical design. Sheet metal layouts are downloaded to our Computer Numeric Controller (CNC) punch press for precision stamping.

7 **Our** CNC punch press eliminates expensive tooling for prototyping your design. Changes can be made at a moment's notice *without* costly tooling charge.

8 **Our** CNC press brake is used for precision forming of intricate mechanical pieces for your high power amplifiers.

12 **PC** board assemblies are constructed in-house by our experienced assembly workers. Every PC board assembly is tested and quality checked by electronic techs so you'll get first-rate products every time.

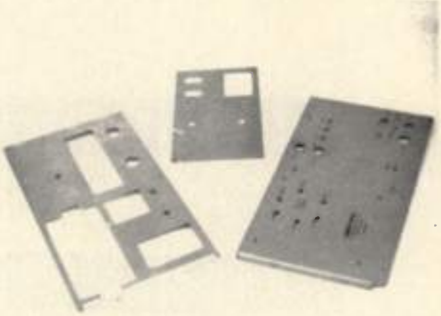
13 **We** have dedicated assembly lines made up of well trained workers to make sure you get quality products.

14 **Proper** QC is stressed at Ameritron. QC tests during the assembly process permit better visual and electrical inspections than are possible after final assembly.

Interested? Call Steven Pan, toll-free . . . 800-647-1801

3 **PCB** layouts are designed using CAD work stations for optimum component and trace placement. Our experienced engineers are familiar with the quirks of RF grounding for feedback-free operation.

4 **Ameritron's** in-house printed circuit board production facility can make prototype boards to rapidly confirm PCB layouts. In-house film and screen processing eliminates outside delays.



5 **Sheet** metal is fitted and proofed in our prototype metal shop. Your changes in sheet metal design can be rapidly implemented.

9 **Ameritron** can chemically clean and etch sheet metal parts in house. Our careful metal preparation helps ensure a durable, attractive finish for your product.

10 **In** Ameritron's paint department we can apply a tough *baked-on* paint to your product. We control the quality of your cabinets from raw material to finished product.

11 **Everything** from artwork to silk-screening is done in house to give you *exactly* what you want. Our graphic arts department can create a cabinet design to your specifications.

15 **Every** amplifier is protected by foam-in-place packing or re-usable die cut closed-cell-foam inserts -- you'll never get a damaged amplifier because of rough shipping and handling.

16 **Your** instruction manuals are printed in Ameritron's printing department on modern off-set printing presses -- you'll never be at the mercy of your printer's schedule again.

17 **You** get excellent technical support from our group of friendly, well trained customer service technicians.

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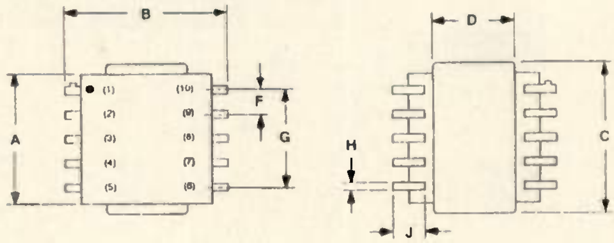
INFO/CARD 52

Stanford Microdevices

SMM-210
1.5-2.5 GHz, 1Watt
GaAs MMIC
June, 1994

Features

- **27dB Gain and 30dBm Output Power**
- **Excellent VSWR: 1.5:1 Typical**
- **High Power Added Efficiency**
- **Characterized at 3 volts for portables**



Description

Stanford Microdevices' SMM-210 is a high performance gallium arsenide monolithic-microwave-integrated-circuit (MMIC) housed in a low-cost surface mount package. Designed for operation in wireless systems operating in the 1500 to 2500 MHz frequency range, this amplifier has 30dBm of output power and 27dB Gain at P1dB.

Also available in die form, its small size (2.0 x 1.5mm) makes it suitable for use on thin and thick-film circuits. Proven gold-based metallization and die passivation add to the reliability and durability of this device.

DIMENSION TABLE		
LTR	DIMENSIONS	NOTES
A	0.270	SQUARE
B	0.355	
C	0.310	
D	0.175	
E	0.060	
F	0.050	TYPICAL
G	0.200	
H	0.015	TYPICAL
J	0.070	TYPICAL
K	0.010	TYPICAL
ALL DIMENSIONS ARE IN INCHES TOLERANCES. +/- 1% NLT 0.005		

PIN DESIGNATION TABLE	
PIN NO	DESCRIPTION
1	GROUND
2	GROUND
3	RF IN
4	GROUND
5	Vg = 5V
6	GROUND
7	GROUND
8	RF OUT
9	GROUND
10	Vd = +5V

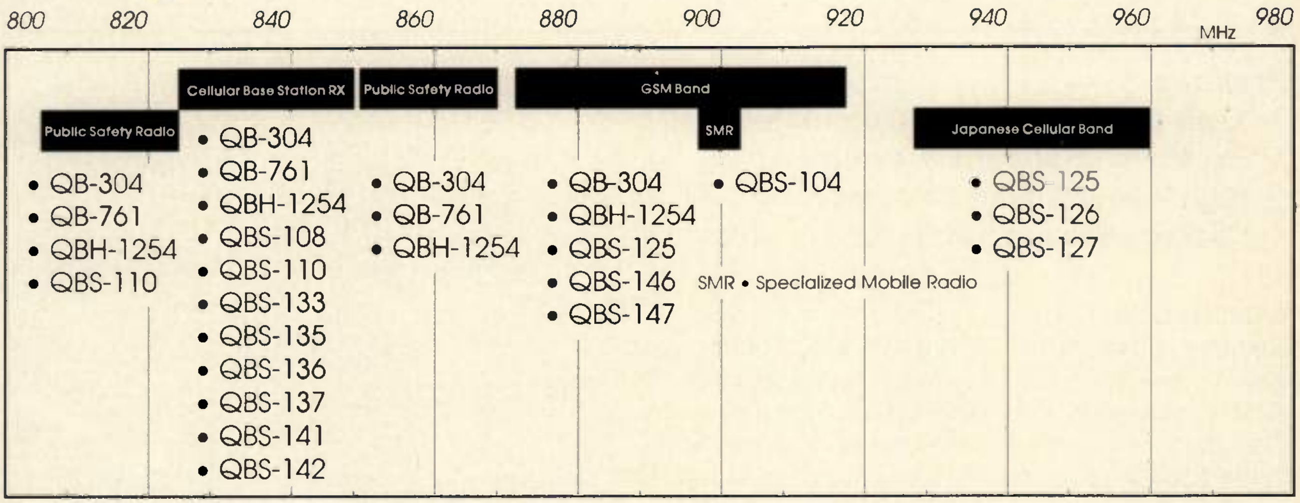
Electrical Specifications at Ta = 25c

Symbol	Parameters: Test Conditions		Units	Min	Typ	Max
P1dB	Output Power at 1dB Compression	f = 2.0 GHz	dBm	30	31	
	Vdd = 7.0 V, Idd = 600 mA	f = 2.4 GHz	dBm		29	
Ga	Associated Power Gain	f = 2.0 GHz	dB	25	27	
	Vdd = 7.0 V, Idd = 600 mA	f = 2.4 GHz	dB		25	
Psat	Saturated Output Power	f = 2.0 GHz	dBm	31	32	
	Vdd = 7.0 V, Idd = 600 mA	f = 2.4 GHz	dBm		30	
P1dB	Output Power at 1dB Compression	f = 2.0 GHz	dBm	24	25	
	Vdd = 3.0 V, Idd = 400 mA	f = 2.4 GHz	dBm		23	
Ga	Associated Power Gain	f = 2.0 GHz	dB	22	24	
	Vdd = 3.0 V, Idd = 400 mA	f = 2.4 GHz	dB		20	
VSWR	Input and Output Match				1.5:1	
IP3	Third Order Intermodulation Distortion		dBm	37	40	
PAE	Power Added Efficiency Vdd = 7.0 V, Idd = 600 mA		%	25	30	

Other Products from Stanford (Late '94)

Model	Freq(GHz)	Description
SMM-228	1.5-2.0	5 Watt MMIC Amp, 34dB Gain
SHM-610	5-7	3 Watt MMIC Amp, 27dB Gain
SMM-910	8-10	5 Watt MMIC Amp, 15dB Gain
SMM-1410	13-15	3 Watt MMIC Amp, 22dB Gain
SMM-108	0.5-3.0	LNA, 2dB NF and P1dB of 17dBm
SMM-810	2-8	Broadband Amp, 25dB Gain, 17dBm Po

Commercial Radio & Cellular Band Amplifiers



Specification Summary

Guaranteed Specifications @ 25 °C

Model	Frequency Range MHz	Gain dB	Output P1dB dBm	VSWR	Noise Figure dB	Reverse Isolation dB	3rd OIP[1] dBm	DC Power Vdc/mA	Housing
QB-304	800-900	20.0	24.0	1.5:1	3.0	37	40/	15/300	19202
QB-761	806-870	23.0	18.0	1.5:1	3.5	42	32/	15/140	187-2
QBH-1254	804-901	12.5	23.5	1.5:1	3.0	26	37/	15/142	TO-8
QBS-104	896-925	27.0	26.0	1.7:1	2.0	37	41/	15/450	19069
QBS-108	824-849	8.0	25.0	2.0:1	5.0	12	40/	15/200	19134
QBS-110	806-849	27.0	26.0	1.7:1	2.0	37	41/	15/450	19069
QBS-125	896-960	40.0	28.0	1.5:1	1.5	51	42/	15/850	19130
QBS-126-1	925-960	40.0	28.0	1.5:1	1.5	51	42/	15/850	19130
QBS-126-2[2]	925-960	40.0	28.0	1.5:1	1.5	51	42/	19-31/850	19105
QBS-127-1	925-960	33.0	22.0	1.5:1	1.5	41	38/	15/450	19130
QBS-127-2[2]	925-960	33.0	22.0	1.5:1	1.5	41	38/	19-31/450	19105
QBS-133	824-849	33.0	19.0	2.0:1	1.3	41	35/	15/250	19121
QBS-135	824-849	40.0	24.0	2.0:1	1.3	51	39/	15/425	19121
QBS-136	824-849	14.0	25.0	2.0:1	5.5	21	40/	15/325	19134
QBS-137	824-849	26.0	15.0	2.0:1	1.3	36	28/	15/150	19134
QBS-141-1	824-849	40.0	28.0	1.5:1	1.5	51	42/	15/850	19130
QBS-141-2[2]	824-849	40.0	28.0	1.5:1	1.5	51	42/	19-31/850	19105
QBS-142-1	824-849	33.0	22.0	1.5:1	1.5	41	38/	15/450	19130
QBS-142-2[2]	824-849	33.0	22.0	1.5:1	1.5	41	38/	19-31/450	19105
QBS-146-1	870-915	40.0	28.0	1.5:1	1.5	51	42/	15/850	19130
QBS-146-2[2]	870-915	40.0	28.0	1.5:1	1.5	51	42/	19-31/850	19105
QBS-147-1	870-915	33.0	22.0	1.5:1	1.5	41	38/	15/450	19130
QBS-147-2[2]	870-915	33.0	22.0	1.5:1	1.5	41	38/	19-31/450	19105
Power Amplifiers									
QBS-227	800-960	40.0	40.0	2.0:1	-	60	50	24/2600	
QBS-230	800-960	40.0	43.0	2.0:1	-	60	53	24/4400	
QBS-233	1800-2200	40.0	40.0	2.0:1	-	60	52	12/4600	

SPECIFICATIONS ARE 25°C TYPICAL

[1] OIP = OUTPUT INTERCEPT POINT

[2] SOFT FAIL DESIGN WITH BUILT IN REGULATION AND FAULT INDICATION CIRCUITRY

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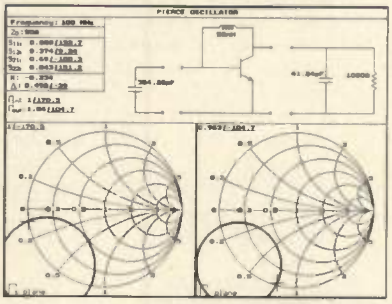

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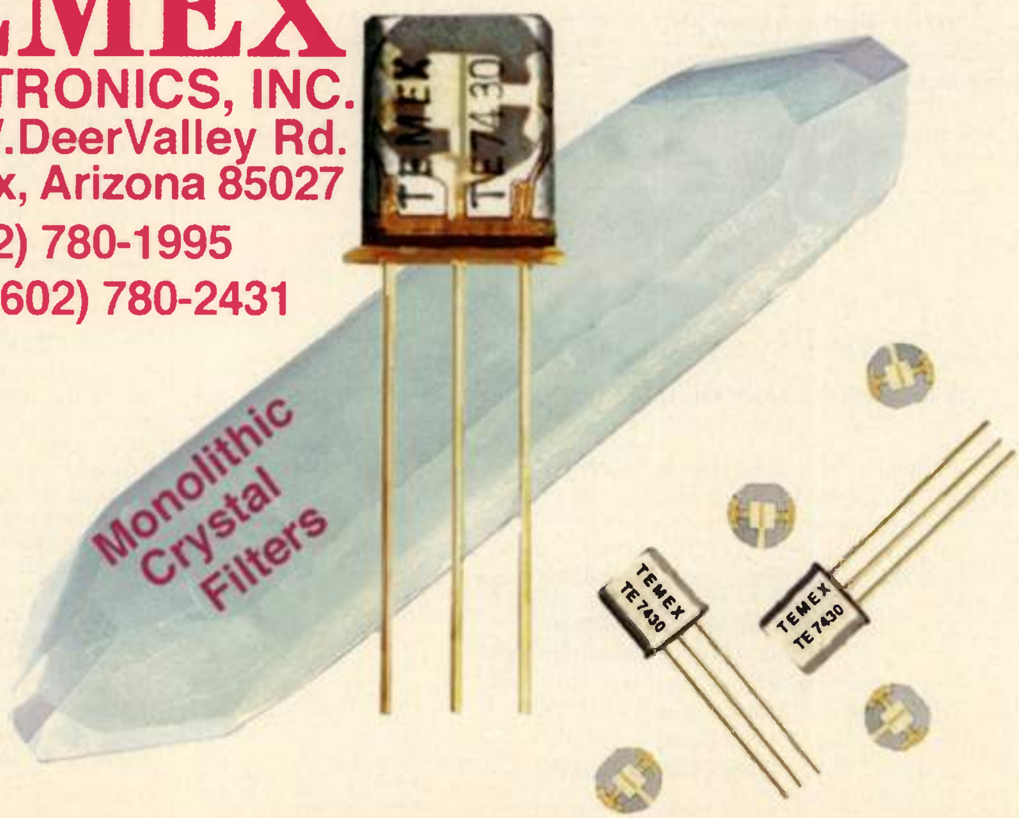

INFO/CARD 55

RF software

Budget Version of SPICE Simulator

ICAP/4Lite is a low-cost analog and mixed-signal circuit simulation system. The software is based on Intusoft's professional version of SPICE called ICAP/4Windows. ICAP/4Lite allows unlimited size circuits with a reduction in features. It performs AC, DC, transient and temperature analyses. In addition, ICAP4/Lite includes an integrated schematic entry program that produces a complete SPICE netlist. Waveforms can be displayed on a reduced features version of IntuScope, a graphical data analysis program.Until September 15, 1994, ICAP/4Lite is available for $445.
Intusoft
INFO/CARD #206

RF Library for DSP Simulation

Alta Group (formerly Comdisco Systems) has introduced its RF Library for the Signal Processing WorkSystem® (SPW™). The RF Library is a collection of blocks for modelling the RF portion of a signal processing system. The library includes laboratory-validated blocks for components such as: nonlinear amplifiers, switches, couplers, A/D converters and mixers. Alta Group's RF Library is priced beginning at $5000 and will be available in the third quarter of 1994.
Alta Group
INFO/CARD #207

Filter Design

Filtroid from Geesof synthesizes, joins, edits and analyzes filter circuits. Lowpass, highpass, bandpass and bandstop filters can be designed using Tchebychev, Butterworth, and Elliptic transfer functions or, user-specified masks, user-specified G-values or user-specified K-Q values. Filtroid provides tabular and graphic output of analysis of VSWR, return loss, phase/phase linearity and other parameters. Mechanical dimensions for many distributed filters can also be calculated. Filtroid sells for $2995.
Geesaman Software, Inc.
INFO/CARD #208

PC-Based 3D EM Simulation

Developed by Zeland Software and Marketed by Bay Technology, IE3D performs 3D electromagnetic simulation of electrical circuits ranging from DC to over 100 GHz on a personal computer operating MS Windows. IE3D supports all 2D and 3D simulation tasks previously done only on workstations. Using a full-wave integral equation method-of-moments algorithm, IE3D keeps the number of nodes to a minimum without any reduction in accuracy and with reduced compute time over workstation products. IE3D for MS-Windows operates on any 386/486 PC and is priced at $5000 and $10,000 (depending on model size) and $20,000 for the Widows NT version.
Bay Technology
INFO/CARD #209

RF literature

Crystal Oscillator Catalog and Handbook

Vectron Laboratories has published its new 1994 comprehensive full-line handbook and catalog. The 80-page publication details a complete line of crystal oscillators available from 0.01 Hz to beyond 2 GHz and highlights new products recently introduced.
Vectron Laboratories, Inc.
INFO/CARD #220

Fiberoptic Communications Guide

Ortel Corp. has released a four-page Product Use and Selection Guide for the Wireless Communications market. The guide includes photos, specifications, technical diagrams and applications for standard and specific application cellular radio fiberoptic transmitters. The guide is available free to all qualified specifiers.
Ortel Corporation
INFO/CARD #219

Antenna and Accessory Catalog

Antenna Research's 127-page catalog includes descriptions of the company's lines of omnidirectional, directional, GPS, microstrip, aerospace, D.F., and search and surveillance antennas, along with their antenna test equipment and accessories. Also described is their line of individually calibrated antennas for EMI/EMC testing.
Antenna Research Associates, Inc.
INFO/CARD #218

Multichannel PA Catalog

AML Communications announces the publication of its Cellular/PCS Multichannel Power Amplifier Catalog. The catalog details amplifiers with PEP powers up to 240 W with intermods as low as –60 dBc. Designs include feed-forward, class AB, and class A types. Operating frequencies cover the North American and International Cellular spectra.
AML Communications
INFO/CARD #217

Cables and Assemblies

Coaxitube is introducing its expanded product catalog featuring semi-rigid and flexible coaxial cables and assemblies. This 64-page multi-color publication contains a cable identification guide and updated descriptions of Coaxitube's hand-formable Al and Cu semi-rigid cables. Flexible cables and cable assemblies are also featured along with a wide choice of specialty type cables.
Precision Tube Co., Inc.
Coaxitube Div.
INFO/CARD #216

Low-Price Circuit Material Literature

Rogers Corp. offers a literature package for its RO3003™ High Frequency Circuit Materials for commercial microwave and RF printed circuit boards. The literature includes a preliminary data sheet and fabrication guidelines.
Rogers Corp.
INFO/CARD #215

Crystal Oscillator Catalog

Wenzel Associates' 1994 catalog Crystal Oscillators, RF Products outlines a variety of high performance crystal oscillators, frequency standards, multipliers, mixers and other RF products designed for MIL, space and commercial applications. The catalog updates performance and engineering capabilities for custom and standard products.
Wenzel Associates, Inc.
INFO/CARD #214

Updated Data Books

Motorola has released its revised RF Device Data book for 1994 (DL110/D Rev 5). The product families include bipolar, LDMOS, MOSFET RF power, and GaAs chip technologies. Motorola's 1994 RF Selector Guide and Cross Reference (SG46/D Rev 11) includes a new RF Integrated Circuits category. Either publication can be ordered by calling (800) 441-2447, or by faxing (602) 994-6430.
Motorola Semiconductor
INFO/CARD #213

Rental/Lease Guide

GE Rental/Lease announces its updated product guide. The 210-page catalog details many of GE Rental/Lease's more than 120,000 name-brand test and measurement instruments. In addition to equipment information, the catalog contains financing option information.
GE Rental/Lease
INFO/CARD #212

Detector/Limiter Brochure

A four-page, color brochure from Advanced Control Components describes their lines of tunnel diode detectors, limiter and pad detectors, schottky diode detectors, and limiters. Design considerations for both detectors and limiters are listed.
Advanced Control Components
INFO/CARD #211

Circuit Fabrication Capabilities

Polyflon has published a four-page, color brochure describing their circuit processing capabilities, including material selection, CAD, plating. plated through holes, machining, quality assurance and control, and testing. In addition, Polyflon offers a design data sheet describing their mulilayer mixed media capability, which allows combination of microstrip and stripline circuits in one unit.
Polyflon Co.
INFO/CARD #210

RF guide to editorial coverage

RF advertising index

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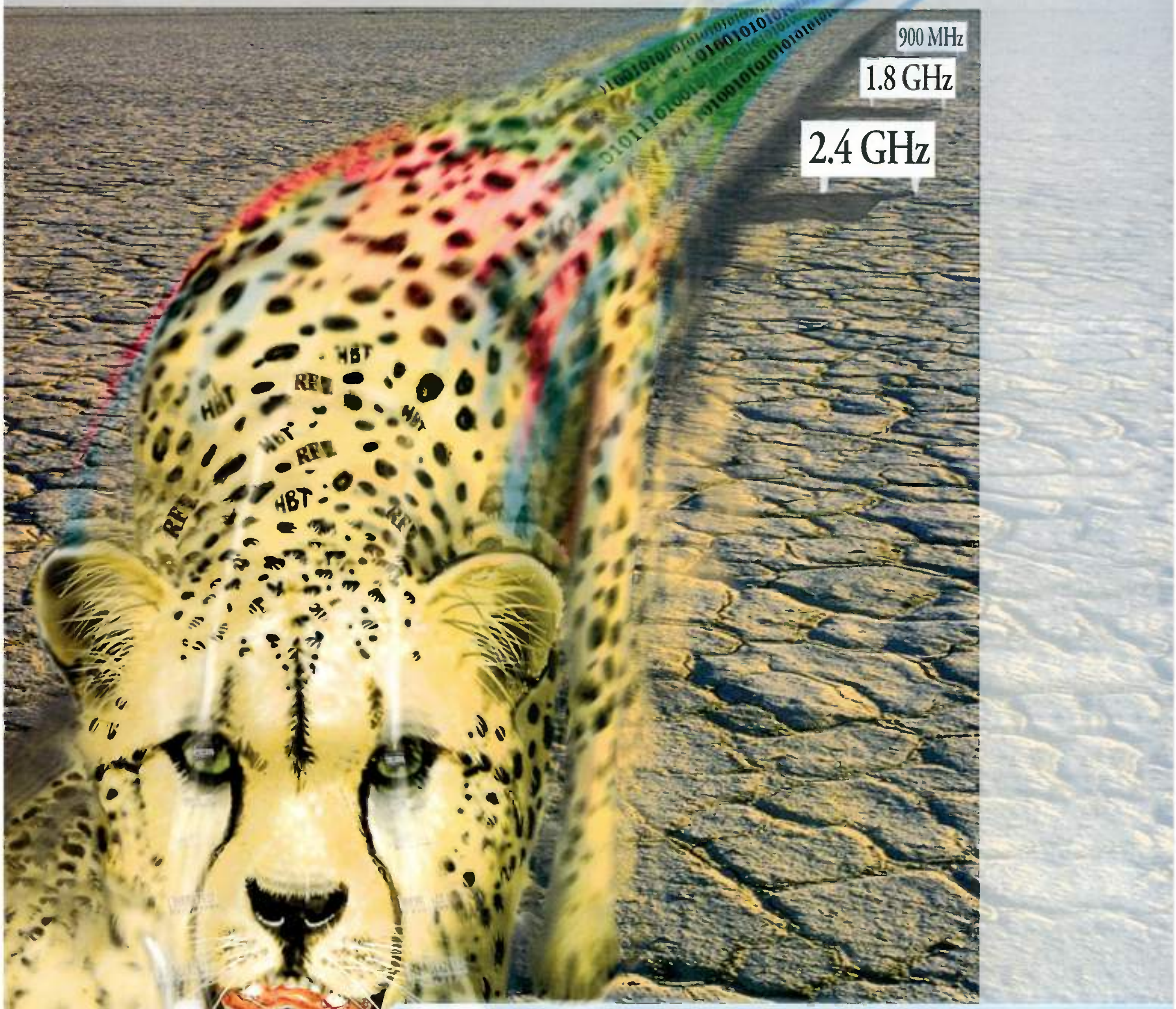
engineering principles and practices

August 1994

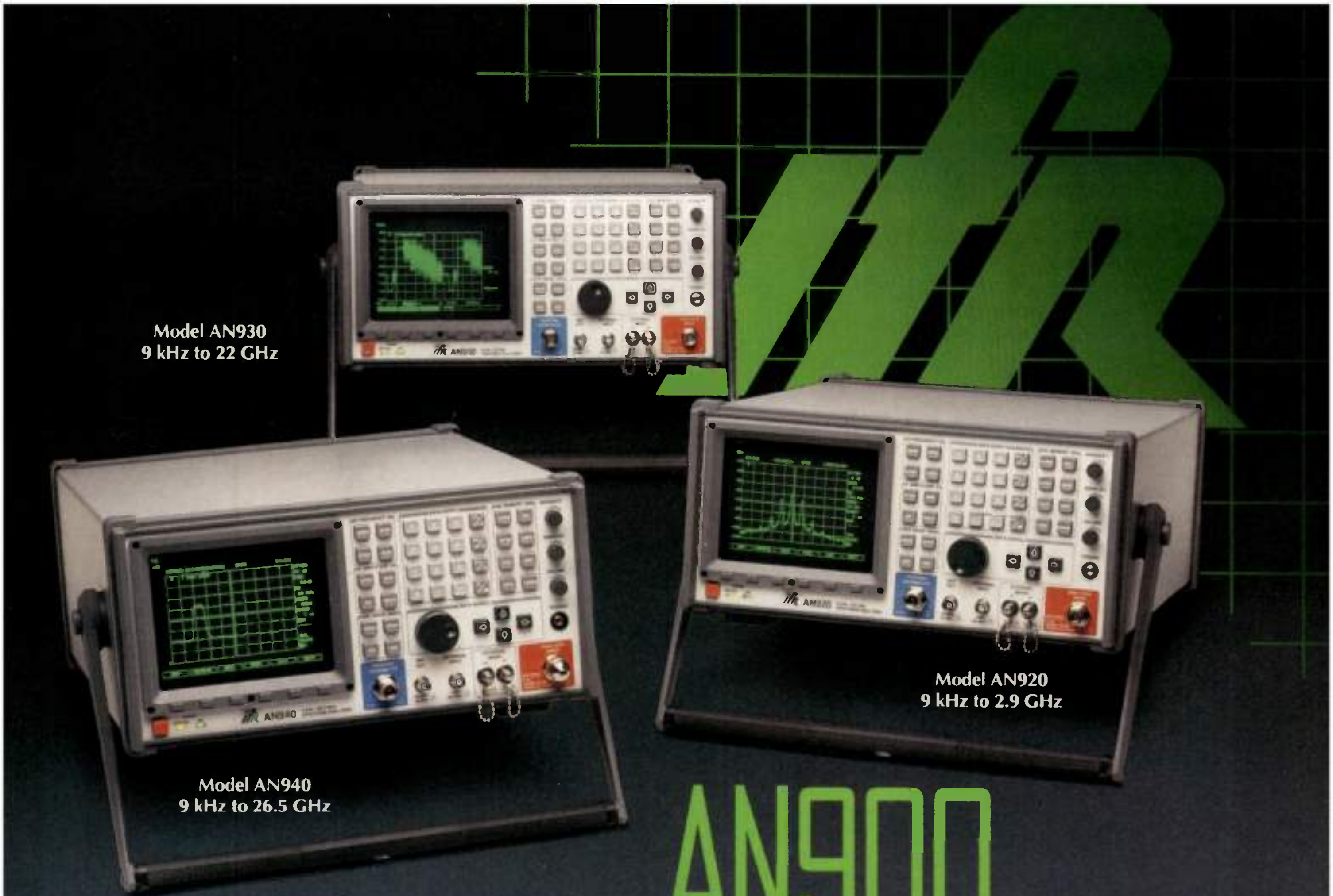


Cover Story

GaAs Quadrature Modulator Covers 900-2500 MHz

Featured Technology

Low Power RF Methods



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Contact IFR for more information or to arrange for a demonstration of the AN920, AN930 or AN940.

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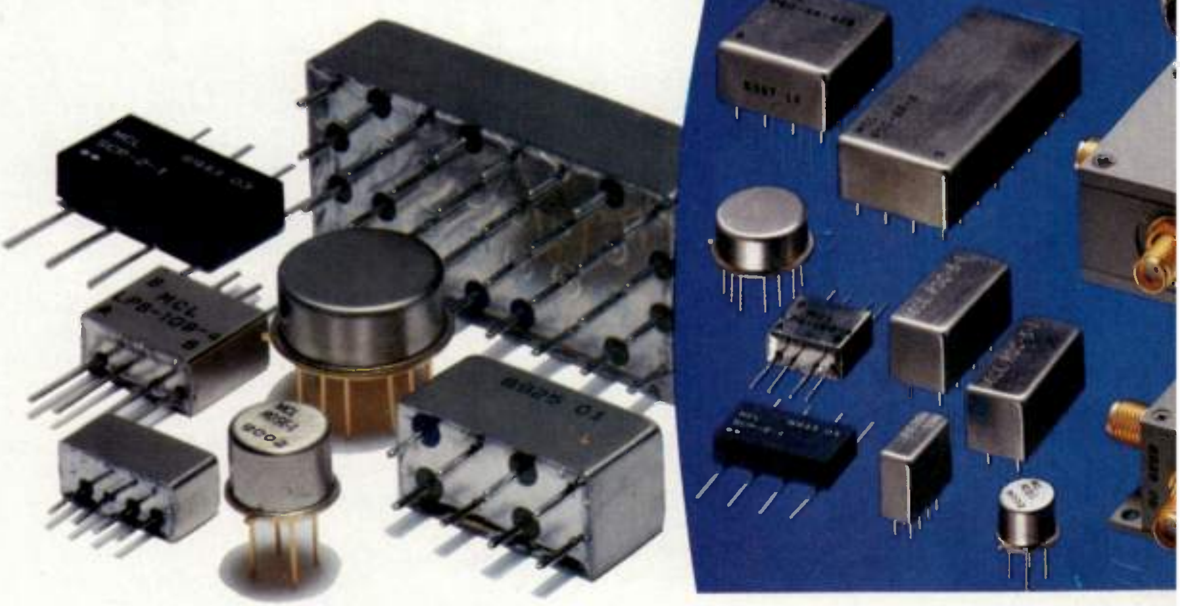

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RF/IF
Designer's
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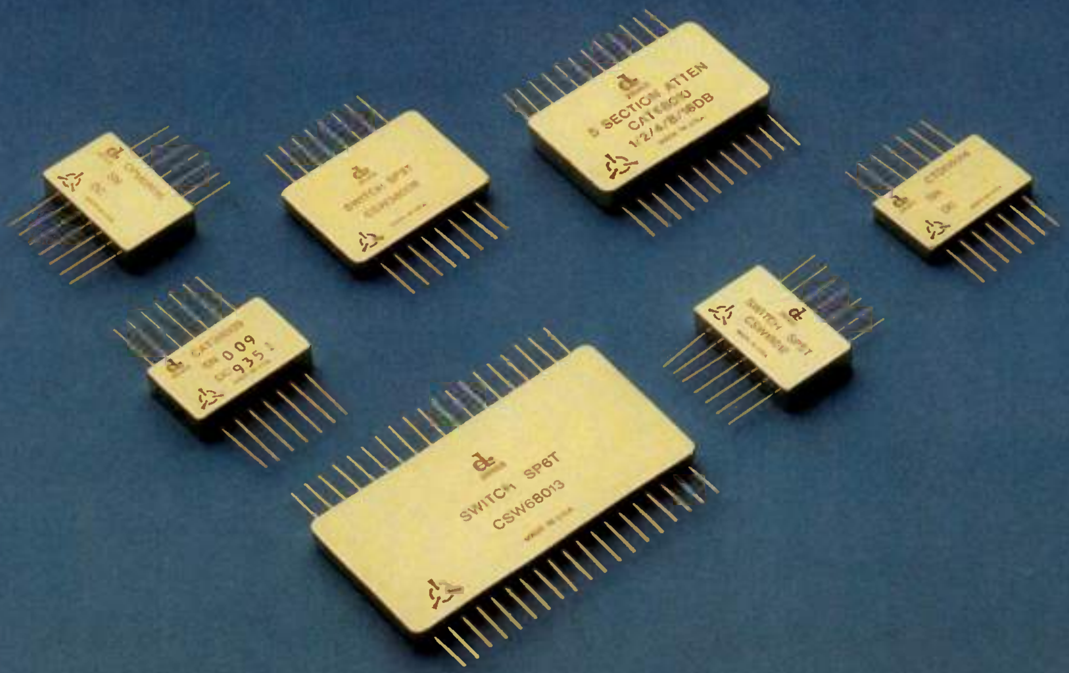
Mini-Circuits

Leader of the FLATPACK



Flatpacks

Con-fig	Freq MHz	IL dB	Iso dB	Switch Speed n SEC	Part No.
SPST	10-1000	1.25	70	35	8012
SPST	400-2000	0.9	67	185	DS0551
SP2T	10-1000	0.7	55	40	DS0860
SP2T	5-2000	1.0	57	24	DS02800
SP2T	5-1000	0.5	70	72	DS0962
SP3T	10-1000	1.2	40	100	8008
SP4T	DC-2000	1.5	50	30	CS048024
SP6T	10-1000	0.75	50	1000	8013
1 Sect Atten	5-1000	0.9	10	30	DA0944-10
1 Sect Atten	800-1200	0.9	50	80	DA0879
3 Sect Atten	30-300	1.0	.25, .5, 1.0	200	8009
5 Sect Atten	10-400	1.7	1, 2, 4, 8, 16	100	8010
Pulse Modulator	10-1000	2	80	300	8015
Threshold Det	10-3000	Detects -25 to -10 dBm		—	8014

Daico broadens it's product line with a proven series of Flatpacks and almost every part in our catalog can be manufactured in one of these packages! Please call us...we have creative ways to meet all of your price, quality and performance requirements.

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INFO/CARD 4

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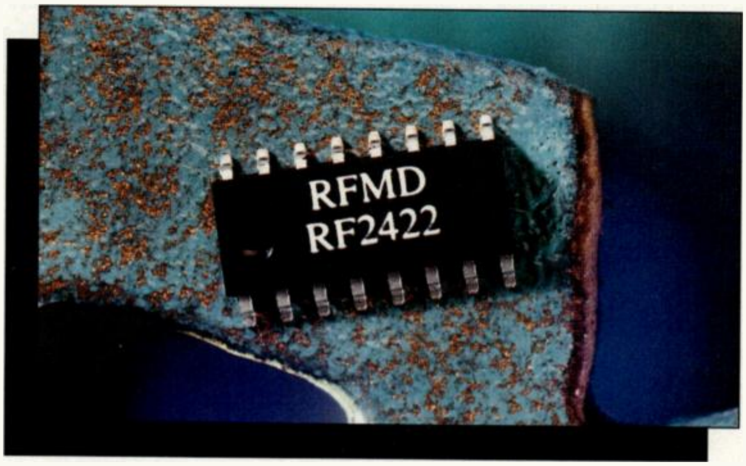
RF design

contents

August 1994



departments

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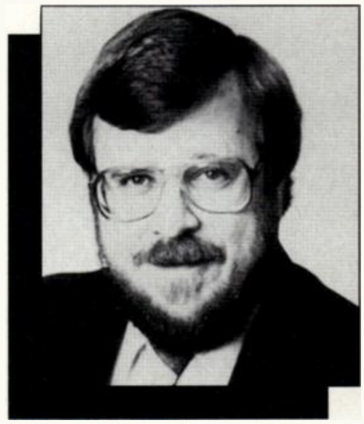
Abjure Nebulous Terminology!



By Gary A. Breed
Editor

ab•jure \ab-'jer\ vt — **1 a:** to renounce upon oath **b:** to reject solemnly **2 :** to abstain from, to avoid.

Engineers require precision, mathematical precision, in their work. It is a necessary part of understanding nature and turning physical principles into useful products. We should all become upset when we encounter language that lacks this kind of precision.

What I'm talking about is unclear enumeration of incompletely-conceptualized ideas and principles — or, *covering up for what you don't know by being intentionally vague*. Politicians are well known for this practice, but lately, it has invaded our world of technology.

For example, does any one of you know what the "information superhighway" really is — or the "national information infrastructure" (NII)? These are terms that that are thrown into conversation as if they were understood perfectly by everyone; but what is their definition?

Here is how the NII is described by the Council on Competitiveness, a distinguished body made up of business, labor and academic leaders:

"The information infrastructure will enable all Americans to access information and communicate with each other easily, reliably, securely and cost effectively in any medium -- voice, data, image or video -- anytime, anywhere. This capability will enhance the productivity of work and lead to dramatic improvements in social service, education and entertainment." (from *Competition Policy: Unlocking the National Information Infrastructure*, Advance Copy, December 1993).

Well, that clears it up for me — NOT! What we just read is a nice generalization that sounds impressive, but lacks precision. To be fair, the report contains plenty of useful information, explores several points of view, and raises important issues. But, the NII is never defined beyond some nebulous collection of telephone, cellular, satellite, broadcast, cable TV and computing technologies.

Perhaps the reason for the lack of clarity is contained in their own conclusions. Two of the four findings by the council are: *Regulations and policies are fragmented*; and, *It is impossible to predict accurately the future path of the market or technology.*

Of course it is hard to define a concept when there is no policy and no direction! But why cover up this uncertainty with the kind of grand language in the earlier quotation?

My point is simple — Tell it like it is! In communications technology, the possibilities for growth are exciting enough without building unreasonable expectations with fancy talk.

Instead, try these clear statements:

- Communications markets and technology are growing at a rate that is exciting to both engineers and businessmen.
- The political and business atmosphere is very supportive of these new communications possibilities.
- There is a great deal of uncertainty about which of the many uses being developed will become major markets.
- We aren't sure who should build an enhanced communications infrastructure and we don't know how to pay for it.
- Despite uncertainties, we will forge ahead. It is in our nature to respond to the kind of technical and market challenges that have been put before us.

P.S. — This discussion applies to any terms that lack clear definition (such as most current references to *wireless*, *portable*, and *personal communications*!)

And, thanks to John Sherman, whose business card says, "abjure obfuscation." It's the inspiration for my comments.

INFO/CARD 6

RF design

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Giga-tronics Presents The Alternative To $30,000 And $40,000 RF Synthesizers.

Hewlett-Packard makes a couple of very good RF synthesizers. And if you can afford the luxury of paying $30,000 or $40,000 for the name, by all means, call HP right now. They'll be happy to take your order, and your money.

However, if you're looking for an RF synthesizer with outstanding performance and proven reliability for about half the price, you'd better call Giga-tronics.

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Check the charts. In virtually every category, the Giga-tronics 6080A and 6082A RF Synthesizers meet or exceed the specs of the HP machines. And they use the same GPIB command set, for direct replacement without expensive new software.

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Granted, Hewlett-Packard has been around a long time. But, Giga-tronics is no Johnny-come-lately.

Giga-tronics has a 14-year history of building test and measurement gear for the most demanding requirements. We've shipped thousands of instruments for use in the testing of radar, EW and communications systems.

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Making reliable RF synthesizers is usually no fluke.

However, in this case, it is.

The Giga-tronics 6080A and 6082A RF Synthesizers give you great performance and proven reliability for a lot less money.

Specifications	Hewlett-Packard HP 8642A	Giga-tronics 6080A	Hewlett-Packard HP 8642B	Giga-tronics 6082A
Frequency Range Switching speed	.1 to 1057 MHz <85 ms	.01 to 1056 MHz <100 ms	.1 to 2115 MHz <85 ms	.1 to 2112 MHz <100 ms
Spectral Purity* Spurious Subharmonics	<-100 dBc None	<-100 dBc None	<-94 dBc <-45 dBc	<-94 dBc <-45 dBc
Phase Noise* @ 20 kHz offset	<-134 dBc/Hz	<-131 dBc/Hz	<-125 dBc/Hz	<-125 dBc/Hz
Residual FM* (.3 to 3 kHz BW)	<2 Hz	<1.5 Hz	<5 Hz	<3 Hz
Output Range* Accuracy Reverse Power Protection	+16 to -140 dBm ±1 dB >-127 dBm 50 Watts/50 Vdc	+17 to -140 dBm ±1 dB >-127 dBm 50 Watts/50 Vdc	+16 to -140 dBm ±1 dB >-127 dBm 25 Watts/25 Vdc	+13 to -140 dBm ±1 dB >-127 dBm 25 Watts/25 Vdc
Amplitude Modulation Depth Distortion @ 30%	0–99.9% <2%	0–99.9% <1.5%	0–99.9% <2%	0–99.9% <1.5%
Frequency Modulation Max. Deviation* Distortion	3 MHz <2%	4 MHz <1% @ 50% Dev.	3 MHz <2%	8 MHz <1% @ 50% Dev.
Phase Modulation Max. Deviation*	100 Rad.	40/400 Rad.	200 Rad.	80/800 Rad.
Pulse Modulation On/off Rise/fall time Minimum Pulse Width	>40 dB <400 ns <2 μs	>40/60 dB <15 ns (Typ 7.5 ns) <30 ns	>40/80 dB <400 ns <2 μs	>80 dB <15 ns (Typ 7.5 ns) <30 ns
Internal Modulation Source Level Range Waveforms Programmable	20 Hz to 100 kHz 0 to 3 Vpk Sine Yes	0.1 Hz to 200 kHz 0 to 4 Vpk Sine/Sq/Tri/Pulse Yes	20 Hz to 100 kHz 0 to 3 Vpk Sine Yes	0.1 Hz to 200 kHz 0 to 4 Vpk Sine/Sq/Tri/Pulse Yes
Memory Locations (NVM)	51 Full Function	50 Full Function	51 Full Function	50 Full Function
U.S. List Price	$30,340	$16,950	$41,680	$22,950

The question is not why Giga-tronics is so much less,

but rather, why Hewlett-Packard wants so much more.

*Specifications for both the 6080A and the HP 8642A are at 1GHz. Specifications for both the 6082A and the HP 8642B are at 2GHz. Prices and specifications for the HP 8642A and HP 8642B are from the Hewlett-Packard 1993 catalog. Prices for the Giga-tronics 6080A and 6082A are U.S. list prices.

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Price.

Considering all this, the real question is not why Giga-tronics is so much less, but rather, why Hewlett-Packard wants so much more?

So, if you're interested in paying a lot less for great performance and proven reliability, backed by a worldwide network of service and support, call us toll free at **800 726 GIGA** (4442). We'll send you more information and arrange for a demonstration.

Giga-tronics

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510 328 4650
Telefax: 510 328 4700

INFO/CARD 9

Letters should be addressed to: Editor, RF Design, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111. Letters may be edited for length or clarity.

RF and DNA

Editor:

The article by Andy Kellett on RF radiation hazards interested me because it is the first time I have ever seen the possibility mentioned that RF can affect ongoing chemical reactions within the cell. It seems that every article I read on the subject assumes the human body to be a lump of inert material (well, I've known some people ...) which is only affected by the heating effects of RF. The reasoning is that if there is not enough energy to blast apart a strand of DNA, how can RF cause cancer? But every time a cell divides, DNA molecules are split and reconstructed, and this happens billions of times each second in the body. The real question we should be asking is, can low level fields bias the body's chemical reactions, increasing the probability that they will not proceed as planned?

Hank Wallace
President, Atlantic Quality Design, Inc.

Biasing Blunder?

Editor:

I'm sure that Stanley Novak knows how to bias transistors for stable operation, but in his article, "Combined Technology Amplifier Design," in the May issue, he has taken a shortcut which should never be used in a real design. Biasing the MRF 571 using just a 220k base resistor to B+ will result in a minimum collector current of 2.58 mA, with a Vce of 8.9 volts, and the full saturation at about 9.5 mA, where the h_{FE} is 178. Since the h_{FE} can be as much as 300, the bias scheme is obviously a no-no.

Two other reasons for avoiding this bias, are that as the V_{ce} and the I_c vary, the S-parameters of the device change, nullifying the design calculations, and even if the base resistor is chosen at test for optimum bias, the bias will vary considerably over temperature.

One of the simplest arragements for stable bias (minimum number of components while maintaining the emitter at DC ground) involves the use of a Zener diode. See Figure 1. Use a Zener voltage about equal to the desired Vce. The base-emitter drop is somewhat compensated for by the fact that the Zener voltage will be lower than marked, due to the low current through the diode.

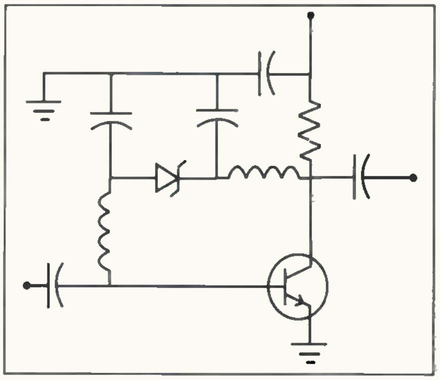
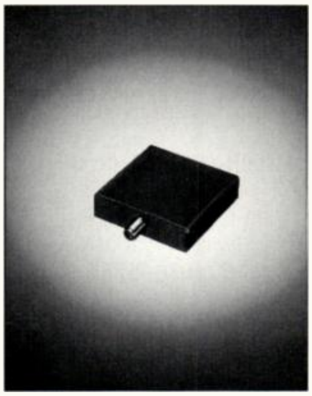


Figure 1. A suggested biasing scheme.

Doug McGarrett
Sr. Engineer, ADEMCO



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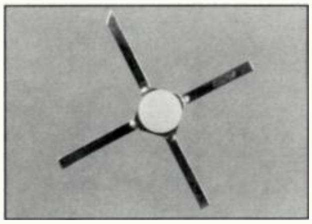

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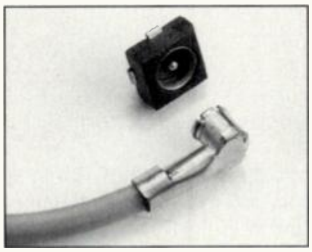

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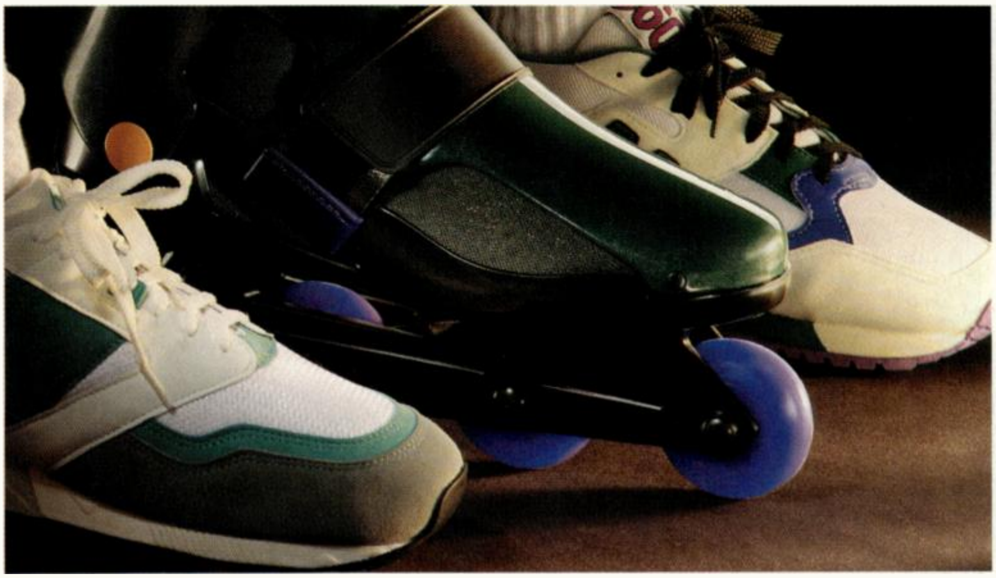

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INFO/CARD 11

RF calendar

August

25-28 **IEEE Electromagnetic Compatibility Symposium**
Chicago, IL
Information: Thomas Braxton, Vice-Chair, AT&T Bell Laboratories, Room 2B-217, 2000 N. Naperville, Road, Naperville, IL 60566. Tel: (708) 979–1299. Fax: (708) 979–5755.

29-1 **Surface Mount International**
San Jose, CA
Information: Institute for Interconnecting and Packaging Electronic Circuits, 7380 N. Lincoln Avenue, Lincolnwood, IL 60646. Tel: (708) 677–2850. Fax: (708) 677–9570.

September

5-8 **The European Microwave Conference 1994**
Cannes, France
Information: Jacqueline Baron, Sales Manager, 24th EuMC, Nexus Business Communications Ltd., Warwick House, Azalea drive, Sawanley, Kent BR8 8HY, UK. Tel: 44 322 660070. Fax: 44 322 667633.

27-29 **Wescon 94**
Anaheim, CA
Information: Wescon/94, 8110 Airport Blvd., Los Angeles, CA 90045. Tel: (800) 877–2668 or (310) 215–3976. Fax: (310) 641–5117.

27-29 **16th Piezoelectric Devices Conference**
Kansas City, MO
Information: Electronic Industries Association, 2001 Pennsylvania Avenue, N.W., Washington, DC 20006. Tel: (202) 457–4930. Fax: (202) 457–4985.

October

3-7 **Antenna Measurement Techniques Association**
Long Beach, CA
Information: 1994 AMTA Symposium, School of Engineering and Computer Science, Center for Research and Sciences, California State University, Northridge, 18111 Nordhoff St. - SECS, Northridge, CA 91330. Tel: (818) 885–2146. Fax: (818) 885–2140.

25-26 **Radio Solutions, Exhibition and Conference for the Low Power Radio Industry**
Birmingham, England
Information: Radio Solutions, Low Power Radio Association, The Old Vicarage, Haley Hill, Halifax, HX3 6DR, UK. Tel: 0422 380397. Fax: 0422 355604.

25-27 **Microwaves '94**
London, England
Information: Anna Tapster, Nexus Business Communications, Warwick House, Swanley, Kent BR8 8HY, United Kingdom. Tel: 44 322 660070. Fax: 44 322 614898.

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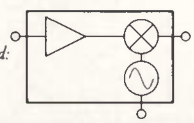

SA620 @900MHz	Vcc	Icc	LNA		Mixer	
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Information: UCLA Extension, Engineering Short Courses, 10995 LeConte Ave., Ste. 542, Los Angeles, CA 90024. Tel: (310) 825-1047. Fax: (310) 206-2815.

Avionics & Weapons Systems Flight Test
August 22-26, 1994, San Diego, CA
High Speed & Microwave Devices & Applications
October 24-27, 1994, Boston, MA
Information: University Consortium for Continuing Education, 16161 Ventura Boulevard, M/S C-752, Encino, CA 91436. Tel: (818) 995–6335. Fax: (818) 995–2932.

Low Earth Orbit Satellite Systems (LEO's)
November 14-16, 1994, Washington, DC
Information: The George Washington University, Continuing Engineering Education, Academic Center, Room T-308, 801 22nd Street, N.W., Washington, DC 20052. Tel: (202) 994–6106 or (800) 424–9773. Fax: (202) 872–0645.

Applied RF 1
August 22-26, 1994, Los Altos, CA
Wireless Systems
August 29-September 2, 1994, Los Altos, CA
Information: Besser Associates, 4600 El Camino Real, Suite 210, Los Altos, CA 94022. Tel: (415) 949–3300. Fax: (415) 949–4400.

DSP Without Tears
August 24-26, 1994, Salt Lake City, UT
September 14-16, 1994, Toronto, Canada
Information: Z Domain Technologies, Inc., 325 Pine Isle Court, Alpharetta, GA 30202. Tel: (800) 967–5034 or (404) 587–4812. Fax: (404) 518–8368.

Optimization Technology and Application in High Frequency and Microwave Circuit Design
October 4-5, 1994, Duisburg, Germany
Information: John Bandler or Adalbert Beyer. Tel: (905) 628–8228 or 49 203 378 9217. Fax: (905) 628–8225 or 49 203 379 3218.

Digital Cellular and PCS Communications - The Radio Interface
October 10-14, 1994, Spain
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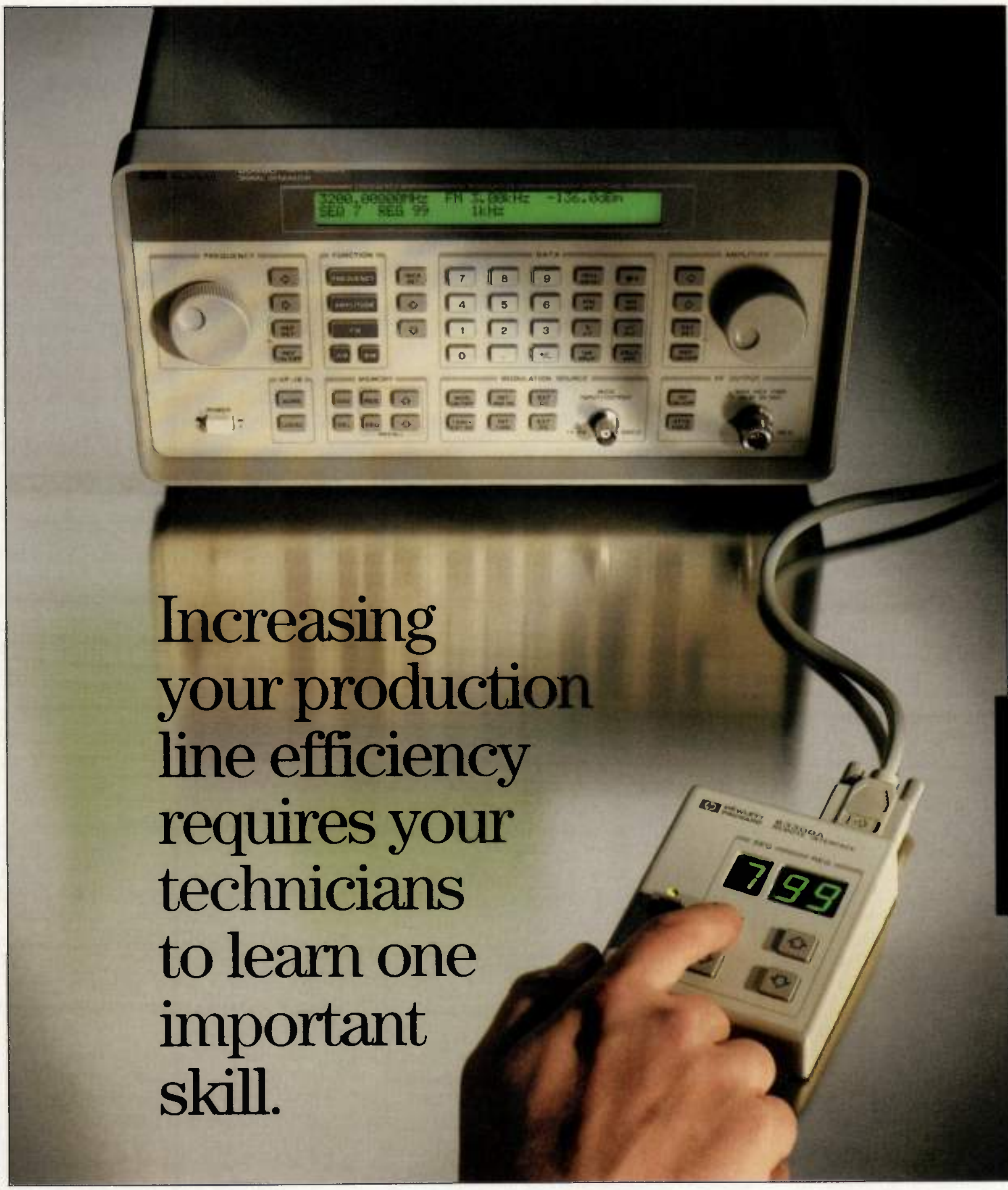
October 10-14, 1994, Spain
Active and Passive RF Components: Measurements, Models, and Data Extraction
October 12-18, 1994, Spain
Wireless Digital Communications
November 7-11, 1994, United Kingdom
Information: CEI-Europe/Elsevier, Mrs. Tina Persson. Tel: (46) 122–175–70. Fax: (46) 122–143–47.



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INFO/CARD 16

EIA Metric Committee Plans Changeover

The Electronics Industry Association's Metric Transition Steering Committee has decided that the change to metric won't happen cold turkey. The EIA policy statement is, "The EIA actively supports a planned transition to the SI based metric practice in the design and manufacture of electronic equipment." This statement is consistent with that of the SAE and other statements from the industrial sector.

As part of the transition, certain industrial "norms" will be identified — internationally accepted practices that are in inch-pound units and not expected to change. Other practices will be "hard metric."

The conversion process has the following timeline:

In 1994, all new and revised EIA standards will include the SI system, either in metric only, or as a dual system with metric dimensions given first and the U.S. customary units in parentheses. In 1996, all new standards will be metric only, unless special circumstances requires dual dimensioning. By 1999, all new, reissued and reaffirmed standards will be metric, also subject to dual dimensioning in special circumstances. Finally, by 2004, all EIA standards will be metric. If required, standards developed before 2000 may be dual dimensioned.

Microwave Update Conference Scheduled for September — The ninth Microwave Update will be held in Estes Park, Colorado from September 22 through 25, 1994. The purpose of the conference is for amateur microwave experimenters to discuss and exchange technical information on all aspects of radio communications on frequencies above 900 MHz. Although an amateur radio activity, a majority of participants in this in-depth, practical conference also are professional RF and microwave engineers and technicians. For more information, contact William McCaa, 181 S. 80th Street, Boulder, CO 80303.

28,800 kbps Modem Standard is Adopted — The International Telecommunications Union – Telecommunication Standardization Sector (ITU-T, formerly known as CCITT), has adopted the V.34 modem standard for telephone line communications. Dubbed V.fast in its development stage, V.34 modems will transfer data at twice the rate as present technology, up to 28,800 kbps. Included in the standard are line-probing techniques that ascertain the quality of the telephone line and adjust themselves for each connection. V.34 will also identify itself to telephone switching equipment (handshaking). Among the applications expected to arise from higher speed capability is color fax transmission.

EIA Forms New Division — The Microwave Solid-State Electronics Division is the newest division of the Electronics Industry Association. The Division will provide a focused voice and a national forum to promote U.S. leadership in the microwave and millimeter-wave industry. The Division expects the microwave solid-state chip market to grow by a factor of 10 to nearly $2 billion by the year 2000. Driving forces in this market include worldwide growth in communications links, military smart sensor defense systems, wireless personal communications, and smart vehicle and highway systems. Companies interested in joining this Division should contact EIA's Group Vice President Gene Lussier at (202) 457-4933.

NIST and Ukraine in Agreement — To enhance trade between the United States and Ukraine, the National Institute of Standards and Technology (NIST) and the State Committee of Ukraine for Standardization, Metrology, and Certification (DERJSTANDART) have signed a memorandum of understanding on scientific and technical cooperation to remove non-tariff trade barriers between the two countries. The memorandum recognizes the growing importance of the harmonization of standards and conformity assessment measures to improve international trade. Ukraine has adopted a law, for which DERJSTANDART has established a product certification program, which requires that all goods and materials must be certified before they are place in the marketplace.

TRW Subsidiary Launches Commercial Venture — ESL Incorporated, a TRW company, has begun a new advanced information technology venture. The new TRW Business Intelligence Systems is headed by general manager William A. Hogan. ESL has extensive information collection, analysis and processing technology that will be used in the development of system and software products for telecommunications, digital video imaging, medical imaging and other markets. Founded in 1964, ESL is a leading supplier of government reconnaissance and intelligence systems, services and products.

Noise Com Forms Wireless Division — The Wireless International Corp. (WIC) has been formed by Noise Com, Inc. to produce test equipment for OEMs developing and manufacturing wireless systems. Initially a supplier of solid state noise-generating and noise measuring devices to the military industry, Noise Com has converted much of its product line to serve commercial markets such as satellite communications, cellular telephone and cable TV. WIC President Dale Sydnor notes that the customer base and selling techniques for wireless-related products are different from conventional electronic test equipment, prompting the decision to create a new division.

AMP Makes Investment in Intellon Corp. — AMP Inc. of Harrisburg, Pa. has taken an equity position in Intellon Corporation, part of Intellon's recent $7.5 million private offering. Intellon is the developer of CEBus® home automation equipment using their Spread Spectrum Carrier™ technology. AMP is a supplier of connectors and interconnection devices.

Anadigics Recognized for Contribution — The City College of New York (CCNY) School of Engineering has honored Anadigics for its continued financial support of the CCNY electronics laboratory. Anadigics contributes $40,000 annually to fund the laboratory, and donates surplus technological equipment, as well. With an enrollment of 3000 undergraduate and 950 graduate students, the School is one of the largest engineering schools in New York state.

Sage Moves to New Facility — Sage Active Microwave, Inc. has established its new headquarters in Hollis, New Hampshire. The facility has 6000 square feet of space, with expansion options, containing a fully equipped hybrid microcircuit manufacturing operation. The address is Sage Active Microwave, Inc., 26 Clinton Drive, Suite 114, Hollis, NH 03049-6521, tel. (603) 598-6900.

RFID Tags Aid Trash Collection — Mandatory recycling plans in many communities are becoming a challenge for consumers and waste collection companies alike. In the city of Santee, Calif., Texas Instruments TIRIS RFID transponders are attached to the various color-coded trash bins containing the various types of waste (see photo). As each is dumped into the collection truck, the RFID tag is read and the information on the household and the contents of the bin is recorded. The data is used to generate reports for evaluation of the recycling program, including the number of bins containing recyclable material, and how often each household sets out the bins. The information can also be used for time-and-motion studies of route performance, such as time per stop, time between stops, and transport time to landfills.

EdB EMC Consultants Opens Office — Edwin L. (Ed) Bronaugh has opened a consulting business under the name EdB EMC Consultants, to provide assistance in the areas of EMC measurements, EMI emissions, EMI control plans, standards, instruments and antennas. Mr. Bronaugh is a NARTE Certified EMC Engineer, Fellow of the IEEE and Senior Member of the SAE. EdB EMC Consultants can be reached at (512) 258-6687 (voice) or (512) 258-6982 (fax).

Dassault to Provide Cordless Public Phone System — The Dassault Electronique Group has singned a contract for the supply of a turnkey cordless public telephone system for city of Chongqing in Sechuan province, People's Republic of China. The system ot be provided is of the digital type, based on microcells. Dassault will provide th entire network infrastructure, including base stations, network interfacing equipment, central supervision and control systems, and the associated handsets. Technical assistance and training are also part of the contract. The Dassualt system is based on the European CT2/CAI protocol, and economical solution that also supports facsimile transmission. The Chongqing region represents a market of several hundred million French francs.

Hewlett-Packard Restructures CAE Business — Hewlett-Packard Company has announced the formation of the HP EEsof Division, formerly part of the Santa Rosa Systems Division (SRSD) and part of the Microwave Communications Group (MCG). According to H-P, the elevation to Division status reflects its continued commitment to the RF/microwave CAE market. The HP EEsof Division includes the merged operations of EEsof, Inc. acquired in 1993, and the H-P high-frequency CAE group.

Vectronics Gets Accelerator Contract — Vectronics Microwave Corporation has been awarded a $376,000 contract from the Continuous Electron Beam Accelerator Facility (CEBAF) in Newport News, Virginia. Vectronics will supply 104 Beam Position Monitor Multiplexers: radiation-hardened modules shich contain four low-loss SP5T PIN diode

Some Standard Features On The 2050 Aren't Even Available As Options Elsewhere

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In Canada contact Canadian Marconi at 514-341-7630 X4695 switches with TTL drivers and control logic. They are used to switch up to four RF signals from five beam position monitors to a single beam position detector. The contract includes four-year options for spare parts for an additional amount up to $223,000.

Compact Software Establishes European Subsidiary — Electronic Software Components GmbH & Co. Trade KG (ESC) has been formed in Munich, Germany by Compact Software. ESC will manage Compact's existing network of European distributors and support marketing activities throughout Europe. Stefan Georgi, formerly of Rohde & Schwarz, has been appointed President of ESC. ESC will also oversee European sales and marketing of Synergy Microwave's product line. The telephone number for ESC is +49-8091-6485.

Micro SMT Receives Patent — A patent has been granted for the semiconductor packaging technology known as Micro or Minimal SMT packaging. The packaging enables semiconductors to be packaged in the wafer state using automated photomasking, silicon etching and encapsulating techniques. The packaged device is approximately the same size as the the semiconductor device, and is sufficiently rugged to withstand multiple test contacts and SMT assembly, according to Micro SMT, Inc. Micro SMT also announces that M-Pulse Microwave is a participant in the MSMT packaging technology.

Amtech Receives Automatic ID Contract — Amtech Corporation announces a $400,000 contract with Matson Navigation to expand automatic equipment identification (AEI) systems to Matson's Los Angeles and Seattle terminals. The equipment uses radio frequency identification (RFID) technology for identification of all tagged tractors, chassis, motor generators, and containers entering and leaving the terminals. A pilot system has been operating since 1992 at Matson's Honolulu terminal, where gantry-crane mounted equipment monitors all containers being loaded and unloaded.

Dataradio Gets RNET™ Line — Dataradio has taken over distribution of the Motorola RNETproduct line , including a telemetry radio and a 9600 bps radio modem. The Motorola division that makes RNET products has chosen to concentrate on manufacturing, and to use other companies for distribution. *RF*

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INFO/CARD 22

RF Issues Help Fill FCC Dockets

by Andy Kellett
Technical Editor

A number of RF systems which were only the subject of speculation just a few years ago are now about to be approved by the FCC. This report will look at a few of those systems and where they stand with respect to FCC action and regulation.

Big LEOs – The spectrum alocation and sharing rules for big LEOs will be made by the FCC late this year, says Lou Manuta, the Washington, D.C.-based editor of *Satellite Communications* magazine. Big LEOs are large constellations of Low Earth Orbiting (hence LEO) satellites, designed to give constant communications coverage everywhere on earth. The most familiar of these proposed systems is Iridium, but systems by Globalstar (a venture which includes Loral and Qualcomm), TRW, Constellation Communications, and Ellipsat are also vying for orbital and spectrum space. The big LEOs seek spectrum space in the 2.4 to 2.5 GHz range.

PCS – Personal Communications Systems (PCS) have been divided into two types, narrowband and broadband. The final rules for narrowband PCS at 900 MHz are out, and spectrum auctions will have taken place by July 25th.

The rules for broadband PCS services have been finalized – after 67 companies asked the FCC to reconsider the plans that were intitially presented in September of last year. According to Fred Thomas, an engnieer with the FCC's Frequency Alocation Branch, the plan that was finally adopted places three 30 MHz blocks and three 10 MHz blocks in the 1850 to 1990 MHz band. Each 10 Mhz block is contiguous with a 30 MHz block. In addition, a 20 MHz block has been approved for PCS from 1910 to 1930 MHz.

HDTV – The "Grand Alliance", the single group that formed after the competing groups developing their own HDTV systems merged, has spent six months with an FCC appointed advisory committee, to form what will be the standard for U.S. television. Prototype versions of all the components in the system are currently being built, and they will begin ten weeks of testing in late November at the Advanced Television Test Center, says Robert Bromery, Deputy Chief of Authorization and Evaluation Division in the FCC's Office of Engineering and Technology. Bromery says he expects the FCC to issue a Notice of Proposed Rulemaking sometime in mid-1995, and to adopt a new television standard by the end of 1995, or early 1996.

Because the new standard will have been developed under the guidance of an advisory committee, the FCC should quickly adopt the HDTV standard, predicts Bromery. What may arouse some controversy could be the FCC's plans to phase out NTSC transmissions after 17 years and the VHF television broadcast bands after 15 years says Bromery.

RF Exposure Strandards – The FCC is currently considering a proposal to adopt the IEEE standard C95.1-91 for RF radiation exposure as its own, says Bob Cleveland, an Environmental Scientist at the FCC's Office of Engineering and Technology. The Notice of Proposed Rulemaking regarding the standard has ellicited some criticism from a few other Federal agencies such as the FDA and EPA says Cleveland.

How to Keep Tabs on the FCC

These are just a few of the RF-related issues the FCC is currently dealing with. To get current, detailed information about what the FCC is doing can be dificult, because as Satellite Communication's Manuta notes, "The FCC rules change every single day – no kidding." However, if you have the stamina, you can keep track of the FCC's daily actions by ftp'ing the FCC's information service on Internet at anonymous.ftp@fcc.gov. *RF*

The Making of an FCC Rule

The FCC executes rules. Some are bona fide laws, for instance, the Cable Television Act, signed into law in 1993. Likewise, the FCC may be called upon to execute a court ruling or executive order. However, the majority of the FCC's work is the result of its own "rulemaking" process

"Anyone could write the FCC and say, 'We want you to start the proceedings to do X', and the FCC could do it," says *Satellite Communications'* Manuta, "that's where seventy-five percent of their rule making comes from"

Figure 1 is a diagram [1] which outlines the flow of a "petition for rulemaking", which is a request for a new rule.

Any petition that is judged meritorious by the FCC office or bureau that is considering it, will eventually result in one or more of four actions being taken by the FCC.

A Notice of Inquiry (NOI) is given when the FCC wants to gather as much information from as many people as it can on some topic.

A Notice of Proposed Rule making (NPRM) is given when the FCC is contemplating a change or addition to its rules.

A Memorandum Opinion and Order (MO&O) is one of two final actions the FCC can take on a petition. In this action, the FCC denies a petion for rulemaking, concludes an inquiry, modifies a decision, or denies a petition for reconsideration of a decision.

Finally, a Report and Order (R&O) is the other ultimate action the FCC can make on a petition, resulting in the statement of a new or amended rule or a statement that the rules will not be changed. This action is almost always preceded by an NPRM.

1. Linthicum, Jack M., "A Guide to the FCC's Rulemaking Procedures", *IEEE Communications*, July 1981, pp. 34 - 37.

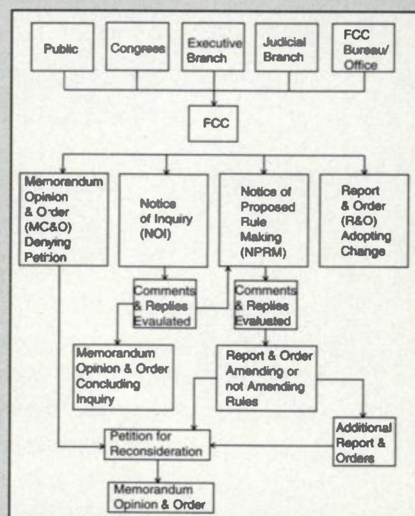
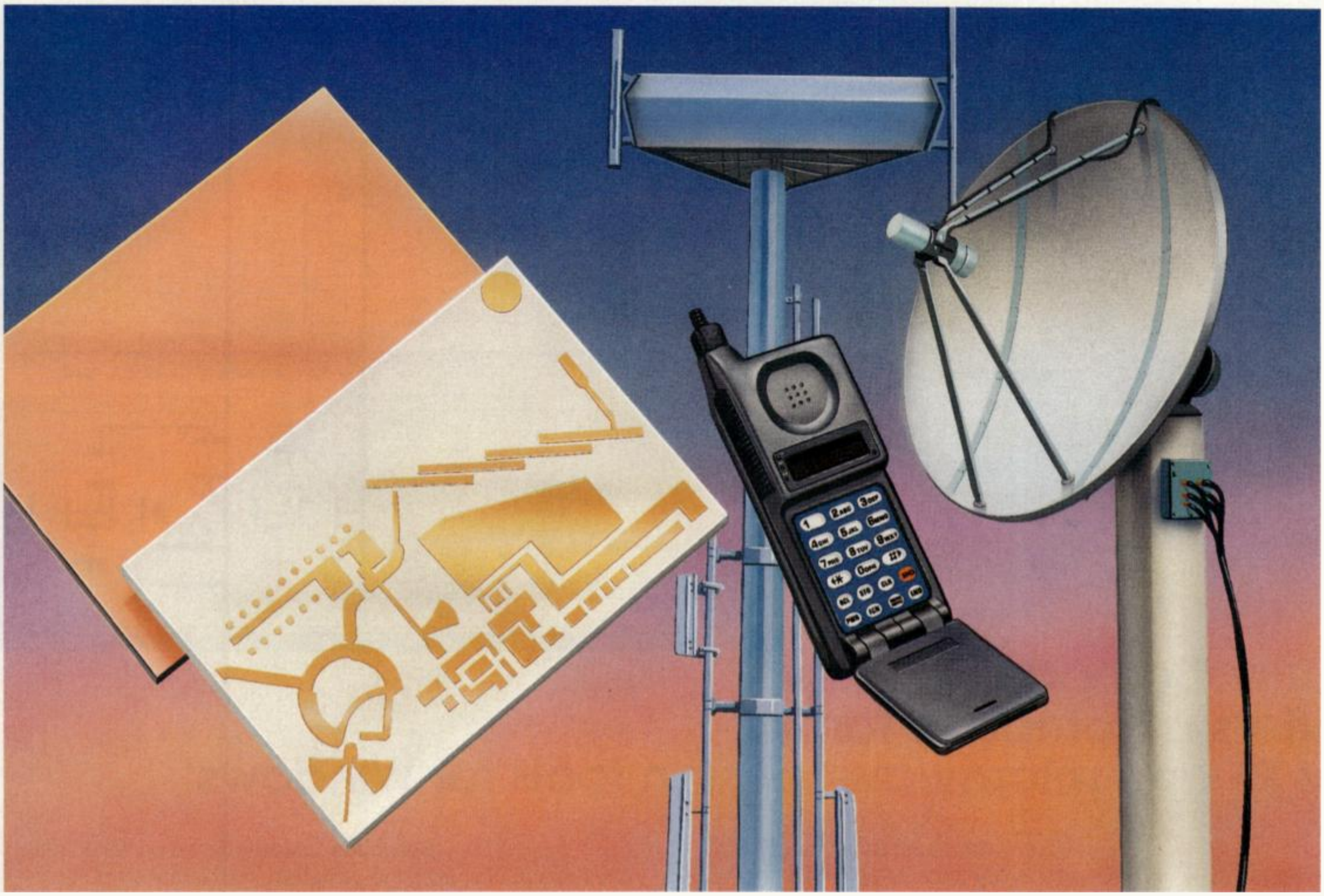


Figure 1. Flow diagram for a proposed FCC rule.



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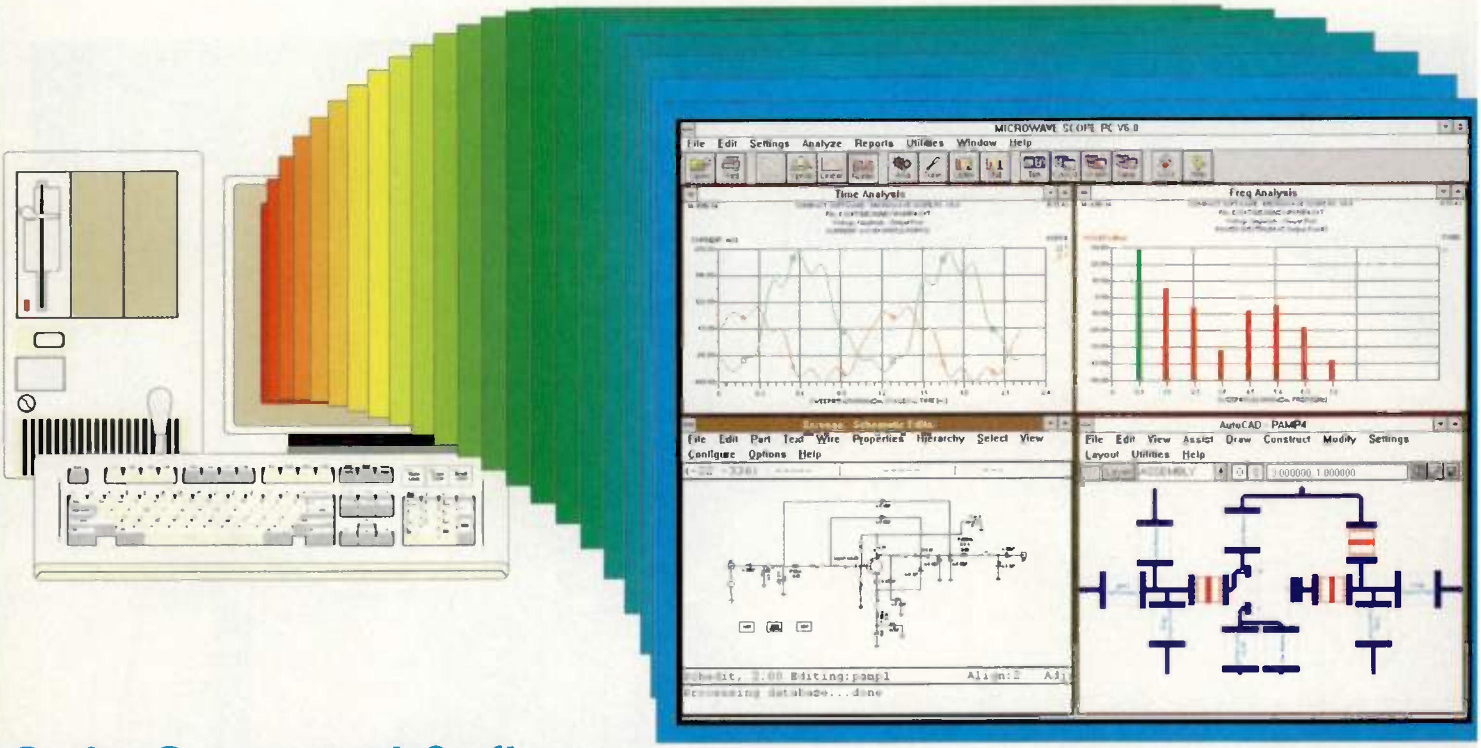

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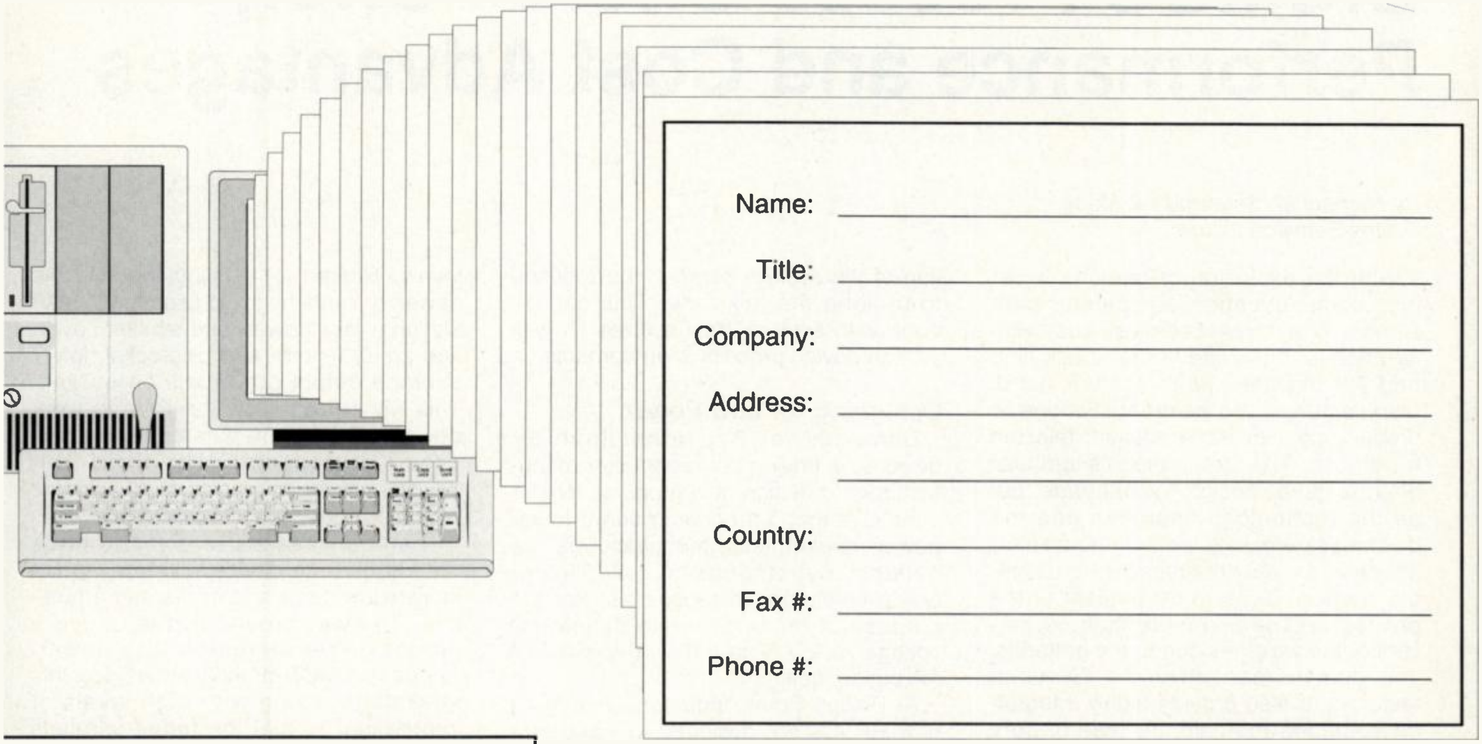

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INFO/CARD 24

BiCMOS Process Offers Power, Performance and Cost Advantages

By Michael M. Sera and Bill Mack
Philips Semiconductors

With the explosion of personal wireless communication equipment, consumers today expect cordless and cellular phones to provide hours of talk time and yet fit in the palm of their hand. Manufacturers are being challenged to produce smaller more efficient telecom terminals. The first portable cellular phones used "bricks" for batteries, but as the technology improves and the demand sky-rockets, phone manufacturers race to create the smallest and lightest phones. Close to 30 percent of the phones volume and more than 50 percent of the weight is due to the batteries. This demand has driven the IC manufacturers to also provide highly integrated solutions that require less battery power.

The "battery bulk" can be reduced by using fewer cells. This is done by reducing the supply voltage from five volts to three. In addition, the current consumption of the system needs to be reduced to prolong the talk time. This can be done with system architectures as well as with device process improvements.

Designing for Low Power

Demands for 3V, rather than 5V devices, is driving semiconductor manufacturers to design new products for this supply range. To accommodate lower power requirements, manufacturers are making investments in new, lower power-consumption processes. For the purpose of this article, we define low voltage as 2.7 V to 3.6 V (three, 1.2 V AA battery cells).

At Philips Semiconductors, nearly all new RF ICs are designed to work from 2.7 V to 5.5 V, to address both the three and five volt markets. The limiting factor in today's radio supply voltage requirements is the PA (Power Amplifier). They still require 4.8 V to provide the power levels required for existing systems. As newer systems begin to use digital modulation (pulse power) and smaller coverage areas (micro- and pico-cells), lower average output power will be utilized. This will in turn allow the PA's to work down to 3.6 V unregulated. Once this occurs, the demand for three volt devices will be enormous as all systems will be designed with three volt supplies.

The one limitation of going to three volts is that the device will now require more current to perform the same function. The way around this is to use a process which requires less power. Philips' BiCMOS processes provide this advantage, along with high levels of integration, to fuel the future wireless communication requirements.

Device Processing

In 1987, Philips started working on a process to create RF devices with high-

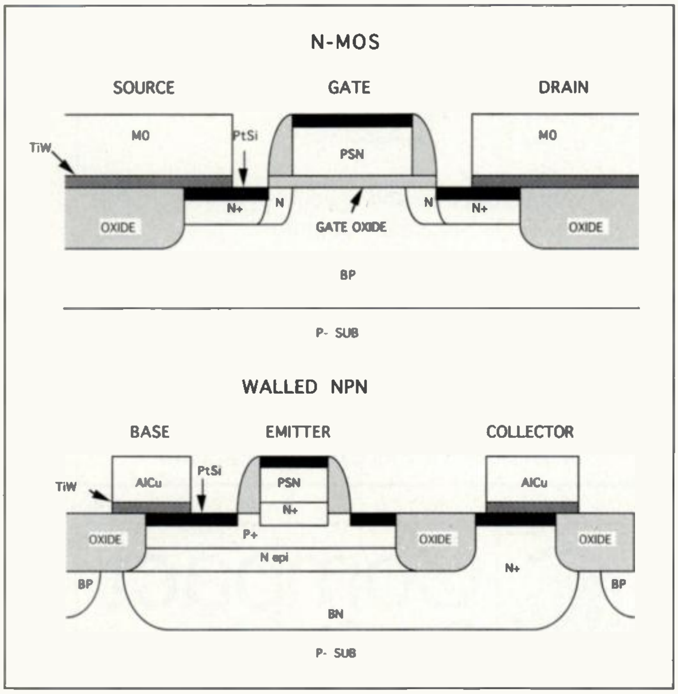

Figure 1. QUBiC N-MOS and NPN cross sections.

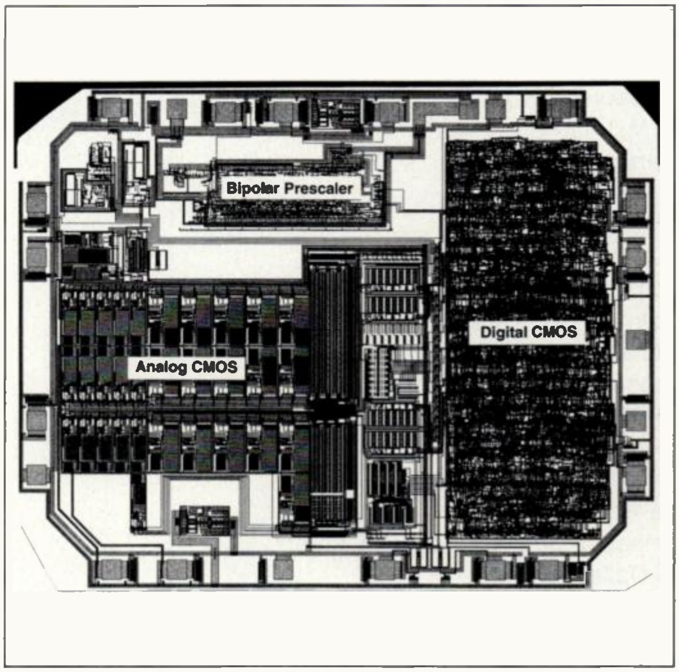

Figure 2. SA7025 1 GHz fractional N synthesizer layout diagram.

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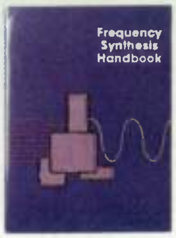

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	QUBiC	QUBiC-2
Fmax	10 GHz	20 GHz
F_T	13 GHz	24 GHz
Bipolar emitter length	1 µm	0.7 µm
CMOS channel length	1 µm	0.8 µm

Table 1. QUBiC and QUBiC-2 process comparison.

er levels of integration as well as reduced power consumption. The resulting BiCMOS process was trademarked QUBiC (QUality BiCMOS) and has been used for most of the RF/wireless devices manufactured by Philips.

QUBiC is a 1µm process (the dimension of the polysilicon is 1µm, the bipolar emitter is 1µm, the CMOS gate length is also 1µm, see Figure 1). It has an NPN F_T of 13 GHz and an f_{max} of about 10 GHz. Combining high speed bipolar with low power CMOS on the same piece of silicon supports higher levels of integration. The biggest advantage is that a designer no longer has to make compromises when designing systems on a chip. They can take advantage of both processes and optimize the design. The Philips RF frequency synthesizer ICs are a good example of QUBiC's capabilities.

The SA7025 and SA8025 fractional-N synthesizers are produced in QUBiC and operate up to 1 and 2 GHz, respectively. The high speed bipolar portion of QUBiC is used for the prescaler function on these devices. For the logic portion of the synthesizer, CMOS is used to reduce current consumption (see Figure 2). Since most of the logic runs under 20 MHz, standard cell CMOS libraries are used to minimize the die area, consistent with lowering cost. For logic that requires faster clock speeds, CML (Current Mode Logic) is used.

The system designers benefit because they can now get an RF device which is highly integrated, runs down to 3 V and consumes less power. Other RF/wireless devices which benefit from the QUBiC process are; SA6XX front-end series, SA575X audio processing series, SA900 modulator upconverter, UMA10XX synthesizer series, SA520X RF amplifier series and the SA630 RF switch.

Next Generation QUBiC

The demand for further levels of integration, lower power consumption and higher operating frequencies has driven Philips to invest in QUBiC-2. QUBiC-2 is a 0.7 µm process, with a very aggressive CMOS. QUBiC-2 is expected to provide three times the CMOS density of QUBiC. It uses a 150 Å gate oxide. CML in QUBiC generally consumes 50 µA per gate. With QUBiC-2, simulations show that 20 µA is adequate for the same clock speeds.

For the bipolar portion of QUBiC-2 we are expecting an NPN F_T of 24 GHz and an f_{max} of 20 GHz (see Table 1). F_{max} is useful for determining gate delays in digital circuits and bandwidths for analog circuits. Although F_T is most often quoted, it really is of lesser importance. It does not factor in the base resistance of the NPN. The base resistance is the fundamental contributor to noise in amplifiers. A very low base resistance is needed for low noise RF front-end products at high frequencies (1 to 3 GHz).

A special technique called "Spacer Technology" has enabled the base contacts to be ten times closer then the actual lithography would allow. This has been crucial in getting low base resistance and therefore low noise. For example, the distance between the base metal and polysilicon emitter is only about 0.1 µm, even using 1.0 µm lithography. Spacer Technology is used in both versions of QUBiC. Thus, unlike many CMOS technologies which add a step or two to produce a low performance bipolar, QUBiC-2 has a highly optimized bipolar process plus state-of-the-art CMOS.

Higher Levels of Integration

Some of our synthesizers, for example, presently have about 5,000 to 10,000 gates. QUBiC-2 will offer in the next two to three years, the capability of manufacturing up to 50,000 gates on a low-cost BiCMOS chip. The biggest advantage will be the current savings in not having to go off and on chip. In

	QUBiC	QUBiC-2
LNA NF	2.5dB @ 1.8 GHz	1.9dB @ 1.8 GHz
Mixer NF	9dB @ 900 MHz	9dB @ 1.8 GHz
Switch Loss	1.8dB @ 900 MHz	0.9dB @ 900 MHz
Prescaler Icc	7mA @ 1.8 GHz	3.5mA @ 1.8 GHz

Table 2. QUBiC and QUBiC-2 RF device performance comparison.

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INFO/CARD 27

existing system designs where multiple devices are used, each device must provide the correct drive levels for the next stage. This requires additional buffering and signal conditioning either on or off chip. This, coupled with matching considerations, regeneration problems and crosstalk could be simplified greatly by putting many of these functions on the same silicon device. Therefore, having the LNA, mixer, VCO, synthesizer and PA driver all on the same chip would require less board space and current. There are obviously partitioning limits that constrain how to divide the amount of gain, which frequencies can be used, etc.. This is less of an issue for digital systems that use TDD (Time Division Duplex).

Comparisons

The SA601 LNA and Mixer (1 GHz) is an RF front-end device produced using QUBiC. The LNA is a bipolar single-stage design with a gain of 11.5 dB, NF (Noise Figure) of 1.6 dB and an IIP3 (Input Third Order Intercept Point) of –2 dBm, all measured at 900 MHz. The mixer is a single-balanced design with a gain of +6.5 dB (depending on the load), NF of 9dB and IIP3 of –2 dBm.

In radio receiver designs the system designer always wants three things in an RF front-end; high gain – because this reduces the effect of the noise figures in the following stages, low NF – because that sets the lowest limit for signals, and a high IIP3 – because this creates a receiver that is more tolerant of distortion and interfering signals. These three parameters are linked together, and improving one usually requires another to be degraded. The other option is increased current consumption, but this only reduces the battery life.

QUBiC-2 provides a much better solution by offering a better fundamental trade off. For example, a QUBiC-2 SA601 LNA gain would be increased from 11.5 dB to 16 dB, because of the lower collector-to-base capacitance, and the lower base resistance of the NPN. The NF would benefit with an improvement from 1.6 dB to 1.4 dB. These enhancements would be realized with no additional current penalty (see Table 2). Even with today's QUBiC process we have products that have excellent performance parameters.

A 2-GHz front end, realized in QUBiC, provides about 13 dB gain on an amplifier with a 2.5 dB noise figure. With QUBiC-2 the same gain is possible, with a 1.9 dB noise figure and 3 mA of current consumption. Thus, the process provides performance tradeoff flexibility. LNAs, mixers and oscillators more or less operate on the same principle. The design sizes the main transistor as large as possible until a loss of bandwidth begins to occur. This large device, then has the lowest noise figure because it has the lowest base resistance.

Conclusions

QUBiC-2 is being driven by the wireless and disk drive market requirements for low power, high performance and cost effective solutions. BiCMOS appears to be the best technology to achieve these objectives. With QUBiC-2's performance and frequency increases of a factor of two, and CMOS device density increases of a factor of three, this technology is ideally suited for the demanding world of personal wireless communications.

Additionally, the traditional supposition that BiCMOS can not compete with GaAs (Gallium Arsenide) technology at 1-2 GHz is unfounded. Cost sensitive versions of GaAs use lithography similar to QUBiC-2, and thus have similar RF performance (e.g. NF, gain, etc...). The inability of GaAs designs to include medium to large blocks of digital circuitry prevents this technology from being used for highly integrated low power solutions in personal wireless communication devices.

The first devices using the QUBiC-2 process will be sampled at the beginning of 1995, with full production later that year. Philips will start producing highly integrated products using this technology, as well as improving the performance of several existing products, by transferring them to QUBiC-2.

Special thanks to Todd Antes and Dr. Saeed Navid for their assistance in editing this article. ***RF***

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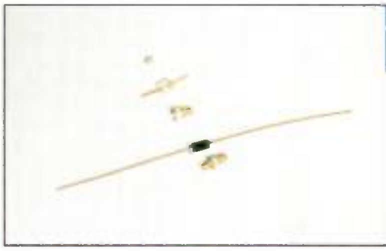


All Noise Com diodes deliver symmetrical white Gaussian noise and flat output power versus frequency. Noise Com diodes are available in a wide variety of package styles, and in special configurations on request.

TYPICAL STANDARD MODELS

MODEL	FREQUENCY RANGE
NC 204	0.1 Hz – 500 MHz
NC 302	10 Hz – 3 GHz
NC 401	100 MHz – 18 GHz
NC 406	18 GHz – 110 GHz

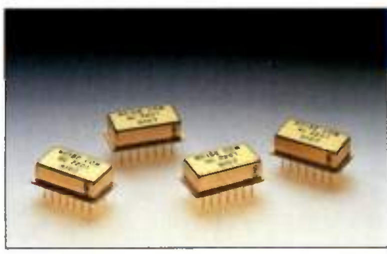
Drop in Modules for BITE

The NC 500 series drop-in noise modules in TO-8 cans are an economical solution for built-in test requirements. These devices contain complete biasing networks and need no external components. Also available are TO-39 and surface mount packages.

TYPICAL STANDARD MODELS

MODEL	FREQUENCY RANGE	OUTPUT ENR
NC 501/15	0.2 MHz – 500 MHz	31 dB
NC 506/15	0.2 MHz – 5 GHz	31 dB
NC 511/15	0.2 MHz – 500 MHz	51 dB
NC 513/15	0.2 MHz – 2 GHz	51 dB

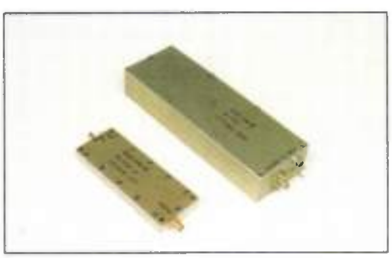
Broadband Amplified Modules



The NC 2000 series amplified noise modules are an excellent choice when a high level noise output is desired and the noise source is to be mounted on a circuit board. 24 pin packages are standard, 14 pins are available.

TYPICAL STANDARD MODELS

MODEL	FREQUENCY RANGE	OUTPUT
NC 2101	100 Hz – 20 kHz	0.15 Vrms
NC 2105	500 Hz – 10 MHz	0.15 Vrms
NC 2201	1 MHz – 100 MHz	+5 dBm
NC 2601	1 MHz – 2 GHz	-5 dBm

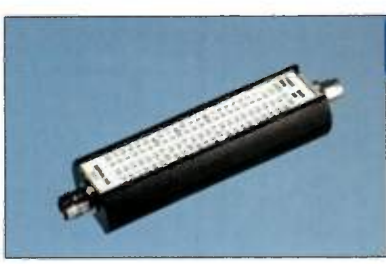


The NC 1000 series amplified noise modules produce white Gaussian noise from -14 dBm to +13 dBm at frequencies up to 6 GHz. They are designed for coaxial test systems, and are available with several bias voltages and connector options.

TYPICAL STANDARD MODELS

MODEL	FREQUENCY RANGE	OUTPUT
NC 1101A	10 Hz – 20 kHz	+13 dBm
NC 1107A	100 Hz– 100 MHz	+13 dBm
NC 1112B	20 MHz – 2 GHz	0 dBm
NC 1126A	2 GHz – 6 GHz	-14 dBm

Broadband Precision, Calibrated Coaxial



Noise Com's NC 346 series is designed for precision noise figure measurement applications. These products are available with coaxial or waveguide outputs. For OEM applications, the NC 3200 series provides high performance in a small ruggedized package.

TYPICAL STANDARD MODELS

MODEL	FREQUENCY RANGE	OUTPUT ENR
NC 346A	0.01 GHz – 18 GHz	6 dB
NC 346B	0.01 GHz – 18 GHz	15 dB
NC 346D	0.01 GHz – 18 GHz	25 dB
NC 346Ka	0.1 GHz – 40 GHz	15 dB

Broadband Calibrated Millimeter-wave

The NC 5000 series noise sources feature outstanding stability and convenience in waveguide bands up to 110 GHz.

TYPICAL STANDARD MODELS

MODEL	FREQUENCY RANGE	WAVEGUIDE
NC 5142	18 GHz – 26.5 GHz	WR-42
NC 5128	26 GHz – 40 GHz	WR-28
NC 5115	50 GHz – 75 GHz	WR-15
NC 5110	75 GHz – 110 GHz	WR-10

Coaxial with Built-in Isolators

The NC 3400 series are precision calibrated noise sources for extreme accuracy and flatness enhanced by their low VSWR 1.25:1.

TYPICAL STANDARD MODELS

MODEL	FREQUENCY RANGE	OUTPUT ENR
NC 3404	2 – 4 GHz	30–36
NC 3405	4 – 8 GHz	30–35
NC 3406	8 – 12 GHz	28–33
NC 3407	12 – 18 GHz	26–32

BER Testing Equipment

The UFX-BER accurately sets and displays Eb/No, C/N, C/No, or C/I between a user supplied signal and internally generated white Gaussian noise. The UFX-BER can be used for back to back or IF loop-back testing with extreme precision over a broad range of input or output power. Eb/No values can be entered directly from the front panel or by IEEE-488 bus.

TYPICAL STANDARD MODELS

MODEL	FREQUENCY RANGE	APPLICATION
UFX-BER-70	50 MHz – 90 MHz	General
UFX-BER-IBS/IDR	50 – 90; 100 – 180 MHz	IBS/IDR
UFX-BER-836	824 MHz – 849 MHz	CDMA
UFX-BER-1850	1800 MHz – 1900 MHz	DCS–1800

Amplifier Test Station

The UFX-NPR series instruments perform automatic distortion measurements in mobile telephone (CDMA and FDM) base stations, satellite communications systems, CATV, and other equipment operating in multi-signal environments. Some models are available with tunable measurement frequency or with multiple measurement frequencies.

TYPICAL STANDARD MODELS

MODEL	FREQUENCY RANGE
UFX-NPR-70	50 MHz – 90 MHz
UFX-NPR-CATV	50 MHz – 1.0 GHz
UFX-NPR-1700	1.6 GHz – 1.9 GHz
UFX-NPR-2400	2.2 GHz – 2.6 GHz
UFX-NPR-11900	10.95 GHz – 12.8 GHz

Broadband Noise Generators

The NC 6000 and NC 8000 series noise generating instruments are designed for applications on the test bench or incorporated with other equipment to provide a wide variety of functions. Each instrument contains a precision noise source, amplification, and step attenuators to provide repeatable symmetrical white Gaussian noise with variable output power.

TYPICAL STANDARD MODELS

MODEL	FREQUENCY RANGE	OUTPUT POWER
NC 6107	100 Hz – 100 MHz	+13 dBm
NC 6110	100 Hz – 1500 MHz	+10 dBm
NC 6124	2 GHz – 4 GHz	-10 dBm
NC 8107	250 kHz – 100 MHz	+30 dBm

The new UFX-7000 series noise generating instruments are extremely easy to use, combining dedicated keys for control of operations and programming, with a large 4 x 20 character LCD display. Control of output power, filter settings, and attenuator step size for both the noise and the signal (for units with internal combiners) is performed from the front panel or remotely using the IEEE-488 interface.

TYPICAL STANDARD MODELS

MODEL	FREQUENCY RANGE	OUTPUT POWER
UFX-7107	10 Hz – 100 MHz	+13 dBm
UFX-7108	100 Hz – 500 MHz	+10 dBm
UFX-7110	100 Hz – 1500 MHz	+10 dBm
UFX-7218	2 GHz – 18 GHz	-20 dBm
UFX-7909	1 MHz – 300 MHz	+30 dBm

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TRAK manufactures a wide range of microwave and RF subsystems and components. These range from highly complex custom synthesizers to basic building blocks, such as oscillators and isolators. A majority of the company's products are based around oscillators and frequency multipliers and include assemblies such as upconverters and down converters. Oscillator types include crystal controlled, phase-locked, dielectrically stabilized and voltage controlled. Other active components include comb generators and IF amplifiers.

RF & IF SIGNAL PROCESSING

In January, 1994 TRAK added a new product line consisting of passive RF and IF signal processing components. These products include mixers; couplers; power splitters; hybrid junctions; I/Q modulators and demodulators; phase shifters; variable attenuators; and matching transformers. They are available in a wide range of packages from surface mount to connectorized versions. The engineers for this product line have many years of design experience, offering products which significantly outperform those from other suppliers.

TIME-RELATED PRODUCTS

TRAK Systems Division manufactures time-related products and systems. These include Primary Reference Clocks (Frequency Standards), GPS Station clocks, time code generators and readers. Related products include distribution amplifiers, micro phase steppers, and tape search and control units.

DIVERSE CUSTOMER BASE

TRAK serves a wide range of customers, including makers of commercial communications systems such as cellular radio, microwave links and VSAT. Defense system manufacturers around the world use TRAK products in many systems such as communications, radar, electronic defense, navigation and identification. Platforms include satellites, deep space vehicles, aircraft, submarines, land vehicles and fixed sites.

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TRAK, located in Tampa, Fla., has been in business since 1960 and has been a subsidiary of Tech-Sym Corporation (NYSE) since 1964. TRAK Europe was established in 1987.

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- VCOs
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- VSAT
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VCOs

- Frequency: 0.5 GHz to 3 GHz
- Electronic Tuning: ± 2 to ± 10 MHz typical
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- Output Power:
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  - +10 dBm min above 12 GHz
- External Reference: Between 10 and 100 MHz
- Load VSWR: 1.7:1 maximum
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IF Freq	10 - 200 MHz	5 - 1000 MHz	10 - 200 MHz
LO Power Level	+17 dBm	+10 dBm	+17dBm
IP3 (input)	+32 dBm typ.	21 dBm typ.	+30 dBm typ.
Conversion Loss	8 dB max.	9 dB max.	8 dB max.
Size (inches)	0.50 x 0.38 x 0.19	0.50 x 0.38 x 0.19	0.50 x 0.38 x 0.19

SMD Couplers	Model No. CPL/20EF-04	Model No. CPL/20BE-04	Model No. CPL/10BE-04
Freq	500 - 2000 MHz	5 - 1000 MHz	5 - 1000 MHz
Loss	0.25 dB typ.	0.5 dB typ.	0.5 dB typ.
Coupling	20 dB nom.	20 dB nom.	10 dB nom.
Directivity	18 dB typ.	20 dB typ.	20 dB typ.
Size (inches)	0.31 x 0.25 x 0.19	0.31 x 0.25 x 0.19	0.31 x 0.25 x 0.19

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MICROWAVES: A GROWING TECHNOLOGY FOR PERSONAL AND BUSINESS COMMUNICATIONS

Let's play word associations:

• **Personal Communications** — Citizens Band radio (27 MHz) — Cordless telephones (49 MHz) — Cellular telephones (900 MHz)

• **Business Communications** — Two-way radio (150 or 450 MHz) — Specialized Mobile Radio (SMR, 800 MHz) — Or, the telephone system (Audio Frequencies)

• **New Applications** — Digital Cellular (900 MHz) — Personal Communications Service (PCS, 1800 MHz) — Part 15 unlicensed products (915 or 2450 MHz)

If these are the things you thought of first, it's time to take another look! Here's the same list with an added microwave perspective:

• **Personal Communications** — Satellite television systems (TVRO, 4 GHz, 13 GHz)

• **Business Communications** — Video and data links (anywhere from 4 to 40 GHz) — Very Small Aperture satellite Terminals (VSAT, 14 GHz)

• **New Applications** — Wireless Local Area Networks (WLANs, 2.45, 5.7, 10, 24 GHz) — Collision-avoidance systems (10-40 GHz)

A LITTLE HISTORY

In the 1970s, proven technology existed in VHF and UHF radio. Many two-way radio systems were in place in the 150 and 450 MHz bands. This technology was reliable and relatively low cost. The first mobile telephones used the 450 MHz band. In reality, they were nothing more than a standard two-way radio connected to a phone line at the base station. Early cordless telephones were introduced about this time, using 1.7 MHz and 49 MHz. Unfortunately, these first efforts were very prone to interference.

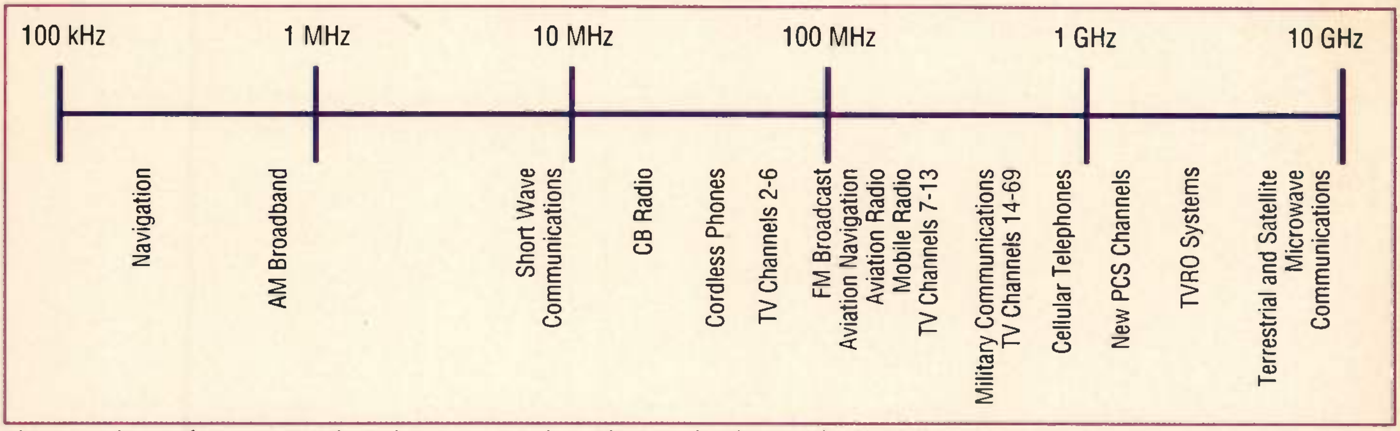
Then came cellular telephones. Because cellular systems had the potential to serve millions of people, a sizable chunk of spectrum was needed. The Federal Communications Commission took that space from the highest television channels in the 800-900 MHz range (mostly unused at the time), and set it aside to be used for both cellular and more-or-less traditional business radio. Once the frequency range was established, the market for portable telephone service was pursued vigorously by a few ambitious providers. As we now know, it took eight to ten years for the idea to be accepted on a large scale, taking a combination of consumer awareness and competitive pricing to reach the high level of usage we see today.

On a parallel course with cellular telephones was the portable computer. Jokingly called "luggable" instead of portable, the first units were definitely not laptop, except maybe for a sumo wrestler. But as the market gained momentum, computing power got smaller, cheaper, and less power-hungry. Again, the consumer had to become accustomed to the technology, learning how to use computers on a regular basis, and then see the need to have one that could go anywhere. Like the cellular phone, it took a while to take hold, but that hold is now firm, with portable equipment representing 15 percent to 20 percent of the personal computer market.

During the same time period, other important trends accelerated the growth of personal and business communications. Increased competition following the breakup of the Bell System lowered telephone prices and increased the number of available services. Cheaper phone service meant more phone lines for fax machines and computer communications. We got cheap voice mail, call waiting, custom ringing, and 800-number cooperatives. We became hooked on lots and lots of communications flexibility.

Today, these three courses have come together, and we can see why people are excited. Portable telephones and portable computing must be combined if we are to have all that wonderful communications capability wherever we go. The voice-based original cellular system isn't enough; we need digital cellular and new services that aren't at all like a telephone. We need high-speed, high-capacity data links. We need secure channels to avoid the loss of confidential information. We need to be able to do everything we're used to doing — anywhere we go!

Then, when we return home or to the office, we don't want to bother with a lot of plugs and cables. We need cheap, short-range wireless communications to replace those inconvenient wires that go everywhere. We want our friends and clients to reach us directly, not some immovable object (that dinosaur,



This is usual way of representing the radio spectrum, a logarithmic scale where each segment is ten times the frequency range of the previous one! The view makes microwaves look like they are just one more ordinary part of the available spectrum.

the telephone) that's stuck to a desk! We want our portable computer to hook into the company network without a messy bunch of cords. And we want that computer on the conference table in front of us instead of a yellow legal pad and a #2 Eberhard-Faber!

This is a tall order, requiring a lot of new ideas and engineering talent to make it happen. The biggest efforts have been mounted around the most familiar way of sending information by wireless means: radio frequency (RF) technology.

Where Do We Put All the Signals?

Radio is defined as the part of the electromagnetic spectrum between audio (up to 20 kilohertz, or kHz) and lightwaves (hundreds of terahertz, or THz). In between, we have many familiar and unseen services that use radio technology: Navigation, voice communications, broadcasting (AM, FM, TV and shortwave), control systems, research systems, radar, and lots more. Each service needs a place to operate.

Each of us is familiar with AM and FM radio. As we tune across the band, we hear one station, then another, and another. They all occupy specific channels, and stations on the same channel are spread a long distance apart so we don't hear two of them at once. Of course, sometimes when we are in just the right place, or if atmospheric conditions are unusual, we can hear more than one radio station on a single channel, a very irritating situation if we only want to hear the program on one of them!

Imagine if all the possible uses for radio-linked communications were to be implemented in a small segment of the spectrum! We would have too many stations and too few channels to put them on — unless we expanded our thinking to that part of the spectrum beyond the familiar radio communications channels — to microwaves, where there is a lot of unused or little-used spectrum space.

Microwave Solutions Cost More, Right?

Well, yes and no.

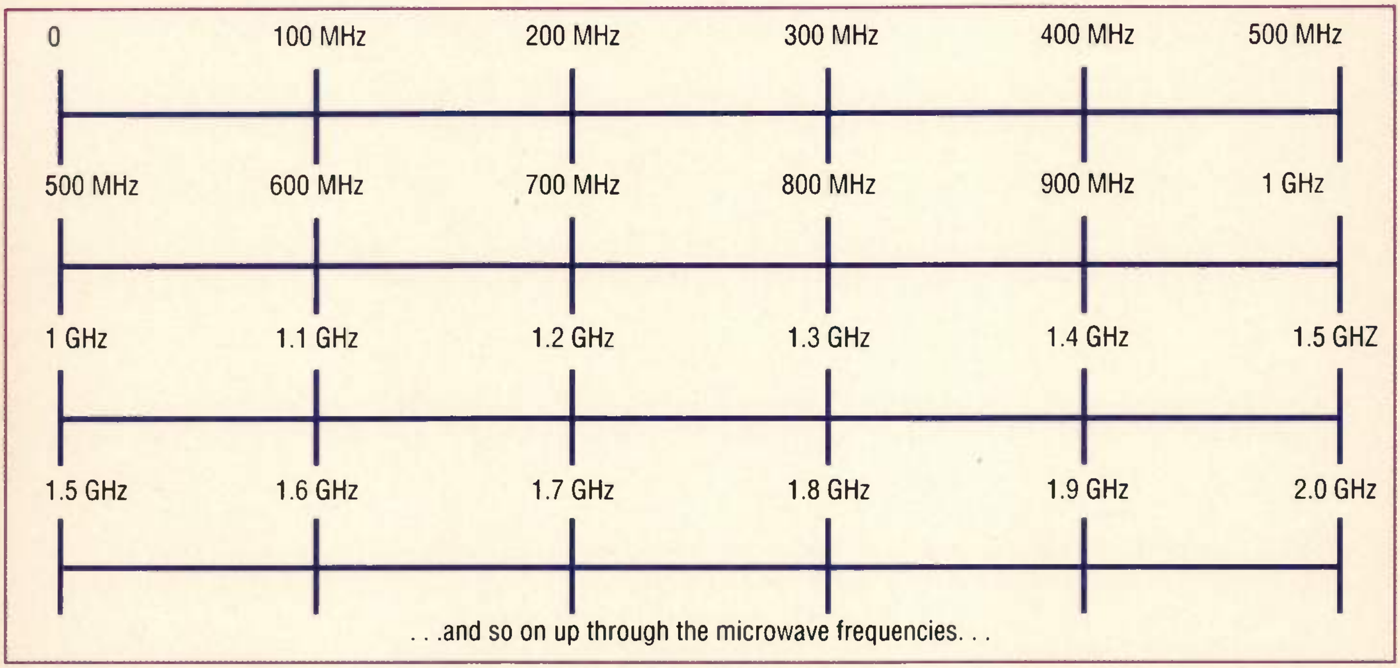
The cellular boom, and an established mobile radio market have created lots of low-cost components and the engineering expertise to use them. Of course, a wireless system that shares technology with an existing application will share in the economy of scale. However, this only applies to early developments. As wireless products reach the same kind of mass market status as cellular, the cost difference between unique and shared technologies will diminish.

Microwave components generally tend to cost more. And there have been some pretty sensible reasons: Either they are smaller, more critical in their construction, or they are more difficult to test. On top of that, they haven't been manufactured in the kind of quantities that have been seen at lower frequencies.

This last statement needs to be qualified, however: In the brief heyday of TVRO satellite dishes (before all the major programming was scrambled), the 4 GHz technology used in low noise amplifiers (LNAs) and downconverters dropped dramatically in price as quantities increased. Several component and system companies started to learn how to make cheap microwave devices and equipment. A new consumer market for microwave technology will allow that process to continue.

As noted before, there isn't room in the familiar mobile radio frequencies to accommodate all the new ideas for wireless communications. Many innovations will go undeveloped unless we use microwave frequencies. The cost issue must be addressed, but history tells us not to worry.

In the early days of radio (the original wireless), it was thought that wavelengths less than 200 meters were useless. Amateur radio operators were given free access to these frequencies, located above the AM broadcast band, and soon discovered that these "short waves" between 2 and 30 MHz were indeed valuable



If the radio spectrum is laid out in a linear manner, where each segment is an equal amount of spectrum space, we can easily see that microwaves represent a huge pool of available frequencies. 2 GHz to 40 GHz is the range of today's technology – that's 19 times the spectrum space represented above – and it may soon reach to 100 GHz. Although many microwave frequencies are already in use for radar, satellite and point-to-point communications, there remains a vast untapped resource of spectrum space for new uses.

for domestic and international communications. Once their value was established, the scientists and experimenters of the era quickly developed the necessary components and design methods to make equipment for these frequencies.

As might be expected, the same kind of technical barriers arose for the very high frequencies (VHF, 30-200 MHz), the ultra high frequencies (UHF, 200-500 MHz), and microwaves (once considered to be everything above a couple hundred MHz). As the value of each frequency range became apparent, engineering efforts were initiated and the technical problems were always solved. Sure, there were roadblocks and difficulties along the way, but they were always surmounted successfully.

There is no reason to think that microwave technology will remain too costly if we have incentive to develop new techniques, materials and components.

New Microwave Applications

Many personal and business communications applications are suitable for microwave implementation. In fact, the very short wavelengths at microwave frequencies can be an advantage where miniaturization is critical – filters, couplers, and other circuit elements can be much smaller than their lower-frequency counterparts with equivalent performance.

Where is this combination of performance and miniaturization needed? PCMCIA card accessories for notebook computers is one instance. Built-in communications for the new generation of Personal Digital Assistants (PDAs) is another.

Microwaves offer an additional advantage – the available bandwidth. There is room to spread out, and signals that must carry a lot of information can be easily accommodated. High-speed data links that rival wired systems are possible only at microwave frequencies, because there is no way to allow such broadband signals at 900, 1800 or other frequencies considered prime for new wireless applications. Satellite systems have been taking advantage of this electromagnetic "open range" for many years, transmitting many channels of wideband video, along with voice and data channels.

Finally, microwaves do not carry very far in the presence of obstructions, which is both a limitation and an advantage. Satellite systems have an unobstructed view of the earth, but it will be difficult to implement a mobile radio service with microwaves, because it won't work well among buildings or indoors. However, the self-limiting range under these conditions makes microwaves ideal for very short range communications – perhaps between your laptop computer and a modem, printer or network connection.

Established Uses are Growing, Too

Satellite communications, point-to-point terrestrial communications and radar are the three biggest uses of microwaves. All of these applications are growing.

We might think of radar as primarily a military business, but there is a huge commercial market as well. Those automatic doors that sense your presence and open as you approach use motion detectors that are simple radar systems. Small water craft owners are buying more radar systems as the prices drop and performance improves. Both the aviation and automotive industries are implementing collision warning and avoidance systems using short-range radar. Radar "speed guns" aren't just used by the police anymore. Every professional baseball scout uses one to evaluate pitching prospects, and they even show up at little league games from time to time!

Satellite communications is growing by leaps and bounds in some applications. VSAT technology can put an inexpensive receiving system on every building to obtain stock market data, real-time information from business analysts, or inventory and financial reports from the home office. At sea, all ships will soon replace their shortwave ship-to-shore radios with satellite communications gear (the large shipping lines already have). Not only do these links carry the usual messages concerning navigation, weather and seagoing traffic, but they provide telephone, data and fax capabilities, as well.

Terrestrial point-to-point services are changing, opening new markets, and scaling down existing ones. Some existing services, like television links between cities, are being replaced by satellite hookups. Telephone system microwave towers are coming down as telecommunications companies bury more fiber optic cables. Instead, the new microwave links tend to be short range, linking buildings in an industrial campus, for example, or connecting several offices located throughout a large city. Instead of relying on the local telephone company, or undertaking the construction of a wire or fiber network, a small microwave network can be inexpensive and flexible. Plus, it's all under the control of its owner.

In short, microwaves are an active part of the electronics business, and more uses are being developed. Cellular, PCS, and other applications in a lower frequency range may be getting most of the attention these days, but that will change as potential applications go to market. Microwaves will be part of many real-world wireless communications products. ■

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This unique partnership delivers high quality semiconductor products and comprehensive engineering support based in the United States.

California Eastern Laboratories (CEL) is NEC's Sales and Marketing arm for RF and Microwave semiconductors in North America. The partnership dates back to the late 1950s, when NEC was not as well-known in the domestic semiconductor market as it is today. To make it easier for engineers to put NEC's devices to work, CEL had to expand considerably the role of the traditional sales representative.

CEL built an extensive test and applications facility and also produced data sheets, catalogs and documentation in English. More recently, a joint NEC/CEL Design Center was established to develop ICs specifically for domestic markets.

Sales and Marketing Independence

CEL develops its own strategic marketing and sales policies and responds to all domestic RFPs and RFQs. The company provides engineering and design assistance, maintains an extensive onshore inventory, sets pricing and extends credit.

Engineering Support and Application-Specific ICs

CEL's engineering facility provides customers with product characterization: measurement of S-parameters, noise, gain and power characteristics, as well as circuit simulation, custom testing and product selection.

The NEC/CEL Design Center develops custom ICs to meet the needs of specific customer applications. Located at CEL headquarters in Santa Clara, the Design Center is staffed by engineers from both CEL and NEC. Fabrication is completed at NEC facilities in Japan, while performance evaluations and characterization are executed by CEL.

6.7 Sigma Quality

NEC product quality is undisputed. While the company ships more than 250 million RF semiconductors a month, the customer return rate is less than 0.04 parts per million — a quality figure exceeding 6.7 Sigma!

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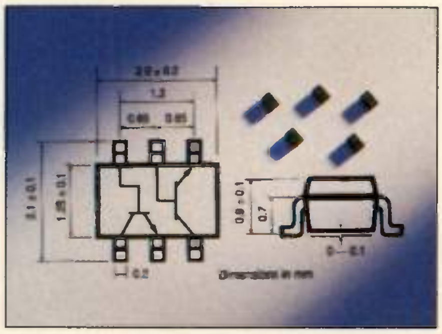

The new UPA800T Array is designed for applications that require two closely matched NPN transistors. The miniature package will reduce the parts count, simplify the assembly, and lower the cost of pager, bar code reader, and other handheld wireless designs.

For wireless applications, CEL offers a wide selection of 3 Volt NEC MMIC amplifiers, downconverters and prescalers in miniature packages.

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- AGC and Wideband Amplifiers
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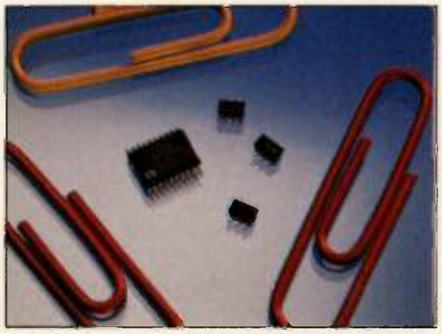

These two new 3 Volt MMICs provide a complete Silicon down conversion solution for GPS receivers. The miniature UPC2756T features an onboard oscillator and typical conversion gain of 14 dB at 5.9 mA Icc. The UPC2753GR combines an RF input amplifier, Gilbert cell mixer, LO input buffer, IF amplifier with AGC, external filter port and IF output limiting amplifier — all in a single package.

CEL has fourteen Field States Offices throughout North America. Product Selection Guides and Data Sheets are available from any one of them, or from Marketing Services at CEL Headquarters in Santa Clara, Calif.

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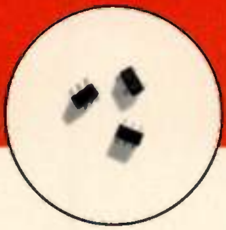
New 3 Volt Downconverters: From RF to IF for 99¢



NEC miniature downconverters are the latest addition to CEL's growing family of 3 Volt RF ICs.

Need low distortion? Our new *UPC2758T* delivers +10dBm output IP_3. Low current application? Choose the *UPC2757T*. It provides 13dB of conversion gain from only 5.6mA. Both feature a mixer, LO and IF buffer amplifier, and a *Power Down* function to prolong battery life.

Another low current device, the *UPC2756T*, helps simplify your designs by combining mixer, IF amplifier and oscillator — all on a single chip.

All three feature 3dB RF bandwidth to 2.0GHz, with 3dB IF bandwidth of 10 to 300 MHz.

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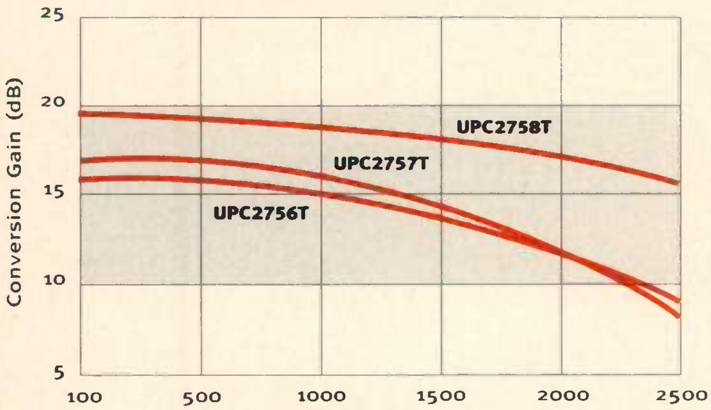
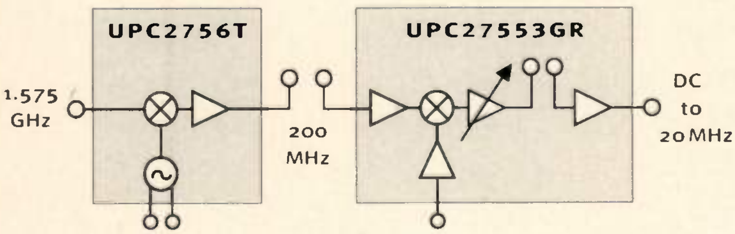
For data sheets and a Silicon MMIC Product Selection Guide, call your nearest CEL Sales Office, or circle the number below.

CONVERSION GAIN



Vcc = 3V   LO Power = -5dBm   IF = 200MHz

RECEIVER LINEUP



TYPICAL SPECIFICATIONS

PART	OPERATING VOLTAGE	Icc	CONVERSION GAIN	OUTPUT IP3
UPC2758T[1]	3V	11mA	17dB	+10dBm
UPC2757T[1]	3V	5.6mA	13dB	+5dBm
UPC2756T[2]	3V	5.9mA	14dB	+5dBm

1. Measured at 2.0GHz   2. Measured at 1.6GHz

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Murata's North American corporate headquarters are located in Atlanta, Georgia, providing one of the world's broadest ceramic components product lines to the United States, Canada and Mexico.

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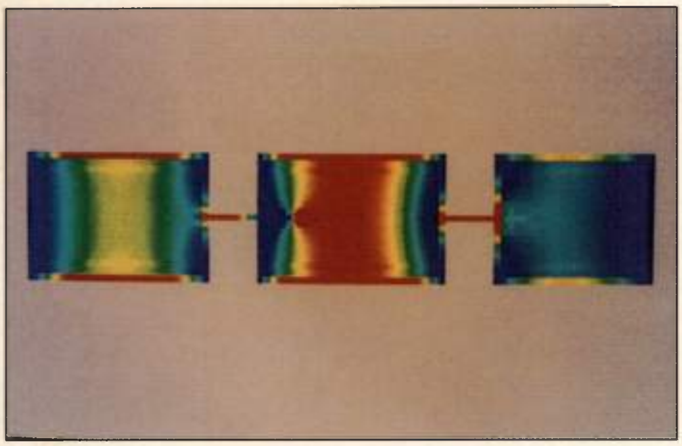
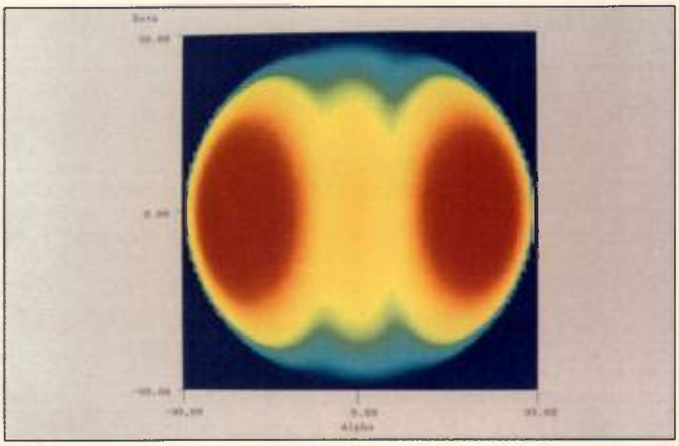
FOR EXAMPLE ...

Here's an example: In the left-hand photo below, the current distribution of a triple patch antenna (from Matra Defense, France) is shown. You can see the feed point (via a coaxial center conductor) near the edge of the center patch. The right photo shows the radiation intensity pattern, with the zenith in the center and the horizon on the edge. Red indicates strong intensity, while blue shows low intensity. Note the detail and the fine resolution of the plots. Current is very high near the edges of the metal and there is another discontinuity in current at the feed point. Notice how the current flows from patch to patch. Fine detail in the current distribution (i.e., small subsection size) means high accuracy. No one in the industry combines accuracy, resolution, speed, and ease of use like Sonnet.





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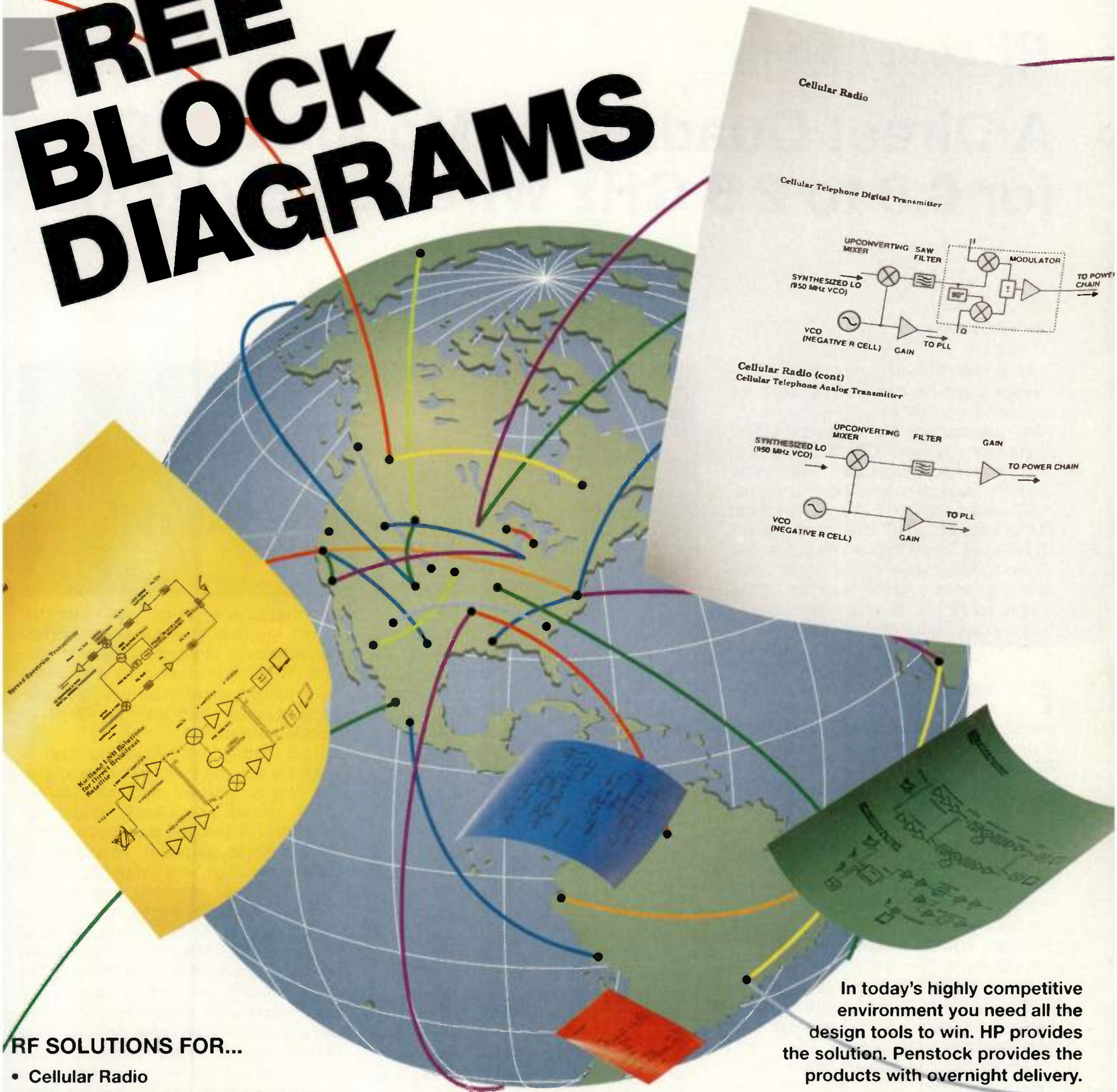

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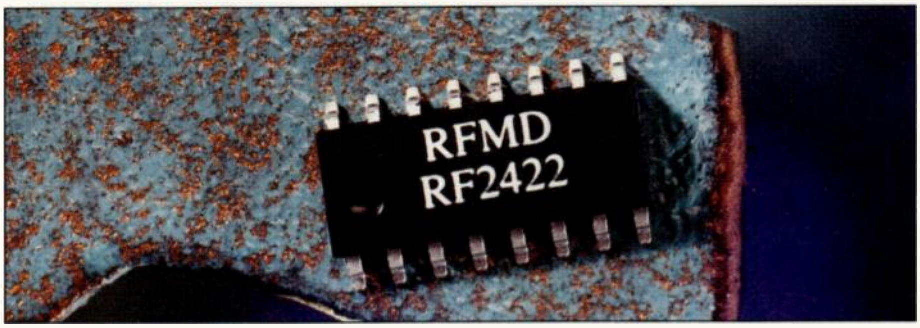
A Direct Quadrature Modulator IC for 0.9 to 2.5 GHz Wireless Systems

William H. Pratt
RF Micro Devices

As wireless system designs have moved from carrier frequencies at approximately 900 MHz to wider bandwidth applications like Personal Communication System (PCS) phones at 1.8 GHz and wireless local area networks at 2.4 GHz, designers have been forced to implement discrete RF designs because of the absence of RF integrated circuits (RFICs) at these higher frequencies. System designs at these higher frequencies have a great need for highly integrated RFICs for quadrature modulators, power amplifiers, and low noise amplifiers/mixers.



Foreseeing the wireless expansion to higher data rates and higher carrier frequencies, RF Micro Devices initiated a product development schedule for RFICs for use in these applications. The first of these high-frequency products is the RF2422 direct quadrature modulator. This low-cost, high performance quadrature modulator (see Figure 1) operates from carrier frequencies of 0.9 to 2.5 GHz and integrates a 90° carrier phase shift network, limiting amplifiers, two doubly-balanced mixers, a summing amplifier, and an output stage that drives 50 ohms. The unit features operation from a single 5 volt power supply, a built-in standby power supply switch, and is packaged in a 16-lead small outline integrated circuit (SOIC).

The RF2422 is implemented using TRW's advanced Gallium Arsenide Heterojunction Bipolar Transistor (GaAs HBT) process. There are many features of this high performance process that make it ideal for the RF2422. First, the process features transistors with f_T of approximately 25 GHz. This high f_T allows the IC designer to use fewer devices and less current to attain gain at high frequencies. The process also provides thin-film resistors and high-Q metal-insulator-metal (MIM) capacitors. Thin film resistors possess excellent matching which is important in a quadrature modulator design where the I and Q circuitry must be identical. MIM capacitors allow the IC designer to implement DC blocking and filtering on chip instead of requiring the system designer to provide these externally. Another extremely important aspect of GaAs HBT is the semi-insulating substrate. The semi-insulating substrate results in negligible metal-to-substrate parasitics which means less high-frequency crosstalk and leakage, and superior grounding.

Operation and Performance

The function of a quadrature modulator (also known as a vector or I/Q modulator) is to modulate a high-frequency carrier with lower frequency data. The beauty of a quadrature modulator is that it can be used to create all forms of analog and digital modulation. Amplitude, phase, and frequency modulation can all be implemented with a quadrature modulator. In order to evaluate the performance of a quadrature modulator, it is necessary to choose a specific modulation that is easy to generate and that allows the user to judge the important characteristics of the modulator. In general, RFIC manufacturers and users have settled on sinusoidal single sideband suppressed carrier (SSB or SSBSC) modulation.

SSB modulation allows the user to evaluate several important characteristics of a quadrature modulator: output power, carrier suppression, image suppression (phase and amplitude error), and harmonic distortion. To implement SSB modulation is a relatively simple task. The user connects a sinusoidal carrier to the local oscillator (LO) input of the modulator at the frequency of transmission. The I and Q ports are each driven with sinusoids of equal frequency and amplitude that are in phase quadrature with each other. The frequency used should reflect the data rate that will be used in the system. The output of the modulator is viewed with a spectrum analyzer centered at the carri-

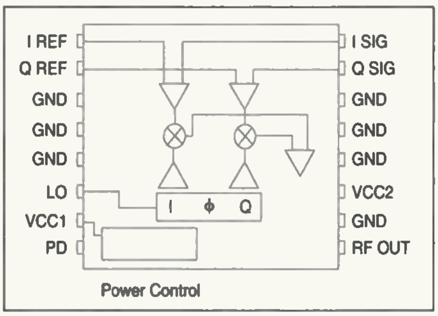


Figure 1. RF2422 functional block diagram.

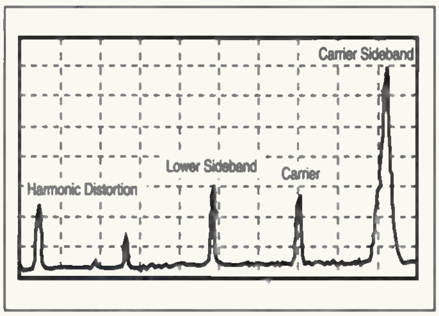


Figure 2. Typical SSB output spectrum.

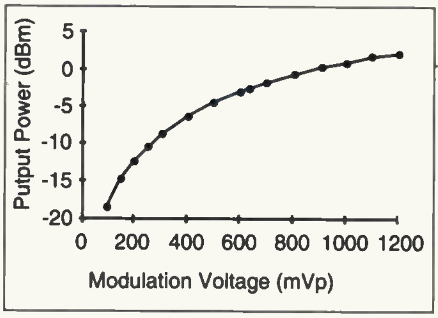


Figure 3. Modulation vs. output power (SSB); LO=2 GHz, –5 dBm.

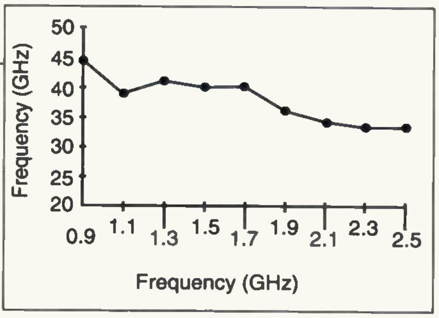


Figure 4. Carrier suppression vs. frequency.

er frequency. This method of evaluating modulator performance is inexpensive and fast for manufacturers and simple for end users to utilize.

A typical SSB output spectrum is shown in Figure 2. Proceeding from right to left, the frequency spikes represent the upper sideband, the carrier, the lower sideband, and harmonic distortion. The upper sideband is, of course, the desired output and the other responses are all unwanted. The power level of the upper sideband, measured using spectrum analyzer, is defined as the SSB output power. Raising and lowering the amplitudes of the I and Q signals will raise and lower the output power. The LO level should be kept constant and not used to change output power. Figure 3 shows a graph of I/Q amplitude versus output power with an LO level of –5 dBm at 2 GHz.

The frequency spike immediately left of the upper sideband is the carrier. The difference in power between the upper sideband and the carrier (in dB) is the carrier suppression. Carrier suppression is determined by the DC voltage matching between the ISIG, IREF, QSIG, and QREF pins, and by the amount of LO leakage to the output. The DC voltages at the I and Q input pins control the DC currents in the I and Q mixers. In order for the carrier to be suppressed, these currents must be identical. If the user provides DC voltages at the four I and Q input pins that are identical, then the RF2422 exhibits excellent carrier suppression. This is due to the superior matching of thin-film resistors in TRW's process. As mentioned before, suppression is also affected by LO leakage through the package and PC board. The higher the carrier frequency, the worse this problem becomes. Even with leakage, carrier suppression can be optimized by adjusting DC voltages at the I and Q inputs relative to each other. Generally, adjustments of just a few millivolts will allow the user to null the carrier. It is important to note that carrier suppression is a relative measurement in that it is dependent on SSB output power. As I and Q modulation levels are decreased, the SSB output power will decrease, but the carrier will not, thus yielding less carrier suppression. It follows that users must be sure of what modulation levels are being used whenever reading a manufacturer's carrier suppression data. Figure 4 illustrates that carrier suppression in the RF2422 is typically below –30 dBc across the operating frequency range, without any adjustment. Note: The I and Q ports were each driven with 500 mV_{pk}.

The next frequency spike is the lower sideband. The difference in power between the upper sideband and the lower sideband (in dB) is the image suppression. Image suppression is an indicator of phase and amplitude error. The more the phase and amplitude error, the worse the image suppression. These errors are caused by such things as package parasitics, nonlinear transistor operation, and layout asymmetry. Although these problems are addressed in design, they can never be completely eradicated. Amplitude and phase errors are largely frequency dependent, but they can also depend in a lesser extent on LO power level and power supply voltage. It is very important to evaluate the modulator under system operating conditions. Image suppression can be adjusted externally by changing the phases and amplitudes of I and Q relative to each other. Phase error in the RF2422 is very minimal. As shown in Figure 5a, phase error is typically within a few degrees at any given frequency. Amplitude error (Figure 5b) is only a few tenths of a dB at the frequency extremes. These small phase and amplitude errors combine to yield image suppression numbers that typically range in the mid 30s, as shown in Figure 5c.

The two frequency spikes furthest to the left are harmonic distortion. Although there are other spurious products that can be viewed if the spectrum is spanned at higher frequencies, these specific products are the closest to the carrier with the most power, and therefore the most difficult to filter. In addition,

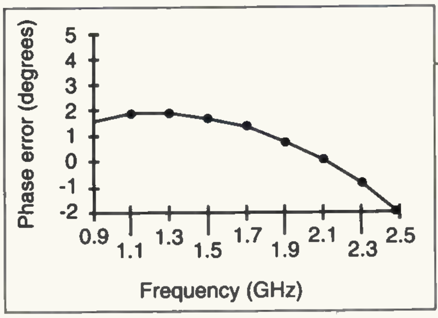


Figure 5a. Phase error vs. frequency.

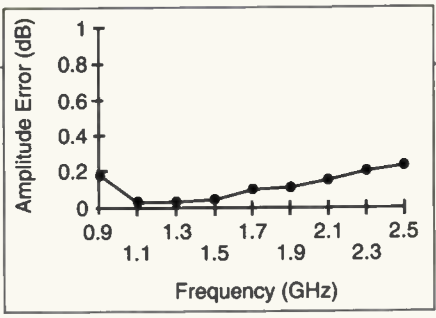


Figure 5b. Amplitude error vs. frequency.

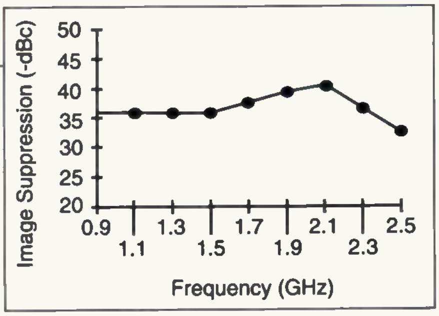


Figure 5c. Image suppression vs. frequency.

manufacturers usually only specify the suppression of the distortion spike furthest to the left since it is stronger than the one that is closer in. As the amplitudes of the I and Q signals are increased, the power of this harmonic will increase, much like an IM_3 product. Like the carrier and the lower sideband, system designers prefer harmonic distortion to be kept to a minimum to prevent saturation of the power amplifier or any components in the receiver.

Description of Design

The LO connection to the RF2422 is a single-ended, 50 ohm termination so that no transformer or balun is needed. The port is DC blocked internally so that no external blocking capacitor is needed. Having entered the part, the LO signal immediately travels through an R-C network that acts a phase splitter. The R-C network consists of a high-pass and a low-pass filter which each shift the LO signal 45 degrees, but in opposite directions. The result is that the LO signal is split into two signals of equal frequency but 90 degrees out of phase. The output of one filter will propagate to the I mixer while the output of the other filter will go to the Q mixer. The R-C network is designed around a 2 GHz center frequency so that when the LO signal is below 2 GHz, the high-pass filter attenuates the amplitude of its signal; likewise for the low-pass filter when the LO is above 2 GHz. In order to equalize the two filter outputs, limiters must be used after the R-C network.

Each of the two limiter stages consists of a high-gain differential amplifier. The limiters' function is to amplify the two quadrature signals to the point where the waveforms are clipping. The clipping effectively equalizes the two signals since both limiters are designed identically and will clip at the same time. Obviously, if the LO signal is low enough in power or far enough in frequency from 2 GHz, the limiters will not be able to equalize the two signals, causing a transmission amplitude error. The recommended LO power level for the RF2422 is –5 dBm.

The quadrature LO signals proceed to the I and Q mixers where they are each coupled to the top four transistors in a Gilbert cell. Because the signals are high amplitude square waves, the top transistors act like high speed switches. The bottom differential pair of each of the mixers (Gilbert cells) act as the inputs for the lower frequency modulating signals. In the I mixer, these input pins are referred to as ISIG and IREF; in the Q mixer as QSIG and QREF. There is no DC blocking on any of these inputs; each input effectively looks into the base of a transistor. This translates to a very high impedance looking into each input (approximately 30 kohms), and therefore these ports will draw very little DC current (40 μA) unless the part is operated in saturation mode. Saturation occurs when the voltage at these inputs approaches 4 V. When the voltages at these pins approach 1.5 V, the transistor current sources associated with the each of the Gilbert cells begin to saturate, causing nonlinear operation. From this information it is clear that for linear operation the I and Q pins should be driven with signal levels between 1.5 to 4 V. The recommended offset voltage is from 2.5 to 3 VDC. In order to boost the input compression point of the mixers, emitter degeneration is used in the bottom differential pair of each mixer.

The output currents of the two mixers are summed at the collectors across two load resistors. The summed outputs are then amplified by a differential amplifier which acts as a driver to the output stage. Emitter degeneration is once again used for maximum linearity.

The output stage is required to convert the differential output from the driver to a single-ended signal. In order to keep current consumption to a minimum, a push-pull configuration is used. The output impedance is designed to look like 50 ohms across the frequency operating range.

External Components

The RF2422 is extremely easy to insert into a wireless system. Only three external components are required to make the RF2422 fully operational. All three components are bypass capacitors. Two capacitors are needed to bypass the VCC1 and VCC2 pins and the third capacitor is used to bypass IREF and QREF if the baseband-to-I/Q connections are single-ended (IREF and QREF would be tied together in this case). If IREF and QREF are being used in a differential connection, then no bypass capacitor would be needed for those pins. As with all RF board designs, bypass capacitors should be placed as close as possible to the part.

The LO port has a 50 ohm input impedance and is generally coupled to a synthesizer with 50 ohm microstrip. Although an input level of –5 dBm is suggested for the LO input, this number is not critical for operation. In fact, the part will continue to operate at levels less than –10 dBm, but with less conversion gain and degraded amplitude accuracy. Therefore, the match between the LO port and the synthesizer may or may not be important, depending on system requirements. The output impedance of

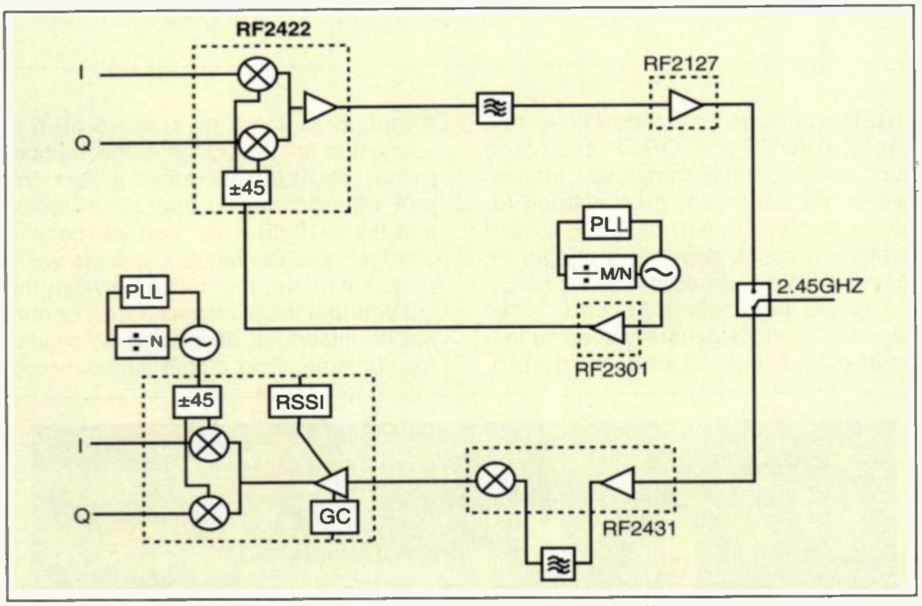


Figure 6. A simplified wireless LAN system block diagram.

the RF2422 is 50 ohms and is usually coupled to a power amplifier or driver with 50 ohm microstrip. There is internal DC blocking so that no external series capacitor is needed. Generally the match between the output and the following amplifier is quite important, so as to achieve maximum power transfer. If the input impedance of the following power amplifier is a 50 ohm termination, then no extra matching components are needed between the two unless DC blocking is required for the amplifier.

The PD pin is used to power down the part when operation is not needed. For example, in time division duplex (TDD) systems where the transmitter and receiver are operated in alternating time slots, the RF2422 could be powered down when the receiver is in use to minimize current consumption and thus extend battery life on handheld units. The PD pin can be directly driven with a CMOS driver where +5 VDC powers up the part and ground powers it down.

The modulation input pins of ISIG, IREF, QSIG, and QREF can be driven with any modulating waveforms. ISIG and IREF are differential inputs to the I mixer on the RF2422 as QSIG and QREF are differential inputs to the Q mixer. For carrier suppression, the DC voltages at all four pins must be equal.

Applications

Wireless local area networks using direct-sequence spread-spectrum modulation can successfully use the RF2422 as illustrated in the simplified system block diagram in Figure 6. In the transmitter, I and Q baseband data are first modulated by a pseudo-random bit code that is much higher in frequency than the I/Q data. Once this frequency spreading has taken place, the resulting signals are fed into the I and Q inputs of the RF2422. The RF2422 enables the spread signals to perform what is typically GMSK or QPSK modulation directly onto a 2.45 GHz carrier. This approach eliminates much of the filtering and LO requirements necessary for multiple upconversion schemes. Other applications include PCS and DCS1800 digital systems operating at 1.8 to 2 GHz, and satellite communications systems operating in L-band.

Conclusion

The RF2422 direct quadrature modulator fills an important gap in 2 GHz wireless systems. Direct modulation up to 2.5 GHz is now possible with a proven chip that can greatly simplify a wireless transmitter. The RF2422 packs numerous discrete functions into one small SOIC package so that system designers can reduce size, cost, and valuable engineering time.

For more information, readers may contact the author at the address below, or circle Info/Card #191 ***RF***

About the Author
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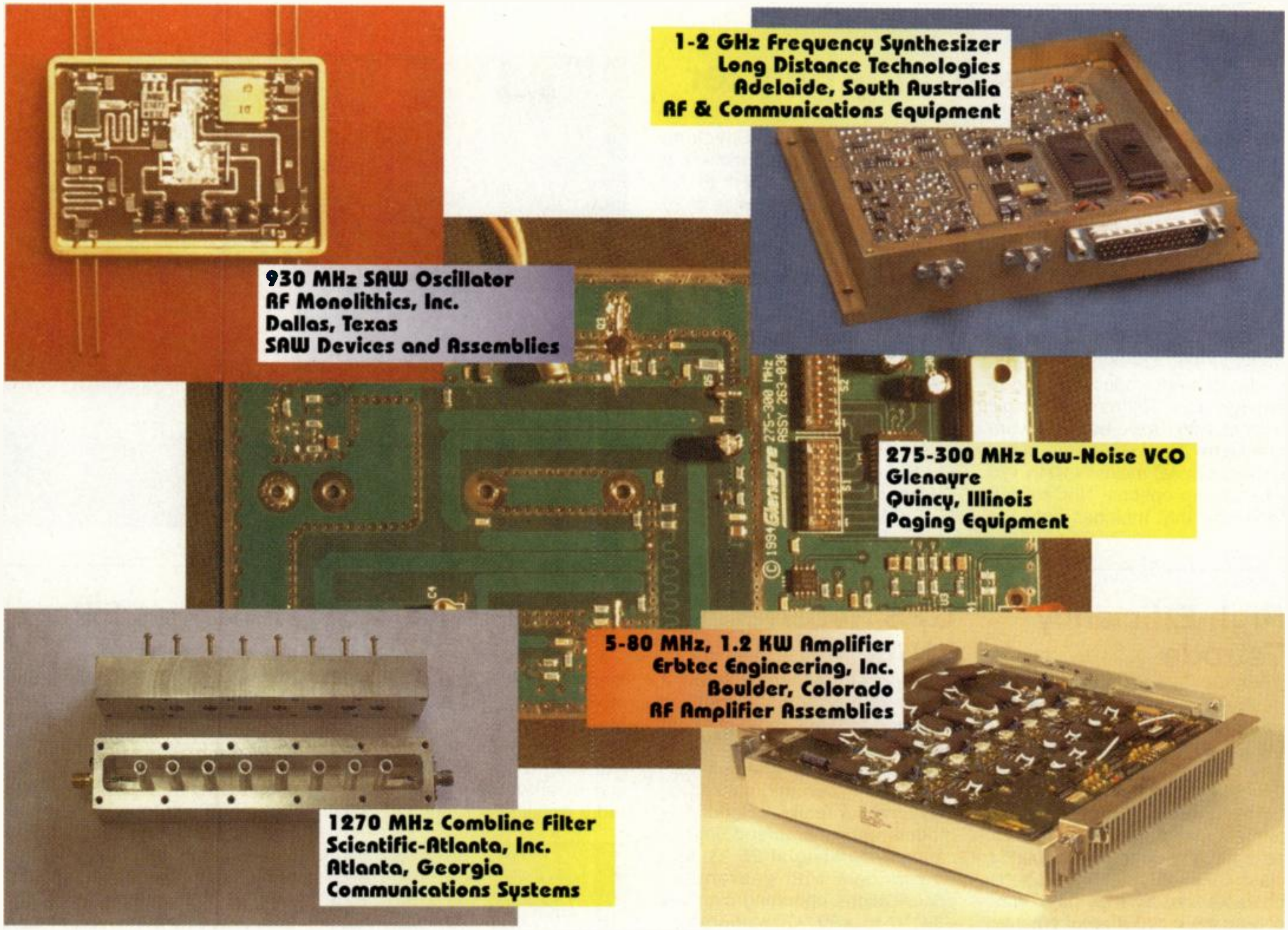
WHAT DO THESE PRODUCTS HAVE IN COMMON?



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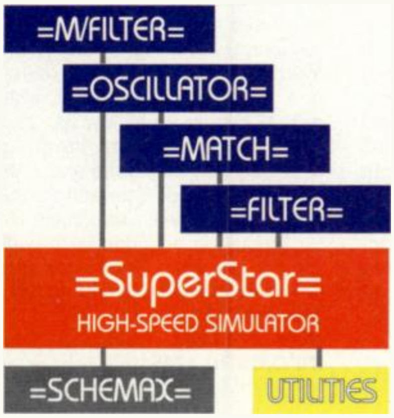

System 32 programs run under DOS, Microsoft Windows and Windows NT. Windows programs are 32-bit for fast and robust multi-program operation. User created files in all operating systems are exchangable for sharing with coworkers and painless future upgrading.

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INFO/CARD 43

Compact Spectrum Analyzer

Tektronix has unveiled what it claims to be the lightest and most compact RF spectrum analyzer on the market, the U4941. The model U4941 weighs only 14 pounds, packs a full 2.2 GHz spectrum analysis capability into just 5.75 x 11.375 x 13.25 inches, and is the only product in its class to feature a color liquid crystal display. The U4941 is the first jointly labeled product offering to emerge from Tektronix' strategic alliance with Tokyo-based Advantest Corp. The U4941 can utilize power from AC mains, +10 to +16 VDC, or an optional Ni-Cad battery pack that attaches onto the back of the analyzer. Spectrum analysis specifications include a frequency range of 9 kHz to 2.2 GHz; display dynamic range of 90 dB; and a frequency counting function with minimum resolution of 1 Hz, which can count the frequency of any displayed signal with SNR ≥ 25 dB. Two standard memory card slots conform to JEIDA Version 4.1 and PCMCIA Release 2.0. GPIB and RS232 interfaces are also included. U.S. pricing of the Tektronix/Advantest U4941 RF spectrum analyzer is $14,500.

Tektronix, Inc.
INFO/CARD #250

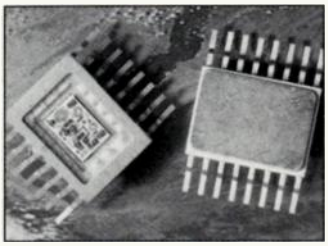
High-Efficiency Tetrode

Varian Associates has designed a cost-effective, multi-phase cooled, high-efficiency tetrode suitable for 100-kilowatt shortwave transmitters. The Eimac® 4CM100,000A is a ceramic/metal high power tetrode, and is well suited for use as a plate-and-screen modulated class C RF amplifier. The tube is characterized by high gain, simplifying drive circuit requirements. Its rugged dense mesh thoriated-tungsten filament provides ample emission for long operating life. The multi-phase water/vapor-cooled anode is capable of dissipation in excess of 100 kW. Direct interelectrode capacitances(with grounded cathode) are C_{in} = 400 pF, C_{out} = 65.6 pF, C_{gp} = 1.1 pF. Direct interelectrode capacitances (with grounded grid) are C_{in} = 200 pF, C_{out} = 66.2 pF, C_{pk} = 0.39 pF.

Varian Associates, Inc.
INFO/CARD #249

GPS Receiver LNAs

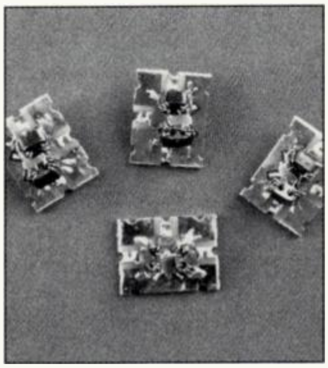
Celeritek has announced a family of low-noise amplifiers designed for GPS receiver applications. The devices are packaged in hermetically sealed, surface-mount, ceramic packages. The amplifier family includes five models with guaranteed specifications operating at 25 °C, and five models with guaranteed specifications operating over the –54 °C to +90 °C temperature range. Noise figures as low as 1.2 dB (model 395-1593), and DC current as low as 18 mA, at +5 VDC (model 395-1592) are available. Frequency ranges in which the amplifiers operate include the commercial and military GPS bands of 1210 to 1240 MHz, 1560 to 1590 MHz, and from 1200 to 1600 MHz. The Celeritek GPS amplifiers are packaged in low-profile, 16-lead ceramic packages (measuring 0.287 x 0.395 x 0.090 inches) which are hermetically sealed and designed for surface mounting. Pricing is approximately $125 in quantities of 1000.



Celeritek
INFO/CARD #248

High IP3 Mixers

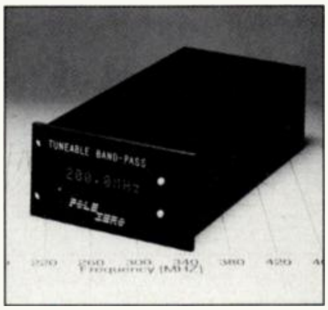
TRAK Microwave Corporation's family of high IP3 surface mount mixers provide an exceptionally high ratio of input third order intercept (IP3) to LO drive. For example, model MXR/2DF-02-T is competitively priced for cellular radio applications and provides an IP3 level of 17 dB above the LO drive level. A further advantage to the system designer is the passive design requires no bias supply, so system efficiency is enhanced. The mixers are designed for RF frequencies of 830 to 970 MHz and IF frequency of 131 MHz (fixed). Typical conversion loss is 6.4 dB, and input IP3 is +27 dBm at +10 dBm LO drive. LO to RF isolation is 33 dB. Temperature range is 0 to 70 °C. Price is less than $25 in 1000 piece lots. Other center frequencies and/or IF output frequencies are available, as are other package styles.



TRAK Microwave Corp.
INFO/CARD #247

Bandpass Filter w/ Readout

A tunable RF bandpass filter with digital readout has been released by Pole Zero. Each module provides the functional equivalence of having 251 filter units readily available for RF testing use. The range of 1.5 MHz to 1000 MHz is covered by eight filter units, each having 251 selectable center frequencies which provide continuous coverage over the entire band. The tunable filter bands are 1.5-4, 4-10, 10-30, 30-90, 90-200, 200-400, 400-700, and 700-1000 MHz. The filters have a two-pole Butterworth response with a slight skew yielding higher side frequency rejection. Selectivity is excellent, with a 3 dB bandwidth as low as 2%. The filter has power handling capability of 1 W inband and 5 W in the stopband. Operating voltage for the tunable bandpass filter module is provided by a wall plug-in source. Prices for the modules, including power supply, start at $840.



Pole Zero Corp.
INFO/CARD #246

Product Spotlight: Signal Generators and Synthesizers

Complex Signal Generator

A signal generator family launched by Marconi Instruments features digital and vector modulation capability. An IQ modulator on the 2050 series enables generation of a wide range of modulation formats. A variety of QAM (quaternary amplitude modulation), PSK (phase shift keying), broadband

AM and spread spectrum signals can be generated. Another capability is Rayleigh and Rician fading simulation. The frequency range for all members of the series begin at 10 kHz, with the 2050 extending to 1.35 GHz, the 2051 extending to 2.7 GHz, and the 2052 extending to 5.4 GHz. Prices for the series start at $19,200.
Marconi Instruments, Inc.
INFO/CARD #245

Direct Analog Synthesizers

Sciteq announces the immediate availability of the ND-1000 series of fast switching frequency synthesizers, built by Schomandl in Germany. The ND-1000 covers 100 kHz to 1000 MHz in 0.10 Hz steps. Switching speed is typically 10 µs (with 20 µs guaranteed), and speed is better that 1 µs when the start/stop frequencies are less than 1 MHz apart. Spurious signals are better than –65 dBc (guaranteed at any frequency), and phase noise is <–120 dBc at 10 kHz from the carrier. Spurs and phase noise improve by about 6 dB under 500 MHz. The ND-10000 is priced at about $9000 plus options.
Sciteq Electronics, Inc.
INFO/CARD #244

20 GHz Signal Generators

Tektronix has introduced the SMP 02 and SMP 22 microwave signal generators, manufactured by Rohde & Schwarz. Operating from 10 MHz to 20 GHz, both the 02 and 22 have harmonic suppression of –50 dBc, non-harmonic suppression of –60 dBc, and SSB phase noise at 10 GHz and 10 kHz offset of –92 dBc/Hz. Both instruments can perform automated test routines, and both can perform AM, FM, PM and pulse modulation in any combination. The SMP 02 has an output level of up to +10 dBm, while the SMP 22 has an output level of up to +20 dBm. U.S. pricing for the SMP 02 and SMP 22 are $26,500 and $34,150, respectively.
Tektronix, Inc.
INFO/CARD #243

TEST EQUIPMENT

Scalar Measurement System

Anritsu Wiltron introduces the 54100A scalar measurement system positioned for both manufacturing and field service applications. There are 11 different models, covering frequency ranges from 1 MHz to 26.5 GHz. The 54100A uses a 486 microprocessor and performs fast data storage in standard ASCII format to a 1.44 MB DOS disk. The series exhibits low source harmonics, with –60 dBc harmonics. Prices for the 54100A series range from $12,300 to $60,000.
Anritsu Wiltron Sales Co.
INFO/CARD #242

Switching Systems

Universal Switching has introduced the model S600A switching mainframe/controller. Switching array sizes ranging from 8 input by 2 output, through 32 input by 32 output are available utilizing individual plug-in modules. Standard control interfaces include RS-232C, RS-422A, IEEE-488, or fiber optic. The S600A can route such signals as RGB video, audio data and RF.
Universal Switching Corp.
INFO/CARD #241

SEMICONDUCTORS

900 MHz Mixer/Exciter

The MRFIC2101 is a transmit mixer and exciter operating with RF frequencies from 800 to 1000 MHz and IF frequencies from 0 to 250 MHz. The on-board LO buffer reduces LO power requirements (–15 dBm typical) and eliminates the need for an external LO balun. The mixer has output IP3 (–5 dBm out/tone) of 14 dBm. The exciter has typical small signal gain of 16 dB. Exciter bias current is externally adjustable. The device typically draws 2 µA when in its power-down mode. Pricing is $2.70 in high volumes.
Motorola Semiconductor
INFO/CARD #240

Semicustom Arrays

Walmsley Microsystems Ltd USA has announced the introduction of their HSB series of analog/digital semicustom arrays. These arrays utilize a 20 GHz Si bipolar

process to permit very high speed RF, analog and digital signal processing. The WMA100, WMA900 and WMA3000 have 100, 900 and 3000 transistors, respectively. Transistors with peak f_T at 1 and 5 mA are included in all arrays, with 0.25 mA transistors included on the WMA900 and 3000. Military screening through S-Level is available.
Walmsley Microsystems Ltd
INFO/CARD #239

2400 MHz GaAs VCO

The PM2501 from Pacific Monolithics is an ultra small, surface mountable, voltage controlled oscillator. The VCO contains a fundamental oscillator, integrated matching network,

buffer amplifier, and all bias networks. A varactor diode and spiral inductor approach provides a low cost oscillator which can be varied from 2100 to 2500 MHz. Power output is +14 dBm, and tuning voltage is between 0 and 10 V. Phase noise is -80 dBc at 2445 MHz and 50 kHz offset. The VCO operates from a +5V supply and typically draws 35 mA.
Pacific Monolithics
INFO/CARD #238

SIGNAL PROCESSING COMPONENTS

Band Reject Filter

Model F-10840 from RLC Electronics provides a minimum 30 dB rejection bandwidth of 10 MHz and maximum 3 dB bandwidth of 24 MHz. Insertion loss is less than 0.5 dB when more than 20 MHz from the notch center frequency of 885 MHz. Typical passband VSWR is 1.5:1. Prices start at $475 in small quantities.
RLC Electronics, Inc.
INFO/CARD #237

2-Way 90° Splitter

Housed in a low-cost plastic surface mount package, the SCPQ-150 2-way 90° splitter from Mini-Circuits has phase balance of 0.5° and amplitude balance of 0.7 dB. Frequency range is 95 to 150 MHz, with typical isolation of 22 dB and typical insertion loss of 0.3 dB. Typical applications include I&Q and QPSK modulators/demodulators, image rejection mixers and signal processing. The SCPQ-150 sells for $14.95 each.
Mini-Circuits
INFO/CARD #236

12-Channel Channelizer

K&L Microwave model 12DM11-700/CT1300-O/O is a 12-channel dielectric resonator channelizer covering the frequency range of 700 to 1300 MHz. The 3 dB bandwidth of each channel is 50 MHz, with selectivity of –45 dBc at f_0 ± 50 MHz. Insertion loss at each channel's center frequency is –16 dB (due to padding). VSWR is 1.8:1 at the input port. Insertion loss flatness is ±0.5 dB among channels.
K&L Microwave, Inc.
INFO/CARD #235

SPDT Switch

ISLT-51000 from ST Olektron is a wideband, phase-matched SPDT switch covering 5-1000 MHz. The device is guaranteed to consistently phase match within 1.5 degrees. Features include current consumption of just 10 mA from a single +5 VDC supply, insertion loss of 2 dB max, and switching rise time of 2 ns max. The ISLT-51000 comes with internal TTL driver in a flatpack package for $195 (qty 1-9).
ST Olektron Corp.
INFO/CARD #234

Double Balanced Mixer

M/A-COM has announced a passive, double balanced mixer in a low cost plastic surface mount package. The mixer has an exceptionally low conversion loss of 8.5 dB. The MD40-7100 has a frequency bandwidth of 1400-2000 MHz and has an LO drive range of +4 to +13 dBm. LO and RF ports are interchangable, with LO to RF isolation of 30 dB. LO to IF isolation is 20 dB.
M/A-COM, Inc.
INFO/CARD #233

High Power Coupler

TRM's 30 dB directional coupler, model DDS 3030, operates over the frequency range of 2.5 to 3.5 GHz. RF power handling is 400 W CW, VSWR is 1.2:1 max, insertion loss is 0.20 ±0.50 dB max, and directivity is 20 dB min. Connectors are SC female on input and output, and SMA female on coupled line. The coupler is designed for the standards of the airbourne environment. Other connectors, frequency bands and power handling capabilities are available.
Technical Research and Manufacturing, Inc.
INFO/CARD #232

Matching Pad

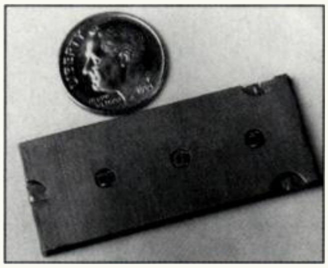
JFW Industries announces an addition to its impedance matching pad line. Models 57Z-3GN and 75Z-3GN offer a frequency range of DC to 3 GHz. Insertion loss accuracy is ±0.3 dB from DC to 1.5 GHz and ±0.5 dB from 1.5 to 3 GHz (above the nominal 5.7 dB insertion loss). Impedance matches are 50 to 75 ohms and 75 to 50 ohms. Maximum VSWR is 1.2:1 from DC to 1.5 GHz and 1.35:1 from 1.5 to 3 GHz.
JFW Industries, Inc.
INFO/CARD #231

Case-Free Hybrid

Merrimac Industries offers a quadrature hybrid in a 0.26 x 0.16 inch case-free package. The QHZ-23A series is available with center frequencies from 30 MHz to 160 MHz, with bandwidths up to one octave. It is designed to be less than 0.135 inches high, so it may be readily integrated into a low profile case along with MMIC components for applications where lumped element components are essential. These models are available for 90-day delivery.
Merrimac Industries, Inc.
INFO/CARD #230

Drop-In Power Dividers

Stripline design power dividers in flat, drop-in packages are available from Polyflon. Model PDI-2WL-1700-6000-SMA oper-



ates from 1700 to 6000 MHz with 0.1 dB amplitude balance and 2° phase balance. Both input and output VSWR are 1.2:1. Insertion loss is 0.3 dB. The divider package measures 1.75 x 0.75 x 0.075 inches. The dividers are priced at $19.95 each in quantities of 100.
Crane Polyflon Co.
INFO/CARD #229

SUBSYSTEMS

Fiberoptic Cellular Transmitters

Ortel has introduced the 3561A 1550 nm cellular radio fiberoptic transmitter. The 3561A transmitter uses a 1550 nm laser and is designed to allow uplink and downlink signals to pass on a single-fiber, bidirectional link by using waveguide division multiplexing. The transmitter is format independent, carrying any cellular format including TDMA, CDMA, analog and dual-mode formats.
Ortel Corp.
INFO/CARD #228

Optical Link

United Technologies Photonics has introduced a high performance externally modulated optical link for microwave and RF applications. The turnkey unit provides engineers with a well characterized RF solution at frequencies to 20 GHz. Spurious-free dynamic range in a 1 Hz bandwidth exceeds 110 dB. The link may incorporate a standard or 200 mW 1320 nm, low noise laser.
United Technologies Photonics, Inc.
INFO/CARD #227

Airborne Control Receiver

Aydin Vector's model RCC-200-SPM airborne command control receiver is a dual conversion superheterodyne UHF receiver capable of operating in L/S or TV-bands with a 100 MHz tuning range. Size is 6.0 x 3.25 x 2.065 inches, and weight is 42 oz. Operating voltage is 24-36 VDC.
Aydin Vector Div.
INFO/CARD #226

Fiberoptic X-mtr/Rcvr.

Two fiberoptic transmitters and a fiberoptic receiver for cellular

link applications have been released by Lasertron. The transmitters come in two wavelengths, 1300 nm (QLXS1300-200) and 1550 nm (QLXS1550-200). The receiver module (QRXS-200) is designed to work with either wavelength. Though designed for the 800-1000 MHz band, they provide excellent performance from 100-1000 MHz.
Lasertron
INFO/CARD #225

Telemetry Radio

E.F. Johnson has announced the DL-3472 synthesized UHF data telemetry radio and the development of an optional 9600 baud telemetry modem. The DL-3472 radio is available at 403-512 MHz, with standard frequency splits. The unit has been upgraded to operate at 12 VDC and can be ordered with or without a 9600 baud modem. Standard features of the DL3472 includes user programmable frequencies, selectable baud rates, and TTL or RS232 interfaces.
E.F. Johnson
INFO/CARD #224

AMPLIFIERS

2-18 GHz Amplifier

Amplica has introduced an ultra-broadband 2-18 GHz amplifier with 25 dB typical gain and ±1.5 dB gain flatness. Typical noise figure is 5.5 dB over a temperature range of +10 to +85 °C. The amplifier has +18 dBm minimum output power at 1 dB gain compression and VSWR of 2.0:1. Current consumption is 450 mA, and size is 1.49 x 0.7 x 0.22 inches.

Amplica, Inc.
INFO/CARD #223

Low Noise, High Gain

Model VMA 052A-342 from Veritech Microwave covers 0.5 to 2.0 GHz with an ultra low noise figure of 0.75 dB (typ.), coupled with gain of 42 dB. Output power is +20 dBm and VSWR is less than 1.5:1. Housed in a 1.5 x 0.99 x 0.22 inch package, this unit operates from +15 VDC at 320 mA. An alternative version measures 1.5 x 0.66 x 0.22 inches. Other amplifier in the series offer noise figures as low as 0.65 dB.
Veritech Microwave, Inc.
INFO/CARD #222

AMPS/GSM, 200W

Chesapeake Microwave Technologies has fielded its model APG 960-200, a 200 W silicon class AB amplifier configured for CW service. CW output power is available in excess of 200 W min., 275 W typ. The gain of the amplifier is in excess of 40 dB. An integral output isolator is included, as is reverse polarity protection to 35 V and an over-temperature interlock. Available options include forced air or liquid cooling, and rack chassis configurations with integral AC power supplies.
Chesapeake Microwave Technologies, Inc.
INFO/CARD #221

SIGNAL SOURCES

High Performance OCXO

A series of high performance oven controlled crystal oscillators (OCXOs) from MTI rival the performance of atomic clocks. The 260 series oscillator offers a thermal stability of $\pm1\times10^{-10}$ over a temperature range of –30 to +65 °C. The aging per day is better than 1×10^{-10} and the annual rate is 1×10^{-8}. This OCXO also achieves supply voltage and load sensitivity performance of $\pm1\times10^{-10}$.
MTI-Milliren Technologies, Inc.
INFO/CARD #220

Dual Polarity VCXOs

Champion Technologies introduces the K1527 series of voltage controlled crystal oscillators. The K1527 series is suitable for applications where the control voltage is bipolar, with the nominal voltage centered at 0.0 V. The output of the K1527 series is both TTL and CMOS compatible. Phase noise for the series is –70 dBc/Hz at 10 Hz offset from the carrier. Members of the series measure 0.82 x 0.52 x 0.245 inches in a DIP metal package and are priced under $15.00 in the hundreds.
Champion Technologies, Inc.
INFO/CARD #219

g-Insensitive Oscillators

Sawtek has introduced a line of ultra-low g-sensitivity fixed frequency oscillators (FFOs). The performance of the FFOs is highlighted by 3×10^{-10}/g average sensitivity, as demonstrated by a 1 GHz FFO vibrated normal to its worst-case axis (i.e., normal to the substrate plane) using a peak acceleration level of 3g. The FFOs are available from 500 to 1000 GHz, with typical noise floor of –170 dBc/Hz. Output power is as much as 14 dBm. Members of the line measure 0.87 x 0.5 x 0.24 inches.
Sawtek Inc.
INFO/CARD #218

DISCRETE COMPONENTS

Sealed Trim Caps

The water-tight MAV SR series sealed air dielectric trimmer capacitor from Microelectronics Ltd. is designed to withstand organic solvents and aqueous solutions used in the cleaning of circuit boards. The capacitor is available in a capacitance range from 1 to 30 pF and 10 mechanical mounting configurations. The series meets or exceeds all requirements of MIL-C-14409.
Microelectronics Ltd.
INFO/CARD #217

Quartz Crystal Resonator

Micro Crystal has introduced an AT strip quartz crystal thickness shear resonator in a 2 mm diameter, 6 mm long, metal can. The MXAT is available in frequencies between 14-25 MHz. The MXAT features high stability (±50 ppm typical) and low aging (±3 ppm the first year). The series is available in through-hole and surface mount versions. Pricing for the 16.00312 MHz, ±20 ppm, extended range tape and reel version is $1.77 in quantities of 100k.
Micro Crystal, a Div of SMH
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Trimmer Capacitors

CERA-TRIM II™ is a high performance ceramic trimmer capacitor from Johanson Manufacturing. The series features a high Q over a broad frequency range, a high operating voltage (400 VDC) and excellent temperature stability. The single-turn, surface mount capacitors are available in capacitance ranges from 0.5 - 2.0 pF to 5.0 - 15.0 pF. Price is $0.85 each in quantities of 1000.
Johanson Manufacturing Corp.
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Shielded SMT Inductor

Dale Electronics has introduced a shielded surface mount inductor, model ISC-1210. The inductor is designed to minimize magnetic coupling to other components in RF circuitry. Model ISC-1210's dimensions are 0.098 x 0.126 x 0.087 inches, and it is available in inductances from 0.01 uH to 100 uH. Standards tolerances are ±20 and ±10 %, with other tolerances available on request. A typical member of the series, with an inductance of 1 uH and a ±10% tolerance is priced at $0.214 each in quantities of 4000.
Dale Electronics, Inc.
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CABLES & CONNECTORS

Coax Coupling Closure

The AMP® CERTI-SEAL™ coax coupling closure is a one piece plastic closure for buried or aerial CATV service drop repair. The gel-filled closure, which meets Bellcore TR-NWT-000975 immersion specifications snaps together to provide a seal and protect the cable splice from harsh elements. Pricing for the closure is approximately $6.00 each in quantities of 500.
AMP Inc.
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Composite Cables

Custom composite cables and assemblies for fiber optic, RF/microwave and twisted pair transmission lines are available from Storm Products. Capabilities include designs with standard inner cables to reduce cost, manufacturing short-run prototypes, terminating channels with a variety of connector options, and providing testing and data for any or all channels.
Storm Products Co.
INFO/CARD #212

Broadband Impedance Matching Methods

By Thomas R. Cuthbert, Jr., Ph.D.
Consultant

Matching complex load impedances to a resistance or to complex source impedances over wide frequency bands is often an essential part in the design of amplifiers, antennas, and many other applications. Given tables of impedances versus frequency, it is a common but flawed practice to guess a matching network topology and values for its components, and then use an optimizer program to see if the power transfer from source to load can be improved over the band. The current, more sophisticated, approach to this problem requires a complete knowledge of complex polynomial and network synthesis theory while still using optimization programs at various design stages.

Figure 1 shows a lossless network inserted between a source and load to improve or control the power transfer over a frequency band. When both Z_S and Z_L are resistances, the network in Figure 1 usually is called a filter or an impedance transformer. Complex impedance terminations require the more difficult broadband matching network. Amplifier input and output networks are often designed to match active device impedances to 50 Ohms over a frequency band (single matching). For amplifier interstage networks, the desired insertion loss between complex source and load impedances (double matching) can be specified versus frequency and may be sloped to offset gain slope. For example, radian frequency samples between 0.3 and 1.0 and corresponding goals of S_{21}=0 dB are contained in the computer file shown in Table 1. The $Z_L=R_L+jX_L$ and $Z_S=R_S+jX_S$ impedances are the complex number sets shown in Tables 2 and 3, respectively, and correspond to the radian frequencies in Table 1.

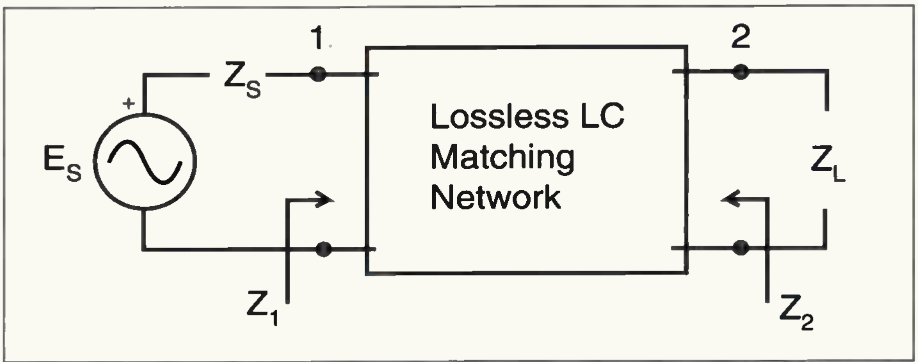

Figure 1. Representation of a network for broadband matching sets of terminating impedances.

Impedance matching data is usually normalized to 1 radian/second and one ohm as in Tables 1-3. Normalization is also convenient, since at 1 radian/second, henrys are equal to ohms and farads are equal to mhos. When unnormalizing, actual L's and C's are *inversely* proportional to radian frequency. Actual L's are *directly* proportional to terminal impedance level, while actual C's are *inversely* proportional to terminal impedance level [1].

Insertion loss S_{21} is the ratio of power delivered to Z_L and the maximum power available from the source:

$$S_{21} = -10\log\left(\frac{P_L}{P_{aS}}\right)\text{dB} \qquad (1)$$

The maximum power available from the source is delivered when $Z_L=Z_S^*$ (Z_S conjugate) in Figure 1:

$$P_{aS} = \frac{|E_S|^2}{4R_S} \qquad (2)$$

"CAS 2/90 EX#3. RAD/SEC & GOAL SET"	
8	
.3	0
.4	0
.5	0
.6	0
.7	0
.8	0
.9	0
1.	0

Table 1. Radians/second and S_{21} dB goals.

"CAS 2/90 EX#3. .3-1., 8 PNTS LINEAR ZL"	
8	
0.59016	0.71680
0.71910	0.74944
0.80000	0.77500
0.85207	0.80503
0.88688	0.84174
0.91103	0.88470
0.92837	0.93288
.94118	0.98529

Table 2. R_L and X_L load impedance data.

"CAS 2/90 EX#3. .3-1., 8 PNTS LINEAR ZL"	
8	
0.71313	−0.45230
0.56081	−0.49629
0.41945	−0.49347
0.29915	−0.45789
0.20274	−0.40204
0.12909	−0.33530
0.07539	−0.26403
0.03846	−0.19231

Table 3. R_S and X_S load impedance data.

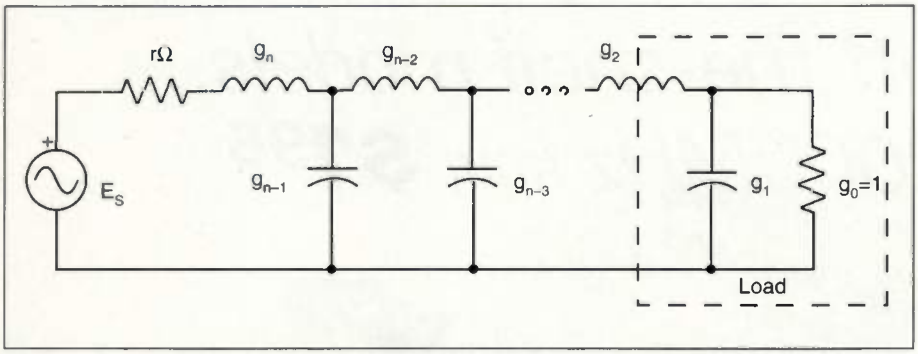

Figure 2. A lowpass matching network with an L-RC load and dependent source resistance r [1].

Any power that enters port 1 in Figure 1 must be delivered to load impedance Z_L, since the network is lossless. Therefore, the matching problem is often expressed in terms of generalized reflection coefficients [1]:

$$\frac{P_L}{P_{aS}} = 1 - |\rho_1|^2 = 1 - |\rho_2|^2 \qquad (3)$$

where

$$\rho_1 \equiv \frac{Z_1 - Z_S^*}{Z_1 + Z_S} \qquad (3a)$$

and

$$\rho_2 \equiv \frac{Z_2 - Z_L}{Z_2 + Z_L} \qquad (3b)$$

Clearly, broadband matching networks must be designed to make $|\rho_1|$ (or $|\rho_2|$) as small as possible over the frequency band.

Current Broadband Matching Methods

There are some very old and very new broadband matching methods available to the designer other than guessing and then using an optimizer. It is helpful to review the essentials of the major methods in order to appreciate the difficulties and rewards that await the designer. References are provided for those interested in more details.

Analytic Gain-Bandwidth Theory

Originally developed by Fano [2] and later extended by Youla [3], this classical approach assumes a resistive source (X_S=0) and a complex load impedance, Z_L, that must be the input impedance of a lossless two-port reactance network terminated in a resistance (i.e., the model). Figure 2 shows a lowpass matching network and a load impedance consisting of the unit resis-

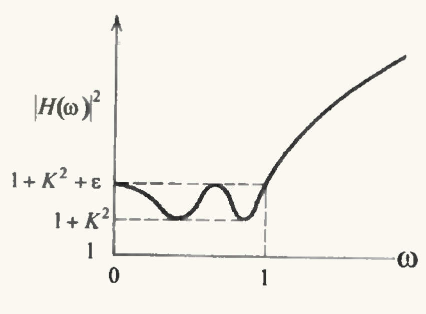

Figure 3. A Chebyshev lowpass response with flat loss for broadband matching [1].

tance, capacitance g_1 and part of inductance g_2. The classical transducer gain function such a system can provide is:

$$H(\omega) \equiv \frac{P_{aS}}{P_L} = 1 + K^2 + \varepsilon^2 (T_n(\omega))^2 \qquad (4)$$

here T_n is the Chebyshev equal ripple function of degree n. The resulting response shape is shown in Figure 3 for a lowpass matching network. For example, consider Figure 2 with n=4, corresponding to four reactive elements g_1, g_2, g_3, and g_4, *which always include the load.* It is common practice to number the elements from load to source.

Broadband matching for only a single reactive element in the load, g_1 in Figure 2, allows minimization of the maximum loss over the entire 0-1 radian/second frequency band in Figure 3. The price of this optimal result is the $1+K^2$ "flat loss" shown in Figure 3. Matching network elements values for this important case have been graphed [4] and can be calculated by simple formulas [5]. When the load consists of an L in series with a parallel CR as in Figure 2, then the one degree of freedom to minimize the maximum passband loss is no longer available. Thus, the flat-loss parameter K then depends on a chosen ripple factor ε and degree n as described by Chen [6]. For practical purposes, this LCR load (and its dual) is the most complicated case treated by analytic theory with any generality, and even this is not simple. To apply analytic theory, your load, perhaps augmented, must be identified as one of the tractable ideal load models.

The single-reactive load case is very important for understanding the fundamental limitations to broadband impedance matching. First, note that the lowpass prototype network in Figure 2 could equally well have had a series LR load. Also, in every lowpass broadband matching case, the source resistance r (often labeled g_{n+1}) cannot be equal to 1 ohm due to the flat loss at DC. Furthermore, a bandpass network with 1 radian/second center frequency may be created from a lowpass prototype network: first, replace all series L's by series LC branches with $L_k = g_k Q_{BW}$ and then replace parallel C's by parallel LC branches with $C_j = g_j Q_{BW}$, and finally, resonate all branches at band center $\omega_0 = 1$ radian/second. The inverse of fractional passband width is:

$$Q_{BW} \equiv \frac{\omega_0}{\omega_2 - \omega_1} \qquad (5)$$

where ω_1 and ω_2 are the lower and upper passband edges corresponding to the loss level at 1 radian/second in Figure 3. $Q_{BW} \equiv 1$ for lowpass networks.

The single-reactive load has a "loaded Q" parameter which is defined at ω=1 as:

$$Q_L \equiv \frac{R_p}{X_p} \equiv \frac{X_s}{R_s} \qquad (6)$$

where "p" denotes a parallel connection, "s" denotes a series connection, and X is the load reactance at ω=1, L or 1/C (minus signs ignored). For example, the loaded Q of g_1 on Figure 2 is $Q_L = g_1$. The definition in equation 6 also applies to bandpass networks with resonant loads, where reactance X is that of either the inductance or capacitance, since they are equal at $\omega_0 = 1$. Now the most important result of analytic gain-bandwidth theory can be illustrated using *the* main parameter in broadband matching – the decrement:

$$\delta \equiv \frac{Q_{BW}}{Q_L} \qquad (7)$$

Figure 4 shows the best broadband match available when the load is a single lowpass reactance or its corresponding resonant LC bandpass branch. The load is the N=1 line shown in Figure 4, i.e., the load is connected to the resistive source with no matching network in between. Looking from the source, the SWR and equivalent reflection coefficient, ρ_1 in equation 3, are seen to decrease with increasing decrement, δ.

Figure 4 shows that very substantial improvement in impedance match across the frequency band is obtained by using just one matching network branch (N=2). There are two clear messages in Figure 4: first, Q_{BW}/Q_L and N are the main parameters, and second, there is very little reason to use more

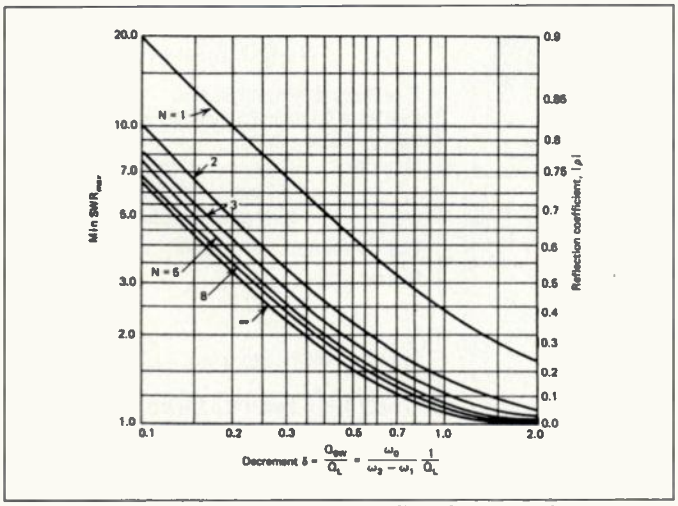

Figure 4. Maximum possible reflection vs. decrement for broadband matching (N=1 is load) [1].

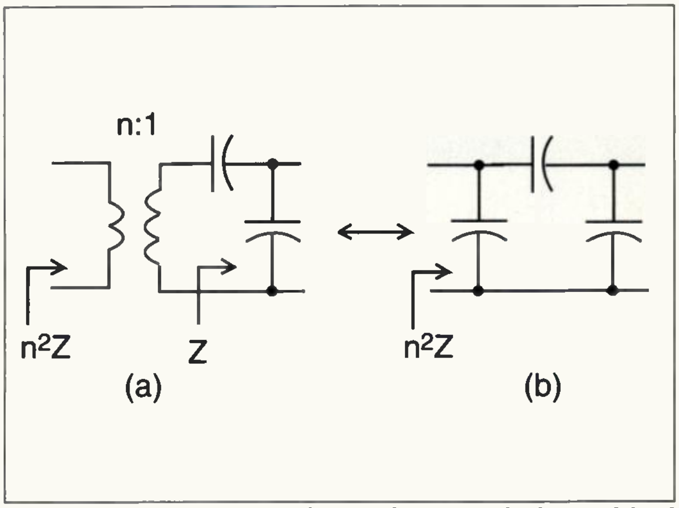

Figure 5. Norton transformation to eliminate ideal transformers.

than about four branches in matching networks (N≤5). This means that there is little reason for more than four L's and C's in lowpass networks and eight in bandpass networks.

Real Frequency Broadband Matching

A big change in broadband matching design was introduced in 1977 by Carlin [7] to deal with the fact that most terminating impedances are encountered in tabular form versus frequency as in Tables 1-3. The single match problem (Z_S real) will be described briefly; the double match problem (both Z_S and Z_L

are complex) also can be solved by this method with some additional complications [8]. The key to the real-frequency method is to note that the Thevenin impedance $Z_2=R_2+jX_2$ in Figure 1 controls the transfer function $H(\omega)=P_{aS}/P_L$ according to equation 3. Furthermore, the Hilbert transformation theorem relates R_2 and X_2, namely, if the R_2 function of ω is known for $0\leq\omega\leq\infty$, then $X(\omega)$ is determined and easily calculated. A brief description of the four design steps follow. The details may be daunting unless you are well acquainted with complex variable theory.

Step 1 is to represent the real part of Z_2 in Figure 1, namely R_2, by a simple function such as a piecewise linear function [7] or a cosine series [9]. A guess at the coefficients of this representation of $R_2(\omega)$ is made, then X_2 at any ω can be obtained by a Hilbert transform calculation, and the resulting Z_2 is substituted into equation 3 to find $H(\omega)=P_{aS}/P_L$ over a set of frequency samples. That result is compared to the desired values of H at those frequencies, and the errors are reduced by an optimization procedure that adjusts the coefficients in the simple $R_2(\omega)$ function. The initial guess of coefficients in the piecewise linear function is usually made by assuming a conjugate match at port 2 in Figure 1.

Step 2 is to create a *rational* function approximating $R_2(\omega)$, since a rational function is required for network synthesis. This requires a second optimization procedure to fit the simple function from step 1 to a rational one of degree n by automatically varying the coefficients of the rational function.

Step 3 is to convert $R_2(\omega)$ to $Z_2(s)$ where $s=\sigma+j\omega$, the Laplace frequency variable. This requires root finders, polynomial operations, and one matrix operation (in the Gewertz procedure) to obtain the rational $Z_2(s)$ impedance function (Figure 1). A reoptimization is usually performed at this point to readjust $Z_2(s)$ to the desired transducer gain function while maintaining a *positive-real function*, a $Z_2(s)$ that represents a passive, physical network.

Step 4 is to convert $Z_2(s)$, an RLC function (the R is R_S), to an LC reactance function (just the LC network) and then realize $Z_2(s)$ in the form of a ladder network by network synthesis. Synthesis will be discussed later, but the software tools and examples of their use in the real-frequency method are available [1].

Parametric Broadband Matching

The optimization operations in steps 1-3 above are complex, and often the polynomials and matrix are numerically ill-conditioned. These difficulties can be avoided by using a parametric polynomial method [10]. One simply starts at step 4 above by representing $Z_2(s)$ in a special form, one similar to a partial fraction expansion, but restricted to represent only *positive-real functions*. Thus, it can be assured that the $Z_2(s)$ represented by these *Brune functions* will definitely be a physical network, but the problem remains of how to initially select the n poles ($s_k=\sigma_k+j\omega_k$) to be adjusted to obtain the desired transducer gain function. The initial choice of the n pairs of σ_k, ω_k is found by performing real-frequency steps 1-3 one time. Then these optimization variables are adjusted from that point to obtain the desired match over the frequency band. Conversion of the RLC impedance function to an LC function and network synthesis are still required.

The claimed advantage of parametric representation by Brune (positive-definite) functions is that broadband matching is thus reduced to a classical problem in numerical optimization. That is also true if some matching network topology is chosen and its LC values are adjusted by an optimizer. But the Brune function method only requires a choice of the number of network elements, n, and the number of zeros of transmission at DC, without any other prior knowledge of the ladder network topology.

Network Synthesis

Most practical matching networks have a simple ladder topology with zeros of transmission only at DC and infinity, produced by parallel L's and series C's, and by series L's and parallel C's, respectively. (Bandpass networks are those having at least one zero of transmission at both DC and infinity). There are 24 classes of lowpass, highpass, and bandpass ladder networks classified according to their port impedance behavior at DC and infinity [11], and each class represents literally dozens of permutations of L's and C's in networks that each realize a particular $Z_2(s)$ function [12]. There are excellent network synthesis computer programs to generate all possible topologies for your inspection [13], but it will be necessary to examine many candidate solutions.

Each of the 24 classes of lowpass and bandpass networks ends in an ideal transformer with a dependent turns ratio. Since there is no such physical transformer, it is important to know that the *Norton transformation* may eliminate an ideal transformer at the price of one additional L or C. Figure 5 shows two subnetworks that are exactly equivalent at *all* frequencies, and a similar equivalent pair exists using all L's instead of all C's. There is no possibility of finding two adjacent C's or two adjacent L's in a lowpass network, so the source r in Figure 2 cannot be modified. Some permutations of L's and C's in synthesized *bandpass* networks may allow an independent source resistance by adding one more like element to eliminate the ideal transformer.

Graphical Methods

The Smith chart was introduced in 1939 and has served ever since as a manual design aid for matching networks composed of lumped and/or distributed elements. Techniques for using the Smith chart for matching have been described in numerous sources, e.g. [14]. Lately, an excellent computer program that displays the impedance transformations versus frequency in color has been made available at no cost [15]. A degree of skill is required to produce efficient matching networks using graphical aids, especially for the double match case.

Intelligent Systematic Search Methods

Abrie [16] has described and programmed a broadband impedance matching method based on the so-called "$1+Q^2$" method for impedance matching at a single frequency. The Q employed at each element's interface in the network is that defined by equation 6. Abrie observed that the value of the Q factor seldom exceeds four, and that the frequency selectivity of the matching circuit can be approximately related to Q (as in Figure 4). Each trial is a set of Q values which are used to design a matching network. His program *MultiMatch* exhaustively searches over a grid in N dimensions (N≤6) for $-4 \le Q \le 4$ in steps of 0.5. Thus there can be 17^N trials, e.g., N=4 results in 83,521 trials. His program avoids some trials of values for input elements by enforcing a $1+Q^2$ impedance match to within a $|\rho_1|$ circle. Also, finer search grids may be applied about solution points. Average run times on 25 MHz PC's with a numeric coprocessor are between 2.5 and 5.5 minutes.

The labor of manual matching design, the complexity of the real-frequency methods, and the skill level required for both methods demand a way to design matching networks that is fast and simple, especially for the double match case. A future article will describe a computer program called *GRABIM* which quickly and simply finds optimal network topologies and element values for matching networks. ***RF***

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About the Author

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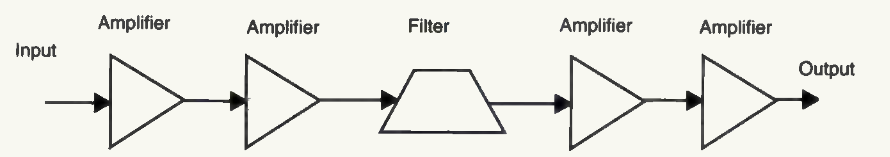
Program Calculates Cascaded System Parameters

by Raymond P. Meixner

An algorithm is presented which analyzes a chain of RF components similar to those in receivers and exciters of radar systems. It uses the component's four major parameters: noise figure, gain or loss, noise bandwidth, and 1 dB compression point to calculate the dynamic range, noise figure, noise output, and system gain of the chain. An example of the power of the algorithm is given by analyzing a simple five element chain. A print out of the results and a listing of the code is given in the appendix.

With the advent 20 years ago of the modular broad band microwave integrated circuit (MIC) amplifier, the ground rules for designing microwave subsystems have changed. System design became one of ganging a chain of components in a line with the appropriate placement of filters to satisfy the system requirements. What this did was to increase the number of building blocks in the system from a few to many. During system tradeoff studies it is difficult and a little complicated to move or change these blocks, compute the new results, and analyze and compare these designs. The algorithm CHAIN GANG, see Appendix A, eases some of this frustration and work load, since it is a simple routine that uses the four major components parameters; noise figure, gain or loss, noise frequency bandwidth, and the one dB compression point. The concept of "noise figure" (NF) in this paper will follow the defined figure of merit for an RF system as Friis did in his classic paper [4], but will not refer to noise factor. When "NF" or "noise figure" is used it will be so stated as to what is used, i.e whether a numerical ratio or a log in dB of that ratio. After initial designs using CHAIN GANG more sophisticated and powerful CAD routines are commercially available that can analyze these designs in greater detail [1].

CHAIN GANG is especially helpful in verifying the design of low power RF receiver and exciter chains for radar systems. These chains usually involve a string of cascaded custom components, such as filters, amplifiers, mixers, switches, attenuators, etc., many of them digitally controlled. This last requirement for digital control is what makes this program highly useful. The system design, which is usually laid out by hand, can quickly be analyzed through most of the digital modes with this algorithm. Reconfigured designs can quickly be analyzed as well.



Parameter	Units					
Element Number		1	2	3	4	5
Gain	Ratio/dB	4/6	5/7	0.5/–3	5/7	6/7.78
Noise Figure	Ratio/dB	2/3	3/4.77	2/3	3/4.77	3/4.77
Noise Bandwidth	Ghz	0.5	2.0	1.0	2.0	3.0
1 dB Compression Point	dBm	+10	+20	+5	+20	+20

Figure 1. Five element cascaded chain with system noise bandwidth of 10 MHz

The author is indebted to two published articles by Bertsche [2] and Sorger [3] that helped improve the crude routines the author had been using for years. Bertsche picks up the effects of the various noise bandwidths in the system and their impact on the output signal to noise ratio (SNR). Sorger does a similar analysis by finalizing the system 1 dB compression level after summing up the contribution of each element in the chain. Reference [S] gives a more detailed analysis of the compression distortion using the third order data for each component.

Significant features of this program are that it can pinpoint in the component chain where the excessive noise figure loading occurs and where the input level for 1 dB compression dramatically changes. It lists the SNRs and determines dynamic range using the criteria of the noise floor and gain compression.

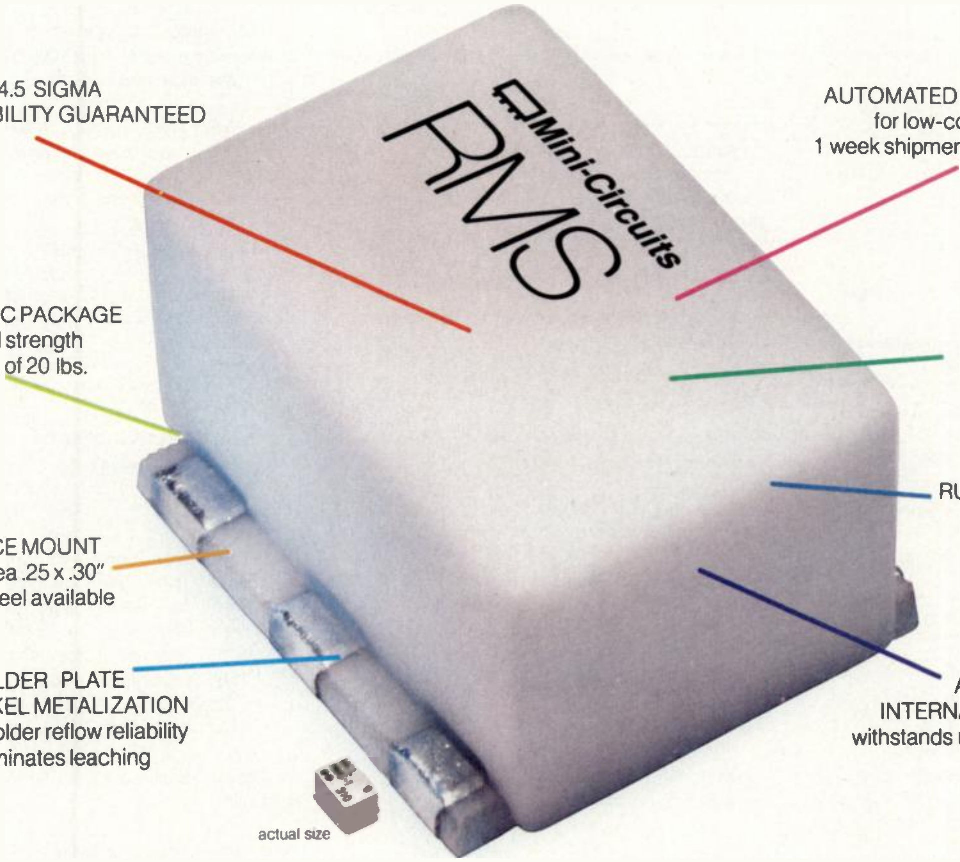
To simplify matters the five element chain of Bertsche [2], as shown in figure one, is used as a demonstration circuit along with some typical values of for 1 dB compression points.

A print out of the calculated data, shown in Figure 2, includes system noise figure, system gain, output signal to noise ratio after each chain element, input signal level for 1 dB compression gain, and dynamic range.

Figure one shows a typical RF chain containing five elements. Once system and component parameters are entered, several DO LOOPs sift this data and calculate all you would want to know about this chain. What follows in an explanation of the printed data for each LOOP as shown in Appendix B which contains the print out for a run of CHAIN GANG.

A note is in order here about how CHAIN GANG works with up and down converters. The algorithm handles them in the same way as any component by using a slightly higher value of

MIXERS UNPRECEDENTED IN VALUE.



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RMS-11F	+7	350-2000	DC-400	5.5	31	30	4.95
RMS-30	+7	200-3000	DC-1000	6.5	26	22	6.95
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Type in one line of less than 80 characters
a descriptionof the system being designed

The number of components in the chain is 5

Individual component parametrs starting from the front

Noise figure in dB

3.000 4.770 3.000 4.770 4.770
.100

Gain {Loss is negative gain} in dB

6.000 7.000 −3.000 7.000 7.780
.100

Bandwidth in Hz

5.000E+082.000E+09 1.000E+09 2.000E+093.000E+09
1.000E−01

−1dB output compression point in dBm

10.000 20.000 5.000 20.000 20.000
.100

....

The required system noise bandwidth is 1.000000E+07

Input dynamic range in dB or input signal level in dBm are
95.500000 or 0.000000E+00

***** The input data printout is done *****

....

***** DATA from DO 40 ****
*****Finding the narrowest system noise bandwidth*****

The system element number that has the smallest noise BW is # 0
at a "BW" of 1.000E+07 Hz

....

****DATA FROM DO LOOP 10****
*BACKWARD LOOP*****

NF in front of each element starting with the last
& adding elements as you progress toward the front.

....

Noise figure in dB
of the system by the {F12=F1+(F2-1)/G} Friis formula
4.452 6.183 8.312 5.312 4.770

....

Apparent noise figure calculation from the output
toward the input using the following equation;
Fa = F1 + {F2(B2/MIN(B1,B2) − 1.0}/G1

Noise figure in dB
6.655 7.592 11.689 5.679 4.770

....

The over all system gain in ratio In front of each components as elements are added in the front:

300.608 75.509 15.066 30.061 5.998

The minimum bandwidth, Bmin, is; 5.00000E+08

The apparent bandwidth, Ba, is; 8.305091E+08

....

The output noise power in dBm due to apparent bandwidth is:
−55.55
The output noise power in dBm due to apparent noise figure is:
−55.55

....

****Data from DO LOOP 15****
*********FORWARD LOOP*******
Front end Friis noise figure in ratio as elements are added in the rear

1.995 2.497 2.547 2.747 2.787

Front end apparent noise figure in ratio as elements are added in the rear

1.995 3.251 3.351 4.350 4.629

System gain in ratio is printed from front to reaer
as elements are added in the rear

3.981 19.953 10.000 50.1119 300.608

....

*****Data from DO LOOP 5****
******Total Noise power after each element******

Input Friis noise figure in ratio as each element
is added in the rear of the cahin

1.995 2.497 2.547 2.747 2.787

Input apparent noise figure in ratio as each element
is added in the rear of the chain

1.995 4.757 3.351 4.350 4.629

Noise output power in dBm as each component is added
in the rear of the chain

−77.988 −67.214 −71.736 −63.602 −55.552

Total gain is: 300.607600: Apparent bandwidth(Ba) is:
8.305089E+08

....

***** DATA FROM DO LOOP 25******
****Total noise power using the Narrowest Bandwidth ****

The thermal noise at input is: −103.977200dBm, using the narrowest system noise bandwidth of 1.000000E+07

Noise power(dBm) after each element using the narrowest system noise BW and the forward noise figure calculations.

−94.977 −87.002 −89.916 −82.588 −74.746

....

*****DATA FROM DO LOOP 95*****
****Summation of system signal to noise ratios*****
*******After each component******

Elmnt. #	System Gain	From 1dBpt	Signal Level	Noise power Actual	Noise power BW	S/N Ratio Actual	S/N Ratio BW
	dB	dB	dBm	dBm	dBm	dB	dB
0	.0	.0	−8.5	−104.0	−104.0	95.5	95.5
1	6.0	12.5	−2.5	−78.0	−95.0	75.5	92.5
2	13.0	15.5	4.5	−67.2	−87.0	71.7	91.5
3	10.0	3.5	1.5	−71.7	−89.9	73.3	91.4
4	17.0	11.5	8.5	−63.6	−82.6	72.1	91.1
5	24.8	3.7	16.3	−55.6	−74.7	71.9	91.0

....

*****DATA FROM DO LOOP 90****
1dB system compression levels after each component

Elmnt. #	System Gain	From 1dBpt	Signal Level	Front Level Input 1dB	Output 1dB Level After Element	Component 1dB Point
	dB	dB	dBm	dBm	dBm	dB
1	6.0	12.5	−2.5	5.0	10.0	10.0
2	13.0	15.5	4.5	3.2	15.2	20.0
3	10.0	3.5	1.5	−4.8	4.2	5.0
4	17.0	11.5	8.5	−5.3	10.7	20.0
5	24.8	3.7	16.3	−7.6	16.2	20.0

Final chain dynamic range for narrowest BW in dB is:
90.912030

Actual dynamic range at the output in dB is: 71.718580

THE PRINT OUT IS OVER YOGI BERRA

Figure 2. Printout of a typical run of Chain Gang with a string of five components.

mixer conversion loss as the parameter for calculating noise figure. The author uses a separate algorithm for analyzing the spurious responses, called MEIXER [6], for each separate frequency conversion when designing cascaded two port components.

DO LOOP 40 searches for the component with smallest RF bandwidth and uses this value in the SNR calculations.

DO LOOPs 10, 15, and 5 correspond to Bertche's subroutines NFACT1, NFACT2, NFACT3 respectively.

DO LOOP 10 determines the system NFs. Calculations start with the last two coupled elements at the end of the chain and continues back on down to the first input component. The loop monitors the NF at each component interface and thus allows you to spot when the NF has a dramatic change in its value. Two NFs are computed; one uses the "apparent" NF and the other the apparent noise bandwidth (Ba). Both give the same results for the actual output noise power. For two stages the Friis NF equation is

$$F = F_1 + \frac{(F_2 - 1.0)}{G_1} \quad (1)$$

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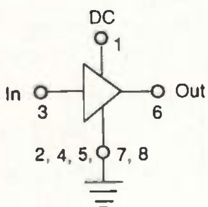

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I P 3rd Order (dBm) typ.	+27	+27	+27	+27
VSWR Output typ.	1.5:1	1.7:1	1.7:1	1.5:1
VSWR Input typ.	6.4:1	2.8:1	2.0:1	1.4:1

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and the "apparent" NF equation [2] is

$$F_a = F_1 + \frac{\left(F_2 \frac{B_2}{MIN(B_1,B_2)} - 1.0\right)}{G_1} \qquad (2)$$

where the minimum between B1 and B2 is B~, and the "apparent" bandwidth B, is defined as

$$B_a = B_{min} \frac{F_a}{F} \qquad (3)$$

The final loop values for the circuit in figure one are used to calculate the final noise power output as follows

$$P = FGK_BTB_a = 55.55 \text{ dBm} \qquad (4)$$

and

$$P = F_aGK_BTB_{min} = 55.55 \text{ dBm} \qquad (5)$$

Do LOOP 15 determines the contribution of ea "apparent" NF and is referenced at the input of the first component as others are added in the rear. Again large NF loading can be spotted with this routine.

Do LOOP 5 computes, using the Friis and "apparent" NF methods, the total noise power after each element. Calculations start at the front end and proceed as one component at a time is added at the rear for each run through loop.

DO LOOP 25 defines each internal interface, the system signal gain and noise power using the narrowest system noise bandwidth obtain from LOOP 40 and the Friis NF from LOOP 5. This is helpful in system design if the determining noise bandwidth lies outside the chain for it allows you to monitor the final SNR as the calculations progress through the chain.

After entering the required dynamic range or the input signal level DO LOOP 95 tabulates all the system signal levels. It lists at each component interface the system gain, signal level, and how far it is from the 1 dB compression level. It goes on to list the actual noise power and noise power referenced to the narrowest system bandwidth (BW) and further list two SNRs using these last two noise power levels. Note by properly picking the correct value for the dynamic range or input signal level an approximate value of the dynamic range from noise power to −1 dB compression point can be evaluated. DO LOOP 90 calculates a more precise value of the system dynamic range.

The final DO LOOP 90 sums up in tabular form the input signal level that drives the chain output signal level to the 1 dB compression point as shown in column six of the print out. Sorger[3] lists several equations for determining the total 1 dB gain compression and this LOOP chooses the input signal level at the front of the chain as the reference point and not the output. The equation, used for k elements in the chain, is

$$\frac{1}{P_{1dB}} = \sum_{N=1}^{k} \frac{1}{P_{1dB,N}} \qquad (6)$$

where P1dB is the input signal level that drives the final output to its compression level, and PldB, N is the input level that drives the Nth intermediate element to its 1 dB compression level. One point needs to be clarified about the phase relationships of the generated 1 dB distortion and how it vectorial adds from two port component to two port component. A worse case analysis is assumed barring a more detailed description of the nonlinearities [5]. Usually this is sufficient since it builds in a safety margin for this requirement.

The last two lines of the printed data define the classic system dynamic range between the noise floor and the one dB compression point. The final dynamic range calculated at the output of the cascaded chain is, for the narrowest system BW, 90.9 dB, and for the actual noise output power, 71.7

The author wishes to acknowledge the following organizations who gave me the time and encouragement to write this program over the last twenty years: the search radar branch of the radar division of the Naval Research Laboratory, in Washington, DC where I started writing these Fortran routines; Norden System at Gaithersburg, MD where I converted the code to Fortran 77; while a Vitronics contract employee at the Harry Diamond Labs in Adelphi, MD where I converted the code to a Microsoft Fortran; and finally at Horizons Technology where this final draft of this paper was written.

CHAIN GANG is available on disk from the Argus Direct Marketing Department. For ordering information please see page 84. **RF**

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About the Author

Raymond P. Meixner holds a BEE and a MEE from the Polytechnic University in Brooklyn, NY. For the past 25 years he has plied his RF and microwave engineering knowledge on receivers and transmitters for use in Navy and FAA surveillance radars. He can be reached at 16524 Redland Road, Rockville, MD 20855, or by telephone at (301) 869-6854.

Spectrum Analyzers Gain Flexibility

IFR's Observations

The spectrum analyzer market is growing, although not as rapidly as several years ago. The slower growth is primarily the result of reductions in spending on military and aerospace programs. As military programs and facilities have been cut back, surplus test equipment has come onto the market, reducing the demand for new equipment.

The emerging wireless and PCS markets have helped to create new opportunities for spectrum analyzers that have, to some extent, offset the decline in the military market. New requirements placed on commercial communications by government regulatory agencies have also helped to boost demand for spectrum analyzers in the past year.

There is a clear trend towards more applications-specific test functions, like those required by the CDMA or GSM cellular phone systems. There is a certain amount of downside risk in pursuing these emerging technologies, however, as not all systems under development today will be implemented.

IFR manufactures RF and microwave spectrum analyzers that cover testing requirements up to 26.5 GHz. They are very optimistic about business for the next two years. Although the growth rate of the market is not expected to change significantly, the company has a new product line that is enjoying good customer response in both U.S. and international markets.

The View from Hewlett-Packard

Hewlett-Packard continues to see worldwide growth in spectrum analyzer products. Key markets are wireless communications test and cable TV test. Industry standards and regulations continue to influence both markets. Manufacturers must stay current on these standards and regulations to fully understand their impact on customers, and to quickly incorporate them into test solutions.

The digital revolution continues to impact the communications industry, especially as the lines between wireless and cable blend. This technology trend will drive a greater investment in the development of digital test equipment for cable as well wireless communications.

HP believes key factors for success in these markets are anticipating customer needs and technology trends. Companies that invest in understanding customers needs will be more successful at developing flexible products that provide accurate, economical and upgradeable test solutions. *RF*

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Novel Design for RF Power Meter

by Larry Candell and Jeff Shultz
MIT Lincoln Laboratory

This RF power meter represents a simple circuit that one can dedicate to systems that must measure peak power levels for both CW and pulsed signals of more than 3 µs duration. Our design goals were low cost, high speed, wide dynamic range, and a logarithmic output.

One possible approach uses a detector diode and corrects for diode non-linearities with complex circuitry to achieve a logarithmic output. The circuit must compensate for both the square law and linear operating regions of the diode. Our solution, by contrast, matches the diode with a voltage variable attenuator that has a logarithmic response. By varying the attenuation until the diode output is zero, the resulting attenuation value then corresponds to the input power level. Because the voltage variable attenuator's output is logarithmic, diode non-linearities become negligible.

This process can be automated with closed loop feedback as shown in Figure 1. For instance, when a power level of -10 dBm is fed to the attenuator's input, the op-amp responds by applying a positive voltage to the to the attenuator's control pin until the detector diode is zeroed. This control voltage is then offset and inverted, thus yielding a value which is proportional to the logarithm of the input power.

Component Specifications

Parts were selected for the meter based on an operating range of 2-4 GHz and a dynamic range of 40 dB (from –30 to 10 dBm). The ARRA 4572-60D voltage variable attenuator, which has a 10 dB/volt output response, 60 dB dynamic range, and a 2-4 GHz frequency range was chosen. The detector is an ACTP1514N tunnel diode, with 2-6 GHz frequency range. As shown in Figure 1, these components comprise the feedback network for an AD811 high speed (2000 V/µs) current feedback op-amp. The current feedback op-amp has an advantage over conventional op-amps in that its low inverting input impedance is better matched to the tunnel diode's video impedance. Therefore, no impedance matching circuitry is required.

A TL082 dual op-amp follows the feedback stage and constitutes offset and inversion stages. The gain adjustment potentiometer R2 calibrates for a 100 mV/dB display output. Potentiometer R4 offsets the sensed control voltage to yield a voltage proportional to the actual input power level (1 V/10 dBm), rather than the nominal control voltage.

A simple volt meter will display the output voltage when operating in CW mode. For pulsed mode operation, an oscilloscope can be used for monitoring the response. An example oscilloscope output, Figure 2, shows the time response of a signal stepping between a level of –10 to –20 dBm. Note that the circuit responds in less than 3 µs and the voltage swings from –1 to –2 volts.

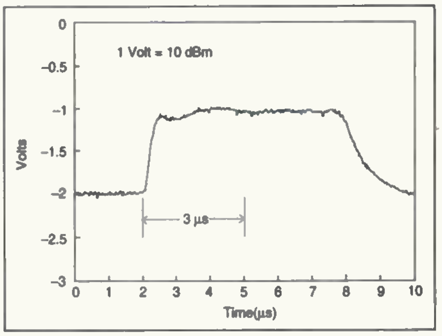

Figure 2. Meter response to a signal stepping from –10 to –20 dBm.

An improved display for the output voltage might consist of an A/D converter that operates in both CW and pulsed mode. In pulsed mode the A/D could sample 3 µs after the initial transition to insure a stabilized output. Further improvements could result from using a 10-bit A/D followed by a PROM. The PROM would store additional calibration information to remove any system non-linearities, while the 10-bit A/D could increase resolution from 0.5 dB to 0.25 dB.

This work was funded by the Air Force. *RF*

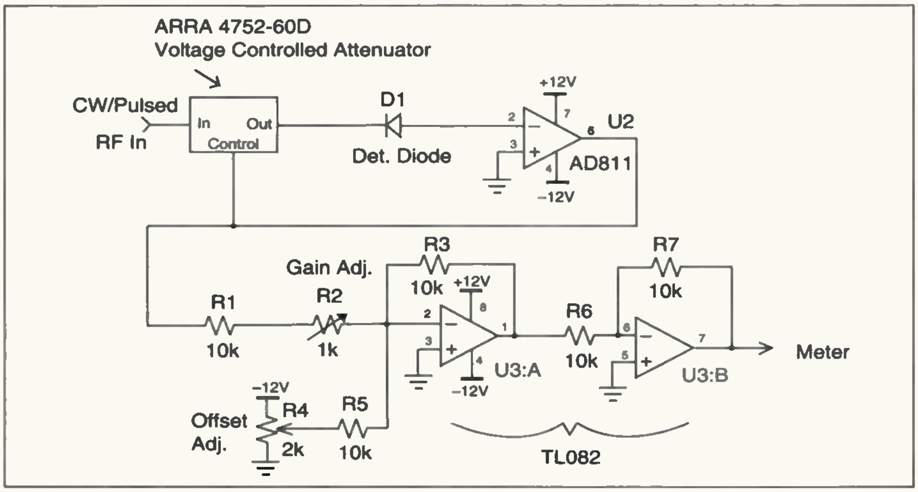

Figure 1. Schematic of the power meter.

About the Authors

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Jeff Shultz is a Senior Technician for the Countermeasures Technology Group of MIT Lincoln Laboratory. He holds a BSEET from the University of Massachusetts, Lowell.

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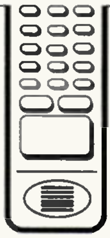

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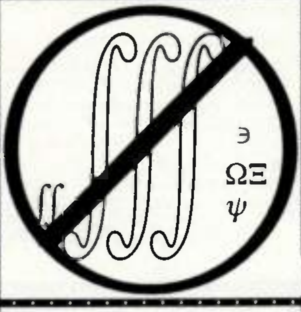

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INFO/CARD #207

System Design Software

SysCad 6, from Webb Laboratories, features compatibility with the HP/EEsof OmniSys® block description standard; swept power; swept frequency, unequal two-tone, and intra-system excitation and analysis modes. The updated block-level simulator also includes the all-new UniSpur spurious analysis engine. UniSpur solves for and classifies all 2^N families of spurs, including all 2^{N-1} classes of coincident products.

Webb Laboratories
INFO/CARD #208

Linear Analysis Worksheet

An Excel spreadsheet from Engineering Solutions performs frequency and transient response analysis of linear system models such as PLLs, AGC loops and autotracking servo control loops. The worksheet also draws the system's block diagram and includes on-line help. The software requires Excel 3.0 or later. Available for the IBM or Macintosh, the software costs $129.

Engineering Solutions
INFO/CARD #209

Bundled EM Analysis Software

Hewlett-Packard has bundled the Series IV Electromagnetic Test Bench with its stand-alone version of the HP Momentum planar electromagnetic simulator. This step continues HP's strategy to develop a merged design software product based on the best features of HP's and EEsof's high-frequency design products. HP offers the stand-alone version of HP Momentum with links to the Electromagnetics Test Bench at $32,000.

HP-EEsof
INFO/CARD #210

Oscillator Design

Crystal Oscillator Design and Analysis (CODA) version 3.0 is now available. This latest version adds varicap control design and also allows the use of MIC and other packaged amplifiers in VHF/UHF designs. The cost for this IBM-compatible program has been reduced to $200 for new users and $100 for qualified updates.

Albert Benjaminson
INFO/CARD #211

RF literature

Integrated Module Brochure

A brochure from Technical Research and Marketing describes their RF and microwave signal processing ASIMs (Application Specific Integrated Modules). A broad range of active and passive components including power amplifiers, beamformer networks, image reject mixers, phase comparators, vector modulators and specialized custom products are offered.

Technical Research and Manufacturing, Inc.
INFO/CARD #196

Capabilities Brochure

An eight-page, full-color brochure from RF Monolithics gives an overview of the company's SAW and RF technical expertise, product lines, manufacturing facilities, qualities standards and customer support programs.

RF Monolithics, Inc.
INFO/CARD #197

RF Component Brochure

A six-page, fold out brochure from Lucas Weinschel describes their lines of attenuators, directional couplers, power splitters/dividers, terminations and loads. For each product category, a table describes the specifications for each model and provides a picture of each individual model.

Lucas Weinschel
INFO/CARD #198

DSP Data Book

A 532-page data book describing high sample rate hardwired DSP chips for communications, video and imaging applications, is now available from Harris Semiconductor. Digital Signal Processing Databook 1994 provides long-form data sheets, applications notes, and general information. To order, contact Harris Semiconductor at 1-800-442-7747 and ask for extension 7250, or FAX 1-407-724-3937.

Harris Semiconductor
INFO/CARD #199

High Voltage and RF Relays

Kilovac now offers specifiers and purchasers of electronic components a free 12-page catalog featuring its high voltage and RF vacuum sealed power "S" series reed relays. The "S" series currently comprises 20 standard models with low contact resistance (as low as 50 milliohms), high isolation resistance, low power consumption and low leakage current.

Kilovac Corp.
INFO/CARD #200

Magnetic Products Brochure

Arnold Engineering offers a six-page brochure Describing their line of cores for inductive products, along with their precision rolling capabilities and permanent magnet shapes and assemblies. Arnold offers tape wound cores of various high permeability materials, bobbin cores, molybdenum-permalloy powder cores, Hi-Flux™ cores and high electrical resistivity cores.

Arnold Engineering Co.
INFO/CARD #201

RF and Microwave Courses

Courses in RF circuit engineering, microwave circuit engineering, wireless communications systems and statistical techniques are described in a six-page brochure from Besser Associates. In addition to course descriptions, the brochure contains a list of instructors and a description of the format of the courses.

Besser Associates
INFO/CARD #202

NIST Electronics Report

A report titled Electronics and Electrical Engineering Laboratory: 1993 Technical Accomplishments (NISTIR 5355) is available from the National Institute of Standards and Technology (NIST). The report outlines research projects in microwaves, electronic compatibility, lightwaves, superconductors, magnetics, and semiconductors. The report is available for $17.50 prepaid from the National Technical Information Service, Springfield, VA 22161, (800) 553-6847. Order by PB 94-136777.

NIST
INFO/CARD #203

Circuit Board Design Guide

A microwave circuit design guide is available without charge from the Soladyne Division of Rogers Corp. The 40-page literature item gives generally accepted fabrication guidelines for multilayer, microstrip, and stripline circuits. Topics covered include material selection, machined features, patterning, PTFE activation, metalization, banding, design for manufacturability, and quality assurance.

Rogers Corp., Soladyne Div.
INFO/CARD #204

Coils, Inductors and Chokes

Standex Electronics has released a catalog of coils, chokes and inductors for RF applications, as well as power supply and EMI/RFI filter assemblies. The catalog offers many types of low inductance, insert molded, variable and fixed, through-hole and surface mount RF inductors. Toroidal inductors and common-mode chokes meet many switching power supply and EMI/RFI filter requirements.

Standex Electronics
INFO/CARD #205

Inductor Catalog

Delevan/SMD Divisions of American Precision Industries offer a 42-page catalog on their extensive line of inductors, with complete specifications and technical notes. The catalog details the company's molded, shielded and unshielded RF coils; variable RF coils; shielded and unshielded surface mount inductors and more.

Delevan/SMD Divisions
INFO/CARD #206

RF guide to editorial coverage

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