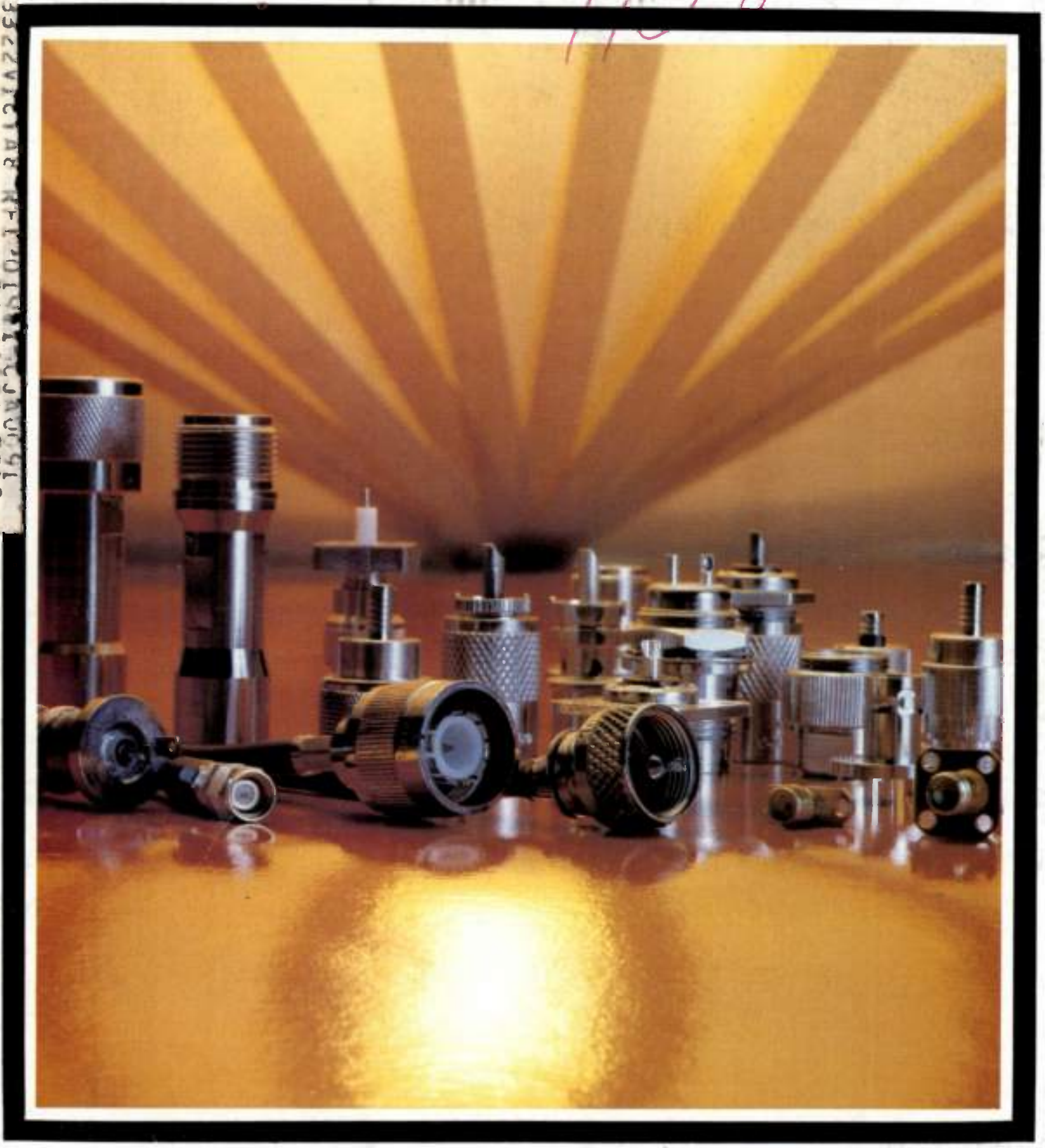
September/October 1980

A Cardiff Publication

rf design



A Designer's Guide to RF Connector Selection

Synthesizer Techniques

Good RF Construction Practices and Techniques

A High Isolation RF Switch

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

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

2. RESOLUTION: 0.1 Hz to 12 MHz, 1 Hz to 50 MHz, 10 Hz over 50 MHz.

3. ALL METAL CASES: Not only are the heavy gauge aluminum cases rugged and attractive, they provide the RF shielding and minimize RFI so necessary in many user environments.

4. EXTERNAL CLOCK INPUT/OUTPUT: Standard on the 8010/8013 series and optional on the 7010 series is a buffered 10 MHz clock time base input/output port on the rear panel. Numerous uses include phase comparison of counter time base with WWVB (U.S. National Bureau of Standards). Standardize calibration of all counters at a facility with a common 10 MHz external clock signal, calibrate scopes and other test equipment with the output from precision time base in counter, etc., etc.

5. ACCURACY: A choice of precision to ultra precision time base oscillators. Our ±1 PPM TCXO (temperature compensated xtal oscillator) and ±0.1 PPM TCXO are sealed units tested over 20-40°C. They contain voltage regulation circuitry for immunity to power variations in main instrument power supply, a 10 turn (50 PPM) calibration adjustment for easy, accurate setability and a heavily buffered output prevents circuit loads from affecting oscillator. Available in the 8010 and 8013 series is our new ultra precision micro power proportional oven oscillator. With ±.05 PPM typical stability over 10-45°C, this new time base incorporates all of the advantages of our TCXO's and virtually none of the disadvantages of the traditional ovenized oscillator. Requires less than 4 minutes warm-up time, small physical size and has a peak current drain of less than 100 ma.

6. RAPID DISPLAY UPDATE: Internal housekeeping functions require only .2 seconds between any gate or sample time period. At a 1 second gate time the counter will display a new count every 1.2 seconds, on a 10 second gate time a new count is displayed every 10.2 seconds. (10.2 seconds is the maximum time required between display updates for any resolution on any model listed).

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

8. COMPACT SIZES: State-of-the-Art circuitry and external AC adapters allowed design of compact easy to use and transport instruments.
Series 8010/8013: 3" H x 7-1/2" W x 6-1/2" D
Series 7010: 1-3/4" H x 4-1/4" W x 5-1/4" D

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

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

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

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

MODEL 8010A/8013 1.1 GHz/1.3 GHz

MODEL 7010A 600 MHz

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

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

SERIES 7010A

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

OPTIONS

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

SERIES 8010A/8013

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

OPTIONS

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

ACCESSORIES

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

Optoelectronics inc
5821 N.E. 14th Avenue, Fort Lauderdale, Florida 33334

1-800-327-5912
FROM FLORIDA (305) 771-2051/2

TERMS: Orders to U.S. and Canada, add 5% for shipping, handling and insurance to a maximum of $10.00. All other orders add 15%. C.O.D. collection fee $2.00. Florida orders add 4% state tax. Personal checks must clear before goods are shipped.

INFO/CARD 1

FREE!

1 Month's Rent*

*** Call for details . . .**
or visit us at Booth 148 at MIDCON/'80 in Dallas

WIDE SELECTION AVAILABLE. . .

Test Equipment Corporation, a leader in microwave product rentals, can provide you with a wide variety of equipment from various manufacturers. Oscilloscopes, power supplies, network analyzers, frequency synthesizers, MLA systems, spectrum analyzers, environmental chambers, sweep generators — all this and more is available immediately.

EQUIPMENT LEAD-TIME REDUCED. . .

Our regional inventory centers and computerized stock system insure that you can have the equipment you need delivered to your door with same-day or next-day service on most items.

CALL NOW. . .

For a quote on a specific piece of equipment, or if you just have questions on rentals and leases, please contact the Test Equipment Corporation office near you. We would be happy to answer your questions and send you our latest rental catalog.

Test Equipment Corporation

Rentals, Sales and Leases of Electronic Test Equipment

SAN FRANCISCO (415) 964-3923
LOS ANGELES (714) 770-6633
BOSTON (617) 272-8389
DALLAS (214) 234-5017

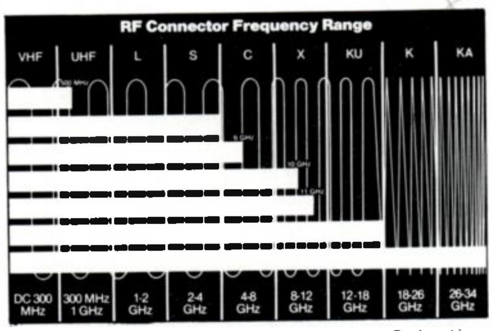
TWO NEW LOCATIONS!

DENVER (303) 777-8650
COLORADO SPRINGS (303) 598-0090

INFO/CARD 2

r.f. design

September/October 1980



A Designer's Guide to RF Connector Selection

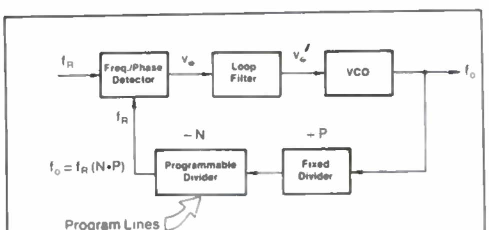


Figure 3. Prescale PLL Synthesizer.

Synthesizer Techniques

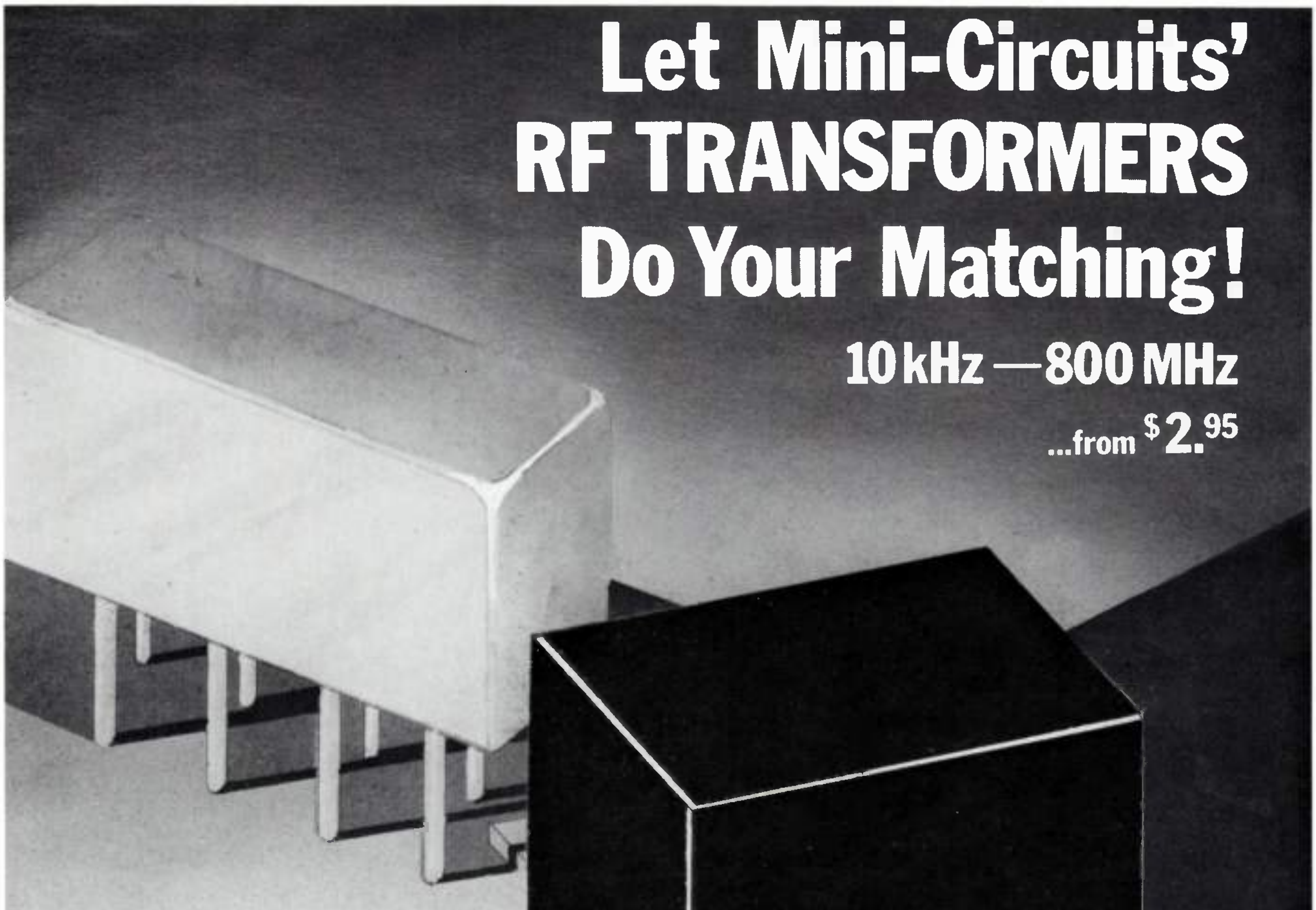
A High Isolation RF Switch

September/October 1980. Volume 3, No. 8. **r.f. design** (ISSN 0163-321X) is published bi-monthly by Cardiff Publishing Company, a subsidiary of Cardiff Industries, Inc., 3900 S. Wadsworth Blvd., Denver, Colo. 80235. (303) 988-4670. Copyright Cardiff Publishing Company. Controlled circulation postage paid at Denver, Colorado. Contents may not be reproduced in any form without written permission. Please address subscription correspondence and Postmaster, please send PS form 3579 to P.O. Box 1077, Skokie, Ill. 60077. Subscriptions: Domestic, Canada & Mexico $15 per year; foreign $20 per year. Please make payment in U.S. funds only. Single copies available at $3 each.

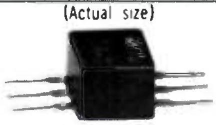
Let Mini-Circuits' RF TRANSFORMERS Do Your Matching!

10 kHz — 800 MHz

...from $2.95



(Actual size)



Models T, TH (Plastic case)
(0.300" sq × 0.230" high)

(Actual size)

Model TMO (Metal case)
(.500" L × .230" W × .255" h)

CENTER-TAPPED DC ISOLATED PRIMARY & SECONDARY

Model No.	Imped. ratio	Freq. (MHz)	Price (10-49)
T1-1T	1	.05-200	$3 95
TM01-1T	1	.05-200	$6 45
T2-1T	2	.07-200	$4 25
TM02-1T	2	.07-200	$6 75
T2.5-6T	2.5	.01-100	$4.25
TM02.5-6T	2.5	.01-100	$6 75
T3-1T	3	.05-250	$3 95
TM03-1T	3	.05-250	$6 45
T4-1	4	.2-350	$2 95
TM04-1	4	.2-350	$4 95
● T4-1H	4	8-350	$4.95
T5-1T	5	.3-300	$4 25
TM05-1T	5	.3-300	$6 75
T13-1T	13	.3-120	$4 25
TM013-1T	13	.3-120	$6 75

DC ISOLATED PRIMARY & SECONDARY

Model No.	Imped. ratio	Freq. (MHz)	Price (10-49)
T1-1	1	.15-400	$2 95
TM01-1	1	.15-400	$4.95
● T1-1H	1	8-300	$4.95
T1.5-1	1.5	.1-300	$3.95
TM01.5-1	1.5	.1-300	$6 75
T2.5-6	2.5	.01-100	$3 95
TM02.5-6	2.5	.01-100	$6 45
T4-6	4	.02-200	$3 95
TM04-6	4	.02-200	$6 45
T9-1	9	.15-200	$3 45
TM09-1	9	.15-200	$6 45
● T9-1H	9	2-90	$5 45
T16-1	16	.3-120	$3 95
TM016-1	16	.3-120	$6 45
● T16-1H	16	7-85	$5 95

● Up to 100mA DC without saturation

UNBALANCED PRIMARY & SECONDARY

Model No.	Imped. ratio	Freq. (MHz)	Price (10-49)
T2-1	2	.025-600	$3 45
TM02-1	2	.025-600	$5 95
T3-1	3	.5-800	$4 25
TM03-1	3	.5-800	$6 95
T4-2	4	.2-600	$3 45
TM04-2	4	.2-600	$5 95
T8-1	8	.15-250	$3 45
TM08-1	3	.15-250	$5 95
T14-1	14	.2-150	$4 25
TM014-1	14	.2-150	$6.75

FOR ADDITIONAL INFORMATION, COMPLETE SPECIFICATIONS, AND PERFORMANCE CURVES, REFER TO 1979-80 MICROWAVES' PRODUCT DATA DIRECTORY pgs. 161 to 368 or 1979 EEM 2770 to 2974.

It's easy to transform impedance and reduce VSWR.

Chose from 40 models, 12.5 to 800 ohms, 10 kHz to 800 MHz, ultra- low distortion (H models) balanced, unbalanced and center-tapped . . . immediate delivery . . . at prices that can't be matched, starting at $ 2.95

World's largest manufacturer of Double-Balanced Mixers

Mini-Circuits

MINI-CIRCUITS LABORATORY
A Division of Scientific Components Corp

2625 East 14th Street Bklyn, New York 11235 (212) 769-0200
Domestic and International Telex 125460 International Telex 620156

42/Rev/B

INFO/CARD 3

7L5
Baseband Measurements
20 Hz to 5 MHz

7L13
Communications applications
1 KHz to 1.8 GHz

7L18
Microwave applications
1.5 GHz to 60 GHz

Our transportable spectrum analyzers are part of the growing family of Tektronix 7000-Series Mainframes and Plug-Ins designed to meet all your test and measurement applications with high performance, flexibility and expandability.

TEKTRONIX SPECTRUM ANALYZER FAMILY

Laboratory performance plus transportability.

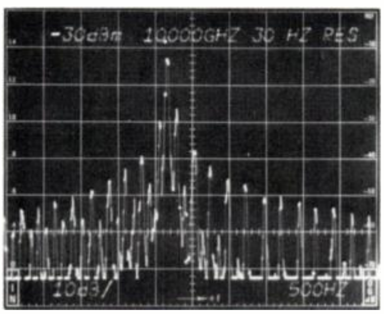
Tektronix Spectrum Analyzers deliver superior performance on the bench and in the field from 20 Hz to 60 GHz.

Top performance at the top of the spectrum: 7L18 (1.5 GHz to 60 GHz)

Engineers who design or measure state-of-the-art microwave systems obtain supreme accuracy from the 7L18.

Imagine resolving frequencies as close as 180 Hz, 60 dB down, with 30 Hz resolution to 12 GHz and 10 Hz residual fm peak-to-peak... with full calibration to 60 GHz—the highest available.

Displays are clear and bright...



like this sample of 240 Hz sidebands at 10 GHz.

And other features like digital storage and digital signal processing are easy to use with the 7L18's microprocessor-aided controls... plus a built-in tracking preselector, automatic and fully calibrated. In application after application, you get flicker-free traces, even at slow sweep speeds. And you can compare waveforms or make a long series of measurements with repeatable accuracy.

The 7L18 is ideal for testing and evaluating new microwave systems, including ECM, satellite communication systems, and microwave links. All this performance costs under $17 thousand.

Communications measurements without the jitters: 7L13 (1 KHz to 1.8 GHz)

Now you can make every important communications measurement accurately and conveniently for EMI, FM, TV, navigation, avionics, two-way and many other applications.

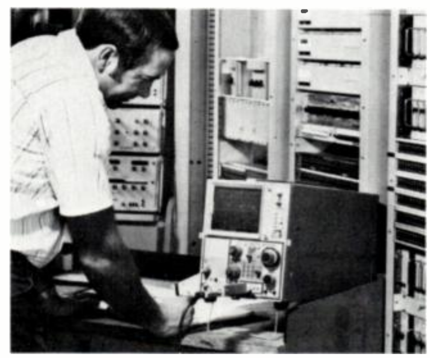
The 7L13 features jitter-free displays even at 30 Hz resolution with designed-in 10 Hz fm stability. This provides the ultra-critical accuracy necessary for design and proof-of-performance measurements.

The 7L13's top performance costs under $13 thousand.

Put a Tektronix Tracking Generator in tandem with the 7L13, and you can make precise swept frequency measurements, too. All parameters, including center frequency, are read out on the crt itself for easy referencing.

Application notes for communications engineers are available. Just write or call.

Precision and convenience for baseband measurements up to 960 channels: 7L5 (20 Hz to 5 MHz)



Sweep your baseband for spurious response, leakage, noise, shifts, distortion and transient bursts with the certainty of 10 Hz resolution.

Comparing baseband channel performance is easy because the 7L5 switches from a single channel to a 60-channel supergroup without retuning. You see all channel amplitudes at a glance, side-by-side. And, you get frequency accuracy that resolves an individual channel frequency down to 10 Hz, including signals at −140 dBv.

A 7L5 Spectrum Analyzer costs under $9 thousand.

With every member of our spectrum analyzer family, you receive Tektronix' reliability, quality and service.

Contact the Tektronix Field Office nearest you for applications assistance, a demonstration or pricing information.

For literature only, call our toll-free number: 1-800-547-1512.
Oregon residents call collect: 644-9051.

In Europe: Tektronix, Ltd., Box 36,
St. Peter Port, Guernsey, Channel Islands

Tektronix®
COMMITTED TO EXCELLENCE

INFO/CARD 4

Published by

Cardiff Publishing Company
Subsidiary of Cardiff Industries, Inc.
3900 So. Wadsworth Blvd.
Denver, Colo. 80235
(303) 988-4670

For subscription inquiries please contact Cardiff Publishing Circulation Service Center, P.O. Box 1077, Skokie, IL 60077

Hey!! What's Happenin'? Or Turning the Corner

I'm sure you've noticed a few changes in *r.f. design* over the past months. The magazine started out bi-monthly with the first issue appearing in November 1978. January 1980 saw it become monthly, up till June.

Then we waited. Where's the July issue a few of you might have wondered. Finally the issue came — it was called July-August and it felt thin.

Rich Rosen

Here we are now with a thick September-October issue which is heavy enough to swat a mature bull-frog and do serious damage. Let me tell you whats been happening and bring you up to date.

In the beginning (I just love that phrase) the powers that be thought the concept of a magazine dedicated and devoted to the RF engineer was a long time in coming. They were right! They noticed that the trend had been, by other magazines, (and still is) to promote the digital and plumbing areas. Not to discount their importance but there are probably 50,000 of us actively designing in the important frequency range 10 kHz-2000 MHz. This does not include the many millions who would be sorely dissappointed by the absence of services in that same range — e.g. TV (and CATV) land mobile, maritime mobile, amateur and CB radio, etc. What I'm trying to say is that our original concept was and is correct.

So what is the problem? Most magazines exist to a greater or lesser extent on advertising revenues. (Greater if it's a free circulation). Last month I asked for your help in terms of sharing articles with us. Your response as usual was fast, interesting and gratifying. I'd like to make one more request.

You must have noticed by now the abundance of tear-out cards in several places in this issue. These are direct inquiry cards that enable you the designing, specifying engineer to rapidly respond to advertisers. Take this opportunity to express your neecs to them. This will help us by helping them make the connection. I'm sure you've seen quite a few formulas in your professional life but let me show you one more:

k_1 Cards = k_2 Inquiries = k_3 Sales = k_4 Advertising =
k_5 Magazine pages = k_6 Articles

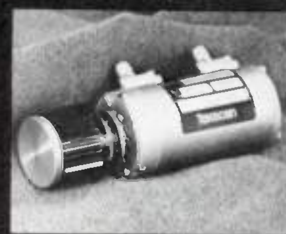
All the proportionality constants are rational positive numbers. You, the reader can help determine their value.

Rich Rosen

It's Clear

...we have the finest selection of attenuators

MICROWAVE



ROTARY

PROGRAMMABLE

FIXED

Texscan offers you 15 years of experience in the manufacture of high quality RF and Microwave Attenuators. We're proud of our extensive product line — over 200 different attenuator models including: fixed pads, rotary, continuously variable and programmable. Whatever your design calls for, chances are we have the attenuator you need with high accuracies and power capabilities up to 10 watts, as well as meeting MIL environmental specs.

We'd be happy to give you the inside story on all our attenuators. Write or call today for our brand new 68 page component catalogue.

Texscan

Texscan Corporation
2446 North Shadeland Avenue
Indianapolis, Indiana 46219
Ph: 317-357-8781
TWX: 810-341-3184
Telex: 272110

Texscan Instruments Ltd.
1, Northbridge Road
Berkhamsted, Hertfordshire
England, UK
Ph: 04427-71138
Telex: 82258

Texscan GMBH
Peschelanger 11
D8000 Munchen 83
West Germany
Ph: 089/6701048
Telex: 5-22915

A Designer's Guide To RF Connector Selection

Allen Nemetz
Amphenol North America Division
Danbury, CT

Coaxial RF connectors are manufactured by the millions. They are used for such diverse applications ranging from CB to precision laboratory measurements. Proper choice from several available "series" of connectors matches the connector performance to the application. The abundance of choices, however, can be confusing to the packaging engineer. The first task is to understand the choices. Why TNC rather than BNC? Should I use a "captivated" contact? Under what circumstances should I specify high-performance precision coaxial connectors? What are the advantages? This article attempts to clarify an admittedly confusing subject by looking at the major RF connector series in construction, performance, and application contexts.

When RF connectors made their debut in the 1930s performance demands placed on connectors were minimal. Consequently, the "UHF" Series was accepted as the industry standard. Military needs during World War II, particularly the development of radar and other sophisticated electronic equipment, fostered parallel development of several new connector series to meet new, more demanding performance requirements. Today the quest for more exacting performance at increasingly higher frequencies has spawned even more new connector types. The simple UHF connector is now the progenitor of 10 major connector series, each suited for specific applications. Further, the series are organized into families. The three main families are "standard," "miniature" and "subminiature." Generally, standard connectors are used on cables ranging from .25" to .60" O.D., miniature connectors terminate cable within the range of .15" to .25" O.D., and subminiature connectors are used on smaller cables and semi-rigid transmission lines.

Standard Connectors

The first true coaxial RF connector series to be developed was the UHF Series. It was developed in the late thirties for the radio industry. This was a time of rapid advances in coaxial cable technology, ultimately leading to solid dielectric constructions similar to today's cables.

The most important member of the UHF family is the venerable PL-259, or 83-1SP connector. It is without doubt the most widely used and best known RF connector in the world. Although marketing "experts" have predicted its demise for years, this connector continues to be the leader in field application year after year. The CB boom, of course, gave it a healthy reprieve from obsolescence. It endures because of a combination of acceptable performance, relative ease of assembly on cable and low cost, making it a very cost-effective connector.

The mating connector is the SO-239, or 83-1R panel receptacle. It is also used by the millions — on two-way radios and various test instruments. Of course, every CB set manufactured uses an SO-239 or a functionally equivalent connector. Just as "PL-259" applies only to the plug, the designation "SO-239" refers specifically to this connector. Many functional equivalents of both connectors have been spawned by the CB boom of recent years and are loosely included under these designations.

Several other UHF connectors and adapters have been popular throughout the years. To just name a few: the PL-258 splice adapter, the right angle and tee adapters, and the bulkhead version of the SO-239 receptacle. The PL-259 plug is designed for RG-8 cable; two adapters allow its use on

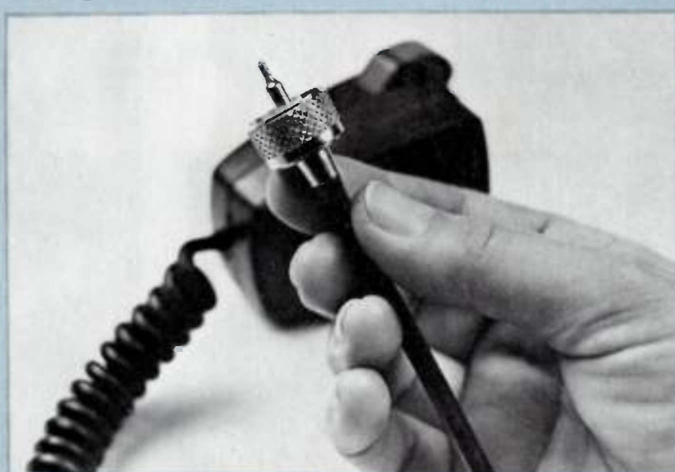
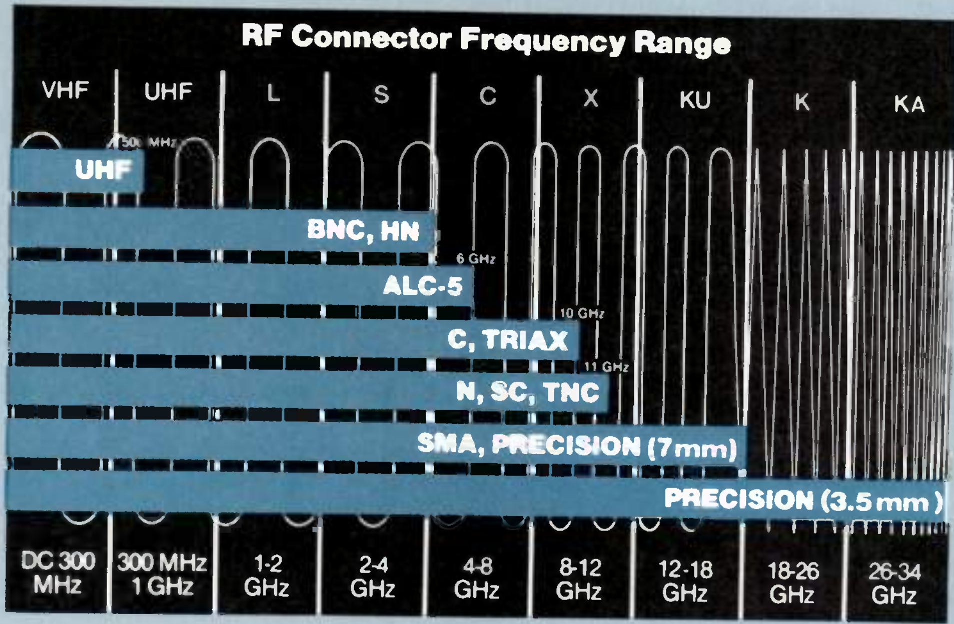


Figure 1.



RG-58 and RG-59, thus giving one connector the ability to terminate the three most popular coaxial cables.

The UHF connector benefited from the CB boom in another way. PL-259 or 83-1SP connectors required careful soldering of the center contact during assembly. To make cable termination easy, Amphenol North America Division incorporated a field crimp concept which eliminates all soldering. Users receive performance equal to the industry-standard PL-259 without the bother of soldering. Generally, UHF connectors are lowest in cost and are usable for many applications up to 500 MHz. (See Figure 1.)

They are non-weatherproof, have a peak voltage rating of 500V and are ideally suited for most citizens band communications applications including mobile radio equipment links between antenna and transmitter/receivers, ship-to-shore communications, landing systems, ground control apparatus, and other uses that call for less than average electrical performance and no requirement for impedance matching.

UHF connectors offer designers acceptable performance at low cost. Unfortunately, they should not be considered as an alternative to other connector types. Of the popular coax connector series available today, the UHF is the only one not performance rated above 1 GHz.

When UHF's were developed, the concept of impedance matching between the connector and transmission line was familiar to few. This refinement came along later. Connectors designed prior to that time are called "non-constant impedance" connectors. We say they are "nominally" 50 ohms, and they perform well on 50 and 70 ohm cable up to 500 MHz with low VSWR. Not until the impedance discontinuity introduced by the connector approaches one-fiftieth of a wavelength does the signal see the discontinuity.

N Series

The N Series connectors were the original microwave series developed to meet urgent needs during World War II. Credit goes to a man named Paul Neill at Bell Labs, hence "N" for Neill.

N Series mating is with a screw thread. Unlike the UHF Series, the N male plug has a separate outer contact to wipe against the female jack body. The UHF outer contact is achieved through the butting of the mating faces. The coupling nut must remain tight to maintain solid contact. The N mating does not depend on this.

The original N connectors — UG-9 through UG-17 are non-constant impedance designs and are usable to about 500 MHz. This group was followed by new designs with significant improvements, resulting in true 50 ohm impedance connectors.

At the same time, a series of important mechanical improvements were also made to keep pace with more sophisticated and demanding applications. The sealing gasket and braid clamp were changed to achieve improved gripping of the braid. When the clamp nut is tightened, the braid clamp actually cuts through the gasket, resulting in greater loading of the braid clamp against the braid (complete metal to metal clamping throughout). Connectors with these electrical and mechanical features are called "improved." Another improvement later was made by fully captivating the contact, thus preventing it from moving axially within the connector. Axial movement can be a real problem with repeated matings, if the connector is applied when the cable is tightly coiled and subsequently uncoiled, or with thermal variations.

The 50 ohm "improved" connector is usable with consistently low VSWR to 11 GHz. To obtain this performance level, the connector employs the principle of "reactive cancellation." Any connector obviously must cause an electrical discontinuity in the transmission line. This impedance bump is minimized by including opposite reactances within the connector in such a way that they will tend to cancel. The connectors are also available in a 70 ohm version.

N's feature weatherproof construction and have a 1500V peak voltage rating. VSWR is 1.3:1 maximum through 11 GHz, RF leakage is – 90 dB at 3 GHz and insertion loss is .15 dB maximum at 10 GHz. These features, coupled with mating face characteristics and electrical performance governed by MIL-C-39012 make the N Series a very popular choice for a broad range of communications equipment utilizing medium-size coaxial cable.

C Series

The man given credit for the design of the C Series was Carl Concelman. It was the first series designed from the beginning as a constant 50 ohm series, with all connectors utilizing the "reactive cancellation" concept and dielectric filled interface. It was also the first of the UHF connectors to feature bayonet-lock mating. Generally, however, the design is similar to the N Series and is used on the same size cables. (The N Series may be used on 75 ohm cable below 300 MHz.)

The C series is still available, but less popular than the N Series. Although they handle more power, C's have a slightly lower frequency range (0-10 GHz), and where relatively large cables are used with less frequent mating cycles, the threaded N coupling offers advantages over the bayonet C coupling which is susceptible to increased RF noise. C connectors are best suited for applications that require frequent coupling and uncoupling of the connector to the equipment.

HN Series

An offshoot of the N Series is the HN or "high-voltage N" Series. As the name suggests, the mating face and threaded coupling are similar to the N. However, the similarity ends there. The outer diameter of the insulator was increased to improve voltage breakdown between center and outer contacts. For the same reason, the body is much longer than an N.

The HN Series is not very popular today. It is included to illustrate a point. When a basic design, such as the N, is altered to improve one characteristic, other characteristics usually suffer. HN's achieve high-voltage performance at or near DC, but this falls off rapidly with frequency. Above 15 MHz, they are no better than standard N connectors. Moreover, to achieve this dubious voltage improvement, the frequency rating of the connector must be reduced to 4 GHz maximum. The HN is a compromise series. It is used in applications where the connector must withstand higher voltages, but because the frequency limits are substantially reduced, HN Series usage has decreased.

SC Series

Similar to C connectors is the SC Series, or "screw C" Series. Coupling is via a threaded nut rather than a bayonet. This series is a latecomer, developed specifically for power handling applications in second and third generation fighter aircraft avionics and electronic countermeasures. Manufacturing standards are relatively high, as dictated by military specification, resulting in costs usually too high for general use. They are usable through 11 GHz, with consistently low VSWR. (See Figure 2.)

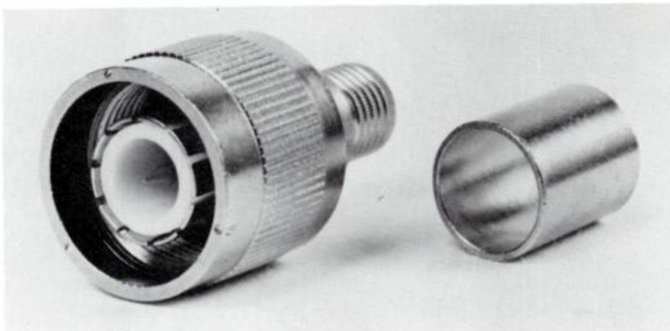


Figure 2.

INFO/CARD 6

Twin Series

Another member of the standard connector family is the twin series primarily used with 95 ohm twin conductor cables. Twinax is a shielded connector used in systems with balanced low level and high sensitivity circuits. Superior shielding characteristics are possible (less than 30 dB) with such connectors and cables. The series breaks down into three sub-series: *The BNC type, the UHF type* and *the keyed twinax type.* The first two, BNC and UHF, are similar to the series from which they take their names: the BNC type is polarized by its mating face configuration; the UHF type is unpolarized. The keyed twinax type has a polarizing key and keyway design. This series, particularly the keyed twinax, is becoming increasingly popular for computer applications where twinaxial cables between mainframe and peripherals must be terminated. (See Figure 3.)

Triax Series

The last standard series is the triax connector which terminates a special coaxial cable called triaxial or "triax" cable. This cable has two braids separated by insulation and is used in critical applications where maximum RF shielding and minimum noise radiation is required and where RF leakage is monitored by the FCC. The connector mating faces look similar to other standard series, but the electrical integrity of the separate braids is maintained through the mated connector pair. Triax connectors have an impedance of 50 ohms but can be used with 75 ohm cable where impedance matching is not critical. The internal structure, and number of components necessary to terminate triaxial cable, needless to say, is relatively complex.

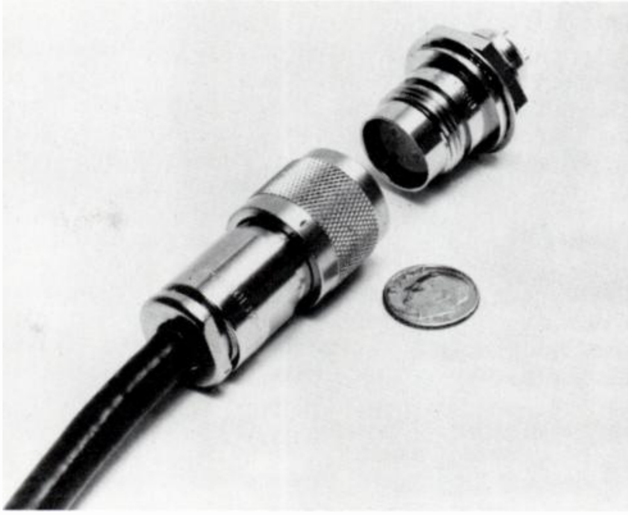


Figure 3.

Miniature Connectors

Most popular of the miniature connectors is the BNC Series. Legend has it that Neill and Concelman collaborated on the design, and the acronym means "Bayonet Neill-Concelman." Largely responsible for the connector's popularity is its ease of mating — simply engage the bayonet and twist the connectors a fraction of a turn. The connectors are also extremely versatile. BNC's may be used with RG-58/U, RG-59/U and RG-62/U cable, are available in several cable affixment styles (including crimp, clamp and solder) and yield extremely low reflection through 4 GHz.

Three additions to the BNC Series have gained special recognition. The first is an isolated BNC receptacle, low in price and requiring no plastic isolating mounting washers. The BNC isolated bulkhead receptacle fits a standard UG1094 "D" hole mount and was developed for applications where the ground is isolated from the chassis. Advantages are low cost, ease of assembly and minimum of piece parts to handle when assembling.

The second addition is designed to assemble more easily than standard BNC's without any special tools and with no sacrifice in performance. This is the patented* FCP™ concept, whereby the user simply slides a ferrule over the cable slotted end first, strips the coax, pushes the connector parts onto the center braid and crimps the contact to the tip to secure the center conductor. Assembly and termination is accomplished in 70 percent less time than with solder-type connectors. (See Figure 4.)

The most recent addition to the BNC Series is a family of low-cost Amphenol® receptacles that enable termination of RG-58/U, RG-59/U and RG-62/U coaxial cable to printed circuit boards. Applications include instrumentation, test equipment, and computer mainframes and peripherals.

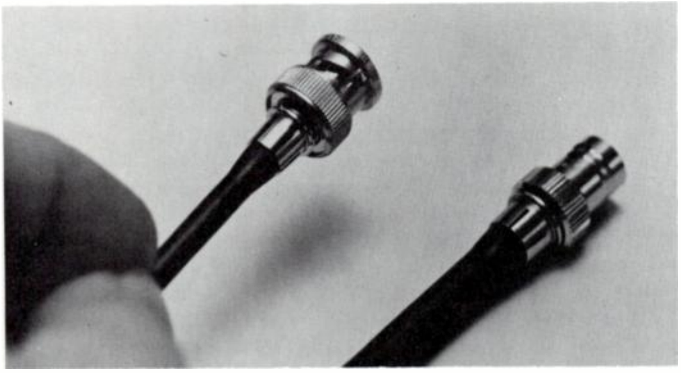


Figure 4.

The first BNC connectors starting at UG-88, were non-constant impedance types. They are still available today and can be used for applications below 300 MHz. Most of the modern or "improved" BNC's are rated to 4 GHz and higher; their designs include the improved braid gripping and reactive cancellation features discussed earlier.

The TNC Series connector is a threaded version of the BNC ("Threaded Neill-Concelman" connector). The mating faces are very similar to BNC's. The threaded coupling results in less electrical noise than with the BNC bayonet lock since relative motion between the mated pair is completely eliminated. Many TNC's have lock-wire holes in the nut to give an added measure of insurance against loosening and electrical noise. For these reasons, TNC's are popular for military and demanding commercial applications where shock and vibration are encountered. With the threaded coupling, TNC connectors perform well to 11 GHz.

Subminiature Connectors

Of the subminiature connectors, the SMA Series is the most important. SMA connectors are semi-precision, high-frequency connectors yielding repeatable performance from DC through 18 GHz. Originally developed to duplicate performance characteristics of .141-in. semi-rigid metal jacketed cable, SMA connectors now accommodate a broad range of interconnection requirements within the upper RF and microwave regions. Typical applications include efficient transition from microstrip or stripline circuitry to coaxial configurations, and as interconnections between precision or high-frequency subsystems, providing an interface with minimum attenuation and VSWR. They are also widely used in instrumentation and test equipment with .085 and .141 semi-rigid cable.

SMAs provide several distinct advantages over the other coaxial connector families, since they offer broadband performance, compact size and low cost. Traditionally used in high-frequency applications, SMAs are finding increasing use in lower frequency situations because of superior performance in that range and the cost advantage of standardizing on a single connector family.

SMA's are available in both stainless steel and beryllium copper, providing users with a wider choice of designs where the application allows flexibility in material. Stainless steel used in early SMAs achieved broad acceptance among users. Stainless steel SMAs remain popular today. Beryllium copper is gaining recognition because it offers greater yield strength, superior plating adhesion qualities and is not susceptible to intermodulation generation by RF connector hardware containing ferromagnetic materials. (See Figure 5.)

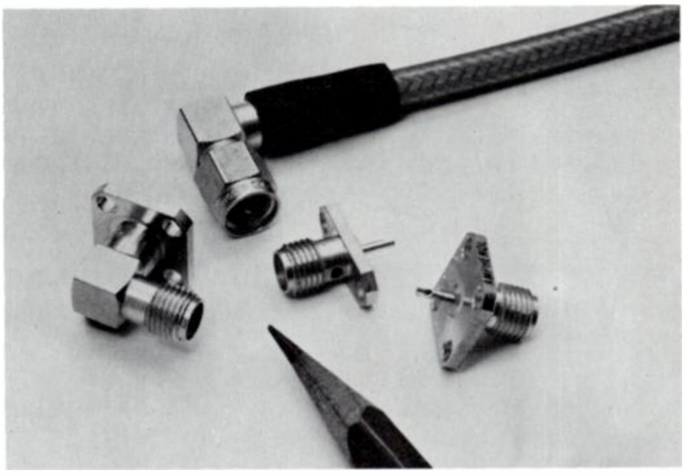


Figure 5.

Variations of standard SMA connectors are available for specialized applications. "Spark Plug" SMA's enable a reliable electrically-sound hermetic seal without the use of gaskets for feed-through applications, and are used primarily in MIC packages.

Phase adjustable SMAs offer precise means of adjustment for instrumentation. Turning a phase adjustment nut creates small-increment changes in cable length and hence phase, up to a maximum of 180° at 18 GHz. For phased array radar, test equipment, landing systems and other instrumentation using phase matching techniques, the connectors eliminate tedious cable trimming.

Other members of the subminiature family include the ALC-5*, a low-cost connector for medium to high-frequency mobile radio, test equipment and telecommunications applications; and matched impedance Subminax* connectors for miniature instrumentation.

Also in the subminiature family are the SMB (subminiature B) and SMC (Subminiature C) series. The former has a snap-on coupling mechanism while the latter is threaded.

*U.S. Patent 4,053,200

*U.S. Patent 3,828,303

A NEW CONCEPT IN RF MEASUREMENT

Now measure frequency, power, AM, FM, ΦM from 150 kHz to 1300 MHz.

HP's New 8901A Modulation Analyzer.

For the first time all the capability you need to measure RF frequency, power and modulation is in one instrument.

The new HP 8901A Modulation Analyzer—essentially a precision calibrated heterodyne receiver—quickly characterizes transmitters and accurately calibrates signal generators.

The 8901A design minimizes measurement error, e.g. residual FM on the internal local oscillator is<1Hz at 100 MHz (50Hz-3kHz BW).

AM & FM accuracy is ± 1% (ΦM±3%). Well isolated detectors let you separate small values of incidental AM or FM from large values of primary modulation.

Easy to use too, the HP 8901A automatically selects the strongest signal, makes the measurement and displays the result. All in all, it's not only a new concept in RF measurements, but an extremely powerful tool for the analysis of modulated signals.

Take a look at the features above, then if you want more information call your nearby HP sales office or write Hewlett Packard Co., 1507 Page Mill Road, Palo Alto, CA 94304.

Price $7800.* Calibrator, $500.*

DESIGNED FOR HP-IB SYSTEMS

*Domestic U.S. Prices Only

04902B

HEWLETT PACKARD

Precision Connectors

Precision connectors represent the ultimate in RF connector performance. They are fabricated to extremely close tolerances in a controlled envrironment and are limited to use in equipment that requires superior electrical performance through 18 GHz.

The precision series is subdivided into sizes, the most common being 7mm and 3.5mm. Precision connectors are designed for use with air lines of corresponding size and precision semi-rigid cables. The "7" and "3.5" refer to the inside diameter in millimeters of the outer conductor of the air lines they terminate.

Precision connectors are typically used in high-performance high-frequency applications where design engineers require an interconnect with negligible resonance, excellent repeatability and low reflection.

The industry's newest and most advanced addition to the precision series is the Amphenol® APC-3.5™. Engineers for the first time may design for resonance-free performance to 34 GHz. Prior to the APC-3.5, only SMA's could be specified to support higher-order transmission modes. However, above 24 GHz, SMA performance is totally unsatisfactory. Use of the APC-3.5 eliminates any connector-related problems and permits the device characteristics to dominate.

A prime advantage of the APC-3.5 is its complete intermatability with SMAs. This enables the APC-3.5 to be used with existing equipment without costly system redesign. (See Figure 6.)

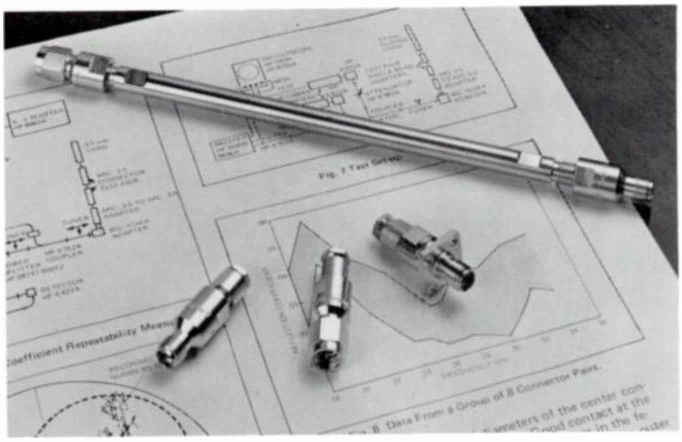


Figure 6.

Choose the Right Connector

From the advent of UHF connectors to the development of state-of-the-art precision interconnects, embraces nearly half a century. For many, RF connectors have become hardware items like nuts and bolts. Even as with nuts and bolts, however, wise and not-so-wise (costly) choices can be made when selecting RF connectors. Careful review of the performance requirements of a given design and a thorough knowledge of the full range of connectors available can avoid costly errors. An additional resource in the connector selection process is close consultation with the connector supplier. By drawing on the expertise of the supplier and providing a detailed list of critical design and performance parameters, the designer stands the best chance of matching the right connector with the application, at the right price. □

CIRQTEL

INCORPORATED

10504 WHEATLEY STREET,
KENSINGTON, MARYLAND 20795
301-946-1800
TWX: 710-828-0521

STANDARD FILTERS

PRODUCT & PRICE LIST 1980

- HARMONIC REJECTION
- LOWPASS
- BANDPASS 1/2 OCTAVE
- BANDPASS 1 OCTAVE
- BANDPASS IF
- BANDPASS ADJUSTABLE
- HIGHPASS
- COMBLINE TUBULAR

WE PUT IT ALL TOGETHER

CUSTOMER SERVICE

INNOVATION

RELIABLE DESIGN

QUICK DELIVERY

TOP QUALITY

EXCELLENT PERFORMANCE

LOW PRICE

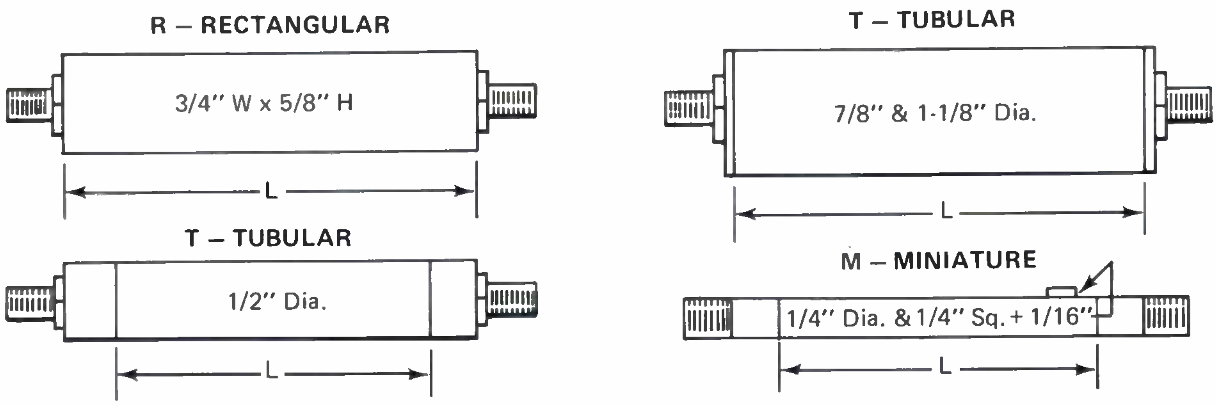
Superior Products ... by Design

STANDARD FILTERS

PRODUCT & PRICE LIST NO. 1980-03
(replaces no. 1929-31A effective 4/1/80)

- STANDARD WARRANTY AND SERVICE (SEE PAGE 9)
- PRICES IN THIS CAT. APPLY FOR QTY. 1-24
- FOR HIGHER QTY. PRICES CALL FACTORY
- ALL PRICES, DETAILS & SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE
- LENGTH (L) SHOWN IN TABLES DOES NOT INCLUDE CONNECTORS EXCEPT HARMONIC REJECTION
- EXPORT PRICES CONTACT FACTORY.
- TYPE 'D' FUSE CLIPS AVAILABLE AT ADDITIONAL CHARGE.

FILTER LENGTH DEFINITION



CONNECTORS

STANDARD PRICES FOR OSM/SMA JACK
FOR OSM/SMA PLUG ADD $3 PER CONNECTOR
FOR BNC OR TNC PLUG OR JACK ADD $4 PER CONNECTOR
FOR PC PINS ADD $9 PER CONNECTOR (For Tubular Filters Only)
FOR TYPE N ADD $6 PER CONNECTOR

CODE & LENGTH INFORMATION APPLICABLE TO THIS CATALOG ONLY.

CONNECTOR CODE

TYPE	FEMALE JACK	MALE PLUG
OSM/SMA	A	B
BNC	C	D
TNC	E	F
PC PIN		G
N	H	J

CONNECTOR LENGTHS FOR EACH FILTER TYPE

TYPE	CONFIGURATION	RECTANGULAR	TUBULAR 1/2"	MINIATURE	TUBULAR 7/8" & 1-1/8"
OSM/SMA	JACK	3/8" Each	3/4" Each	1/2" Each	7/16" Each
OSM/SMA	PLUG	3/8" Each	3/4" Each	1/2" Each	7/16" Each
BNC	JACK	1" Each	1" Each	—	1" Each
BNC	PLUG	1" Each	1" Each	—	1" Each
TNC	JACK	1" Each	1" Each	—	1" Each
TNC	PLUG	1" Each	1" Each	—	1" Each
PC PIN	RT. ANGLE ONLY	0	1/2" Each	3/8" Each	—
N	JACK/PLUG	—	1 3/8" Each	—	1 3/8" Each

HARMONIC REJECTION FILTERS

LOWPASS FILTERS

SPECIFICALLY DESIGNED FOR SWEEP GENERATORS NETWORK ANALYZERS AND OTHER INSTRUMENTS

PART NUMBER DEFINITION

2L 150

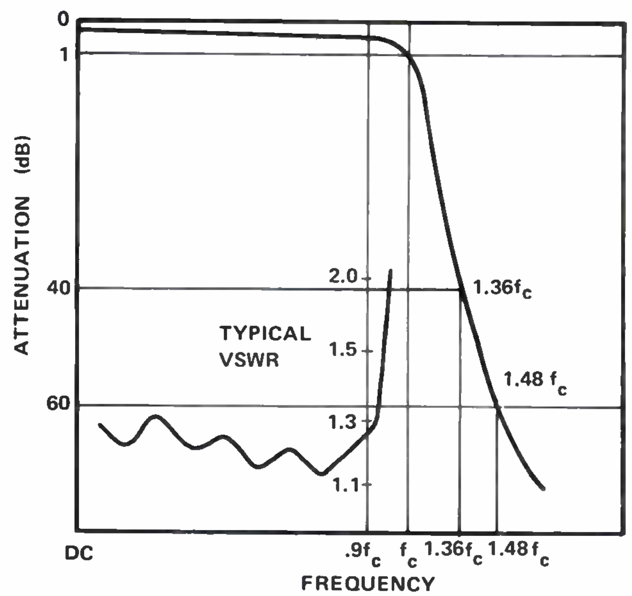
- 1L: 1/2" OD; 2L: 1/4" OD
- L: Lowpass
- 150: 1 dB Cutoff Frequency MHz, Add One Zero

SPECIFICATIONS

CUTOFF FREQ'S.:	250 MHz - 16,000 MHz
CUTOFF FREQ.:	1 dB Min.
PASSBAND INSERTION LOSS:	≤0.8 dB DC to .9 f_c
REJECTION:	≥40 dB 1.36 f_c to Max. Band* ≥60 dB 1.48 f_c to Max. Band*
IMPEDANCE:	50 Ohms IN/OUT Nom.
VSWR:	As shown DC to .9 f_c
POWER CAPACITY:	1L - 10 W. CW Standard 2L - 2 W. CW Standard
DIMENSIONS:	As shown - Dia. X Length including connector
CONNECTORS:	OSM/SMA Jack

*TYPICAL
**NOT WARRANTED

TYPICAL RESPONSE



PART NO.	PASSBAND MHz	MAX. VSWR	60 dB NOMINAL STOP BAND MHz	NOMINAL SIZE DIA. X LENGTH T.T	PRICE
1L25	DC-250	1.4:1	370-5000*	1/2" OD x 5-1/2"	SEE CURRENT PRICE LIST
1L50	DC-500	1.4:1	740-5500*	1/2" OD x 5-1/2"	
1L75	DC-750	1.4:1	1100-6000*	1/2" OD x 5-1/2"	
1L100	DC-1000	1.4:1	1480-6500*	1/2" OD x 5-1/2"	
2L150	DC-1500	1.4:1	2230-7500*	1/4" OD x 3-1/2"	
2L200	DC-2000	1.4:1	2970-10,000*	1/4" OD x 3"	
2L250	DC-2500	1.4:1	3700-12,500*	1/4" OD x 3"	
2L300	DC-3000	1.5:1	4450-14,000*	1/4" OD x 3"	
2L400	DC-4000	1.5:1	5950-16,000*	1/4" OD x 3"	
2L600	DC-6000	1.8:1	8900->18,000*	1/4" OD x 3-1/8"	
2L800	DC-8000	1.8:1	11,700->20,000**	1/4" OD x 2-3/4"	
2L1000	DC-10,000	2:1	14,700->20,000**	1/4" OD x 2-3/4"	
2L1240	DC-12,400	2:1	18,400->20,000**	1/4" OD x 2-3/4"	
2L1600	DC-16,000	2.2:1	23,800->26,000**	1/4" OD x 2-3/4"	

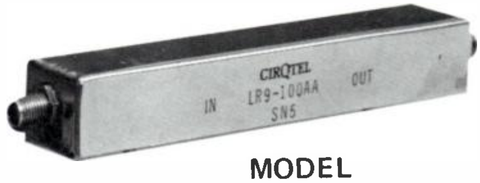
STANDARD
LOWPASS
FILTERS

1 MHz to 16 GHz FREQUENCY RANGE
SMALL SIZE
LOW LOSS
HIGH PERFORMANCE

PART NUMBER DEFINITION

LR9 - 400 AA

- L: Lowpass
- R: R — Rectangular, T — Tubular, M — Miniature
- 9: Number of Elements
- 400: 1 dB Cutoff Frequency MHz
- AA: Connectors In/Out



MODEL
LR-

MODEL
LT-

MODEL
LM-

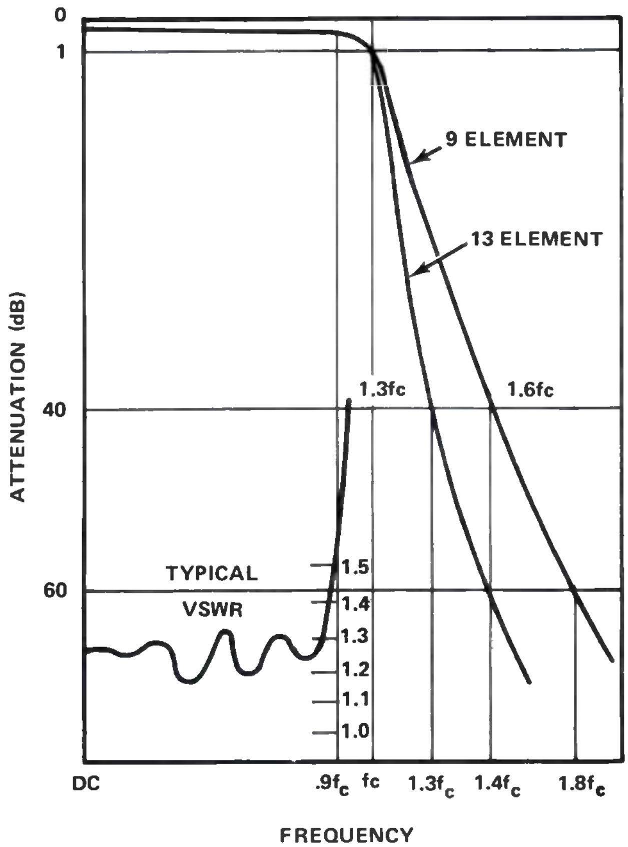
SPECIFICATIONS

CUTOFF FREQ'S:	Model LR:	1 MHz-100MHz
	Model LT:	150 MHz-1400MHz
	Model LM:	1500 MHz - 16,000 MHz
CUTOFF FREQ'S:	= 1 dB Min.	
PASSBAND INSERTION LOSS:	≤0.5 dB DC to .9 f_c	
ATTENUATION: (Nominal)	9 Element: ≥60 dB @ 1.8 f_c**	
	13 Element: ≥60 dB @ 1.4 f_c**	
IMPEDANCE:	50 ohms IN/OUT Nom.	
VSWR: (Nominal)	≤1.5:1 DC to .9 f_c (up to 8 GHz)	
	≤2.1:1 DC to .9 f_c (8 to 16 GHz)	
DIMENSIONS:	LR - 3/4" W x 5/8" H x Length*	
	LT - 1/2" OD x Length*	
	LM - 1/4" OD x Length*	
POWER CAPACITY:	LR - 2 W. CW Standard	
	LT - 10 W. CW Standard	
	LM - 2 W. CW Standard	
CONNECTORS:	OSM/SMA Female Standard	
OPTIONS:	LR:	BNC, TNC, PC pins
	LT:	BNC, TNC, PC pins, N
	LM:	PC pins to 2 GHz

**1 to 20 MHz: 9 elements ≥60 dB @ 2 f_c
13 elements ≥60 dB @ 1.6 f_c

NOTE: LU9 & 13 Models, 1-1/8" O.D. are available if tubular configuration is preferred to LR:Rectangular types.

TYPICAL RESPONSE



LOWPASS FILTERS-9 ELEMENTS

PART NO.	*L"	PRICE	PART NO.	*L"	PRICE	PART NO.	*L"	PRICE	PART NO.	*L"	PRICE
LR9-1AA	4	SEE CURRENT PRICE LIST	LR9-50AA	4	SEE CURRENT PRICE LIST	LT9-950AA	2	SEE CURRENT PRICE LIST	LM9-4500AA	1	SEE CURRENT PRICE LIST
LR9-1.5AA	4		LR9-60AA	4		LT9-1000AA	2		LM9-5000AA	1	
LR9-2AA	4		LR9-70AA	4		LT9-1100AA	2		LM9-5500AA	1	
LR9-2.5AA	4		LR9-80AA	4		LT9-1200AA	2		LM9-6000AA	1	
LR9-3AA	4		LR9-90AA	4		LT9-1300AA	2		LM9-6500AA	1	
LR9-3.5AA	4		LR9-100AA	4		LT9-1400AA	2		LM9-7000AA	1	
LR9-4AA	4		LT9-150AA	4		LM9-1500AA	1½		LM9-7500AA	1	
LR9-4.5AA	4		LT9-200AA	4		LM9-1600AA	1½		LM9-8000AA	1	
LR9-5AA	4		LT9-250AA	2		LM9-1700AA	1½		LM9-8500AA	1	
LR9-5.5AA	4		LT9-300AA	2		LM9-1800AA	1½		LM9-9000AA	1	
LR9-6AA	4		LT9-350AA	2		LM9-1900AA	1½		LM9-9500AA	1	
LR9-6.5AA	4		LT9-400AA	2		LM9-2000AA	1½		LM9-10,000AA	1	
LR9-7AA	4		LT9-450AA	2		LM9-2200AA	1½		LM9-10,500AA	1	
LR9-7.5AA	4		LT9-500AA	2		LM9-2400AA	1½		LM9-11,000AA	1	
LR9-8AA	4		LT9-550AA	2		LM9-2600AA	1½		LM9-11,500AA	1	
LR9-8.5AA	4		LT9-600AA	2		LM9-2800AA	1½		LM9-12,000AA	1	
LR9-9AA	4		LT9-650AA	2		LM9-3000AA	1½		LM9-12,400AA	1	
LR9-9.5AA	4		LT9-700AA	2		LM9-3200AA	1		LM9-13,000AA	1	
LR9-10AA	4		LT9-750AA	2		LM9-3400AA	1		LM9-14,000AA	1	
LR9-20AA	4		LT9-800AA	2		LM9-3600AA	1		LM9-16,000AA	1	
LR9-30AA	4		LT9-850AA	2		LM9-3800AA	1				
LR9-40AA	4		LT9-900AA	2		LM9-4000AA	1				

LOWPASS FILTERS-13 ELEMENTS

LR13-1AA	6	SEE CURRENT PRICE LIST	LR13-50AA	6	SEE CURRENT PRICE LIST	LT13-950AA	3	SEE CURRENT PRICE LIST	LM13-4500AA	1½	SEE CURRENT PRICE LIST
LR13-1.5AA	6		LR13-60AA	6		LT13-1000AA	3		LM13-5000AA	1½	
LR13-2AA	6		LR13-70AA	6		LT13-1100AA	3		LM13-5500AA	1½	
LR13-2.5AA	6		LR13-80AA	6		LT13-1200AA	3		LM13-6000AA	1½	
LR13-3AA	6		LR13-90AA	6		LT13-1300AA	3		LM13-6500AA	1½	
LR13-3.5AA	6		LR13-100AA	6		LT13-1400AA	3		LM13-7000AA	1½	
LR13-4AA	6		LT13-150AA	6		LM13-1500AA	2		LM13-7500AA	1½	
LR13-4.5AA	6		LT13-200AA	6		LM13-1600AA	2		LM13-8000AA	1½	
LR13-5AA	6		LT13-250AA	4½		LM13-1700AA	2		LM13-8500AA	1½	
LR13-5.5AA	6		LT13-300AA	3½		LM13-1800AA	2		LM13-9000AA	1½	
LR13-6AA	6		LT13-350AA	3½		LM13-1900AA	2		LM13-9500AA	1½	
LR13-6.5AA	6		LT13-400AA	3		LM13-2000AA	2		LM13-10,000AA	1½	
LR13-7AA	6		LT13-450AA	3		LM13-2200AA	2		LM13-10,500AA	1½	
LR13-7.5AA	6		LT13-500AA	3		LM13-2400AA	2		LM13-11,000AA	1½	
LR13-8AA	6		LT13-550AA	3		LM13-2600AA	2		LM13-11,500AA	1½	
LR13-8.5AA	6		LT13-600AA	3		LM13-2800AA	2		LM13-12,000AA	1½	
LR13-9AA	6		LT13-650AA	3		LM13-3000AA	2		LM13-12,400AA	1½	
LR13-9.5AA	6		LT13-700AA	3		LM13-3200AA	1½		LM13-13,000AA	1½	
LR13-10AA	6		LT13-750AA	3		LM13-3400AA	1½		LM13-14,000AA	1½	
LR13-20AA	6		LT13-800AA	3		LM13-3600AA	1½		LM13-16,000AA	1½	
LR13-30AA	6		LT13-850AA	3		LM13-3800AA	1½				
LR13-40AA	6		LT13-900AA	3		LM13-4000AA	1½				

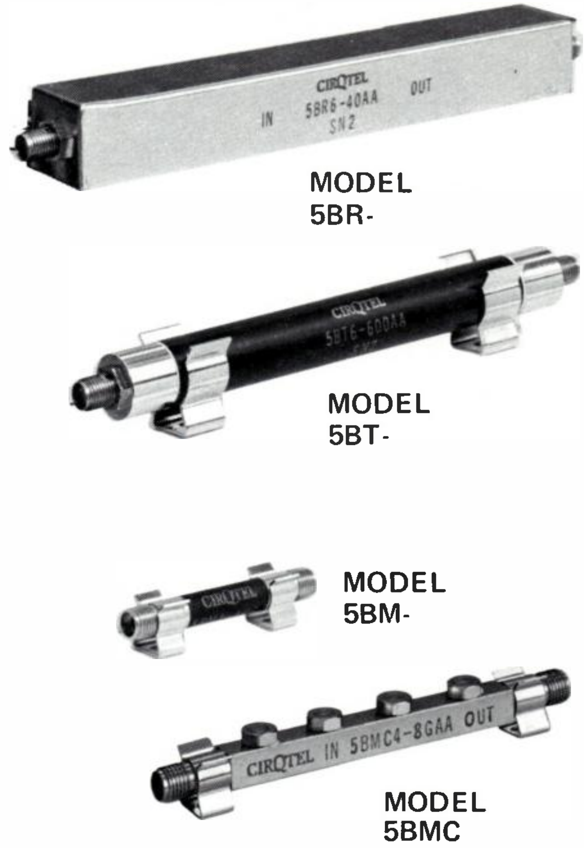
STANDARD
BANDPASS
FILTERS

1/2 OCTAVE BW
1MHz to 12GHz
FREQUENCY RANGE
LOW LOSS
HIGH PERFORMANCE

PART NUMBER DEFINITION

5BR4 - 200 AA

- 5 — 1/2 Octave (1 dB BW)
- B — Bandpass
- R — R — Rectangular; T — Tubular; M — Miniature; MC — Miniature Cavity
- 4 — Number of Poles
- 200 — Low Side/1 dB Cutoff Frequency MHz (F_L)
- AA — Connectors In/Out

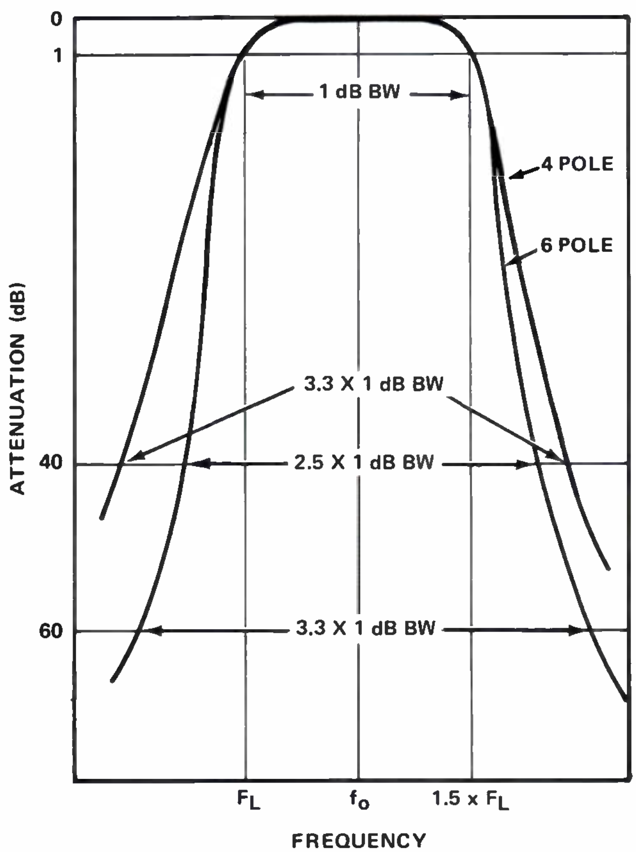


SPECIFICATIONS

LOW SIDE CUTOFF FREQUENCIES:	BR - 1 to 90 MHz BT - 100 to 2000 MHz BM - 2200 to 5000 MHz BMC - 5.5 GHz to 12 GHz
INSERTION LOSS @ f_0:	= 1 dB Max.
1 dB BANDWIDTH:	1/2 Octave from F_L to 1.5 x F_L
ATTENUATION: (NOMINAL)	4 Pole: 40 dB/1 dB Shape Factor = 3.3/1 6 Pole: 40 dB/1 dB Shape Factor = 2.5/1 60 dB/1 dB Shape Factor = 3.3/1
IMPEDANCE:	50 Ohms IN/OUT Nom.
VSWR:	≤1.5:1 over 60% of Passband Min. to 6 GHz ≤1.8:1 over 60% of Passband Min. to 10 GHz ≤2:1 over 60% of Passband Min. to 16 GHz
DIMENSIONS:	BR - 3/4" W x 5/8" H x Length* BT - 1/2" OD x Length* BM - 1/4" OD x Length* BMC - 1/4" Square x Length*
CONNECTORS:	OSM/SMA Female Standard
OPTIONS:	BR - BNC, TNC, PC pins BT-BNC, TNC, PC pins, N BM - PC pins to 1400 MHz BMC - no options

*See page 7 for typical lengths.
NOTE: 5BU Model, 1-1/8" O.D. is available in place of 5BR Models if tubular configuration is desired.

TYPICAL RESPONSE



1/2 OCTAVE BANDPASS FILTERS-4 POLES

PART NO.	*L"	PRICE	PART NO.	*L"	PRICE	PART NO.	*L"	PRICE	PART NO.	*L"	PRICE
5BR4-1AA	5	SEE CURRENT PRICE LIST	5BR4-90AA	4	SEE CURRENT PRICE LIST	5BT4-900AA	2½	SEE CURRENT PRICE LIST	5BM4-3000AA	2½	SEE CURRENT PRICE LIST
5BF4-2AA	5		5BT4-100AA	4		5BT4-950AA	2½		5BM4-3200AA	2½	
5BR4-3AA	5		5BT4-150AA	4		5BT4-1000AA	2½		5BM4-3400AA	2½	
5BR4-4AA	5		5BT4-200AA	3		5BT4-1100AA	2½		5BM4-3600AA	2½	
5BR4-5AA	5		5BT4-250AA	3		5BT4-1200AA	2½		5BM4-3800AA	1	
5BR4-6AA	5		5BT4-300AA	3		5BT4-1300AA	2½		5BM4-4000AA	1	
5BR4-7AA	5		5BT4-350AA	3		5BT4-1400AA	2½		5BM4-4500AA	1	
5BR4-8AA	5		5BT4-400AA	3		5BT4-1500AA	2½		5BM4-5000AA	1	
5BR4-9AA	5		5BT4-450AA	3		5BT4-1600AA	2½		5BMC4-5500AA	1	
5BR4-10AA	5		5BR4-500AA	3		5BT4-1700AA	2½		5BMC4-6000AA	1	
5BR4-20AA	5		5BT4-550AA	3		5BT4-1800AA	2½		5BMC4-6500AA	1	
5BR4-30AA	5		5BT4-600AA	3		5BT4-1900AA	2½		5BMC4-7GAA	1½	
5BR4-40AA	4		5BT4-650AA	3		5BT4-2000AA	2½		5BMC4-7.5GAA	1½	
5BR4-50AA	4		5BT4-700AA	3		5BM4-2200AA	2½		5BMC4-8GAA	1½	
5BR4-60AA	4		5BT4-750AA	2½		5BM4-2400AA	2½		5BMC4-9GAA	1½	
5BR4-70AA	4		5BT4-800AA	2½		5BM4-2600AA	2½		5BMC4-10GAA	1½	
5BR4-80AA	4		5BT4-850AA	2½		5BM4-2800AA	2½		5BMC4-12GAA	1½	

1/2 OCTAVE BANDPASS FILTERS-6 POLES

5BR6-1AA	6	SEE CURRENT PRICE LIST	5BR6-90AA	5½	SEE CURRENT PRICE LIST	5BT6-900AA	3½	SEE CURRENT PRICE LIST	5BM6-3000AA	2½	SEE CURRENT PRICE LIST
5BR6-2AA	6		5BT6-100AA	5½		5BT6-950AA	3½		5BM6-3200AA	2½	
5BR6-3AA	6		5BT6-150AA	5½		5BT6-1000AA	3½		5BM6-3400AA	2½	
5BR6-4AA	6		5BT6-200AA	4		5BT6-1100AA	3½		5BM6-3600AA	1½	
5BR6-5AA	6		5BT6-250AA	4		5BT6-1200AA	3½		5BM6-3800AA	1½	
5BR6-6AA	6		5BT6-300AA	4		5BT6-1300AA	3½		5BM6-4000AA	1½	
5BR6-7AA	6		5BT6-350AA	4		5BT6-1400AA	3½		5BM6-4500AA	1½	
5BR6-8AA	6		5BT6-400AA	4		5BT6-1500AA	3½		5BM6-5000AA	1½	
5BR6-9AA	6		5BT6-450AA	4		5BT6-1600AA	3½		5BMC6-5500AA	1½	
5BR6-10AA	6		5BT6-500AA	4		5BT6-1700AA	3½		5BMC6-6000AA	1½	
5BR6-20AA	6		5BT6-550AA	4		5BT6-1800AA	3½		5BMC6-6500AA	1½	
5BR6-30AA	6		5BT6-600AA	4		5BT6-1900AA	3½		5BMC6-7GAA	1¾	
5BR6-40AA	5½		5BT6-650AA	4		5BT6-2000AA	3½		5BMC6-7.5GAA	1¾	
5BR6-50AA	5½		5BT6-700AA	4		5BM6-2200AA	3½		5BMC6-8GAA	1¾	
5BR6-60AA	5½		5BT6-750AA	3½		5BM6-2400AA	2½		5BMC6-9GAA	1½	
5BR6-70AA	5½		5BT6-800AA	3½		5BM6-2600AA	2½		5BMC6-10GAA	1¾	
5BR6-80AA	5½		5BT6-850AA	3½		5BM6-2800AA	2½		5BMC6-12GAA	1¾	

SINCE 1962 CIRQTEL HAS BEEN THE TOP NAME TO BUY FOR FILTERS DESIGNED TO YOUR SPECIFICATION. FOR ADDITIONAL INFORMATION AND PRICES ON NON-STANDARD PRODUCTS WRITE OR CALL COLLECT.

CIRQTEL INCORPORATED
10504 WHEATELEY ST.
KENSINGTON, MD. 20795
PHONE: 301-946-1800
TWX: 710-828-0521

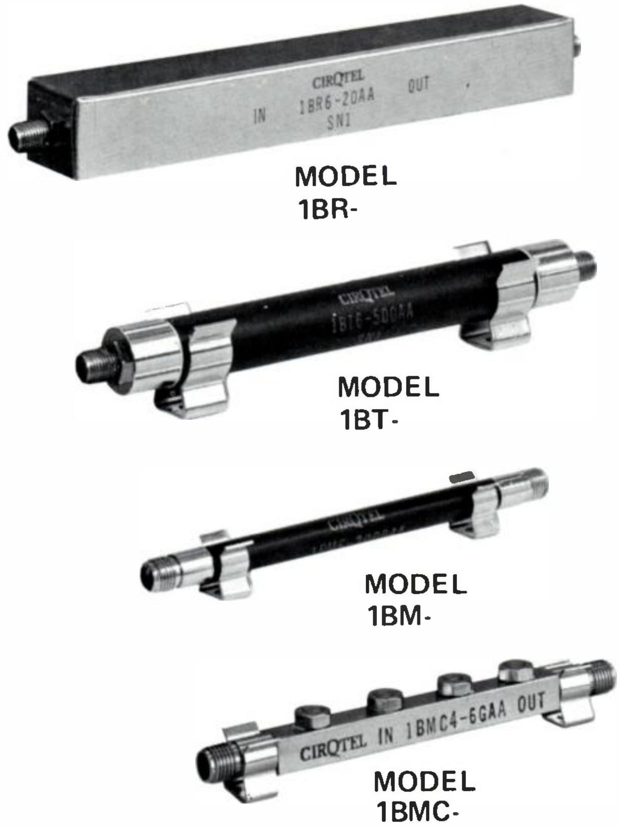
STANDARD
BANDPASS
FILTERS

1 OCTAVE BW
1MHz to 6000MHz
FREQUENCY RANGE
LOW LOSS
HIGH PERFORMANCE

PART NUMBER DEFINITION

1BR6 - 200 AA

- 1 Octave (1 dB/BW) Bandpass
- R — Rectangular
- T — Tubular
- M — Miniature
- MC — Miniature Cavity
- Number of Poles
- Low Side 1 dB Cutoff Frequency MHz (F_L)
- Connectors In/Out

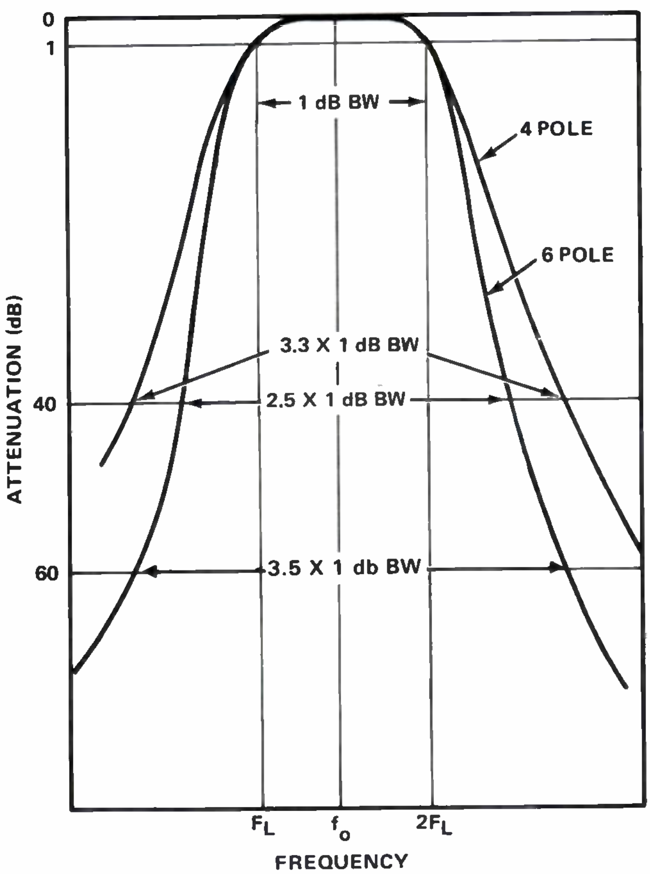


SPECIFICATIONS

LOW SIDE CUTOFF FREQUENCIES:	1 BR - 1 to 70 MHz 1 BT - 80 to 950 MHz 1 BM - 1000 to 3800 MHz 1 BMC - 4000 to 6000 MHz
INSERTION LOSS:	≤1 dB @ f_0
1 dB BANDWIDTH:	= 1 Octave from F_L to 2 F_L
ATTENUATION: (Nominal)	4 Pole: 40 dB/1 dB Shape Factor = 3.3/1 6 Pole: 40 dB/1 dB Shape Factor = 2.5/1 60 dB/1 dB Shape Factor = 3.5/1
IMPEDANCE:	50 Ohms IN/OUT (nominal)
DIMENSIONS:	1 BR - 3/4" W x 5/8" H x Length* 1 BT - 1/2" OD x Length* 1 BM - 1/4" OD x Length*
CONNECTORS:	OSM/SMA Female Standard
OPTIONS:	1 BR - BNC, TNC, PC pins 1 BT - BNC, TNC, PC pins, N 1 BM - PC pins to 1000 MHz
VSWR:	≤1.5:1 over 60% of Passband Min. to 3800 MHz ≤1.8:1 over 60% of Passband Min. to 6 GHz ≤2.2:1 over 60% of Passband Min. to 12 GHz

NOTE: IBU Model is available in place of 1BR — IBU is 1-1/8" O.D. If tubular configuration is desired.

TYPICAL RESPONSE



1 OCTAVE BANDPASS FILTERS-4 POLES

PART NO.	*L"	PRICE	PART NO.	*L"	PRICE	PART NO.	*L"	PRICE	PART NO.	*L"	PRICE
1BR4-1AA	5	SEE CURRENT PRICE LIST	1BR4-70AA	4	SEE CURRENT PRICE LIST	1BT4-700AA	2½	SEE CURRENT PRICE LIST	1BM4-1900AA	2½	SEE CURRENT PRICE LIST
1BR4-2AA	5		1BR4-80AA	4		1BT4-750AA	2½		1BM4-2000AA	2½	
1BR4-3AA	5		1BR4-90AA	4		1BT4-800AA	2½		1BM4-2200AA	2½	
1BR4-4AA	5		1BT4-100AA	4		1BT4-850AA	2½		1BM4-2400AA	2½	
1BR4-5AA	5		1BT4-150AA	3		1BT4-900AA	2½		1BM4-2600AA	1	
1BR4-6AA	5		1BT4-200AA	3		1BT4-950AA	2½		1BM4-2800AA	1	
1BR4-7AA	5		1BT4-250AA	3		1BM4-1000AA	2½		1BM4-3000AA	1	
1BR4-8AA	5		1BT4-300AA	3		1BM4-1100AA	2½		1BM4-3200AA	1	
1BR4-9AA	5		1BT4-350AA	3		1BM4-1200AA	2½		1BM4-3400AA	1	
1BR4-10AA	5		1BT4-400AA	3		1BM4-1300AA	2½		1BM4-3600AA	1	
1BR4-20AA	5		1BT4-450AA	3		1BM4-1400AA	2½		1BM4-3800AA	1	
1BR4-30AA	5		1BT4-500AA	2½		1BM4-1500AA	2½		1BMC4-4000AA	1	
1BR4-40AA	4		1BT4-550AA	2½		1BM4-1600AA	2½		1BMC4-6GAA	1½	
1BR4-50AA	4		1BT4-600AA	2½		1BM4-1700AA	2½				
1BR4-60AA	4		1BT4-650AA	2½		1BM4-1800AA	2½				

1 OCTAVE BANDPASS FILTERS-6 POLES

1BR6-1AA	6	SEE CURRENT PRICE LIST	1BR6-70AA	5½	SEE CURRENT PRICE LIST	1BT6-700AA	3½	SEE CURRENT PRICE LIST	1BM6-1900AA	3½	SEE CURRENT PRICE LIST
1BR6-2AA	6		1BR6-80AA	5½		1BT6-750AA	3½		1BM6-2000AA	3½	
1BR6-3AA	6		1BR6-90AA	5½		1BT6-800AA	3½		1BM6-2200AA	3½	
1BR6-4AA	6		1BT6-100AA	5½		1BT6-850AA	3½		1BM6-2400AA	3½	
1BR6-5AA	6		1BT6-150AA	4		1BT6-900AA	3½		1BM6-2600AA	1½	
1BR6-6AA	6		1BT6-200AA	4		1BT6-950AA	3½		1BM6-2800AA	1½	
1BR6-7AA	6		1BT6-250AA	4		1BM6-1000AA	3½		1BM6-3000AA	1½	
1BR6-8AA	6		1BT6-300AA	4		1BM6-1100AA	3½		1BM6-3200AA	1½	
1BR6-9AA	6		1BT6-350AA	4		1BM6-1200AA	3½		1BM6-3400AA	1½	
1BR6-10AA	6		1BT6-400AA	4		1BM6-1300AA	3½		1BM6-3600AA	1½	
1BR6-20AA	6		1BT6-450AA	4		1BM6-1400AA	3½		1BM6-3800AA	1½	
1BR6-30AA	6		1BT6-500AA	3½		1BM6-1500AA	3½		1BMC6-4000AA	1½	
1BR6-40AA	5½		1BT6-550AA	3½		1BM6-1600AA	3½		1BMC6-6GAA	2	
1BR6-50AA	5½		1BT6-600AA	3½		1BM6-1700AA	3½				
1BR6-60AA	5½		1BT6-650AA	3½		1BM6-1800AA	3½				

WARRANTY

All products manufactured by CIRQTEL, INC. are guaranteed against defective materials and workmanship for a period of one year from date of original shipment. CIRQTEL expressly limits its liability to replacement or repair of products found to be defective, such replacement or repair to be at its option.

This warranty is null and void for any products disassembled for any purpose whatsoever, modified in any way, or subjected to environments exceeding those applicable to that (those) particular item(s). CIRQTEL shall be the sole judge in determining guarantee validity.

CIRQTEL disclaims any warranty or guarantees expressed or implied other than those set forth herein and reserves the right to discontinue or alter any of its products, procedures, or guarantees at any time without notice.

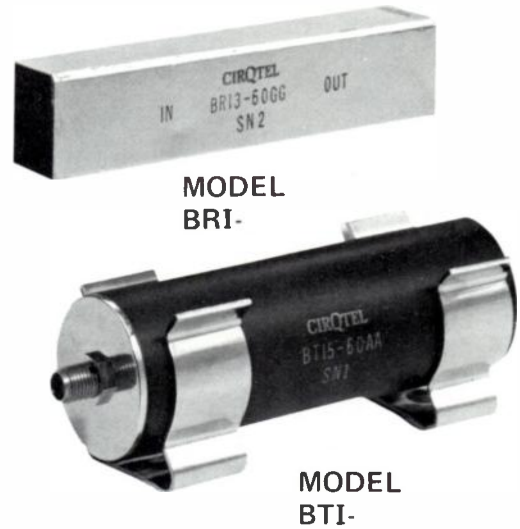
STANDARD IF BANDPASS FILTERS

2% to 30% BANDWIDTH
BUTTERWORTH RESPONSE
CHOICE OF CONFIGURATION

PART NUMBER DEFINITION

BRI3 - 60 AA 2

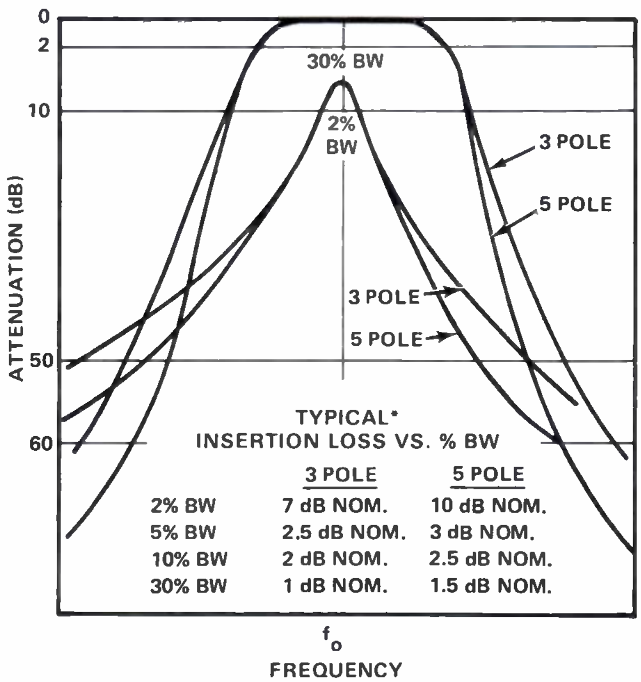
- B — Bandpass
- R — Rectangular; T — Tubular
- I — IF
- 3 — Number of Poles
- 60 — Center Frequency MHz
- AA — Connectors In/Out
- 2 — % Bandwidth



SPECIFICATIONS

CENTER FREQ'S.:	10.7, 21.4, 30, 60, 70 and 120 MHz
INSERTION LOSS @ f_0	From < 1 dB to 10 dB depending on BW
BANDWIDTH @ 1 dB:	2% to 30% nominal — in steps of 1% only.
ATTENUATION:	3 Pole: Typical Butterworth 5 Pole: Response
IMPEDANCE:	50 Ohms IN/OUT nominal
VSWR:	≤1.5:1 over 50% of Passband Min.
DIMENSIONS:	BRI - 3/4" W x 5/8" H x Length* BTI - 1-1/8" OD x Length* or 1/2 OD x Length (above 100MHz)
CONNECTORS:	OSM/SMA Female Standard
OPTIONS:	BRI: BNC, TNC, PC pins BTI : BNC, TNC, N BRI up to 70 MHz only

*BTI USUALLY HAS LOWER LOSS AND IS AVAILABLE FOR ALL FREQUENCIES



PART NO. – 3 POLE BLANKS FOR TYPE & BW %	*"L" BTI	*"L" BRI	PRICE	PART NO. – 5 POLE BLANKS FOR TYPE & BW %	*"L" BTI	*"L" BRI	PRICE
B....I3-10.7AA....	4-7/32	4	SEE CURRENT PRICE LIST	B....I5-10.7AA....	5-13/16	6	SEE CURRENT PRICE LIST
B....I3-21.4AA....	4-7/32	4		B....I5-21.4AA....	5-13/16	6	
B....I3-30AA....	4-7/32	4		B....I5-30AA....	5-13/16	6	
B....I3-60AA....	4-7/32	3		B....I5-60AA....	5-13/16	4½	
B....I3-70AA....	4-7/32	3		B....I5-70AA....	5-13/16	4½	
B....I3-120AA....	4-7/32	3		B....I5-120AA....	5-13/16	4½	

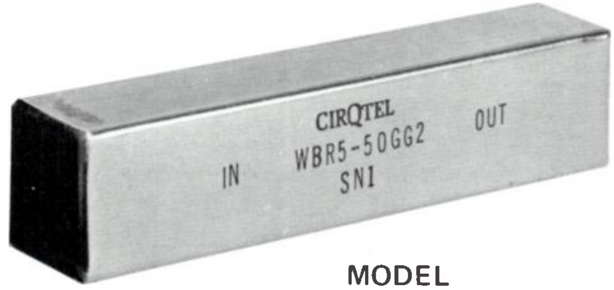
STANDARD WIDEBAND BANDPASS FILTERS

UP TO 10X F_L BW
5 or 9 POLES
HIGH PERFORMANCE

PART NUMBER DEFINITION

WBR5 - 300 AA3

- WB — Wideband Bandpass
- R — Rectangular / T — Tubular
- 5 — Number of Poles
- 300 — F_L Low Edge Cutoff Frequency
- AA — Connectors In/Out
- 3 — 2 - 10 X F_L



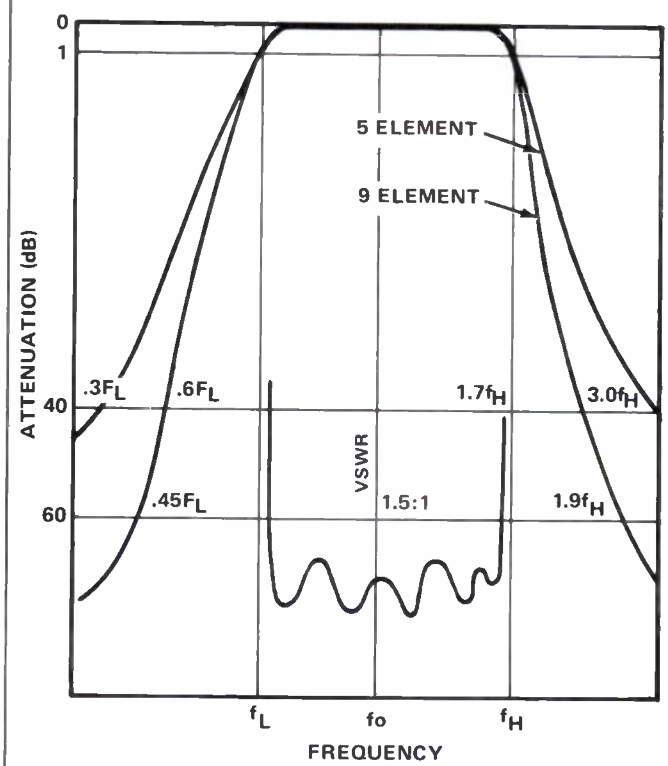
MODEL WBR-

MODEL WBT-

SPECIFICATIONS

LOW SIDE 1 dB CUTOFF:	F_L = 1 to 400 MHz
HIGHSIDE CUTOFF:	F_H = Up to 1200 MHz
INSERTION LOSS @ f_0:	$\leqslant$1 dB
1 dB BANDWIDTHS:	Low Side Cutoff 1 to 400 MHz 2 - 10 X F_L BW (1200 MHz Max. Highside Cutoff)
ATTENUATION:	5 Pole: $\geqslant$40 dB @ .3F_L & 3F_H 9 Pole: $\geqslant$40 dB @ .6F_L & 1.7F_H 9 Pole: $\geqslant$60 dB @ .45F_L & 1.9 F_H
IMPEDANCE:	50 Ohms IN/OUT (nominal)
VSWR:	$\leqslant$1.5:1 over 60% of Passband Min.
DIMENSIONS:	WBR – 3/4″ W x 5/8″ H x Length WBT – 7/8″ or 1-1/8″ OD x Length
CONNECTORS:	OSM/SMA Female Standard
OPTIONS:	BNC, TNC, PC Pins on WBR only N on WBT only
LENGTHS:	5 Pole: 4″ 9 Pole: 6″

TYPICAL RESPONSE



PRICE FOR F_H/F_L	2 - 2.5	2.51 - 3.5	3.51 - 5	5.1 - 8	8.1 - 10
5 Pole WBR5 5 Pole WBT5 9 Pole WBR5 9 Pole WBT5	SEE CURRENT PRICE LIST	SEE CURRENT PRICE LIST	SEE CURRENT PRICE LIST	SEE CURRENT PRICE LIST	SEE CURRENT PRICE LIST

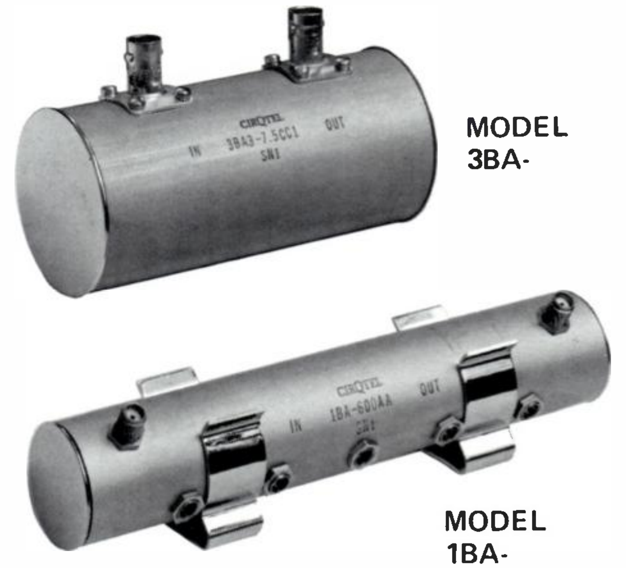
STANDARD
ADJUSTABLE
FILTERS

1 OCTAVE TUNING RANGE
1%, 3%, or 5% BANDWIDTH
NOMINAL BUTTERWORTH RESPONSE

PART NUMBER DEFINITION

3BA3 - 7.5CC1

- Series 1 or 3
- Bandpass
- Adjustable
- No. of Poles
- Center Frequency
- Connectors In/Out
- % Bandwidth



TUNE W/APPROPRIATE
JEWELERS SCREWDRIVER ONLY

SPECIFICATIONS

CENTER FREQ'S.: 7.5 to 7500 MHz

TUNING RANGE: 1 Octave Min.

BANDWIDTH @ 3 dB: 1%, 3% or 5%

ATTENUATION: 3 Pole: / 5 Pole: Typical Butterworth Response

IMPEDANCE: 50 Ohms IN/OUT

VSWR: ⩽1.5:1 over 40% of 1 dB BW Min.

NOMINAL DIMENSIONS:

	3 Pole	5 Pole
3BA	1-7/8"-2" Dia. x 8-1/2" *	1-7/8"-2" Dia. x 12" *
1BA	5/8"-1-1/8" Dia. x 7-1/2" *	5/8"-1-1/8" Dia. x 10" *

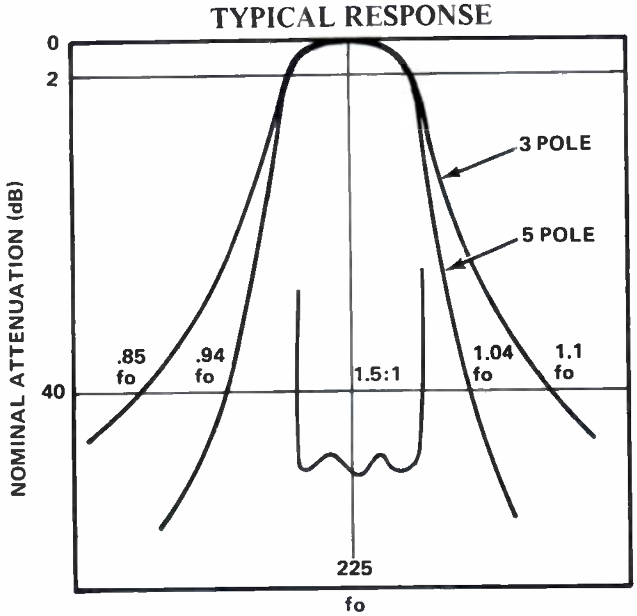
CONNECTORS: (RADIAL ONLY)
3BA - BNC Jack Standard Options: TNC, SMA
1BA - OSM/SMA Jack Standard Options: BNC, TNC

TUNING RANGES: (MHz)

3BA F_0	RANGE	3BA F_0	RANGE	1BA F_0	RANGE
7.5	5-10	75.0	50-100	1125	750-1500
11.25	7.5-15	112.5	75-150	1500	1000-2000
15.0	10-20	150	100-200	1800	1200-2400
22.5	15-30	225	150-300	2250	1500-3000
30.0	20-40	300	200-400	2700	1800-3600
45.0	30-60	450	300-600	3000	2000-4000
		600	400-800	3375	2250-4500
		750	500-1000	4000	4000-8000
				5000	5000-10,000

*These dimensions are nominal max.

TYPICAL RESPONSE



FREQUENCY RESPONSE
FOR TYPICAL 5% 3 dB BW @ 225 MHz

3 POLE PART NO. BLANK FOR % BW	PRICE	3 POLE PART NO. BLANK FOR % BW	PRICE	5 POLE PART NO. BLANK FOR % BW	PRICE	5 POLE PART NO. BLANK FOR % BW	PRICE
3BA3-7.5CC...	SEE CURRENT PRICE LIST	3BA3-450CC...	SEE CURRENT PRICE LIST	3BA5-7.5CC...	SEE CURRENT PRICE LIST	3BA5-450CC...	SEE CURRENT PRICE LIST
3BA3-11.25CC...		3BA3-600AA...		3BA5-11.25CC...		3BA5-600AA...	
3BA3-22.5CC...		3BA3-750AA...		3BA5-15CC...		3BA5-750AA...	
3BA3-30CC...		1BA3-1125AA...		3BA5-22.5CC...		1BA5-1125AA...	
3BA3-45CC...		1BA3-1500AA...		3BA5-30CC...		1BA5-1500AA...	
3BA3-75CC...		1BA3-1800AA...		3BA5-45CC...		1BA5-1800AA...	
3BA3-112.5CC...		1BA3-2250AA...		3BA5-75CC...		1BA5-2250AA...	
3BA3-150CC...		1BA3-2700AA...		3BA5-112.5CC...		1BA5-2700AA...	
3BA3-225CC...		1BA3-3000AA...		3BA5-150CC...		1BA5-3000AA...	
3BA3-300CC...		1BA3-3375AA...		3BA5-225CC...		1BA5-3375AA...	
		1BA3-4000AA...		3BA5-300CC...		1BA5-4000AA...	
		1BA3-5000AA...				1BA5-5000AA...	

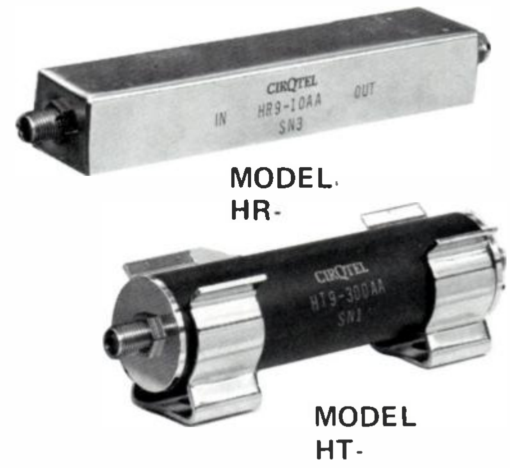
STANDARD HIGHPASS FILTERS

1 MHz to 400 MHz FREQUENCY RANGE

PART NUMBER DEFINITION

HR9 - 150 AA

- H: Highpass
- R: R — Rectangular; T — Tubular
- 9: Number of Elements
- 150: 1 dB Cutoff Frequency MHz
- AA: Connectors In/Out

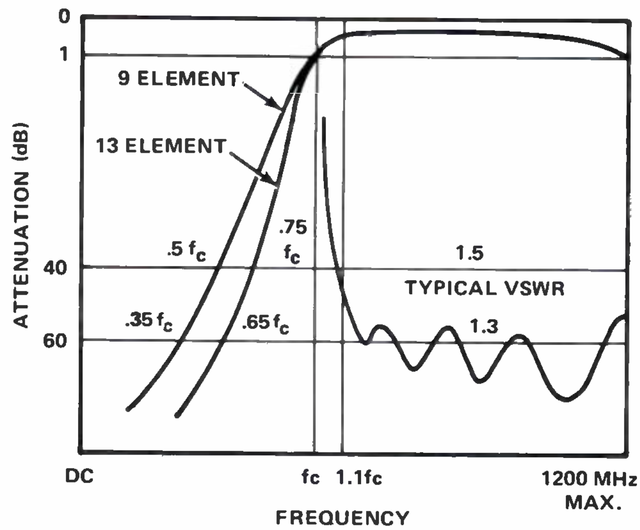


SPECIFICATIONS

CUTOFF FREQ. (f_c):	HR-1 - 200 MHz HT-250 - 400 MHz
CUTOFF FREQ.:	= 1 dB Max.
PASSBAND INSERTION LOSS:	
f_c = 1 - 20 MHz:	⩽0.5 dB 1.1 f_c to 10 f_c (500 MHz Max.)
f_c = 20 - 200 MHz:	⩽0.5 dB 1.1 f_c to 10 f_c (1000 MHz Max.)
f_c = 250 - 400 MHz:	⩽0.5 dB 1.1 f_c to 4 f_c (1200 MHz Max.)
ATTENUATION: (Nominal)	9 Element: ⩾60 dB @ .35f_c 13 Element: ⩾60 dB @ .65f_c
IMPEDANCE:	50 Ohms IN/OUT (Nominal)
VSWR:	⩽1.5:1 @ 1.1 f_c to Upper Passband Limit
DIMENSIONS:	HR - 3/4" W x 5/8" H x Length* HT - 7/8" or 1 1/8" OD x Length*
CONNECTORS:	OSM/SMA Jack Standard
OPTIONS:	HR - BNC, TNC, PC pins HT - BNC, TNC, N

NOTE: HU9 & HU13 Models, 1-1/8" O.D. available in place of HR — for tubular designs.

TYPICAL RESPONSE



HIGHPASS — 9 ELEMENTS

PART NO.	*L"	PRICE	PART NO.	*L"	PRICE
HR9-1AA	4	SEE CURRENT PRICE LIST	HR9-9.5AA	4	SEE CURRENT PRICE LIST
HR9-1.5AA	4		HR9-10AA	4	
HR9-2AA	4		HR9-20AA	4	
HR9-2.5AA	4		HR9-30AA	4	
HR9-3AA	4		HR9-40AA	4	
HR9-3.5AA	4		HR9-50AA	4	
HR9-4AA	4		HR9-60AA	4	
HR9-4.5AA	4		HR9-70AA	4	
HR9-5AA	4		HR9-80AA	4	
HR9-5.5AA	4		HR9-90AA	4	
HR9-6AA	4		HR9-100AA	4	
HR9-6.5AA	4		HR9-150AA	4	
HR9-7AA	4		HR9-200AA	4	
HR9-7.5AA	4		HT9-250AA	3	
HR9-8AA	4		HT9-300AA	3	
HR9-8.5AA	4		HT9-350AA	3	
HR9-9AA	4		HT9-400AA	3	

HIGHPASS — 13 ELEMENTS

PART NO.	*L"	PRICE	PART NO.	*L"	PRICE
HR13-1AA	6	SEE CURRENT PRICE LIST	HR13-9.5AA	6	SEE CURRENT PRICE LIST
HR13-1.5AA	6		HR13-10AA	6	
HR13-2AA	6		HR13-20AA	6	
HR13-2.5AA	6		HR13-30AA	6	
HR13-3AA	6		HR13-40AA	6	
HR13-3.5AA	6		HR13-50AA	6	
HR13-4AA	6		HR13-60AA	6	
HR13-4.5AA	6		HR13-70AA	6	
HR13-5AA	6		HR13-80AA	6	
HR13-5.5AA	6		HR13-90AA	6	
HR13-6AA	6		HR13-100AA	6	
HR13-6.5AA	6		HR13-150AA	6	
HR13-7AA	6		HR13-200AA	6	
HR13-7.5AA	6		HT13-250AA	4	
HR13-8AA	6		HT13-300AA	4	
HR13-8.5AA	6		HT13-350AA	4	
HR13-9AA	6		HT13-400AA	4	

STANDARD
COMBLINE
BANDPASS FILTERS

NOMINAL BUTTERWORTH RESPONSE

5 MHz-18 GHz (fo) RANGE FOR PROTOTYPE, LABORATORY AND GENERAL USE FIXED TUNED AT FACTORY CAN BE MANUALLY TUNED WITHIN fo RANGE

See Page 15

MODEL CB-
1-7/8" O.D.

MODEL CB-
7/8" O.D.

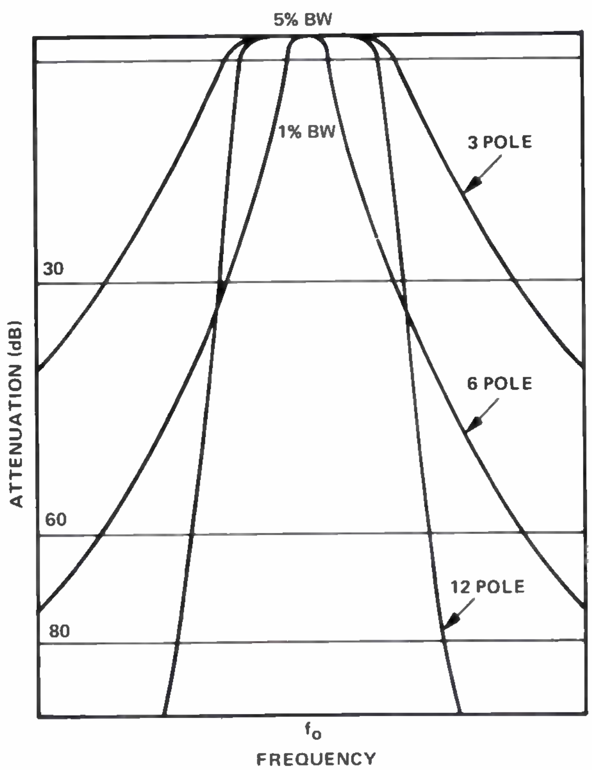
SPECIFICATIONS

CENTER FREQ'S:	5 MHz - 18 GHz
fo TUNING RANGE:	Up to 3:1, Most Models: 2:1
BANDWIDTH @ 3 dB:	1-5% of fo in steps of 1%
ATTENUATION:	Nominal Butterworth response
IMPEDANCE:	50 Ohms IN/OUT (nominal)
VSWR:	⩽1.5:1 @ f_0 and over 50% of passband minimum.
SIZE:	1/2"*, 5/8"*, 7/8", 1-1/8", 1-7/8", 2-1/2" OD. Depends upon f_0 & % BW. Higher freq. – smaller OD more poles & narrow BW are longer.
CONNECTORS: (Radial Only)	SMA/OSM Female Standard.
OPTIONS:	SMA Male, BNC, TNC & Type N *OSSM

CHASSIS MOUNT: PAD AND STUD IF REQUESTED AT ADDITIONAL CHARGE

*NOTICE — Miniature OSSM Type may be only type available on 1/2" & 5/8" OD Models.

TYPICAL RESPONSE



FIXED AND TUNABLE COMBLINE FILTERS

—Replace Heavy Interdigital and Cavity Filters in Your Designs—

—Write Your Own Part Numbers—

For Tunable Models

2CBB 78 - 3G - 8AA 4A or B (See Notes)

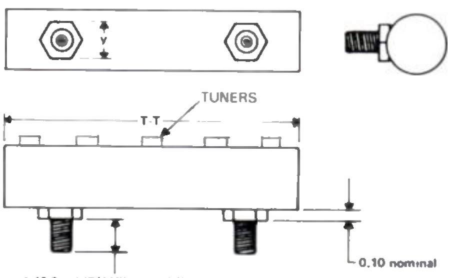
- 2: Tuning Range 2:1 Min.
- CB: Combline Bandpass
- B: Butterworth Response
- C: Chebyshev
- L: Linear Phase
- 78: O.D. Nom. 7/8 inch
- 3G: Low End of Tuning Range 2:1.3—6GHz
- 8: 8 Pole
- AA: Connectors SMA Female (Radial Std.)
- 4: % BW Nominal 3dB
- A: Mounting Style

For Fixed Tuned Models

CBB 78 - 4.5G - 6AA 3A or B (See Notes)

- CB: Combline Bandpass
- B: Butterworth Response
- C: Chebyshev
- L: Linear Phase
- 78: 7/8 Dia. Nom.
- 4.5G: f_o:4.5 GHz
- 6: 6 Pole
- AA: Connectors SMA Female (Radial Std.)
- 3: 3% 3 dB BW
- A: Mounting Style

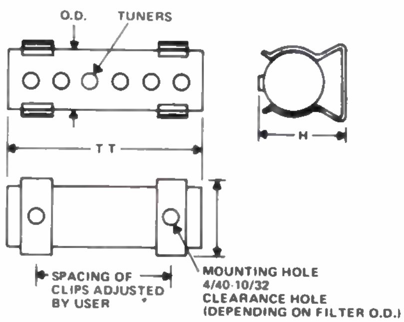
MOUNTING STYLE 'A'



4-40 Stud (3/16") up to 5/8" diameter
6-32 Stud (1/4") from 3/4 to 1-1/8" diameter
10-32 Stud (5/16") from 1-1/4 to 1-1/8" diameter
1/4-28 Stud (5/16") from 1-7/8 to 6" diameter

NOTE: 3-4 Studs on some units if required, or heavier studs may be supplied with more than 5-6 resonators, depending on weight, etc.

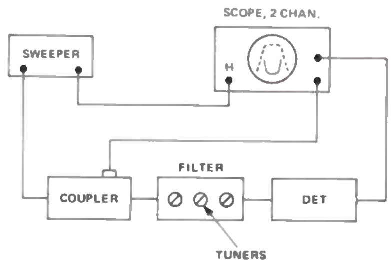
MOUNTING STYLE 'B' (for diameter ≤ 1.125 only)
SPRING-CLIP MOUNT



X & T-T VARY w/fo BANDWIDTH & 'n'

H	OD
3/4"	1/2"
1.1"	7/8 & 3/4"
1.3"	1-1/8"

TUNING/TEST-SET UP



ADJ. TUNERS IN-TO OUT
FOR VSWR/AMPL. RESPONSE
AT DESIRED FREQUENCY.
JEWELERS SCREWDRIVER ONLY

NOTE:

1. Clip mounts will be provided on 1/2", 7/8" and 1-1/8" O.D. units unless otherwise specified. Add $10.00 to price for mounting style A -please specify when ordering.
2. When Type A mount is specified, it will usually have a 'Y' dimension equal to O.D. or less
3. Square (hard mount) end blocks will add approximately 10% to filter price. —Special
4. O.D. sizes may in some instances vary slightly to optimize performance.
5. Standard 'n,' no. of resonators are 2, 3, 4, 5, 6, 8, 10, 12 and 15 on most models.
6. Insertion Loss, @ f_o dB depends heavily on f_o,% BW, n, type of design: Butterworth, Chebyshev, etc.
7. Length depends on $1/f_o$, n, 1/BW.
8. There are many other outer diameters available and we may, with your permission, or if required (at our option), change O.D. to optimize performance, loss, etc.
9. NA: Not available at time of this printing.
10. For fixed tuned units pick the lowest price unit out of the overlapping frequency column that includes your frequency of interest.

SEE
CURRENT
PRICE
LIST

DELIVERY

Super Hot:	3 to 10 days
Hot:	3 to 8 weeks
Standard:	16 weeks

CIRQTEL

THE ONE STOP SHOP

From 300 Hz ———————————— 30 Ghz

New Technology — CIR-Q-TEL, is — as always, on the leading edge since 1962

Exciting new things we've developed over the past year include:

1. Multiplexers to 18 GHz — & Beyond
2. Multiple Band Pass Filters: Two, Three or Four Passbands in a Single Filter
3. Multiple Band Reject Filters: Two, Three or Four Reject Bands in a Single Filter
4. Extremely Broad-Band High Pass Filters
   e.g. 10 MHz to Beyond 1 GHz, 100 KHz to Beyond 100 MHz
5. Very Broad Band Tunable Filters — up to 5:1 tuning range such as 200 MHz-1 GHz. 3:1 Range 1-3 GHz & 350-1050MHz Range :5MHz-18 GHz; n available : 2-12 Resonators.

These new designs include:

(a) Suspended substrate technology
(b) Unique frequency dependent damping of circuit elements for very broad band high pass filters.
(c) Unique very broadband isolation networks — for ultra broadband multiplexers
(d) Linear phase, Butterworth, Chebishev & Pseudo-Elliptic Properties.
(e) Power handling capabilities to >25 KW C. W. and >100 KW peak power.
(f) High Pass Filters: Some with >100:1 Pass Bands, all with >2:1 Passbands Extending to 30 GHz
(g) Sugar-Cube Sizes for Highpass and Lowpass Responses 40db/1.5:1 VSWR — Reject/Pass Band Ratios. of ≤1.06:1
(h) Diplexers, Triplexers, Quadruplexers from <100 KHz to 30 GHz in: Lumped element, Coaxial, Interdigital, Combline and Waveguide Manifolds

Connector/Connection Types: SMA, Cable, Solder Lug, P.C. Pins, N, BNC, TNC, SMC, HN, Coax Flanges and other Types
Impedance Levels: 600, 93, 75, & 50 Ohms at suitable frequencies.

Other Products Include: Voltage Variable Attenuators, Pin Diode switches, Multicouplers and Power dividers

Broad Band Power Dividers — 2 & 4 way: 10 MHz-1 GHz

Wide Band Solid State Switches: SP-DT & 5P-3T———2 MHz-2 GHz

PIN DIODE Attenuators 1.4-8 GHz to 25 DB, Continuous & Programmable

Digital Controlled Microwave Preselectors 2-18 GHz

Wideband Detector — Amplifier — Limiter: 2-18 GHz

Pulse Amplitude Digitizers

Multicouplers 30-1000 MHz: 8 & 10 WAY

The Pot's-abrewing & our warlocks are busy developing stranger Gadgets
Still, try 301-946-1800 for solutions to your tough filtering problems.

Your Local Representative

CIRQTEL, Inc. Standard Filters — Price List

CIRQTEL Capabilities extend from 300 HZ-30 GHZ. Amplitude/phase matching — phase linear. Tubular, interdigital, combline, lumped, coaxial, waveguide, suspended substrate, strip and micro-strip line

PART NO.	PRICE
1L25	$ 94
1L50	94
1L75	94
1L100	94
2L150	105
2L200	105
2L250	105
2L300	105
2L400	105
2L600	118
2L800	118
2L1000	131
2L1240	131
2L1600	147
LR9-1AA	100
LR9-1.5AA	100
LR9-2AA	95
LR9-2.5AA	90
LR9-3AA	90
LR9-3.5AA	84
— THRU —	84
	84
LR9-10AA	84
LR9-20AA	74
—THRU —	74
LT9-150AA	74
LR9-200AA	74
LT9-250AA	69
— THRU —	69
	69
LT9-1000AA	69
LT9-1100AA	74
LT9-1200AA	74
LT9-1400AA	74
LM9-1500AA	82
LM9-1600AA	82
— THRU —	82
	82
LM9-4000AA	82
LM9-4500AA	85
— THRU —	85
	85
LM9-8000AA	85
LM9-8500AA	88
LM9-9000AA	88
LM9-9500AA	88
LM9-10,000AA	88
LM9-10,500AA	99
LM9-11,000AA	99
LM9-11,500A	99
LM9-12,000AA	99
LM9-12,400AA	99
LM9-13,000AA	112
LM9-14,000AA	112
LM9-16,000AA	120
LR13-1AA	144
LR13-1.5AA	144
LR13-2AA	137
LR13-2.5AA	130
LR13-3AA	130
LR13-3.5AA	121
— THRU —	121
	121
LR13-10AA	121

PART NO.	PRICE
LR13-20AA	$ 107
— THRU —	107
	107
LR13-100AA	107
LT13-150AA	89
— THRU —	89
LM13-1900AA	89
LM13-2000AA	94
— THRU —	94
	94
LM13-4000AA	94
LM13-4500AA	100
LM13-5000AA	100
LM13-5500AA	109
LM13-6000AA	109
LM13-6500AA	109
LM13-7000AA	109
LM13-7500AA	109
LM13-8000AA	109
LM13-8500AA	113
LM13-9000AA	113
LM13-9500AA	113
LM13-10,000AA	123
LM13010,500AA	123
LM13-11,000AA	123
LM13-11,500AA	123
LM13-12,000AA	123
LM13-12,400AA	123
LM13-13,000AA	127
LM13-14,000AA	127
LM13-16,000AA	135
5BR4-1AA	99
5BR4-2AA	99
5BR4-3AA	99
5BR4-4AA	93
5BR4-5AA	93
5BR4-6AA	93
5BR4-7AA	93
5BR4-8AA	93
5BR4-9AA	93
5BR4-10AA	93
5BR4-20AA	93
5BR4-30AA	93
5BR4-40AA	93
5BR4-50AA	89
5BR4-60AA	89
5BR4-70AA	89
5BR4-80AA	89
5BR4-90AA	98
5BT4-100AA	98
5BT4-150AA	98
5BT4-200AA	95
5BT4-250AA	95
5BT4-300AA	95
5BT4-400AA	95
5BT4-450AA	95
5BR4-500AA	95
5BT4-550AA	95
5BT4-600AA	95
5BT4-650AA	95
5BT4-700AA	95
5BT4-750AA	95
5BT4-800AA	95
5BT4-850AA	95

PART NO.	PRICE
5BT4-900AA	$ 95
5BT4-950AA	95
5BT4-1000AA	95
5BT4-1100AA	95
5BT4-1200AA	95
5BT4-1300AA	95
5BT4-1400AA	95
5BT4-1500AA	95
5BT4-1600AA	95
5BT4-1700AA	95
5BT4-1800AA	95
5BT4-1900AA	95
5BM4-2000AA	105
5BM4-2200AA	105
5BM4-1400AA	105
5BM4-2600AA	105
5BM4-2800AA	105
5BM4-3000AA	115
5BM4-3200AA	115
5BM4-3400AA	115
5BM4-3600AA	115
5BM4-3800AA	115
5BM4-4000AA	115
5BM4-4500AA	115
5BM4-5000AA	115
5BMC-5500AA	150
5BMC-6000AA	160
5BMC-6500AA	170
5BMC4-7GAA	175
5BMC4-7.5GAA	180
5BMC4-8GAA	200
5BMC4-9GAA	220
5BMC4-10GAA	250
5BMC4-12GAA	290
5BR6-1AA	149
5BR6-2AA	149
5BR6-3AA	139
5BR6-4AA	134
5BR6-5AA	129
— THRU —	129
	129
5BR6-40AA	129
5BR6-50AA	121
— THRU —	121
	121
5BT6-150AA	121
5BT6-200AA	132
— THRU —	132
	132
5BT6-1000AA	132
5BT6-1100AA	139
— THRU —	139
	139
5BT6-1700AA	139
5BT6-1800AA	139
5BT6-1900AA	139
5BM6-2000AA	139
5BM6-2200AA	139
5BM6-2400AA	139
5BM6-2600AA	139
5BM6-2800AA	149
5BM6-3000AA	149
5BM6-3200AA	149
5BM6-3400AA	154

PART NO.	PRICE
5BM6-3600AA	$ 154
5BM6-3800AA	154
5BM6-4000AA	154
5BM6-4500AA	154
5BM6-5000AA	154
5BMC6-5500AA	192
5BMC6-6000AA	192
5BMC6-6500AA	214
5BMC6-7GAA	265
5BMC6-7.5GAA	276
5BMC6-8GAA	287
5BMC6-9GAA	294
5BMC6-10GAA	308
5BMC6-12GAA	347
1BR4-1AA	135
1BR4-2AA	131
1BR4-3AA	129
1BR4-4AA	123
1BR4-5AA	119
— THRU —	119
	119
1BR4-40AA	119
1BR4-50AA	111
1BR4-60AA	111
1BR4-70AA	109
1BT4-80AA	109
1BT4-90AA	109
1BT4-100AA	112
1BT4-150AA	112
1BT4-200AA	117
— THRU —	117
	117
1BT4-650AA	117
1BT4-700AA	125
1BT4-750AA	125
1BT4-800AA	125
1BT4-850AA	125
1BT4-900AA	125
1BT4-950AA	125
1BM4-1000AA	133
1BM4-1100AA	133
1BM4-1200AA	133
1BM4-1300AA	133
1BM4-1400AA	133
1BM4-1500AA	133
1BM4-1600AA	155
1BM4-1700AA	155
1BM4-1800AA	158
1BM4-1900AA	161
1BM4-2000AA	167
1BM4-2200AA	175
1BM4-2400AA	175
1BM4-2600AA	175
1BM4-2800AA	175
1BM4-3000AA	182
1BM4-3200AA	197
1BM4-3400AA	205
1BM4-3600AA	205
1BM4-3800AA	245
1BMC4-4000AA	341
1BMC4-6GAA	453
1BR6-1AA	181
1BR6-2AA	171

Intermediate Frequencies Available With All Models At Comparable Prices.

need a system band-aid? dial 301-946-1800

4/80 50K

CIRQTEL, Inc. Standard Filters — Price List

since Jan. 1962 — Designs for: Bessel, Butterworth, Chebishev, Elliptic, Gaussian, Pseudo-Elliptic, Zolotarev, Zobel and custom shaping of responses.
Multiple pass bands, Multiple reject bands, Diplexers, Multiplexers, Tunables — 3 MHZ to 18 GHZ, Switches, Voltage variable attenuators, Multicouplers.

PART NO.	PRICE
1BR6-3AA	$ 161
1BR6-4AA	159
1BR6-5AA	159
1BR6-6AA	159
1BR6-7AA	159
1BR6-8AA	159
1BR6-9AA	159
1BR6-10AA	159
1BR6-20AA	159
1BR6-30AA	159
1BR6-40AA	159
1BR6-50AA	151
1BR6-60AA	151
1BR6-70AA	151
1BR6-80AA	151
1BR6-90AA	153
1BT6-100AA	165
1BT6-150AA	165
1BT6-200AA	165
1BT6-250AA	151
1BT6-300AA	151
1BT6-350AA	151
1BT6-400AA	151
1BT6-450AA	151
1BT6-500AA	151
1BT6-550AA	151
1BT6-600AA	151
1BT6-650AA	151
1BT6-700AA	167
1BT6-750AA	167
1BT6-800AA	167
1BT6-850AA	167
1BT6-900AA	167
1BT6-950AA	167
1BM6-1000AA	174
1BM6-1100AA	174

PART NO.	PRICE
1BM6-1200AA	$ 174
1BM6-1300AA	174
1BM6-1400AA	179
1BM6-1500AA	179
1BM6-1600AA	179
1BM6-1700AA	193
1BM6-1800AA	193
1BM6-1900AA	234
1BM6-2000AA	234
1BM6-2200AA	235
1BM6-2400AA	235
1BM6-2600AA	235
1BM6-2800AA	235
1BM6-3000AA	264
1BM6-3200AA	264
1BM6-3400AA	276
1BM6-3600AA	289
1BM6-3800AA	334
1BMC6-4000AA	412
1BMC6-6GAA	516
B. .13-10.7AA	85
B. .13-21.4AA	85
B. .13-30AA	85
B. .13-60AA	85
B. .13-70AA	85
B. .13-120AA	89
B. .15-10.7AA	109
B. .15-21.4AA	109
B. .15-30AA	109
B. .15-60AA	109
B. .15-70AA	109
B. .15-120AA	109
3BA3-7.5CC	251
3BA3-11.25CC	251

PART NO.	PRICE
3BA3-15CC	$ 251
3BA3-22.5CC	251
3BA3-30CC	253
3BA3-45CC	260
3BA3-75CC	265
3BA3-112.5CC	265
3BA3-150CC	265
3BA3-225CC	251
3BA3-300CC	251
3BA3-450CC	251
3BA3-600AA	251
3BA3-750AA	251
1BA3-1125AA	251
1BA3-1500AA	251
1BA3-1800AA	251
1BA3-2250AA	251
1BA3-2700AA	251
1BA3-3000AA	251
1BA3-3375AA	268
1BA3-4500AA	284
1BA3-7500AA	304
3BA5-7.5CC	355
3BA5-11.25CC	328
3BA5-15CC	317
3BA5-22.5CC	306
3BA5-30CC	300
3BA5-45CC	300
3BA5-75CC	300
3BA5-112.5CC	300
3BA5-150CC	300
3BA5-225CC	300
3BA5-300CC	300
3BA5-450CC	300
3BA5-600AA	300
3BA5-750AA	300

PART NO.	PRICE
1BA5-1125AA	$311
1BA5-1500AA	311
1BA5-1800AA	311
1BA5-2250AA	340
1BA5-2700AA	340
1BA5-3000AA	340
1BA5-3375AA	365
1BA5-4500AA	370
1BA5-7500AA	390
HR9-1AA	120
HR9-1.5AA	110
HR9-2AA	110
HR9-2.5AA	105
HR9-3AA	100
	100
— THRU —	100
HT9-400AA	100
HR13-1AA	140
HR13-1.5AA	137
HR13-2AA	135
HR13-2.5AA	132
HR13-3AA	130
— THRU —	130
	130
HR13-80AA	130
HR13-90AA	131
HR13-100AA	131
HR13-150AA	133
HR13-200AA	135
HT13-250AA	137
HT13-300AA	139
HT13-350AA	139
HT13-400AA	146

Price for F_H/F_L	2-2.5	2.51-3.5	3.51-5	5.1-8	8.1-10
5 Pole WBR5	135	144	158	188	214
5 Pole WBT5	118	139	150	175	200
9 Pole WBR9	170	182	182	214	238
9 Pole WBT9	148	163	175	207	225

Operating Range (Fixed) — or — Minimum Tuning Range (Tunable) (MHz)	O.D.[8] Nom (Inches)	COMBLINE PRICE — NOMINAL BUTTERWORTH RESPONSE UNITS						
		2 Pole Fixed/Tunable	3 Pole Fixed/Tunable	4 Pole Fixed/Tunable	5 Pole Fixed/Tunable	6 Pole Fixed/Tunable	8 Pole Fixed/Tunable	10 Pole Fixed/Tunable
3 - 6	3	10[illegible] / 270	295 / 340	290 / 425	NA	NA	NA	NA
4 - 8	3	180 / 260	275 / 310	280 / 390	NA	NA	NA	NA
5 - 10	3	150 / 195	190 / 250	230 / 305	270 / 350	NA	NA	NA
7.5 - 15	3	150 / 190	[illegible] / 250	220 / 295	250 / 340	NA	NA	NA
10 - 20	3	140 / 195	[illegible] / 225	210 / 280	240 / 330	NA	NA	NA
15 - 30	2 1/2	140 / 195	[illegible] / 225	210 / 275	240 / 320	260 / 360	NA	NA
20 - 40	2 1/2	140 / 195	[illegible] / 225	210 / 275	240 / 320	260 / 360	NA	NA
30 - 60	2 1/2	135 / 180	[illegible]	205 / 275	235 / 320	260 / 360	NA	NA
50 - 100	2 1/2	135 / 180	[illegible]	195 / 275	235 / 320	255 / 360	NA	NA
75 - 150	2 1/2	135 / 10[illegible]	[illegible]	175 / 275	230 / 315	255 / 355	NA	NA
80 - 160	2 1/2	135 / 150	[illegible]	195 / 275	230 / 315	255 / 355	NA	NA
100 - 200	2	135 / 180	[illegible]	195 / 275	230 / 315	255 / 355	280 / 440	NA
125 - 250	2	135 / 180	[illegible]	195 / 275	230 / 315	255 / 355	290 / 440	320 / 620
150 - 300	2	135 / 180	[illegible]	195 / 290	230 / 315	255 / 355	290 / 450	320 / 635
175 - 350	2	140 / 195	[illegible]	195 / 270	240 / 325	265 / 370	290 / 450	340 / 635
200 - 400	2	140 / 190	[illegible]	240 / 320	265 / 360	290 / 395	320 / 495	385 / 635
225 - 450	2	140 / 190	[illegible]	240 / 320	265 / 360	280 / 395	340 / 495	380 / 635
250 - 500	2	140 / 190	205 / [illegible]	240 / 310	265 / 360	280 / 395	340 / 480	385 / 630
300 - 1000	2	150 / 220	20[illegible] / [illegible]	240 / 320	270 / 370	285 / 405	340 / 490	395 / 645
400 - 1200	1 3/4	150 / 220	200 / 285	240 / 320	270 / 370	285 / 405	340 / 490	385 / 634
500 - 1500	1 3/4	150 / 225	200 / 285	240 / 320	270 / 370	285 / 405	340 / 490	385 / 645
600 - 1750	1 1/2	150 / 215	190 / 275	235 / 320	265 / 365	285 / 405	340 / 490	385 / 640
700 - 1800	1 1/2	150 / 215	190 / 275	235 / 320	265 / 365	285 / 405	340 / 490	390 / 640
750 - 1900	1 1/4	150 / 215	180 / 275	235 / 320	266 / 365	285 / 405	340 / 490	390 / 640
800 - 2000	1 1/4	160 / 225	190 / 275	235 / 320	265 / 380	285 / 405	340 / 490	390 / 640
900 - 2100	1 1/4	160 / 225	190 / 275	230 / 320	255 / 360	285 / 405	340 / 490	390 / 640
1000 - 2400	1 1/8	160 / 225	190 / 2[illegible]	230 / 320	255 / 260	295 / 410	345 / 495	390 / 640
1200 - 2600	1 1/8	165 / 235	190 / 280	230 / 320	255 / 360	295 / 410	350 / 495	395 / 690
1300 - 2800	1 1/8	165 / 235	180 / 280	230 / 370	255 / 355	295 / 410	350 / 505	395 / 640
1500 - 3500	1	165 / 235	200 / 2[illegible]	240 / 330	255 / 360	295 / 410	350 / 505	405 / 640
1600 - 3800	1	170 / 245	200 / 290	240 / 330	255 / 380	295 / 410	350 / 505	415 / 640
1700 - 3900	1	170 / 245	200 / 290	240 / 330	255 / 360	285 / 410	350 / 505	415 / 630
1900 - 4100	1	170 / 245	220 / 300	245 / 340	260 / 375	290 / 430	350 / 505	415 / 825
2000 - 4500	1	175 / 250	225 / 305	250 / 345	275 / 380	305 / 445	365 / 505	430 / 620
2500 - 5500	1	180 / 260	230 / 315	265 / 365	285 / 295	315 / 465	380 / 525	430 / 630
2.75G - 6.5G	7/8	190 / 275	230 / 325	270 / 365	290 / 400	320 / 480	385 / 580	430 / 630
3.0G - 6.0G	7/8	200 / 325	230 / 335	275 / 370	300 / 410	325 / 480	390 / 580	440 / 630
3.2G - 6.4G	7/8	220 / 335	240 / 340	280 / 380	300 / 420	330 / 480	390 / 580	450 / 640
3.5G - 7.5G	7/8	245 / 335	265 / 350	295 / 380	320 / 450	350 / 520	395 / 590	450 / 660
4G - 9G	3/4	250 / 340	280 / 370	310 / 405	330 / 460	355 / 525	400 / 600	465 / 670
5G - 11G	3/4	250 / 350	285 / 390	320 / 430	350 / 475	375 / 545	420 / 630	470 / 680
6G - 13G	3/4	260 / 375	290 / 400	330 / 440	360 / 495	390 / 560	435 / 640	475 / 700
7G - 15G	5/8	280 / 390	295 / 430	360 / 465	380 / 510	410 / 580	455 / 660	495 / 730
8G - 16G	5/8	300 / 415	335 / 450	385 / 495	415 / 548	435 / 590	485 / 670	530 / 750
9G - 18G	5/8	300 / 435	385 / 520	430 / 550	470 / 595	515 / 635	580 / 715	NA
12G - 18G	3/8	300 / 415	385 / 490	430 / 540	470 / 580	515 / 620	560 / 685	NA

Band pass, Lowpass, Highpass and Band reject
High power filters in coaxial & wave guide up to 25 kw average & 100 kw peak
The one stop shop for filters
Prices subject to change, verify with factory

MINIMUM INVOICE $100

CIRQTEL Custom Highpass Filters from 500MHZ-18GHZ

Speedy delivery available, at additional cost, for small quantities

3 days	**3 weeks**
1 week	**4-8 weeks**
2 weeks	

5% discount for check with order!

CIRQTEL, Inc.
10504 Wheatley Street
Kensington, Maryland 20795
301-946-1800
TWX 710-823-0521

CIRQTEL
Sales Representatives

No. California
MK: V Assoc.
415-964-6275

Long Island
No. NJ So. Conn.
Spectrum Sales
914-997-1166

Fla. and Ga.
Snow Company
305-563-2448
Ft. Lauderdale, Fla.

International
(except Canada)
Ad-Auriema
Suite 1829
One World Trade Center
New York, New York
212-938-0930

Synthesizer Techniques

A review of synthesizer techniques as they relate to the basic Phase Lock Loop (PLL) synthesizer, the mixer PLL synthesizer, the prescale PLL synthesizer and dual modulus prescale PLL synthesizer.

*Harold E. Myers, P.E.**
SAB Harmon Industries
Grain Valley, Md.

The synthesis of radio frequencies represents a technological advance in communication that is comparable to DeForest's vacuum tube or the development of Single Sideband Communication. In recent years frequency synthesis has become widespread with its applications touching all our lives. Applications of synthesizer technology can be found in the televisions, FM stereo receivers, AM radios and other entertainment equipment we find within our homes. Still other applications of frequency synthesis are found in the aviation, marine, space and terrestrial communication industries.

Frequency synthesis first came into existence in the 40's and embodied many crystal oscillators, mixers and filters. In these early generations of equipment, two signals were mixed together to produce two others, and in turn those two were mixed with other signals to produce even more, and so on. To produce a large number of individually selected frequencies with reasonable spectrum quality, many crystal oscillators, mixers and filters were necessary. Although these instruments represented a major advance in the technology of frequency generation, the instruments themselves were large, restricting their use to the laboratory or engineering environment. Technological advances in the 50's allowed for major reductions in the physical size of the instruments, but still not to the point that synthesis could be conveniently used in field application.

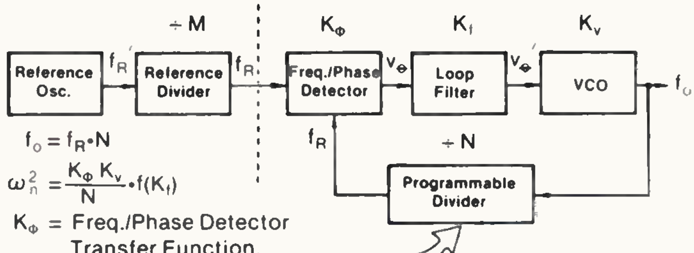
Phase Lock Loops

Phase lock loop technology is simply a unique application of modern (closed loop) control system theory. Define a closed loop as "A circuit whose output is the net result of the circuit input, the forward transfer function of the circuit, and a modified portion of the output fed back to the input of the circuit."

Basic PLL Synthesizer

The *Basic PLL Synthesizer* represented in block diagram form (Figure 1) has six functional blocks. These six functional blocks are the *reference oscillator* and *reference divider* which generate the desired input reference frequency (f_r) to the phase lock loop, and the *Frequency/*

**This is an edited version of a copyrighted article by Harold E. Myers, 1980.*



$f_o = f_R \cdot N$

$\omega_n^2 = \frac{K_\Phi K_v}{N} \cdot f(K_f)$

K_Φ = Freq./Phase Detector Transfer Function.
K_f = Loop Filter Transfer Function.
K_v = V.C.O. Transfer Function.
N = Programmable Divide Ratio.
ω_n = Loop Natural Frequency.

Figure 1. Phase Lock Loop Synthesizer.

Phase Comparator, Loop Filter, Voltage Controlled Oscillator (VCO) and *Programmable Divider* which comprise the phase lock loop. Each of these blocks is unique in its function and purpose and collectively they make up the synthesizer.

Reference Oscillator

The *Reference Oscillator* has often been called the "Heart of the Synthesizer" because it establishes the stability performance characteristics of the synthesizer output. Generally the oscillator will operate between 1 MHz and 11 MHz where high quality fundamental crystals can be obtained. The actual frequency that is chosen depends upon many factors such as the overall design approach, performance requirements of the synthesizer, other uses within the radio for the oscillator, etc. As noted in the block diagram the reference oscillator produces an output frequency (f_r') which is the input to the reference divider.

Reference Divider

The *Reference Divider* function is to reduce f_r' to f_r, the loop reference frequency, and is simply a circuit that produces one output pulse for a predetermined number of input pulses. The ratio of the input pulses received for one output pulse is defined as the *divide ratio*. The divide ratio can quickly be defined given the reference oscillator output frequency and the desired loop reference frequency. As an example, assume that f_r' is 10 MHz (10×10^6 PPS) and that f_r is to be 5 kHz (5×10^3 PPS) then M the divide ratio is:

$$M = \frac{f_r'}{f_r} = \frac{10 \times 10^6 PPS}{5 \times 10^3 PPS} = 2000$$

In the vast majority of cases M is a fixed number and for the purpose of this writing it shall be treated as such. It is worth noting however, that in some specialized cases M can vary. In either case, the divide ratio must always be an integer. As noted previously, the reference oscillator and divider produce the desired reference input frequency (f_r) for the phase lock loop.

Frequency/Phase Comparator

The *Frequency/Phase Comparator* uses the reference input frequency (f_r) as a standard for comparison with the signal fed back from the loop output. The Frequency/Phase Comparator produces an output voltage which is proportional to the amount of frequency/phase difference between the two input signals, with a voltage sense that is related to the lead/lag relationship of the two signals. The frequency/phase to voltage transfer function is defined as KØ and in most cases is a linear function. Many types of circuit configurations have been derived to accomplish this task. These range from simple flip-flops or 4 bit up-down shift registers to complex sample/hold circuits or combinational logic circuits with charge pumps. In today's technology frequency/phase comparator circuits are available as integrated circuits.

Loop Filter

The *Loop Filter* receives from the frequency/phase comparator a proportional voltage signal as its input. In turn it provides a signal voltage to the voltage controlled oscillator (VCO) for controlling the frequency of oscillation. As the voltage passes thru the loop filter, it is filtered to reduce any residual components of the reference frequency and amplified to provide the proper control voltage range. In addition the loop filter is used to control the loop gain/bandwidth characteristics. Actual loop filter implementation encompasses technologies ranging from lump constant L-C filters to state-of-the-art negative impedance operational amplifier/filter circuits. The transfer characteristics of the loop filter is defined as K_f and is constant within any given design.

Voltage Controlled Oscillator

The *Voltage Controlled Oscillator* or *VCO* as it is commonly referred to can be simply described as an oscillator whose frequency is controlled by an external voltage source. The usual means of varying the oscillator frequency is through the use of a voltage variable capacitor in the oscillator tank circuit. The transfer function Kv of the oscillator is a very important design consideration in the PLL and is a measure of the change in oscillator frequency for a corresponding change in input control voltage. This function is not constant with respect to frequency, although in recent times considerable improvements have been made in voltage variable capacitor characteristics to improve the linearity of this transfer function. The nature of this function is such that at the low end of the oscillator frequency range the transfer function or sensitivity is the largest and decreases as frequency increases. The oscillator output is used as an injection source in the radio and as an input signal to the synthesizer programmable divider.

Programmable Divider

The *Programmable Divider's* function is to reduce the VCO output frequency (f_o) to the loop reference frequency (f_r). It is very similar to the reference divider with one exception, its divide ratio is programmable over a range of values. The advantage of this becomes obvious with a simple example. Assuming that f_r is 5 kHz and that the desired VCO output frequency is 160 MHz, then the programmable divide ratio N will be:

$$N = \frac{f_o}{f_r} = \frac{160 \times 10^6 Hz}{5 \times 10^3 Hz} = 32000$$

Since the divider is programmable, it can be set up to divide by 32000. It can also be programmed for a divide ratio of 32001 or 31999 or any other value within the divide ratio range. The output frequency of the VCO will change in increments of f_r, as indicated below.

Divide Ratio (N)	VCO Frequency (f_o)
.	.
32002	160.010 MHz
32001	160.005 MHz
32000	160.000 MHz
31999	159.995 MHz
31998	159.990 MHz
.	.

To generate or synthesize a new frequency from the PLL all that is necessary is to change the divide ratio of the programmable divider.

In the early days of phase lock loop synthesizers, logic speed was limited to about 10 or 12 MHz. With special techniques this could be extended somewhat but not above 18 MHz. This limited the maximum synthesizer output frequency to 18 MHz.

In addition, loop dynamics varied greatly over the operating range of the loop. This is evidenced by a review of the formula for the loop's natural frequency (ω_n) given by:

$$\omega_n^2 = \frac{K\Phi\, K_v}{N} \cdot f(K_f)$$

Where: KØ = Freq./Phase Detector Transfer Function
K_f = Loop Filter Transfer Function
K_v = V.C.O. Transfer Function
N = Programmable Divide Ratio

KØ and Kf are constant in the formula for any specific design and, therefore, will not influence the dynamics of ω_n over the tuning range of the synthesizer. K_v and N, however, are divergent variables; as N decreases K_v increases and vice versa. Because K_v is in the numerator and N is in the denominator of the equation, ω_n will vary greatly over the range of N and the corresponding K_v. These wide variations cause the *gain/bandwith* products of the loop to vary greatly and affect the overall stability of the loop and the loop lock time.

Mixer PLL Synthesizer

The Mixer PLL Synthesizer (Figure 2) is very similar to the PLL already discussed with the exception of a mixer between the VCO and the programmable divider. The mixer loop produces two advantages for the designer that the basic loop cannot offer, namely operation of a VCO at frequencies much higher than the speed capability of the programmable divider and reversal of the 'N' divide

A Programmable Cavity Oscillator?

The Measure of Excellence Continues with the AILTECH 460 Signal Generator

If you're a believer in instrument versatility, you'll want to know more about the new AILTECH 460 Signal Generator.

Using the same instrument, now you can experience the low noise performance of a cavity generator in a programmable frequency synthesizer. The AILTECH 460 takes you from initial development through your production ATE operation, and it's no longer necessary to settle for a noisy synthesizer incapable of providing selectivity and spurious measurements at the expense of giving up programmability.

Not only is the 460 a low noise source, but check the AM performance—100% at levels to +13 dBm.

If that isn't enough, it has FM, φM, output power from +20 to −140 dBm, from 0.3 MHz to 650 MHz and an optional 1300 MHz range at +10 dBm to −140 dBm.

Complete with Spin-Wheel Tuning, the AILTECH 460 not only operates like a Signal Generator, but also delivers Synthesizer accuracy tied to its internal 10 MHz frequency standard.

Why not see the 460 in action in the convenience of your own laboratory. Simply call or write Eaton Corporation, Electronic Instrumentation Division, 2070 Fifth Avenue, Ronkonkoma, New York 11779, (516) 588-3600 today... and don't forget to ask about our new equipment leasing plan.

EATON Advanced Electronics

ratio to stablize loop dynamics. Since mixing is strictly a translation process, the other characteristics of the loop are retained.

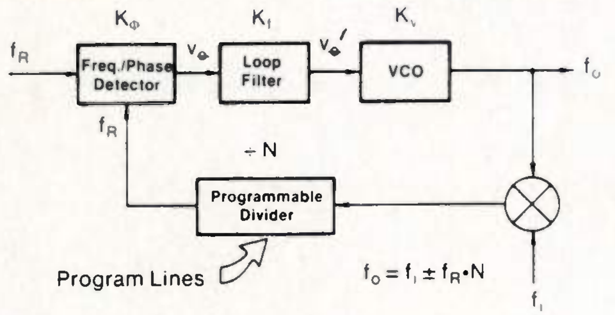


Figure 2. Mixer PLL Synthesizer.

With this technique, a VCO output in the VHF spectrum is heterodyned into a frequency range compatible with the speed capability of the programmable divider. In addition, by choosing the mixer injection frequency (f_i) above that of the VCO output frequency (f_o) the sense of N is reversed, such that as K_v increases, N also increases, greatly reducing ω_n variations over the loop operating range. The net result is a phase-locked loop that operates with a much higher output frequency and reduced variation of loop dynamics. The obvious disadvantage is that another signal has to be provided in the form of a mixer injection (f_i) and the characteristics of this injection are directly transferred to the loop output. This injection is typically provided by another crystal oscillator or by harmonic multiplication of the reference oscillator, or in some cases another phase-lock source.

Prescale PLL Synthesizer

With the appearance of high speed logic, direct divide ratios could be obtained in both the VHF and UHF range. In addition, technological advances have taken place in the voltage controlled oscillator area that allowed for an almost linear oscillator transfer function. These achievements contributed to the development of a *Prescale PLL Synthesizer* shown in Figure 3.

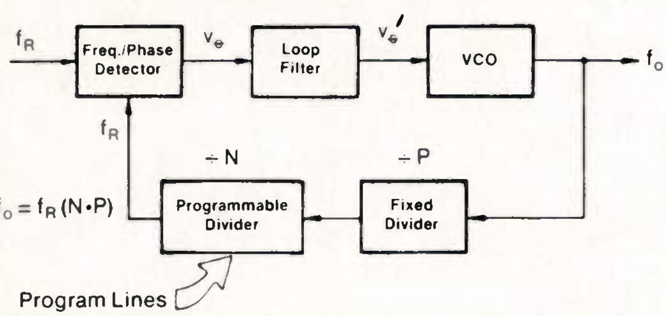


Figure 3. Prescale PLL Synthesizer.

Unfortunately, however, these high speed dividers are not programmable and, therefore, had to be handled as mathematical constants within the loop formulas. The net result is the loop reference frequency has to be reduced by a factor equal to the *prescale ratio P*. Using our previous example where f_r was 5 kHz, if the prescale ratio P is 10, then the new f_r will have to be 500 Hz to insure that the VCO output frequency still moves in 5 kHz increments. Because of the lower reference frequency the loop filter bandwidth characteristics have to be reduced thereby extending both loop response time and loop lock time.

Dual Modulus Prescale PLL Synthesizer

Some of the latest developments in synthesizer technology have taken place in the area of high speed programmable divider logic and control logic. In the divider logic area a device known as the *Dual Modulus Prescaler* which can provide divide ratios of P or P + 1 have been developed. Synthesizers that use this type of circuitry therefore are referred to as *Dual Modulus Prescale PLL Synthesizers*. The uniqueness of this type of synthesizer can be understood by referring to Figure 4 during the following explanation.

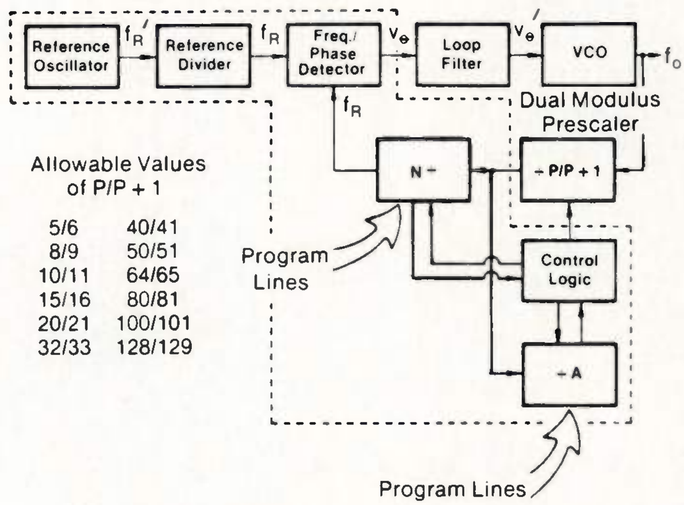


Figure 4. Dual Modulus Prescale PLL Synthesizer.

Assume that it is desired to have an output frequency (f_o) of 160.015 MHz from the loop VCO and that the loop reference frequency (f_r) is 5 kHz, the required *Total Divide Ratio TDR* is given as:

$$TDR = \frac{160.015 \times 10^6 \text{ Hz}}{5 \times 10^3 \text{ Hz}} = 32{,}003$$

Assume further that the values for P/P + 1 are chosen to be 20/21. This particular choice is somewhat arbitrary and it should be remembered that the specific value chosen is dependent upon the individual designer's specific requirements and what hardware is available to him. Presently available values for P/P + 1 are indicated in Figure 4. In any event, the value chosen for this example is 20/21.

The key to achieving the proper total divide ratio lies in the P + 1 function which the dual modulus prescaler can provide. If the total divide ratio is divided by the P modulus the quotient obtained is the N program value and the remainder is the A program value for the synthesizer. For our example:

$$\frac{TDR}{P} = \frac{32{,}003}{20} = 1600 \text{ with a remainder of } 3$$

Resulting in N = 1600
A = 3

Total Divide Ratio = (P + 1)A + P(N-A)
32,003 = (21 x 3) + (20 x 1597)

When the dual modulus prescale PLL synthesizer is programmed with these numbers the loop will operate in the following manner:

The divide by N counter is programmed to output a pulse for every 1600 input pulses it receives. The divide by A counter is programmed to output a pulse for every 3 input pulses it receives. The P/P + 1 divider is initially set to divide by 21, i.e. output one pulse for every 21 input pulses it receives. The output of the P/P + 1 divider is connected to the inputs of both the N and A dividers.

Pulses are received at the input of the P/P + 1 divider and after 21 input pulses it will produce an output pulse to the N divider and A divider. This same sequence will repeat itself two more times at which time, after three input pulses to the A and N divider the A divider will output a pulse to the control logic. This A divider output pulse instructs the control logic to change the divide ratio of the P/P + 1 divider from 21 to 20. In addition the A counter is inhibited from any further counting until such time as it is reset thereby eliminating any additional A divider output pulses from being sent to the control logic.

Input pulses to the P/P + 1 counter continue to produce output pulses at a ratio of 20:1. The necessary number of additional P/P + 1 divider output pulses needed to produce an output pulse from the N divider is 1597 (1600-3). When this number of pulses have been produced by the P/P + 1 divider the N divider produces one output pulse which is sent to the frequency/phase comparator. In addition this pulse is sent to the control logic indicating that the total count sequence is complete. The control logic initiates the reset of all divider logic to restart the divide sequence. The process is repeated.

Had another set of values been chosen for P/P + 1 the sequence would remain the same, only the program values of N and A would change. As an example, if the value 15/16 had been chosen for the values for P/P + 1, the program value for N would be 2133 and the program value for A would be 8 to achieve the total divide ratio of 32,003.

In the dual modulus prescale PLL synthesizer variation of both the N and A program values is necessary to operate the loop over its full frequency range. The advantage of this type of loop is its ability to directly divide high frequency VCO output signals without the restriction of fixed modulus prescale. This maintains the loop reference frequency (f_r) at its maximum value and permits the loop response time and lock time to be minimized.

Interfaces

A review of synthesizer techniques would not be complete without an examination of the radio interfaces to the synthesizer. These interfaces play an important role in defining the operational and performance specification for a synthesizer, thereby influencing the design philosophy of any specific synthesizer. The number of interfaces is dependent upon the features and performance required in the radio product. The following is a brief examination of a number of these interfaces that are common in all applications.

Control Interface

The *Control Interface*, also referred to as the *Logic Interface*, provides to the synthesizer the required program logic to establish the desired output frequency. As noted previously, the output frequency of the synthesizer is determined by the total divide ratio of the programmable divider(s). It is the function of the control interface to

Fluke introduces two new advanc synthesized signal generators you

With 20 years experience in RF instrumentation, we're driving down the cost of high performance.

The 6070A and 6071A are designed to fill a critical gap in today's signal generator market: the price/performance gap that separates $10,000 synthesizers with limited capabilities from the more sophisticated, state-of-the-art units costing $25,000 and up. As such, they represent a new generation of RF synthesizers from Fluke that deliver the industry's most-wanted features at a very affordable price.

Innovative design achieves signal purity and broad frequency coverage.

Fluke engineers developed a number of unique and cost-effective synthesis techniques for the 6070A and 6071A that deliver a high degree of spectral purity without sacrificing broadband range.

The frequency range of the 6070A is 200 kHz to 520 MHz and the 6071A extends the range to 1040 MHz. Yet both instruments have spurious output levels of 90 to 100 dB below carrier, performance equalling or exceeding the best cavity-tuned generators on the market today. Microprocessor control — which Fluke introduced to signal generator design in 1975 with the 6010A — allows precision resolution and settability you can't find from any other manufacturer.

Fluke's new approach to synthesis in the 6070A and 6071A combines several unique elements: a refined single loop de-

***Internal modulation** is fully programmable from 20 Hz to 200 kHz with 3 digits resolution. The generators can also function simultaneously as signal generators and independent audio oscillators — two instruments in one.*

***Pinpoint frequency tuning** provided by optically coupled, magnetically detented spin knob. Combines digital precision with the speed and convenience of analog control.*

***Built-in, easy-to-program IEEE-488** interface ties the signal generator capability of the instruments to the power of automated system control. Talk/listen capability provides "learn" and "teach" modes.*

***Output level adjustable** in 0.1 dB steps from + 19 dBm (13 dBm above 520 MHz) to -140 dBm — displayed in dBm or volts and in relative or absolute units.*

...ed technology ...can specify with confidence.

...sign that both improves reliability and lowers maintenance costs; a Surface Acoustic Wave (SAW) device to achieve low noise performance; and a delay line discriminator in a phase-locked loop that improves spectral purity and increases the modulation flexibility of the instruments.

A major emphasis on packaging design minimizes RF leakage and insures spectral purity during servicing. Fluke's own thick film hybrids improve RF performance and keep the parts count low. And a high efficiency power supply helps reduce weight, volume and heat rise.

Versatile modulation brings you two instruments for the price of one.

AM, FM and ØM are internally selectable. Modulation frequencies from 20 Hz to 200 kHz can be selected. Modulation can be applied separately or simultaneously for frequency, amplitude or phase, and the internal signal can also be used as an independent signal source, separate from the RF output, giving the user two instruments — a signal generator and an audio oscillator — in one high performance package.

A high deviation mode of up to 1 MHz or 100 radians is provided for frequency of phase modulation. External dc coupling for AM and FM is also available.

More microprocessor benefits.

The advanced 16-bit microprocessor control of the 6070A and 6071A makes these signal generators easy to operate and a pleasure to use.

Complex functions are executed rapidly from simple, direct keyboard commands.

A remarkably fluid-feeling spin knob gives even greater precision and control by allowing you to tune around any frequency, amplitude or modulation parameter, or spin quickly to another setting: rapid-tuning convenience with digital precision.

A built-in memory for storage of front panel set-ups is provided to save time and reduce operator errors. And the 6070A and 6071A also include a relative units function that allows you to define a zero point for subsequent programming, useful in both the frequency and amplitude domains.

Both instruments are IEEE-488 programmable for complete system use. Plus self-diagnostics, error code displays, digital sweep and other special functions combine to simplify testing in any RF design application. A full line of options and accessories is available to expand the capabilities of the 6070A and 6071A.

For more information on these new signal generators, call toll free **800-426-0361,** use the coupon below or contact your nearest Fluke sales office.

FLUKE®

INFO/CARD 15
For technical data circle no.

Fast-Response Coupon

IN THE U.S. AND NON-EUROPEAN COUNTRIES:	IN EUROPE:
John Fluke Mfg. Co., Inc. P.O. Box 43210 MS #2B Mountlake Terrace, WA 98043 (206) 774-2481 Telex: 152662	Fluke (Holland) B.V. P.O. Box 5053, 5004 EB Tilburg, The Netherlands (013) 673973 Tlx: 52237

☐ Please send me complete 6070A specifications and applications literature.
☐ Send information on other IEEE products.
☐ Have a Sales Engineer contact me for a demonstration.

Name ______________________
Title ______________ Mail Stop ________
Company ______________________
Address ______________________
City ____________ State ______ Zip ______
Telephone ( ) ____________ Ext. ______

provide to the synthesizer the proper program logic word(s) to establish the proper divide ratio(s) in the programmable divider(s).

The specific logic word(s) used in any particular design are unique to that design. Elements involved in defining the specific program words are:

Type of CODE	BCD, Binary, Gray, etc.
Code FORMAT	Word length, Bit location, etc.
READ Format	Serial, Parallel, Series-parallel
DYNAMICS	Refresh, Static
AUXILIARY Bits	Special flags for secondary control

The structure of the program word used to control a synthesizer may be defined by the type of hardware available to the designer or by the specification restrictions placed on the product. In most cases the program word used is a result of a combination of these two considerations in varying degrees.

The implementation of the control interface has been accomplished in a variety of ways. In its simplest form control interfaces have been made using toggle switches. In its most complex form microprocessors have been used. Between these extremes, designers have used combinational logic, coded rotary and thumbwheel switches, PROM's, ROM's, RAM's, card readers and code converters to directly program synthesizers. In combination these methods have been used to indirectly program synthesizers.

VCO Output Interface

The *VCO Output Interface* provides to the radio the proper injection frequencies for receiver and transmitter operation. The actual frequencies and range of frequencies required from the synthesizer VCO is dependent upon how these injections will be used in the radio. As a case in point, the output frequency required for the receiver injection can vary by 21.4 MHz, dependent upon whether high side or low side injection is used at the first mixer to establish a 10.7 MHz IF.

Elements involved in establishing the VCO output interface requirements, and indirectly the control interface requirements, are:

Injection	High side, Low side, On channel
IF	Audio, 455 kHz, 10.7 MHz, 21.4 MHz, etc.
Scheme	Multipliers, On frequency
Modulation	AM, FM, PM, SSB, ISB, CW, etc.

Decisions relative to the VCO output interface are in most cases strongly influenced by other design considerations within the radio to achieve the required performance.

Loss-of-Lock Interface

The *Loss-of-Lock Interface* is usually provided to advise the receiver, transmitter and operator that the synthesizer is out of phase lock. This signal is used to inhibit the transmitter from transmitting and quiets or blanks the receiver. In addition, it has been used to provide a visual indication to the radio operator that the synthesizer is out of lock.

Other Interfaces

Thus far we have examined three of the most important interfaces that exist between a radio and a synthesizer; to be sure there are other interfaces that exist. They are, however, not as directly associated with synthesizer techniques as those examined. A list of the other interfaces might include the power supply, reference oscillator output, loop mixer injection, etc. □

H.O. Granberg
Motorola Semiconductor Products Inc.
Phoenix, Arizona

Good RF Construction Practices and Techniques

Categories considered include Device Selection; Emitter Inductance; Amplifier Instability; Single, Parallel or Push-Pull Configurations and Thermal Design.

Many designers of RF equipment with vacuum tubes or solid-state small signal equipment are not familiar with solid-state RF power design, and the importance of many aspects in developing the hardware. It is true that the same rules apply in each case, but the physical construction of RF power circuits is much more critical due to the low input impedance levels involved. The importance of these aspects are frequency, supply voltage and power level dependency. For a given supply voltage the input impedances are about equal for UHF at 10-15 watts, VHF at 35-40 watts and HF at around 100 watts. This means that the impedance levels of properly selected devices for each application (except the output) are nearly equal, but the RF currents are a function of the power level. Thus, it can be deduced for example that equal emitter inductances, in common emitter operation, can be tolerated in each case.

Selecting The Device

RF power transistors are being made for three basic supply voltages: 12.5V (12-15.5V) for land mobile and marine applications; 28V (24-32V) and 50V (40-50V) for aircraft, military and base stations. The high voltage devices have higher collector resistivities than the ones designed for low voltage operation, and the emitter ballast resistors have higher values. Devices designed for high voltage operation can be used at lower voltages, but not vice-versa. This would result in saturation at a lower power level than normal, but will give a rugged design. An example of this is a high level AM modulated amplifier, where the breakdown voltages must be high enough not to be exceeded by the modulation peaks.

UHF devices have a thinner epitaxial layer than parts designed for VHF and the same is true from VHF to HF. The higher frequency devices also use much finer geometries than the lower frequency devices, resulting in higher f_T and higher power gain. It is not recommended in general, that a UHF or VHF device be used at HF frequencies, except at reduced supply voltages and reduced power levels. Even then, stability problems may be encountered due to the high power gain. A 2N3866 is a popular low level driver at HF, but some power gain must be sacrificed by heavy emitter feedback. Going the opposite way, HF devices are often used at VHF and VHF devices at UHF in applications where a low gain stage (3-6 dB) is required. Most newer RF power transistors are specified to withstand infinite load mismatches under a variety of operating conditions. However, this is providing that the maximum total dissipation rating is not exceeded. This can happen if the device goes into self oscillation, usually a circuit oriented problem. The total dissipation is specified under RF conditions, and does not mean that the device can be DC biased up to that point at the operating voltage, although some devices could survive it. All transistors can be used for linear operation providing the power output is kept low to avoid the saturation knee. Devices specified for linear operation employ a much larger die for this reason, and have been specially processed to improve the linearity of the transfer curve.

Other important factors to consider are the input Q and matching of devices for push-pull or parallel systems. The input Q determines the broadband performance of the device, especially at the higher frequencies. For broadband application a low Q device should be selected. The Q is primarily determined by the ratio of the reactive and resistive components (X_S/R_S). The output Q is usually much lower and is not the limiting factor in most cases. Device matching should be done on power gain for class B and C, and in addition on h_{FE} and V_{BE} forward voltage for class A and AB. The power gain follows the h_{FE} to a great extent as long as the device is not saturated, and in most instances, at lower frequencies 10-15 percent h_{FE} matching is considered sufficient.

The Emitter Inductance

For simplicity we will only discuss the common emitter amplifier configuration. It should be realized that in a common base circuit, the base inductance is equally critical. To obtain the maximum power gain of a given device, the emitter-to-ground inductance must be kept as small as possible. This inductance outside the transistor consists of the transistor lead inductance to ground and the impedance of the circuit board ground plane. In most good designs it is necessary to employ a double-sided circuit board where a continuous ground plane is provided at the bottom side of the board. This is electrically accessible by feed-through eyelets or plated-through holes around the transistor mount opening, near the emitter area. For even better performance, the transistor mount opening in the board can be wrapped around with straps of metal foil, connecting areas on the top of the

board to the ground plane. To minimize the lead inductance, the transistor mount opening in the circuit board, which is necessary to allow the device to be attached to a heat sink, should not be made larger than necessary for a given package type. If the lead inductance is converted to reactance at the frequency of operation, its effect can be compared to that of an equal value resistance between the emitter and ground. This will allow us to calculate the actual gain loss in each case.

The transistor wire bond and lead frame inductance are fixed parameters, and can only be changed by selecting a device in the physically smallest package that will do the job. Sometimes the same transistor die is available in various package styles such as the standard .380 SOE,* .500 SOE, or plastic TO-220. For a given die, it would be possible to obtain the highest power gain out of the .380 style since the internal package inductance is lower than in the two other cases. Also, the stud-mounted packages, although not as good thermally as a flange type, allows closer access to the ground plane, since openings for the flange ears in the circuit board are not required.

In a push-pull configuration the emitter-to-ground inductance becomes non-important, and this path only provides the DC supply to the devices. Analyzing the push-pull operation reveals that the RF current is now flowing from emitter to emitter. For this reason, the devices should be physically mounted as close to each other as possible. If this cannot be done due to an existing circuit layout or other reasons, some improvement can be obtained by connecting all the emitters together with a wide metal strip over the transistor caps. With flange-mounted parts, each emitter can be connected to the flange using solder lugs or wire loops under the mounting screws, enabling the heat sink to provide a low inductance connection between the emitters. For push-pull operation at UHF, special eight lead packages have been developed, where the two transistor die are attached next to each other, thus limiting the emitter to emitter inductance to that of the bonding wires. This is probably the only practical approach to UHF push-pull techniques at higher power levels.

Amplifier Instability

There are many reasons for an amplifier stage to reach conditions

*Stripline Opposed Emitter

of instability. Sometimes it is device oriented, depending upon the amount of feedback capacitance compared to the electrical size of the device, and the phase angle of the feedback. Somewhere higher than the operating frequency the feedback phase angle will be 360°, and if the device F_T is high enough, it will oscillate. The oscillations may occur only at reduced drive levels or reduced supply voltage. In most cases it can be remedied by lowering the Q of the input circuit or making the tank circuit Q higher.

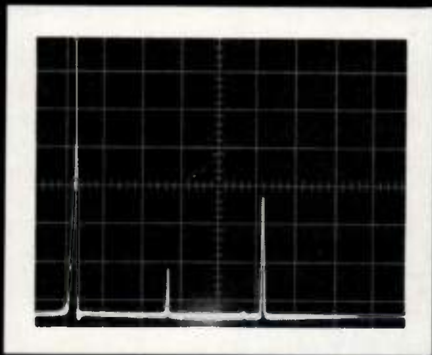
The so called half F_0 instability is fairly common with VHF and UHF amplifiers. It is more or less device oriented and is caused by a varactor effect in the base-collector junction diode or a combination of it and the base-emitter junction diode. The half F_0 usually occurs at reduced supply voltages in 12.5V systems, at some specific drive level, which indicates that when the diode DC bias is reduced, the junction capacitance will be increased, and the RF voltage swing will drive it into a parametric mode. The amplitude of the half F_0 can be reduced or sometimes totally eliminated by narrowing the system bandwidth.

Another possible cure for both problems above is de-Q'ing the base bias choke (Class B, C). This can be done with a high μ ferrite bead in line with the choke or an external low value resistor in parallel with it.

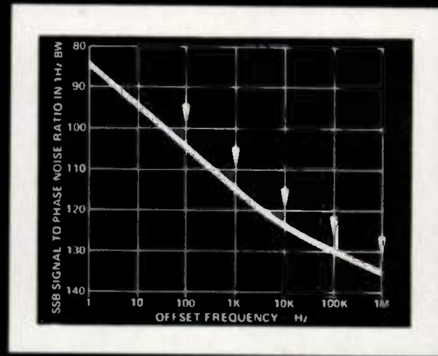
Low frequency instability is probably the most troublesome mode of self-oscillation. It usually occurs at audio frequencies or VLF, where the device has extremely high power gain. Since its oscillation is broadband in nature, it results in high collector currents, and often the device is destroyed by overdissipation. Causes for the low frequency instability are usually inadequate collector DC feed bypassing or an extremely poor ground in that area. Two or three RF chokes together with various values of bypass capacitors from 1000 pF to several μF may be required in the DC line to stabilize the circuit. (See examples in Reference 1.)

Negative feedback through an RLC network from the collector to the base will reduce the device gain at low frequencies, and is found to be helpful on many occasions. The above modes of instability can be present when the amplifier is operated into a proper load. In addition, instabilities usually occur when operated into a mismatched or reactive load. The general rule is: The higher the stage gain, the less stable it can be under these conditions. This naturally

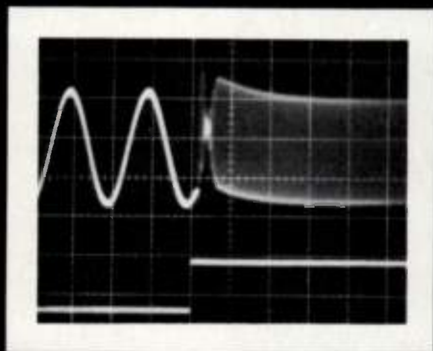
Take the direct approach.



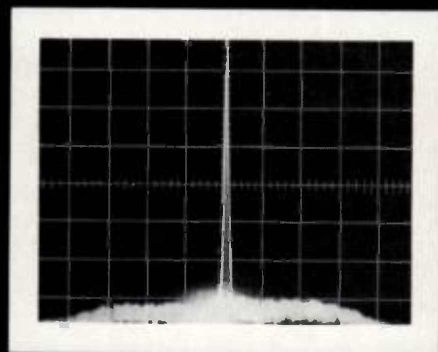
Low Harmonics



Low Phase Noise



Fast Switching



Low Spurious

Our 160MHz frequency synthesizers outperform PLL designs, at lower-than-PLL prices.

The 5600 progammable frequency synthesizer provides *direct synthesis* from 0.1 to 160mHz. Yet it's priced lower than many PLL designs in its range.

That's real value, especially when you consider the exceptional precision and performance characteristics it offers: outstanding spectral purity (−70dB spurious, −35dB harmonics, and −70dB phase noise), fast switching (20 μs), constant resolution (no multipliers), and uniformly tight output leveling (±0.5dB).

The 5600 includes full remote digital programmability. GPIB is available as an option. For even greater value there's the 5610A, our remote-only version for OEM applications.

Contact us or your nearest Wavetek Rockland sales representative for complete data or a demonstration.

Wavetek Rockland, Inc.
Rockleigh Industrial Park
Rockleigh, NJ 07647
(201) 767-7900

WAVETEK®/ROCKLAND

Demonstration — INFO/CARD 21 Literature — INFO/CARD 37 assumes, that the amplifier is not unstable for reasons discussed earlier. A reactive load can be present in the form of a low-pass filter, and if not properly designed, will cause amplifier instabilities. A good solution to analyze the stability is presented in Reference 2. An amplifier can be tested for stability using a load mismatch simulator. (Figure 1).

L and C values will of course depend on the frequency of operation. Typically C_1 and C_2 are equal and L_1 has twice the value of L_2. The circuit should have a point, which presents a complete short and a complete open circuit and all phase angles between, which can be verified using a vector impedance meter. Attenuators can be connected between the simulator and the amplifier to limit the maximum mismatch. For example: A 3 dB attenuator would represent 6 dB return loss, limiting the VSWR to 3:1. Similarly a 2 dB attenuator would give about 4.5:1 maximum mismatch. A directional coupler and a spectrum analyzer can be used to monitor the amplifier behavior. Stability under a 3:1 mismatch is usually considered sufficient for most purposes.

Single-Ended, Parallel or Push-Pull

Each of the above configurations has its own application with regards to frequency spectrum, bandwidth and power level. A single-ended narrow-band amplifier design usually produces optimum performance of the device. These circuits are employed when power gain or other information is compiled for a device data sheet, or if an amplifier for single frequency operation is required. Lump constant matching networks can be used up to about 200 MHz and stripline designs are common at 150 MHz and up, and in fact are the most practical design concepts at UHF and microwave. With proper techniques, it is possible to achieve bandwidths of one octave or more. Tapered line or step line approach, where the line impedance varies exponentially per unit length, or a number of quarter wave lines in series, having various characteristic impedances, is widely used for this purpose. A disadvantage is that the physical layouts become rather bulky at frequencies below 500 MHz, unless substrate material with a high dielectric constant is used. (Reference 3.)

At lower frequencies, up to 100 MHz, broadband transformer matching techniques are only practical at 40-50W power levels at 12.5V or 90-100W levels at higher supply voltages. The low impedance levels and the high RF currents involved, make it difficult to adequately by-pass the transformer ground returns.

Between 100 and 200 MHz, broadband designs are difficult to implement. Lumped constant matching networks can be used, but since several sections in the input and output are required, production repeatibility may be poor. The etched air line inductors described in Reference 4 may be the best solution to this problem.

In the past it was considered poor practice to directly parallel transistors in order to obtain higher power levels. This was mainly because of uneven current sharing

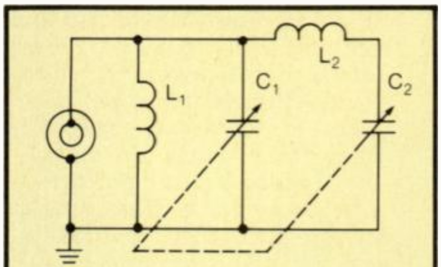


Figure 1.

between the devices, which usually led to thermal runaway and destruction of one device. However, most RF power transistors are now emitter ballasted with a built-in resistor for each emitter site. This minimizes the problem, but it is also difficult to design low loss matching networks for the reduced input and output impedance levels. Thus, the direct paralleling of transistors is not recommended in general. Paralleling may be done in such manner, that the input and output impedance of each unit are first transformed to some intermediate level or directly to 100 ohms, where the inputs and outputs are then paralleled. The best way to generate higher power levels with low power transistors is to use 50 ohm in-out "building blocks" of which any number can be combined by in-phase, quadrature or hybrid couplers. (References 5, 6, 7, 8.) This also provides isolation between the individual amplifier units.

Push-pull configuration has several advantages over single-ended amplifiers:

1. Even harmonic suppression.
2. Easier input-output matching due to higher impedance levels.
3. Emitter grounding and collector DC feed by-passing less critical.
4. Automatically combines the powers of two devices.

A push-pull circuit can be designed as a narrow-band system using lumped constant elements, or using stripline techniques at higher frequencies. These circuits are rather critical however, and require extreme symmetry between each side. A broadband circuit, using RF transformers is much more tolerable in this respect due to the tight coupling possible between the transformer windings. Push-pull circuits of this type have been designed up to 150 MHz or higher, depending on the power level and supply voltage. With proper transformer design, several octave bandwidths can be achieved. Other means of designing push-pull circuits include: a) A quarter-wave balun to provide the unbalanced to balanced function and 180° phase shift for two single-ended amplifiers, b) Two single-ended amplifiers, of which one is fed directly, while the other one is fed through a delay line, providing a 180° lag in phase at the frequency of interest. The same must be done at the output. Quarter-wave lines are commonly used for this purpose. Both a) and b) operate only within a narrow bandwidth, since the phase angle varies with frequency. The latter method is especially adaptable to UHF and higher frequencies, where the lines will be of moderate length. a) and b) also differ from conventional push-pull designs, discussed earlier, in that the phase shifting is done at the 50 ohm impedance levels rather than at the base and collector directly.

Thermal Considerations

On the reliability viewpoint it is important that the transistor die temperature is kept below a certain limit. This varies slightly with different geometries, but 160-165°C is usually considered the maximum recommended. Take the MRF422 as an example, which has a junction-to-case thermal resistance ($R_{\Theta JC}$) of 0.6°C/W. If the transistor is operated at 150W dissipation, the case temperature should not exceed: $(T_J - (P_D R_{\Theta JC}) = 165 - (150X0.6) = 75°C$. The $R_{\Theta JC}$ number published in data sheets is an average, and actually varies with power dissipation (Reference 9). Considering the thermal resistance of the heat sink, which most manufacturers specify as from the mounting surface to ambient, but do not specify the mounting suface area, the heat sink ambient temperature must be considerably cooler than 75°C. Thus, the $R_{\theta JC}$ of a heat sink actually depends on the transistor package style. An aluminum heat sink with surface thickness of 0.25" was tested. Its temperature was measured three inches from the transistor, which was mounted directly on the surface. The temperature was kept at 25°C with forced air cooling. With the 150W dissipation the transistor case temperature rose to 72°C. The case to ambient temperature then is:

$$\frac{\Delta T_{SA}}{Pd} = \frac{72\text{-}25}{150} = 0.31\,°C/W.$$

The die temperature is $T_J - (T_C - T_C') = 165 - (75 - 72) = 162°C$. The same measurement was done using a copper block of 2" x 2" x 0.125" as a heat spreader under the transistor. The case temperature was measured at 58°C, and the thermal resistance decreased to (58 − 25)/150 = 0.22°C/W, and the die temperature was lowered to 148°C. The 150W dissipation is hardly realistic under normal operating conditions, but can be reached during a load mismatch. Regarding the above data, more attention should be paid to the heat sink material and not only its size. □

References

1. Motorola RF Data Manual.
2. R. Jack Frost, "Large-Scale S Parameters Help Analyze Stability." *Electronic Design*, May 24, 1980.
3. "RCA Power Circuits, DC to Microwave," Technical Series SP-51, 1969.
4. Granberg, "A Simplified Approach to VHF Power Amplifier Design." Application Note AN-791, Motorola Semiconductor Products Inc.
5. Chen Y. Ho, "Design of Lumped Constant Quadrature Couplers." *Microwave Journal*, Sept. 1979.
6. Harlan Howe, Jr. "Simplified Design of High Power, N-Way In-Phase Power divider/Combiners." *Microwave Journal*, Dec. 1979.
7. Granberg, "Broadband Transformers and Power Combining Techniques for RF." Application Note AN-749, Motorola Semiconductor Products Inc.
8. Dufour, "60 Watt VHF Amplifier Uses Splitting/Combining Techniques." Engineering Bulletin EB-93, Motorola Semiconductor Products Inc.
9. Robert J. Johnsen, "Thermal Rating of RF Power Transistors." Application Note AN-790, Motorola Semiconductor Products Inc.

A High Isolation RF Switch

A dual gate DMOSFET RF switch with 65 dB of isolation at 100 MHz and low insertion loss is described.

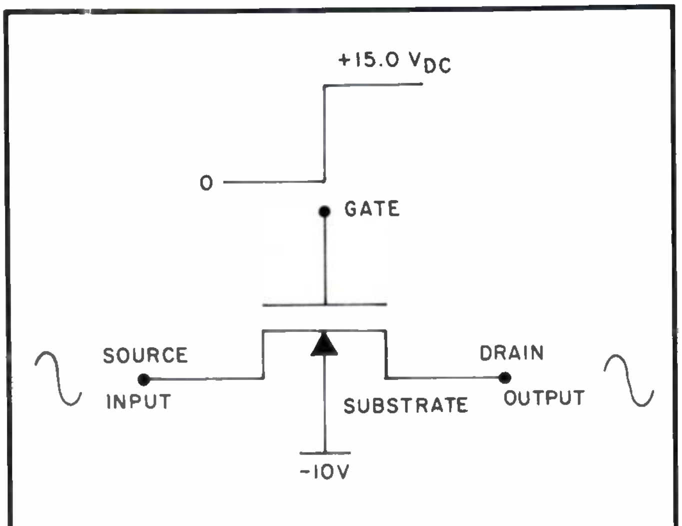


Figure 1.

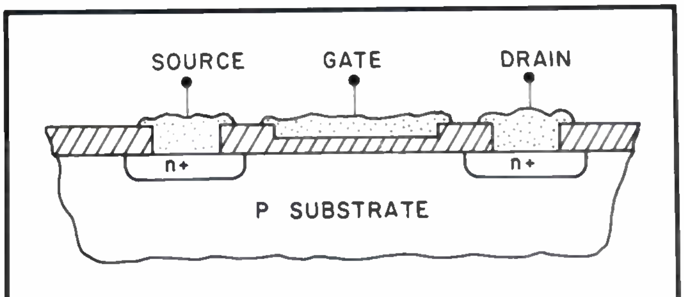


Figure 2.

Ed Fong
Consultant, Signetics
Santa Clara, CA

In recent years the popularity of electronic entertainment products operating in the VHF spectrum have saturated the consumer market. These include VHF receivers, cable television, video tape machines, and video games. In these circuits, low frequency techniques cannot be used. At the present time, broadband RF switching is accomplished mechanically, by pin diodes or by manually changing input cables. The mechanical switch results in high electrical losses, mechanical failures and difficulty in remote control switching. A double pole single throw mechanical version costs around $10.00 and a multiple input version costs much more. Therefore, most home hobbyists are left with manually changing coax cables each time they desire a different input. This article describes a technique using a dual gate DMOSFET for RF switching. It offers 65 dB of isolation at 100 MHz with minimum insertion loss and is usable up to 300 MHz. It is TTL open collector compatible and thus the switching signal can come from a microcomputer or other logic control circuitry. The key lies in a technology known as DMOS[1,2] (double diffused metal oxide semiconductor). The circuit proposed here is a four input/single output RF switch. This technique can be expanded to more inputs if desired. Although ideal for switching RF video signals, it is a general RF switch capable of handling a 2 volt P-P signal.

Design Considerations in an RF Switch

Conventional MOS transistor switches have been in the market over ten years. Figure 1 illustrates a typical configuration for an analog switch.

When + 15.0v is applied to the gate, the device turns on. The signal is fed into the source and the output is taken at the drain. This circuit has three disadvantages:

1. The substrate must be biased more negative than the most negative portion of the signal to avoid current flow to the bulk. From the device structure, which is shown in Figure 2, it is obvious that if the source to substrate dropped more than 0.7 volts, the forward biased PN-diode junction would allow current flow. Thus the scheme shown in Figure 1 requires a negative bias at the substrate for proper operation.

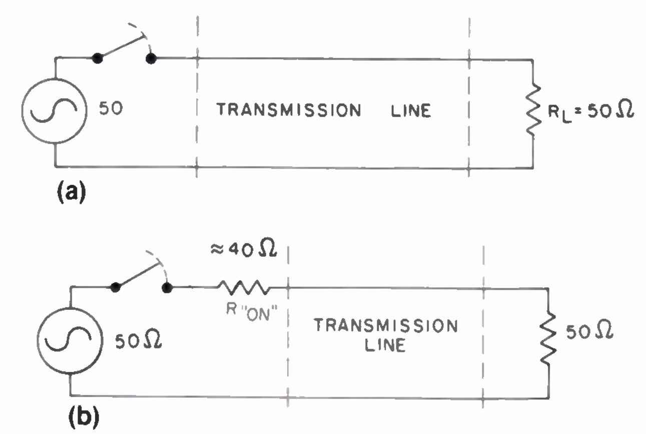


Figure 3.

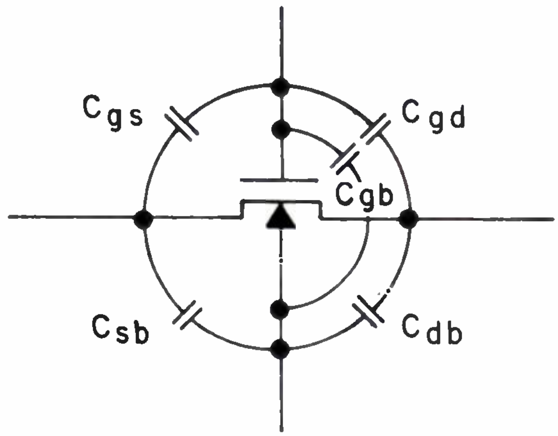


Figure 4.

2. The switch is unlike a true mechanical switch in that the series resistance is not 0.0 ohms when the trigger voltage is applied. This gives an insertion loss which may be intolerable in low impedance systems. In the SD210 series* the "on resistance" is about 40 ohms. In an audio system where the line impedance is 600 ohms, the additional "on resistance" in series with the line is perhaps acceptable. However, in a 50 or 75 ohm system, the addition of this impedance will result in insertion losses and mismatch problems. A circuit model of an ideal switch is shown in Figure 3a. No insertion loss is included in the presence of the switch.

A model considering the "on resistance" produced by the active switch is shown in Figure 3b.

The figure illustrates that only about half the voltage appears across the load. The total power into the system is:

$$P = \frac{V^2}{2R_T} \quad (1)$$

The power into the load is:

$$P_{\sim} \frac{\left(\frac{V}{2}\right)^2}{R_L} = \frac{V^2}{4\,R_L} \quad (2)$$

Therefore, only half of the original power is delivered to the load. The mismatch will also create standing waves in the transmission line resulting in "ghost" if the information is video and multipath distortion if the information is audio.

3. It is advantageous to obtain a switch which has very low "on resistance" for low impedance systems. This requires an extremely large switching device or multiple devices in parallel. However, the stray capacitances in the system will increase proportionally.

A model of a DMOS with stray capacitance is given in Figure 4.

*Signetics product.

The major capacitance which determines the isolation in Figure 1 is C_{ds} (drain to source capacitance). This capacitance is a combination of C_{gs}, C_{gd}, C_{sb} and C_{db}. It cannot be removed by circuit techniques or by changing the control voltage. Typically in a SD210 device, this capacitance is on the order of 2.0 pFd. This produces an impedance of about −j800 ohms at 100 MHz. Thus whether the switch is "ON" or "OFF", a reactive term of −j800 ohms is always present. This corresponds to about 12 dB of isolation at 100 MHz in a 50 ohm system. If two devices are paralleled, the "on resistance" will be halved but the isolation capacitance will double, thus losing another 3 dB of isolation. The trade-offs in such a scheme is either low "on resistance" with poor isolation or moderate "on resistance" with moderate isolation. Either choice is not adequate for most applications at VHF.

An Active Broadband RF Switch

It is apparent from the above discussion that some "on resistance" will always be present. In a 50-75 ohm system the scheme described above is impractical unless the "on resistance" can be reduced to under 5 ohms. This will take on the order of ten devices in parallel and the associated capacitance will be 20 pFd. The isolation will then only be a few dB. Thus one is led to an active switching scheme where input/output matching can be varied and "ON" resistance is not a factor. A single channel active RF switch is shown in Figure 5.

Figure 5 is basically a common source amplifier using a DMOS device. R2 and R3 are large value resistors used for biasing. The switch is activated by the control signal at R2. R1 is used for matching and is determined by the system impedance. R4 should also be matched to the system impedance which also determines the gain ($A_v = -gm \cdot R_L$). Thus a compromise must be made between

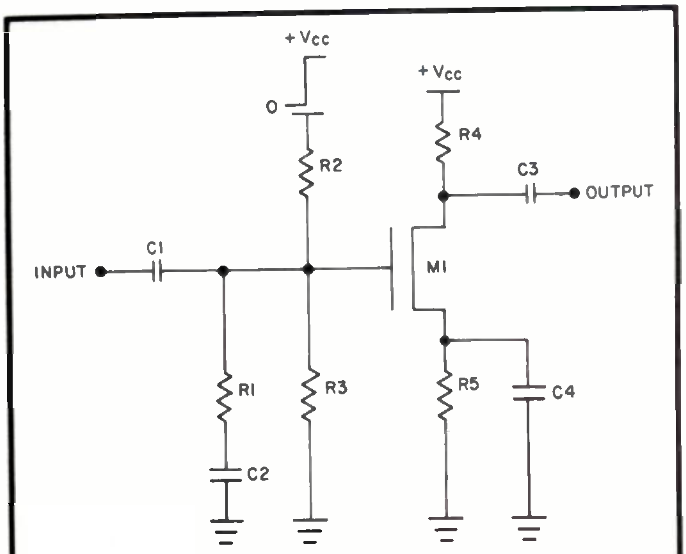


Figure 5.

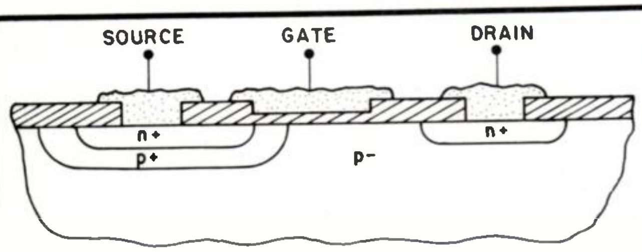


Figure 6.

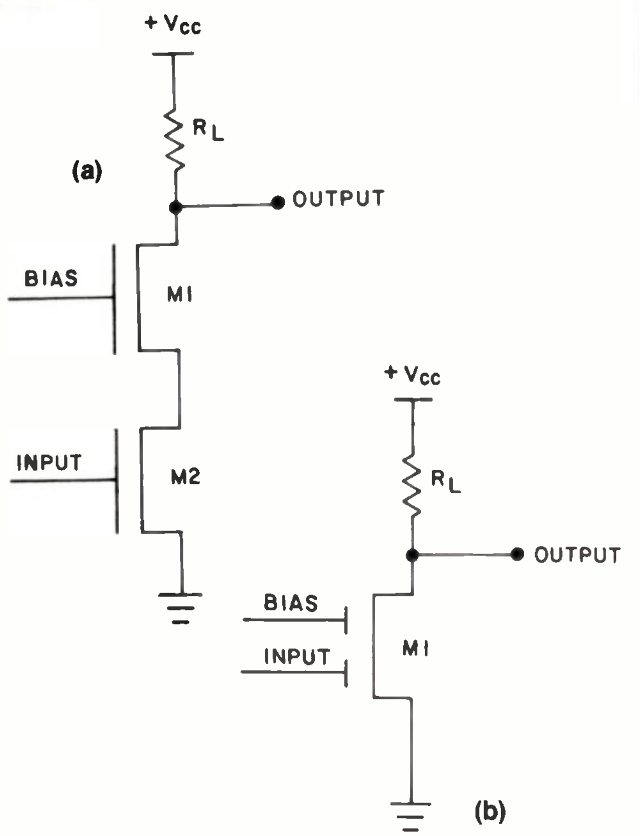


Figure 7.

system losses and matching. For R4 = 75 ohms, the gain is approximately unity for a SD200 DMOS device.* DMOS's are an ideal choice for this application since in a common source configuration their f_T is approximately 1.5 GHz. As a high frequency amplifier, it easily performs above 500 MHz. As previously discussed, low capacitance is the key for good input/output isolation. In the SD200 series the associated capacitances are:

$$C_{gs} \sim 3.0 \text{ pFd}$$
$$C_{ds} \sim 2.0 \text{ pFd}$$
$$C_{gd} \sim 0.2 \text{ pFd}$$

Notice that the gate-to-drain capacitance is extremely low. It is about one magnitude smaller than the other stray capacitances. Thus it is advantageous to have the input signal at the gate and the output signal at the drain for good isolation. This will give an "OFF" impedance of about 8K ohms. The reason for this is best demonstrated by a sideview of a DMOS device shown in Figure 6. Notice that the gate and drain are separated by a P region. This increases the gate to drain distance and thus decreases the associated capacitance. Breakdown voltages are also increased due to the larger distance between the source and drain.

Other advantages of this structure have been discussed in the literature[1,2]. Using this scheme in a common source configuration has yielded 40 dB of isolation at 100 MHz. This is much better than the traditional configuration shown in Figure 1. Since C_{gd} is small, "Miller capacitance," is also kept to a minimum thus yielding better high frequency performance. However, this nonlinear capacitance can cause loading of the input signal and thus increase distortion products. A cascode configuration[3], shown in Figure 7, can improve the high frequency distortion characteristics, frequency response and at th same time

*Signetics.

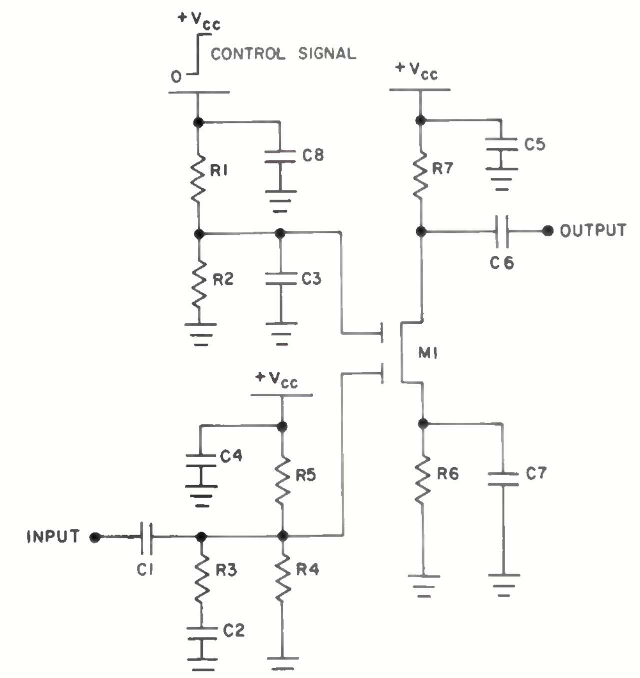
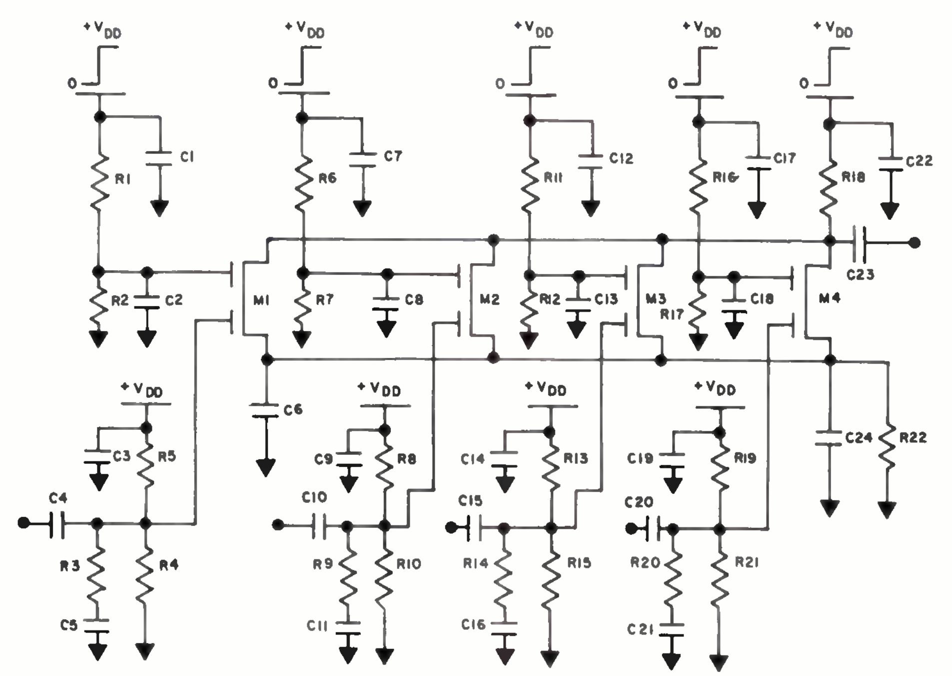


Figure 8.



C1-C24 — 0.1μF — emcon 5021 E550RD 104M
R2, R7, R12, R17 — 20k ohms
R1, R6, R11, R16 — 100 ohms
R3, R9, R14, R20 — 75 ohms
R5, R8, R13, R19 — 39k ohms
R4, R10, R15, R21 — 56k ohms
R18 — ohms
R22 — 200 ohms
M1, M2, M3, M4 — SD305

Figure 9. Components.

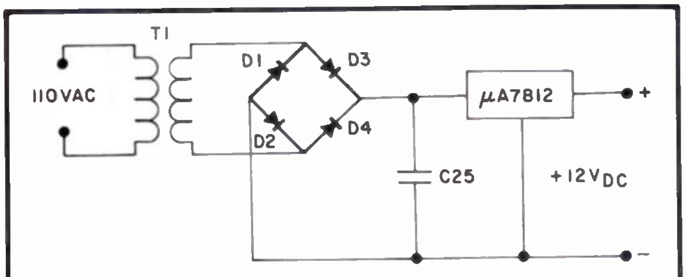
improve the isolation. A basic configuration is shown in Figure 7a.

Signetics carries a line of dual gate devices, called the SD300 series, which is the circuit equivalent of a cascode. The construction is on a single substrate and is cost competitive with the single gate devices. The equivalent cascode circuit is shown in Figure 7b. The economics and performance of the SD305 make these devices extremely desirable. Capacitance from the gate-to-drain in these devices is 0.03 pFd. Thus one achieves an order of magnitude improvement in isolation with the dual-gate devices. In prototype single channel versions, 80 dB of isolation has been achieved at 100 MHz using stringent layout rules and a low dielectric duroid board.

Other critical parameters in an RF switch is input/output matching, noise and biasing. For minimum power dissipation, large value resistors are desirable for biasing. Gate 2 can be bypassed to ground since the circuit is in a cascode configuration. The thermal noise (4 KTR) at gate 2 is shunted to ground with a bypass capacitor. Gate 1 must also be biased by large resistors to minimize power dissipation. Since the input must see 50-75 ohms, a 75 ohm resistor is used in series with a bypass capacitor to simulate the load. This also shunts the large bias resistors and results in the total 4 KTR noise being that of the 75 ohm resistor.

Output matching is not as critical since there is only a forward transmission of the signal to the load. Another factor in DMOS (and also in any MOSFET) is DC stability. It turns out that the threshold voltage has a wide range, typically 0.5 to 1.50 volts in the SD300 series. Feedback must be applied to compensate for this variation. This is accomplished by source degeneration in combination with a bypass capacitor. The complete schematic for a single channel dual gate analog switch is shown in Figure 8.

The optimum bias point for the SD305 is 9-15mA. Since the DMOS devices are enhancement mode devices, the device is activated when a positive voltage is applied at both gates. This is typically 2.0 volts at gate 1 and close to V_{DD} for gate 2. Gate 2's voltage is not critical and is used for the control signal. In Figure 8, with a 12.0 volt supply, a 1.0 volt drop appears across the load resistor. This still allows for a 2.0 volt P-P swing which is more than adequate for receiver applications. A 75 ohm resistor at the load will limit voltage swings. 100 ohms was found to be optimum and was determined experimently.



Radio Shack 12 VAC transformer 273-1385
D1-D4 1N4007 silicon diodes
µA7812 — 12 VDC regulator
C25 — 100µF 25.0V electrolytic capacitor

Figure 10. Components.

A Four Input/Single Output Active Switch

The circuit proposed here is ideal for RF switching and offers 60 dB of isolation at 100 MHz when using standard G-10 epoxy board. It works well for most RF receiver applications up to 300 MHz where the isolation drops to about 28 dB. A graph showing isolation and loss with respect to frequency is shown in Figure 12. The circuit can be constructed for under $15.00 and uses the principles introduced in the previous section. By utilizing four devices, one obtains four inputs to a single output.

The circuit can be expanded to more inputs with the addition of devices. However circuit layout is extremely critical and coax cables must have extremely good grounds.

(Continued on page 73.)

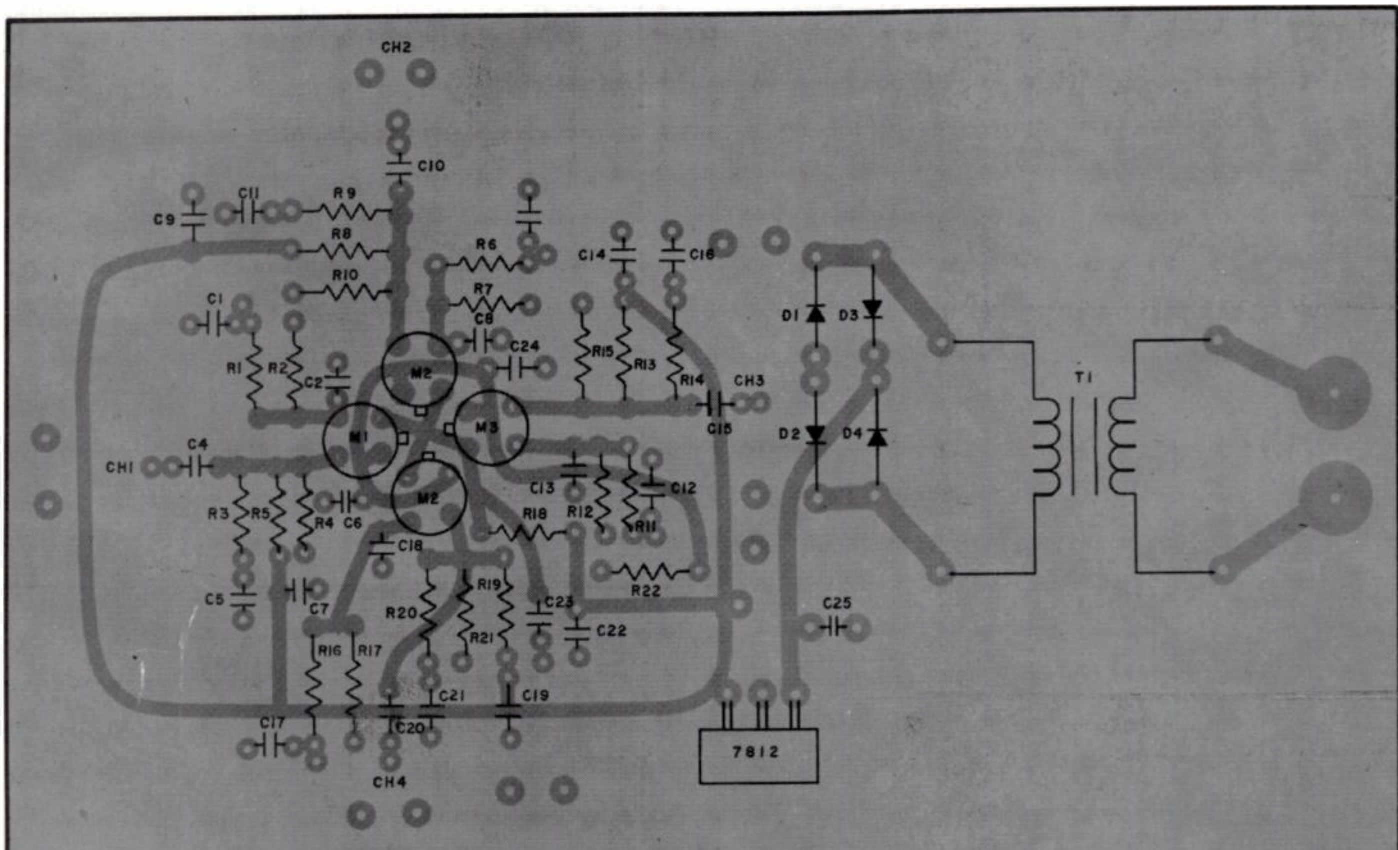


Figure 11.

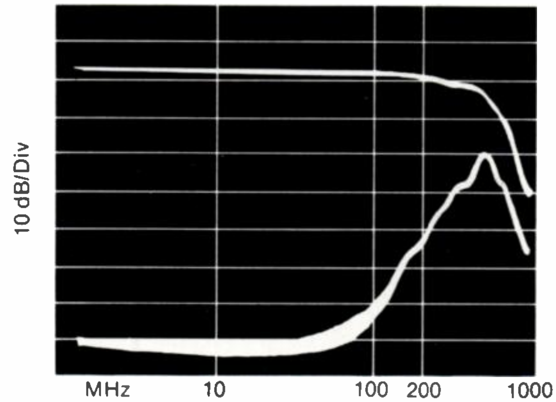


Figure 12.

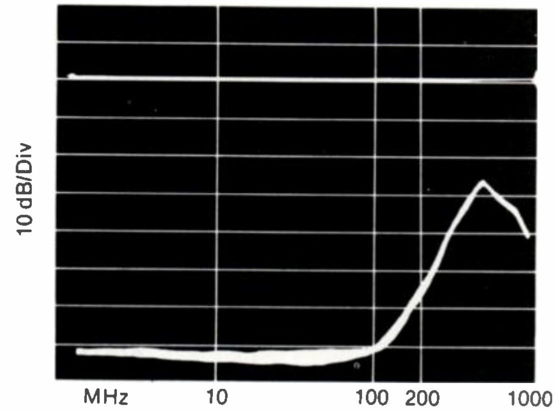


Figure 13.

(Continued from page 64.)

Dozens of input channels for a single output would not be practical at high frequencies due to stray capacitances. It was found that by varying the grounds, isolation changed by as much as 20 dB. If connectors are used on the chassis to interface with the outside world, the respective grounds on each connector must be maintained with the transmission line. Ground loops must be avoided if isolation is of primary concern. The complete schematic is shown in Figure 9.

Notice in Figure 9 that only one source and load resistor is necessary since at any given time only one device is on. This minimizes component count which can contribute to stray capacitances. Since only 10mA is required for any given time, an elaborate power supply is not necessary. An inexpensive transformer with a bridge rectifier and regulator is more than adequate.

The printed circuit layout for both the switch and power supply is shown in Figure 11.

Conclusion

A new scheme for switching RF small signals using a DMOS device has been given. Because of the inherent low gate to drain capacitance of DMOS, extremely good isolation is obtained. The circuit scheme can be matched to any low impedance and offers as high as 70 dB of isolation at 100 MHz if duroid board is used and careful layout techniques are followed. A schematic diagram and printed circuit board layout is given for a four input/single channel output version. It offers 60 dB of isolation at 100 MHz and uses standard G-10 epoxy circuit boards. The parts are relatively inexpensive and the entire unit can be built for under $15.00. ☐

Figure 14.

References

1. T.P. Cauge, J. Kocsis, H.J. Sigg, and G.D. Vendelin, "Double-diffused MOS transistor achieves microwave gain," *Electronics*, Vol. 43, pp. 99-104, Feb. 15, 1971.
2. E. Fong, D. Pitzer, and R. Zeman, "Power DMOS for High Frequency and Switching Applications" *IEEE Transaction Electron Devices*, Vol. ED-27, No. 2, Feb. 1980, pp. 322-330.
3. R.G. Meyer and P.R. Gray, "Analysis and Design of Integrated Circuits," 1977, Wily and Sons, pp. 412.

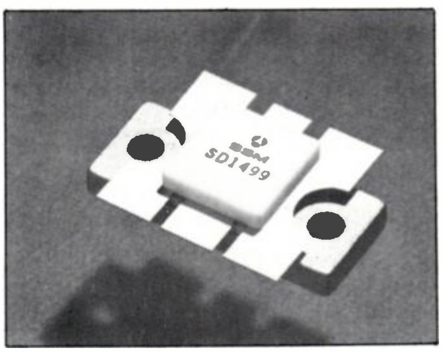
Acknowledgments

I would like to thank Vickie Saunders for the art work and Richard Zeman for his encouragement.

65 Watt 12.5 Volt RF Power Transistor

The Solid State Microwave Division of Thomson-CSF has introduced a new internally matched 65 Watt 12.5 Volt RF power transistor designed specifically for 100 Watt UHF land mobile radio applications. The SD1499 produces a minimum of 65 Watts of power output across the full 440 to 512 MHz band. This device features diffused emitter resistor ballasting and will withstand infinite VSWR loading at high line collector voltage (15.5V) conditions. This high gain device is supplied in a low inductance .400 square package utilizing gold metallization and gold bonding wires.

Contact Bob Tyson, Thomson-CSF Components Corporation, Solid State Microwave Division, Montgomeryville Industrial Center, Montgomeryville, PA 18936, (215) 362-8500. INFO/CARD #123.

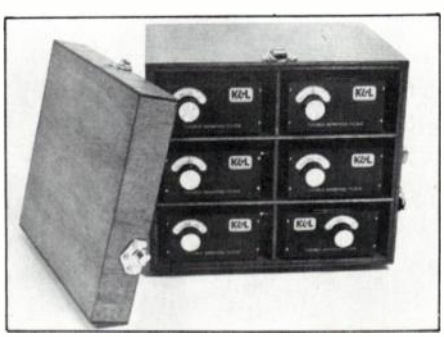


Tunable Bandpass Filter Kits

K & L Microwave announces the release of their new Tunable Band Pass Filter Kits. Designed for convenient use and storage in the laboratory, the kits each contain six tunable band pass filters in the RF and microwave frequency range. These tunable band pass filters which individually cover an octave tuning range, are selected for the kits to provide continuous band coverage within their respective frequency ranges. Kits may be chosen to cover various bands in the 24 MHz to 18.0 GHZ spectrum.

Nominal performance for the individual filters in a kit include: One half to one octave tuning range; 3dB bandwidth: 5 percent of tuned frequency; 50 ohm impedance with 1.5:1 VSWR; 50 watt power handling capability; 1 percent dial accuracy.

Contact Charles Schaub at: K & L Microwave, Inc., 408 Coles Circle, Salisbury, Md. 21801. INFO/CARD #125.



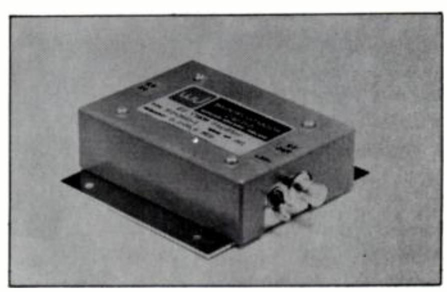
Wideband HF Amplifier

Watkins-Johnson Limited has introduced the WJ-7033 HF Amplifier which features 0.5 to 35 MHz frequency coverage, 13.5 and 9.5 dB gain options and a gain flatness of ±1 dB. The typical third-order output intercept point is +48 dBm with an output power of +34 dBm at the 1 dB compression point.

The amplifier, manufactured at the firm's Windsor, England, facility, employs advanced VMOS technology to achieve extremely low intermodulation products required for handling high-level HF signals. The WJ-7033 is ideally suited for HF circuit design where linearity is important and can be used as a low-distortion amplifier or front-end amplifier where great dynamic range is required.

The amplifier has a guaranteed 6 dB noise figure, 1.6:1 VSWR and a second-order output intercept point of +80 dBm. It operates from 20 volts DC with 850 mA current. The unit measures 128 x 102 x 30 mm, including BNC connectors. Options include weatherproof housing, N-type connectors, transient protection and switched filtering.

Contact Watkins-Johnson Limited, Shirley Avenue, Windsor, Berkshire SL4 5JU, England. INFO/CARD #128.



Your 1st Choice in Bench Attenuators is from Weinschel !!

Our New 3050, 3051, 3052 Series . . . meets your needs from dc — 2GHz

Does *your* bench attenuator give you what you want in frequency range? What about attenuation range – accuracy and repeatability throughout its life span? And what about price?

To give you the *right* answers to all these questions, we designed the Models 3050, 3051, and 3052 Bench Attenuators – with *your* needs in mind. Look at the choices available to you!

Model	Range and Resolution/Steps	Price
3050-100	0-100 dB/10 dB	$295.
3050-10	0-10 dB/1 dB	295.
3050-1.0	0-1 dB/0.1dB	295.
3051-110	0-110 dB/ dB	450.
3051-11	0-11 dB/0.1 dB	450.
3052-140	0-140 dB/10 dB	450.

Now to answer your questions, take our Model 3051-110 as an example, and compare it to *your* bench attenuator needs. With the 3051-110 you get:

- Frequency range from dc to 1.25 GHz
- Attenuation range of 110 dB in 1 dB steps
- Attenuation accuracy of ± 0.3 dB to 10 dB, ± 0.3 dB or 1% to 60 dB, and ± 2% to 110 dB
- Repeatability of ± 0.1 dB over frequency range and throughout life span of 1,000,000 steps
- Zero insertion loss of 1.0 dB
- VSWR of 1.30:1
- Dual step performance in ONE box at a price of $450!!

Better overall performance, longer life *and* lower price* – *these* are what you get from the 3050, 3051 and 3052!

Whether you are selecting your first bench attenuator or replacing an old one, the Models 3050, 3051 and 3052 are for *you*!

Contact your local representative or the factory for further information.

Do it today!

*at *no* sacrifice of quality!

WEINSCHEL ENGINEERING

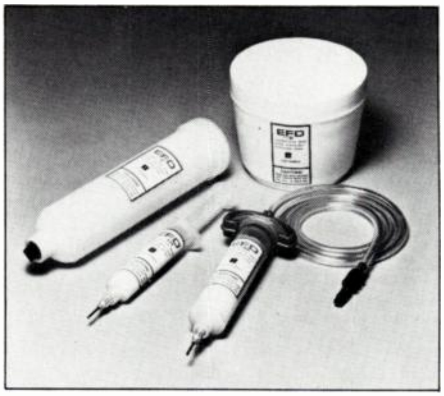
One Weinschel Lane
Gaithersburg, Maryland 20760
(301) 948-3434/TWX (710) 828-9705
Telex 89-8352. Baltimore (301) 792-4067
Los Angeles (213) 457-4563

Specifications and Prices subject to change without notice.

C28

Heat Sink Compound

A new, silicone-free heat sink compound for mounting all heat generating components including semiconductors, transistors, diodes, and rectifiers is being introduced by Electron Fusion Devices, Inc. of East Providence, Rhode Island.



EFD #70 Heat Sink Compound is a synthetic, metal oxide-filled, ester-based grease that provides 16.7 x 10^{-4} calories/cm²/°C/sec/cm thermal conductivity and 220 Volt/mil dielectric strength over a −50° to +200°C operating range. Silicone-free, the non-toxic homogeneous white paste exhibits no particle migration or fluid separation.

Meeting Western Electric Specification KS21343, EFD #70 Heat Sink Compound is rated at 0.09% (max) bleed and 0.6% (max) evaporation at 200°C for 24 hours. High lubricity facilitates no-mess manual and automatic dispensing from disposable 25 and 75 gm barrels, 400 gm cartridges, and 1000 gm jars. Shelf life is 24 mos. at 24°C.

Contact Electron Fusion Devices, Inc., 977 Waterman Avenue, East Providence, R.I. 02914. INFO/CARD #133.

SMA Between-Series Adapters

Cablewave Systems, Inc. has announced a complete redesign of their SMA Between-Series Adapters to improve RF and mechanical performance.

These improved Adapters are available from SMA to Type N, TNC, and BNC connectors. Typical performance

Advertiser Index

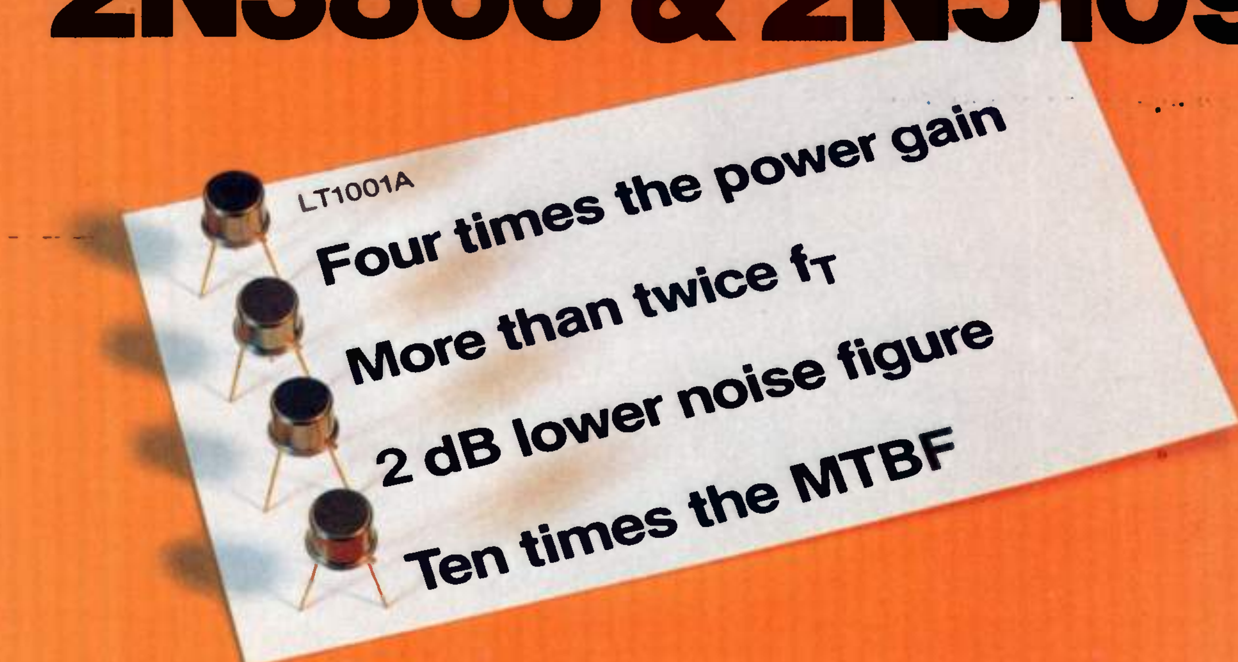
for the SMA to N adapter — VSWR 1.05 + .005F (GHz) DC to 18.0 (GHz), Insertion Loss .04 x F (GHz).

The improved designs carry the same base part number as the older designs with a – 101 suffix; for example, 705718-001 becomes 705718-101.

Contact Steven Raucci, Jr., Cablewave Systems, Inc., 60 Dodge Avenue, North Haven, Conn. 06473. Circle INFO/CARD #134. □

Classifieds

Sample TRW's "drop ins" for 2N3866 & 2N5109



TRW will send you a couple of LT1001A's to prove they are a more than perfect "drop in" replacement for 2N5109 or 2N3866 because our LT1001A does so much more, so much longer. (A glance at the specs tells it all.)

And there's more good news. The LT1001A is just one of a complete family of fifteen high frequency, low noise, small signal RF transistors in a variety of packages. Test them as replacements in current applications or for that new design you're working on—they'll do a better job, longer. And they're all available for immediate delivery, so if you like the tests, you can keep on getting the best. Send for samples now!

Just compare:

	LT1001A	**2N5109**	**2N3866**
f_T (200 MHz)	3,000 MHz	1,200 MHz	500 MHz
Gain* (200 MHz)	16 dB	11 dB	10 dB
BV_{CEO} (5 mA)	20V	20V	30V
C_{OB} (15V)	2.5 pF	3.5 pF	3.0 pF
h_{FE} (5V/50 mA)	70 MIN.	40 MIN.	20 MIN.
N.F.* (200 MHz)	6.5 dB	8.5 dB	8.5 dB
MTBF** (T_C = 95 °C)	140 YRS.	14 YRS.	14 YRS.
METALLIZATION	GOLD	ALUMINUM	ALUMINUM
EMITTER BALLASTING	DIFFUSED	NONE	NONE

*Gain & N.F. are broadband measurements
**Based on actual accelerated life tests

TRW RF Semiconductors
INH Box 4095
N. Hollywood, CA 91607

Drop me a few samples of the new **TRW LT1001A** and your complete small signal, low noise transistor catalog.

Name ____________________

Mail Stop ____________________

Company Name ____________________

Address ____________________

City/State/Zip ____________________

TRW RF SEMICONDUCTORS
An Electronic Components Division of TRW Inc.

INFO/CARD 35