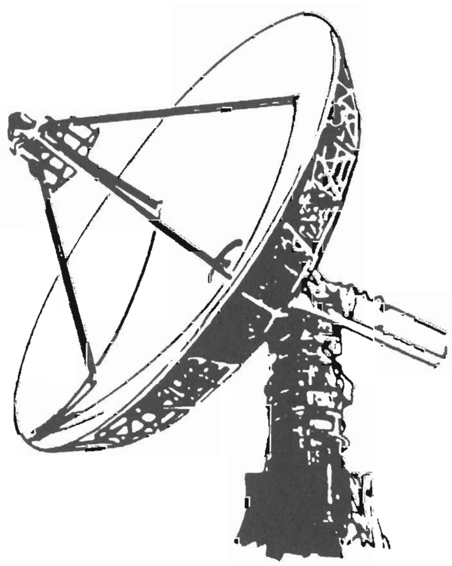
AN OVERVIEW OF MICROWAVE DESIGN CONSIDERATIONS FOR SWEPT SOURCES

ARLEN DETHLEFSEN
NETWORK MEASUREMENTS DIVISION
1400 FOUNTAIN GROVE PARKWAY
SANTA ROSA, CALIFORNIA 95401

RF & Microwave Measurement Symposium and Exhibition



HEWLETT PACKARD

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INTRODUCTION

Microwave design and testing is highly dependent upon the use of microwave swept sources. This paper describes some of the design considerations necessary to achieve superior performance in a microwave Swept Source used for design and production testing applications.

Many of these concepts would apply in the general sense to any electronically tuned microwave source.

MICROWAVE SWEPT SOURCE DESIGN CONSIDERATIONS

1. BLOCK DIAGRAM
2. MICROWAVE COMPONENTS
3. CONTROL AND DRIVE CIRCUITRY

The performance of a microwave swept source is highly dependent on three major areas:

1. The block diagram concept.

2. The microwave components used in the source.

3. The control and drive circuitry.

This presentation will focus on the first two of these areas.

There are many block diagram concepts that can be considered for a swept source. We will look at some of the more commonly used concepts and review the advantages of each. When considering the block diagrams, the performance parameters shown here have to be kept in mind.

The designer has to make decisions on the relative importance of each of these performance perameters in choosing the appropriate block diagram concept.

The design of the microwave components as well as the drive an control circuitry would also have considerable impact on these parameters.

Let's now look at some of the block diagram concepts and determine how these various configurations would effect the performance of the source.

PARAMETERS TO CONSIDER WHEN CHOOSING A BLOCK DIAGRAM FOR A SWEPT MICROWAVE SOURCE

1. FREQUENCY COVERAGE
2. OUTPUT POWER
3. FREQUENCY ACCURACY AND DRIFT
4. HARMONIC AND SPURIOUS SIGNALS
5. RESIDUAL FM
6. MODULATION REQUIREMEMENTS
7. RELIBILITY
8. COST

The block diagrams may be placed into these four basic categories.

Category A and B cover a single band of frequencies using a fundamental oscillator or an oscillator driving a single harmonic multiplier. Category C & D are block diagrams for sources covering frequency ranges which can not be spanned by a single fundamental oscillator.

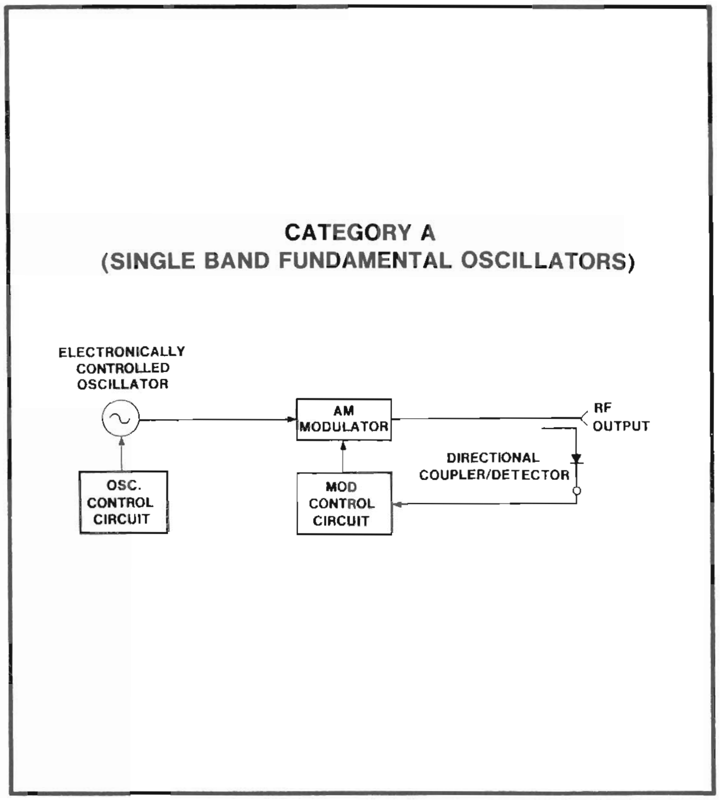
BLOCK DIAGRAM CATEGORIES FOR MICROWAVE SWEPT SOURCES

	SINGLE BAND*	MULTI/BAND**
FUNDAMENTAL OSCILLATORS	A	C
FREQUENCY MULTIPLACATION	B	D

DEFINITIONS

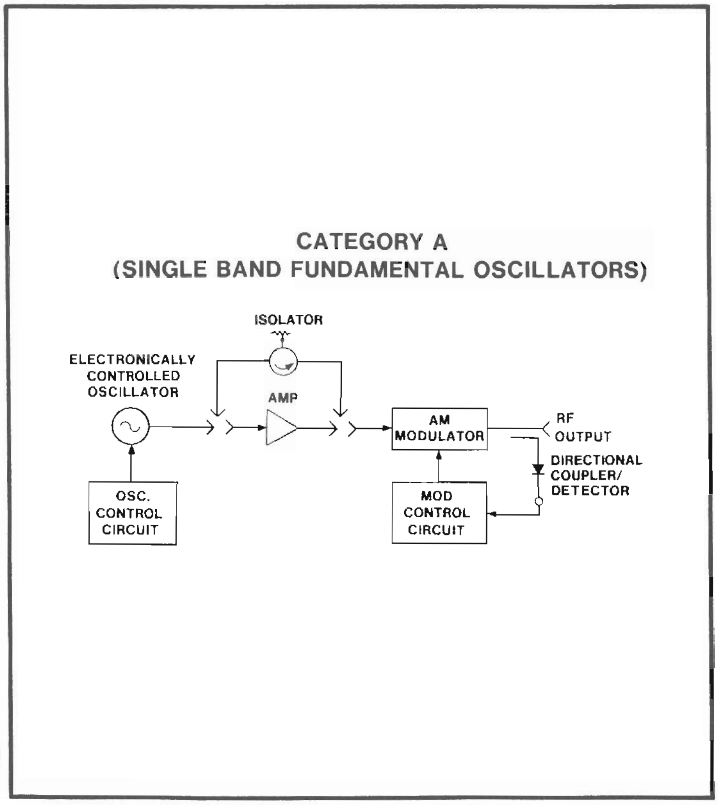
* WOULD NORMALLY REQUIRE ONE FUNDAMENTAL OSCILLATOR TO COVER THE DESIRED BAND OF FREQUENCIES.

** WOULD NORMALLY REQUIRE TWO OR MORE FUNDAMENTAL OSCILLATORS OR MULTIPLICATION BY MORE THAN ONE HARMONIC NUMBER TO COVER THE DESIRED BAND OF FREQUENCIES.



Shown here is a block diagram that fits into Category A.

This is the most basic and has the advantage of lowest cost and highest reliability. The output power would be relatively low. Harmonics would be relatively high and FM incidental to AM would be high because the oscillator is not sufficiently isolated from the amplitude modulator.



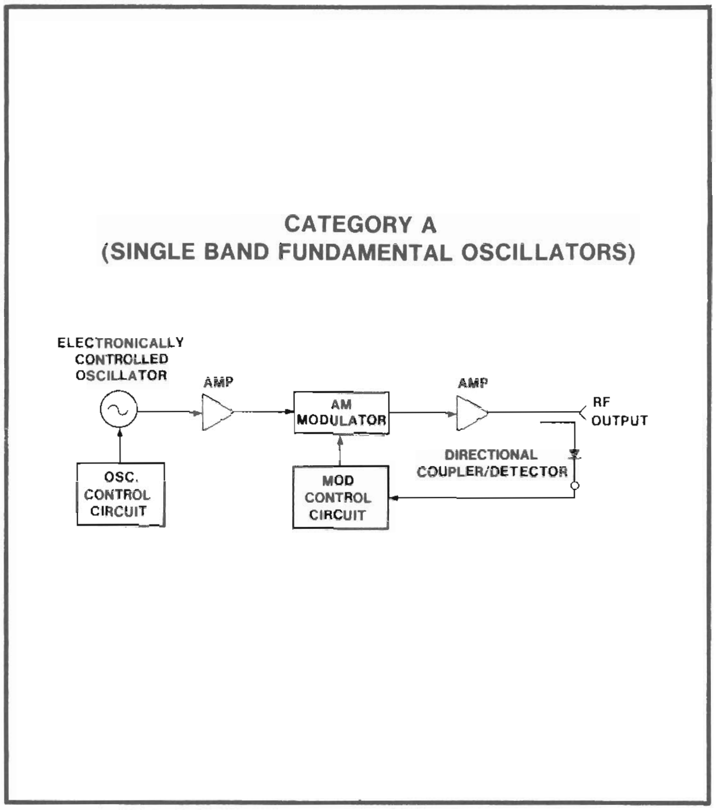
This is identical to the previous diagram with the exception that an amplifier or isolator is added to isolate the amplitude modulator from the oscillator. This addition greatly reduces the Incidental FM.

The use of the amplifier has two potential advantages over the use of the isolator:

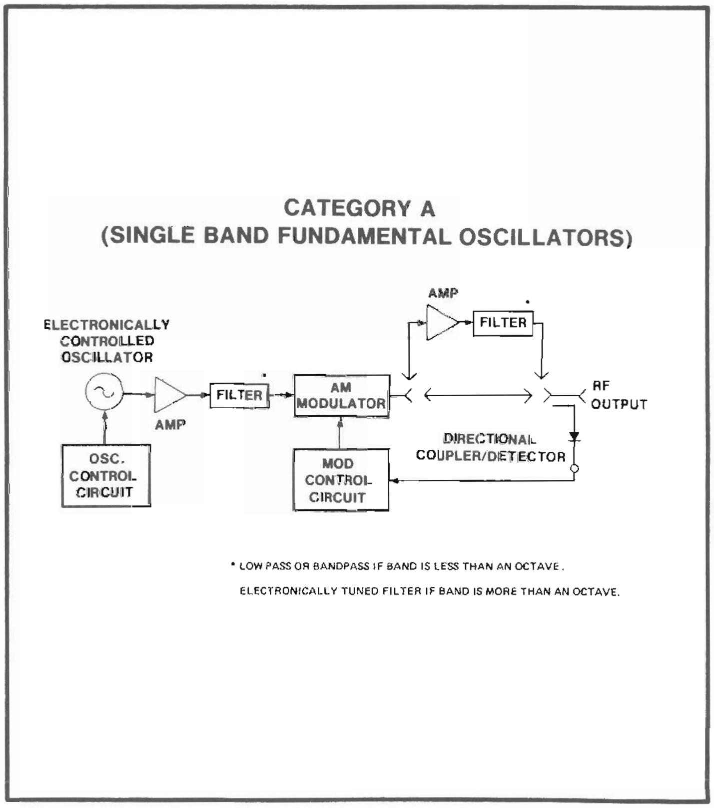
1. Output power would be increased.

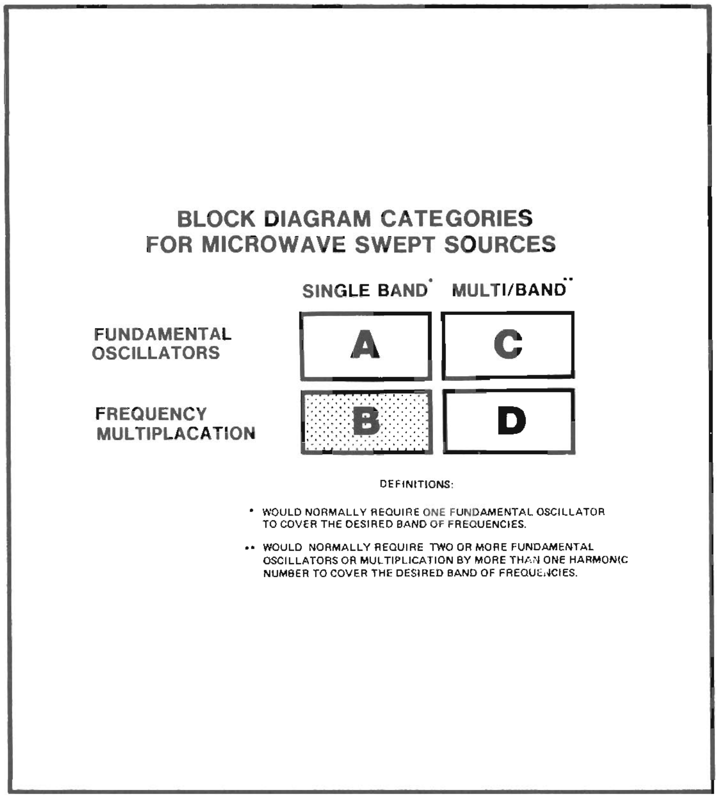
2. Harmonics from the oscillator could be improved if the amplifier were designed to have a negative gain slope as a function of frequency.

This diagram has another amplifier added after the amplitude modulator for highest output power.



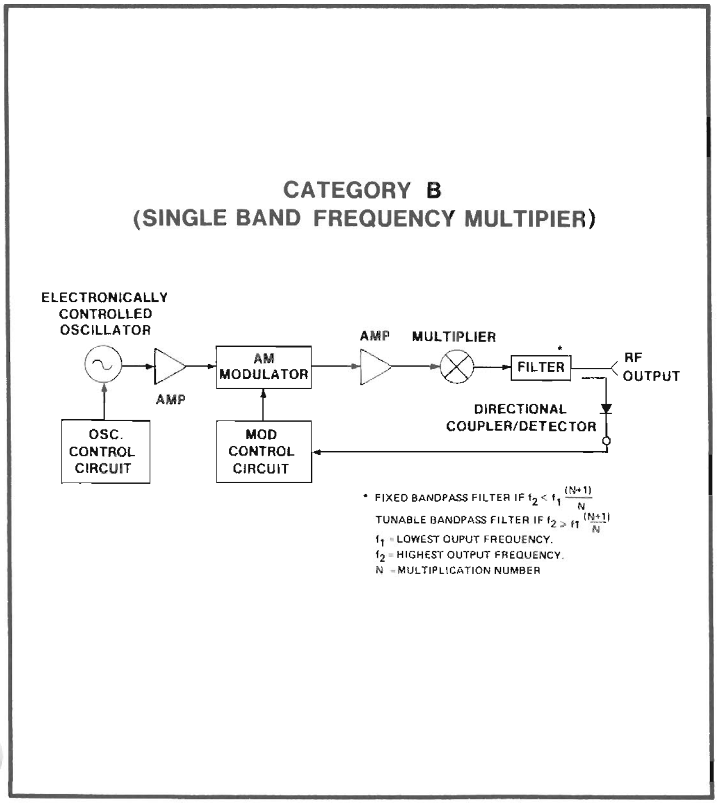
Here a filter has been added to reduce the harmonic output signals. This filter can be a low pass or band pass filter if the band of frequencies to be covered is less than an octave. If the band of frequencies is greater than an octave, the filter could then be a YIG tuned band pass filter which is controlled by circuitry to track the oscillator. More output power can be obtained by placing an amplifier with a filter after the modulator. If this is done, the filter ahead of the modulator could be eliminated.





Let's now look at two category B block diagrams.

This category is particularly useful when the frequency of operation is high enough to make the multiplication approach more desirable from a performance/cost point of view. It also allows for a convenient way to provide an auxiliary output at a sub multiple of the output frequency. This output is useful for phase-locking the source or for using a frequency counter.

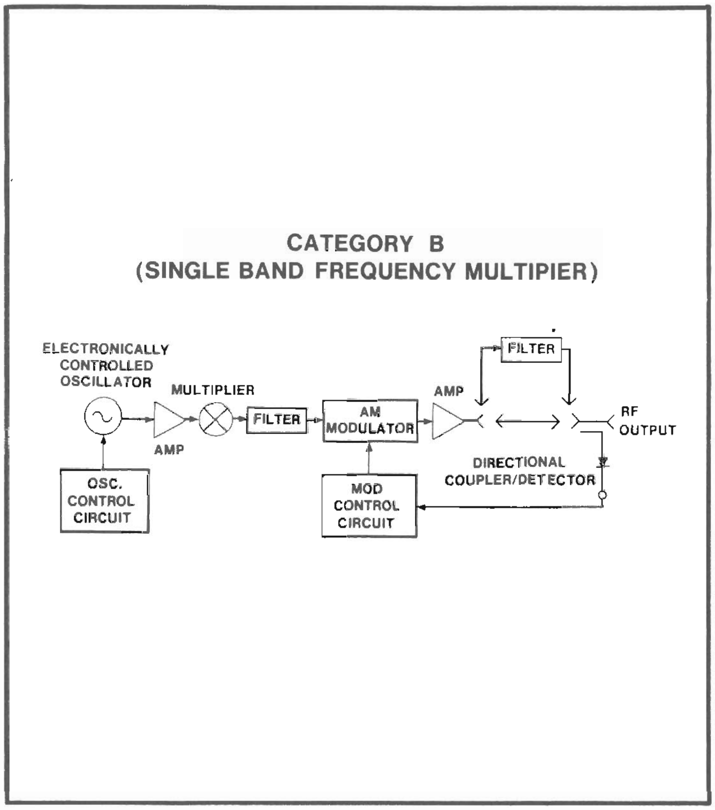


This Category B diagram has the modulator and amplifier ahead of the multiplication process. The filter may be a fixed broadband band-pass filter provided f2 is less than f1(N+1)/N. If f2 is greater than f1(N+1)/N, the filter would need to be a tunable bandpass filter. f1 is defined as the lowest output frequency, f2 is the highest output frequency and N is the multiplication number.

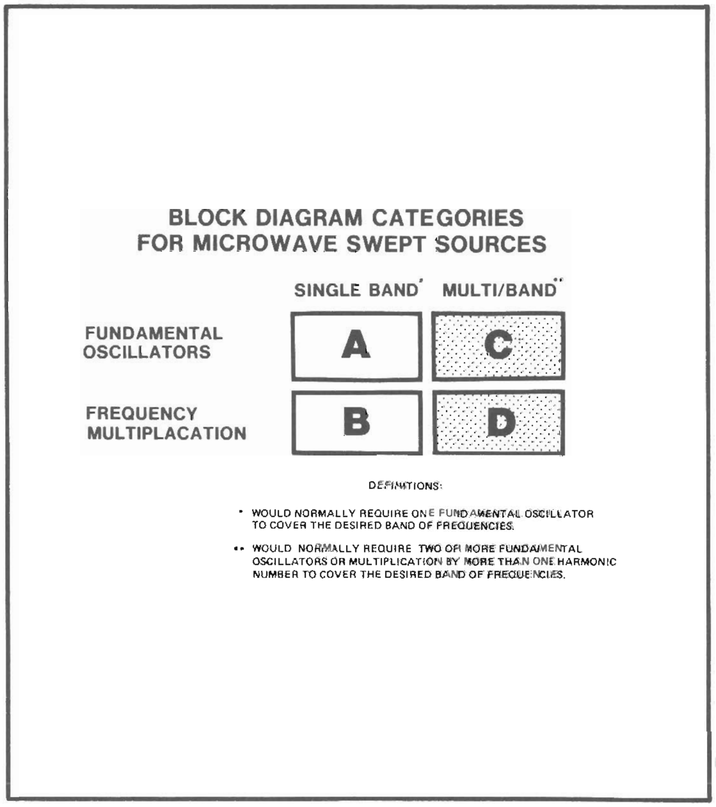
It is also possible to design multipliers to balance out the odd or even harmonics. This minimizes or eliminates the need for a bandpass filter.

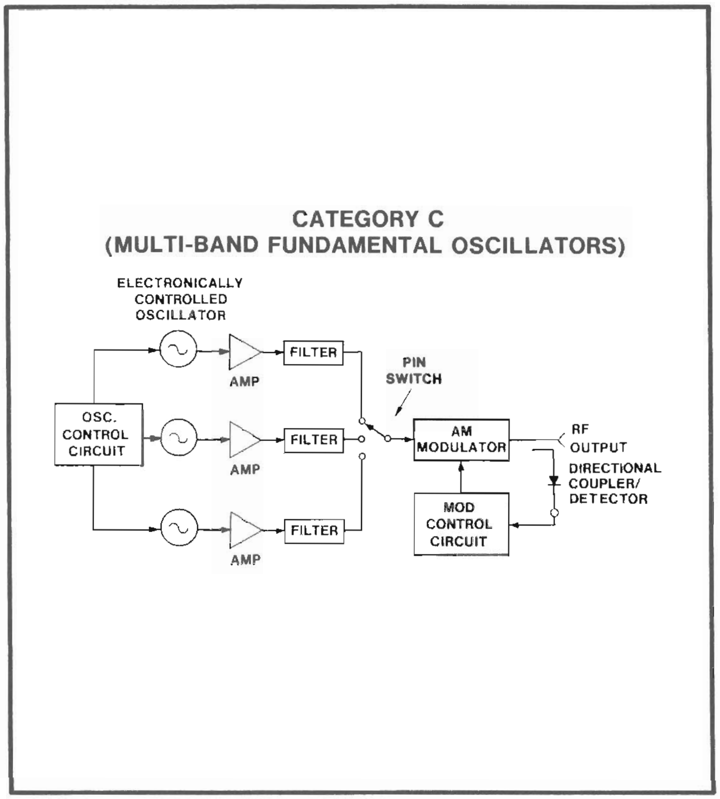
In this diagram, you will notice that the modulator and amplifier are after the multiplication process. The previous diagram had the advantage of modulating and amplifying at lower microwave frequencies.

This configuration has the potential for higher output power and, in the case of some types of multipliers, the unwanted harmonics can be more easily controlled as the output power is varied.

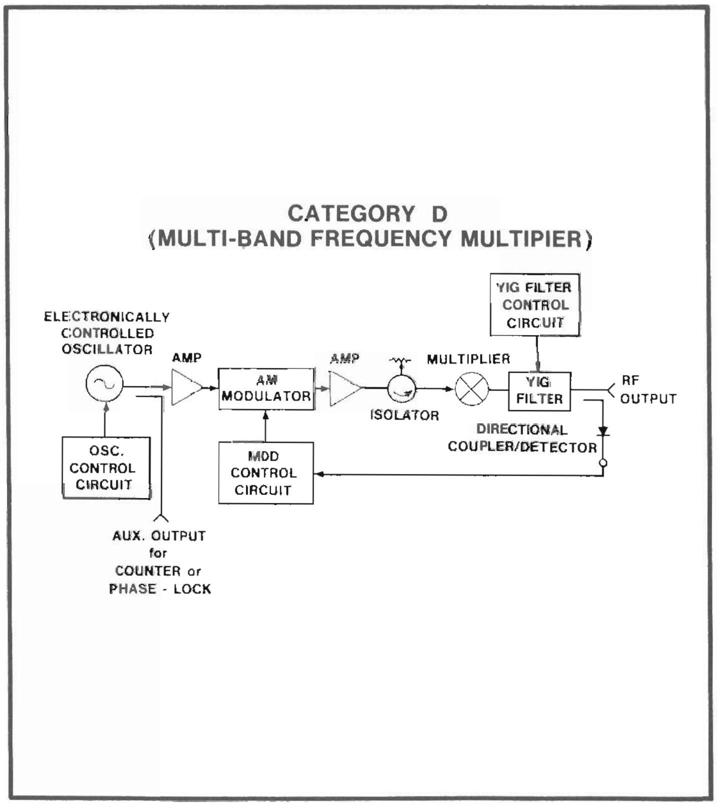


Let's now look at the block diagrams in the multi-band area.





This block diagram using fundamental oscillators has the advantage that the harmonics can be more easily filtered and there are no harmonic products below the desired signal. The oscillators and amplifiers are designed to cover discrete frequency bands but the modulator and switch must operate over the lowest to the highest frequency of interest.



The frequency multiplier approach has the advantage of better frequency accuracy and less frequency drift due to temperature. This is because the oscillator operates at a lower microwave frequency where it is easier to design a stable, linear oscillator with low hysteresis. This will become more apparent when we review the component designs. The relatively low frequency of the fundamental oscillator can easily be coupled to an auxillary port for frequency measurements or for phase locking to a stable reference. The only components which require designs at the highest microwave frequencies are the multiplier/filter and the directional coupler. This concept also minimizes the number of microwave components and drive circuitry.

Now let's focus on the various microwave components used in these block diagrams and how their design effects the overall performance of the product.

Shown here are the six major microwave components that are used in swept sources.

Most of the effort will be spent on the selection and design of the microwave oscillator since the oscillators performance has a significant bearing on most of the electrical parameters of the swept source.

MAJOR MICROWAVE COMPONENTS USED IN SWEPT SOURCES

- OSCILLATOR
- AMPLIFIER
- AM MODULATOR
- MULTIPLIERS
- FILTERS
- DIRECTIONAL COUPLER/DETECTOR

Here is a list of important parameters for electrically tuned microwave Oscillators. The oscillator design can be broken down into four areas: the tuning device, active devices, circuit design and mechanical design. As you can see, the decisions made for each of these areas impact most if not all of the performance parameters. Let's take a brief look at each of these areas.

DESIGN DECISIONS THAT EFFECT ELECTRICALLY TUNED MICROWAVE OSCILLATOR PERFORMANCE PARAMETERS

	Devices and Designs that effect the parameter			
Parameter	Tuning Device	Active Devices	Circuit Design	Package and Mechanical Design
Operating Frequency	X	X	X	X
Tuning Range	X	X	X	X
Output Power	X	X	X	X
Tuning Signal Linearity	X	X	X	X
Frequency Accuracy	X	X	X	X
Frequency Changes vs. temperature	X	X	X	X
Tuning Sensitivity	X		X	X
Harmonic and Spurious outputs	X	X	X	
Noise and Residual FM	X	X	X	
Magnetic Susceptibility	X		X	X
Pulling/Pushing	X		X	X
Weight & Size	X	X	X	X
Power Consumption	X	X	X	
Total Parameters Effected	14	11	14	10

COMPARISION OF THE YIG SPHERE AND VARACTOR DIODE FOR TUNING MICROWAVE OSCILLATORS

Performance Parameter	Device	
	YIG	VARACTOR
Operating Frequency	~1 - 40 GHz*	<20 GHz
Tuning Range	Multi-octave*	Octave
Tuning Rate	Slow	Fast*
Tuning Linearity	Linear*	Exponential
Frequency Accuracy	*	
Noise & Residual FM	*	
Weight & Size		*
Power Consumption		*
Tuning Method	Magnetic Field	Voltage

* Device has an inherent advantage on this parameter.

The tuning device chosen for an oscillator has considerable impact on the oscillators performance since it effects virtually every parameter.

The most commonly used electronic tuning devices for microwave oscillators is the varactor diode and the Yttrium-Iron-Garnet (YIG) sphere. Shown here is a comparison of these two devices.

We have indicated where a specific device has an inherent advantage for a given parameter.

In summary, the YIG tuning device is most suitable to applications requiring high frequencies, broad tuning ranges, good noise performance and linear change in output frequency as a function of the tuning signal.

The varactor tuning device is most suitable for applications requiring fast tuning or where there is a size, cost, or power consumption constraint.

The power consumption and size of YIG tuned oscillators generally do not present a problem for most swept sources. Sweep speeds on the order of 10 to 30 milliseconds are generally accpetable for most applications. Therefore, the YIG tuned oscillator, with its advantages in frequency of operation, tuning range, noise and tuning linearity, has become the oscillator that is predominantly used in swept microwave sources.

The following discussions on oscillator design considerations will therefore be limited to the YIG tuned oscillator.

ACTIVE DEVICES USED IN WIDEBAND YIG TUNED OSCILLATORS

Device	Typical Oscillator Performance Characteristics
Bi-Polar Transistor	Useable to 10 GHz Greater than Octave operating range can be achieved Lowest close-in Phase Noise Good efficiency Output Power 10 mw
Field-Effect Transistor	Useable to 26 GHz Greater than Octave operating range can be achieved Good efficiency Low Phase Noise Output Power 10 mw
Bulk GaAs diode	Useable 8 to 40 GHz Poor efficiency Power output approximately 10 to 40 mw Low Phase Noise Octave Tuning Range

The active devices used in broadband YIG tuned oscillators are shown in this diagram. Below 10 GHz, either the Bipolar or FET devices are generally used. Bipolar transistors presently have an advantage in the area of close-in phase noise, so for low noise applications, the Bipolar devices are generally used.

In the past, bulk GaAs diodes have been predominantly used at frequencies above 8 GHz. However, with the advent of 26 GHz FET devices, many new applications above 8 GHz will be using the FET transistors because the circuit may be designed to tune over greater than octave frequency ranges. It also has the advantage of requiring less supply power.

Broadband microwave oscillator designs using transistors are normally designed using circuit configurations shown here. This design allows for maximum bandwidth while still achieving reasonable performance in the areas of output power, noise, and harmonic level. Oscillators using this topology are presently available that span 1.5 to 2 octaves. With improvements in devices and by using multiple tuning elements, further increases in bandwidth can be expected in the future.

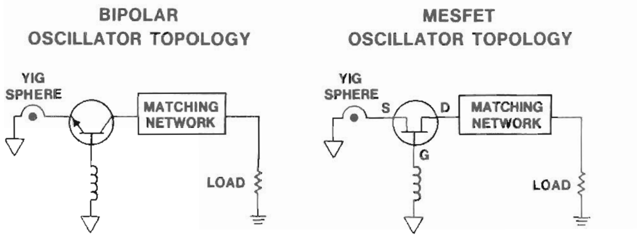
Listed below are some reference articles that deal with wideband microwave oscillator design.

Oscillator Design References:

1. Ganesh R. Basawapatna and Roger B. Stancliff, "A Unified Approach to the Design of Wide-band Microwave Solid-state Oscillators" IEEE Trans. Microwave Theory Tech. Vol Mtt-27, No. 5. pp 379 - 385, May 1979.

2. James C. Papp and Yoshiomi Y. Koyano, "An 8 - 18 GHz YIG-Tuned FET Oscillator" IEEE Trans. Microwave Theory Tech. Vol MTT-28, No. 7, pp 762.

MICROWAVE BROAD BAND YIG TUNED TRANSISTOR OSCILLATOR CIRCUIT TOPOLOGIES



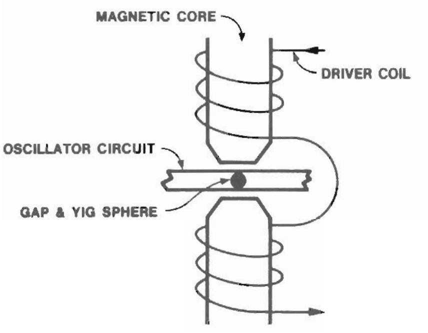
The remaining area of the oscillator design that has to be addressed is the magnetic structure. This is a key element in the design since it affects such things as tuning linearity, frequency drift with temperature and tuning sensitivity.

The basic structure required to provide a magnetic field for the YIG Sphere is shown here.

It consists of a magnetic core, a gap for the YIG sphere, a driver coil and a means to support the oscillator circuit.

Let's take a brief look at some of the key properties of electromagnets and see how they effect the performance of the YIG tuned oscillator.

BASIC MAGNETIC STRUCTURE FOR TUNING YIG OSCILLATORS

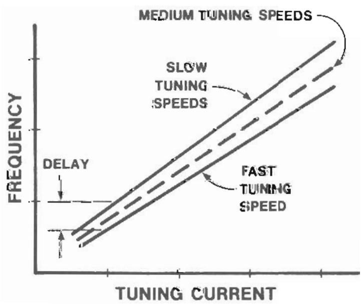


PARAMETERS OF MAGNETIC STRUCTURES THAT EFFECT OSCILLATOR PERFORMANCE

1. SWEEP DELAY
2. HYSTERESIS
3. LINEARITY & SATURATION
4. TUNING SENSITIVITY

These are the four primary parameters of magnetic structures that affect oscillator performance.

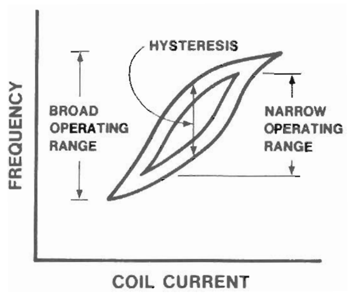
SWEEP DELAY OF YIG TUNED OSCILLATORS



Sweep delay is defined as the frequency lag relative to the tuning current under continuous sweep conditions. "Delay", in this context, represents frequency inaccuracy as a function of tuning speed. As shown here, this delay increases with increased tuning speeds. Typical numbers for uncorrected delay would be 100 MHz for an oscillator in the 8 GHz range sweeping at a 10 ms sweep rate. Choosing a magnetic material with high resisitivity minimizes this effect. However, in order to maintain good frequency accuracy as a function of sweep speeds, additional corrections are normally required in th oscillator drive circuitry.

Hysteresis is defined as the maximum differential frequency (at a fixed-coil current) due to the hysteresis of the magnetic circuit when tuned in both directions through the operating range. Hysteresis can be minimized by carefully choosing the magnetic material. As shown, hysteresis increases with wider operating ranges. It also increases with increases in flux density and therefore higher frequency YIG tuned oscillators have larger values of hysteresis. Hysteresis has a direct bearing on the frequency accuracy of the tuned oscillator since there is no simple way of compensating for this phenomenon with external circuitry.

HYSTERESIS OF YIG TUNED OSCILLATORS



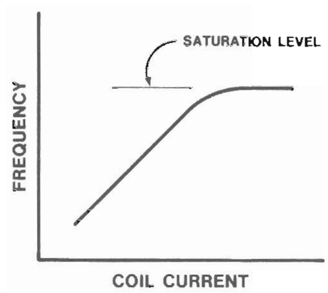
Saturation occurs when increases in coil current do not produce further linear increases in the flux density. The saturation level depends on the properties of the magnetic material as well as the design of the magnetic structure. Unfortunately, magnetic material which is chosen for high saturation levels has properties which increase the hysteresis of the magnet.

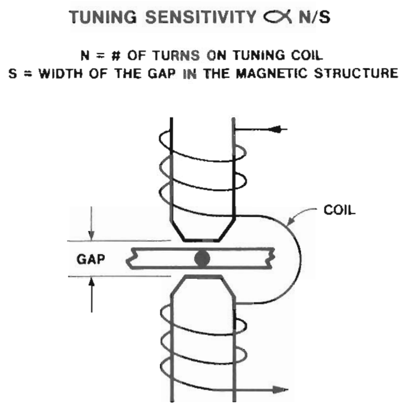
The saturation level determines the maximum frequency to which the oscillator may be tuned and also has a bearing on oscillator linearity since any deviations from a straight line relationship between flux density and coil current will effect frequency accuracy as a function of the tuning signal.

Frequency linearity is also affected by the tuning device, circuit design and active devices.

Careful circuit and magnetic designs are essential in this area to produce good performance.

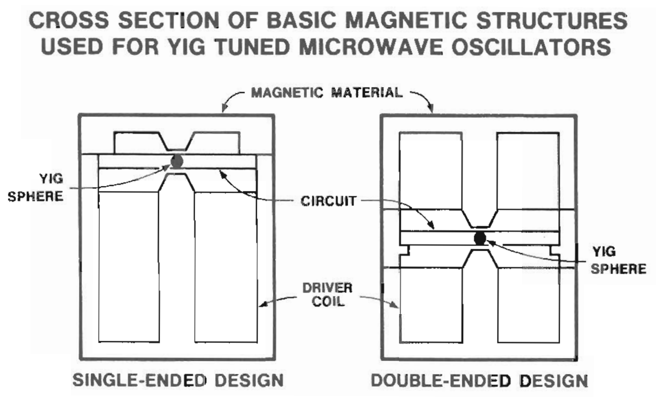
MAGNETIC SATURATION AND LINEARITY





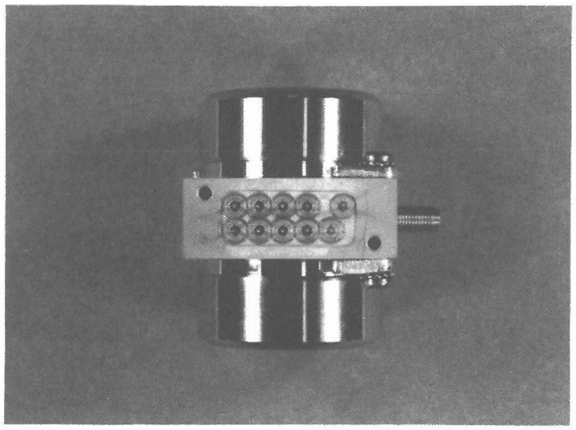
Tuning sensitivity is defined as the differential current required to tune across the operating frequency range divided by the frequency range. The sensitivity is a function of the number of turns and the width of the gap.

In order to minimize the power necessary to tune the oscillator, it is essential that the gap be kept as small as possible. The mechanical design of the magnet must also be such that the gap size does not vary as a function of temperature since this would cause inaccuracies in the frequency of the source.

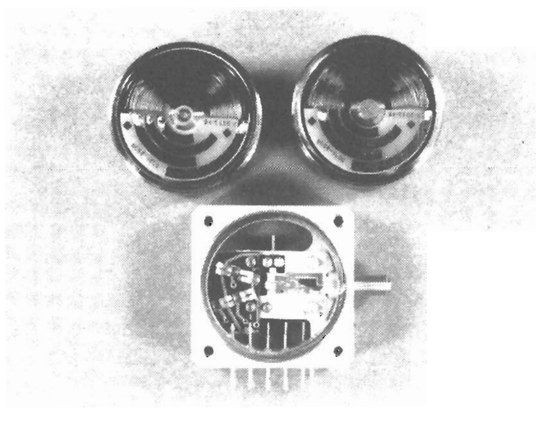


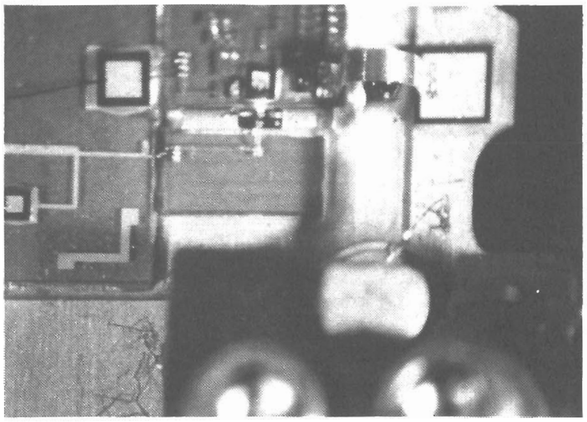
The two magnetic structures that are normally used are shown here. The single ended design is simpler and therefore less costly. The double ended design has the advantage of better hysteresis and is capable of higher saturation levels since there are fewer leakage paths for the flux. The double ended design is also less susceptible to externally applied magnetic fields.

An example of a 2 to 8.4 GHz Bipolar transistor oscillator is shown here.



The magnets are made of a low hysteresis material. The coils are layer-wound which minimizes the size of the magnet. This structure has a saturation frequency in excess of 12 GHz.





The oscillator transistor is a Silicon Bipolar device followed with a FET buffer amplifier. It uses a 660 micron diameter sphere (26 mil) with an unloaded Q of 1700.

The sphere is mounted on a sapphire rod and oriented on a temperature compensated axis. In addition, it is kept at a constant temperature with a thermostatically controlled heater. This keeps the post tuning drift of the oscillator under 100 KHz.

The sphere and devices were specially designed at Hewlett Packard for this product.

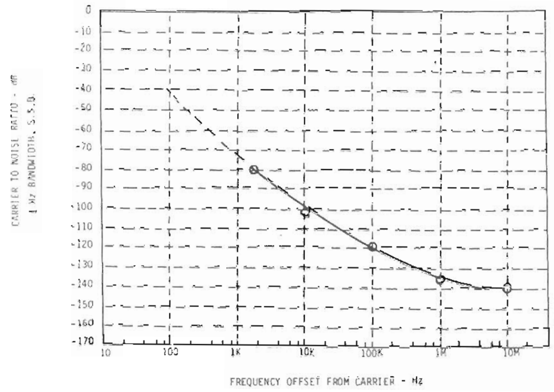
TYPICAL PERFORMANCE OF 2-8.4 GHz TRANSISTOR YIG TUNED OSCILLATOR

OUTPUT POWER	15 mW
HARMONICS	20 dBc
TUNING SENSITIVITY	24 ma/GHz
HYSTERESIS	2 MHz
LINEARITY	16 MHz

The oscillator actually operates between 1.8 and 8.6 GHz and its basic performance is listed here.

The phase noise characteristics are shown here. The single side band noise is typically 100 dB below the carrier at a 10 KHz offset.

2 – 8.4 GHz OSCILLATOR PHASE NOISE AS A FUNCTION OF FREQUENCY



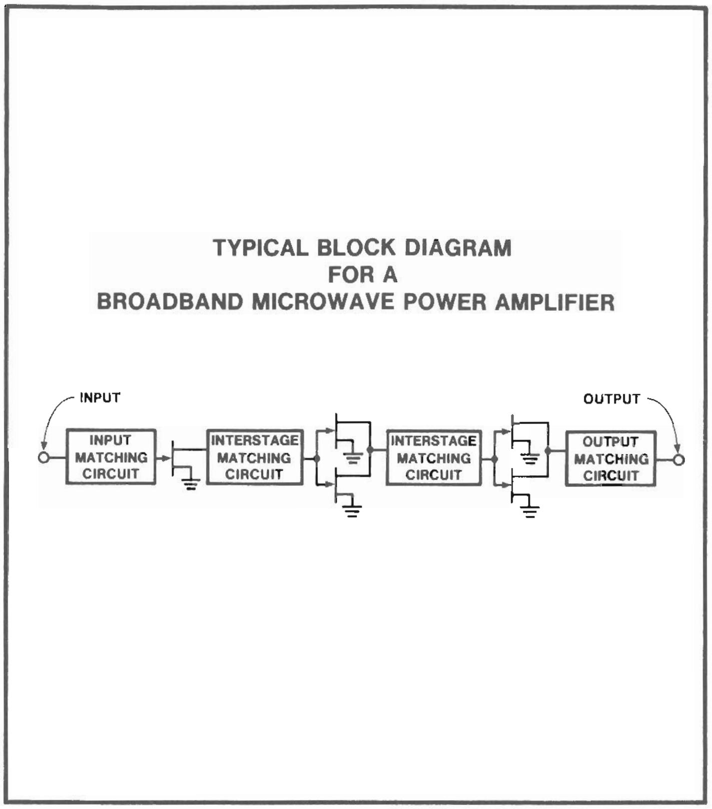
Now let's briefly review some of the key design considerations for the other components.

The key parameters for amplifiers used in microwave sources are shown here.

The performance requirements would vary depending on the requirements of the specific product. However, it is normally beneficial to achieve as broad a band of operation as the devices and circuit design will allow.

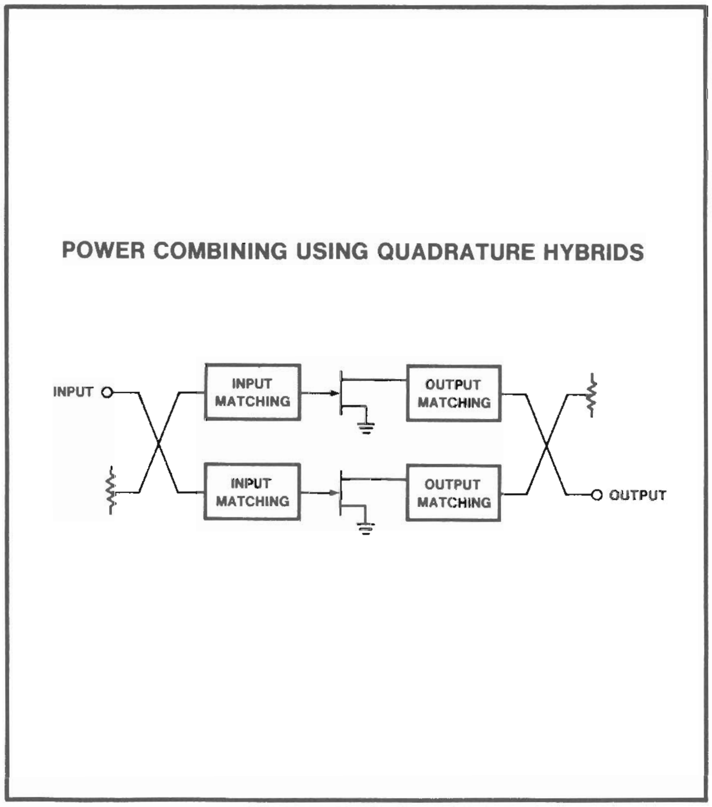
IMPORTANT AMPLIFIER PARAMETERS FOR USE IN SWEPT SOURCES AND TYPICAL PERFORMANCE REQUIREMENTS

PARAMETER	TYPICAL PERFORMANCE REQUIREMENTS
FREQUENCY RANGE	2:1 to 10:1
OUTPUT POWER	40 to 400 mW
HARMONICS	20 to 40 dBc
INPUT & OUTPUT MATCH	2:1 V.S.W.R.



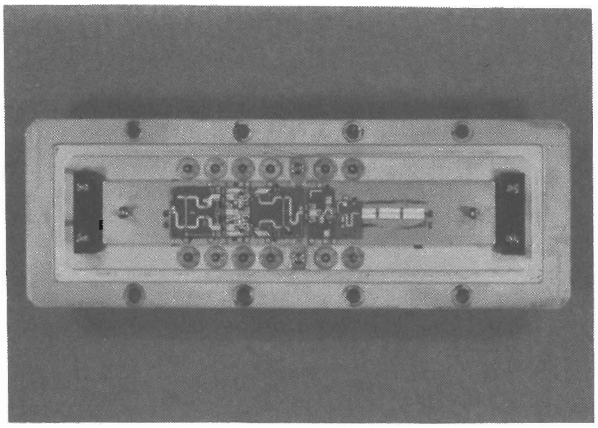
Broadband high power designs are normally best achieved by using a design approach as shown here.

The interstage matching networks are designed such that they provide maximum gain at the highest frequency of operation and reduce the gain at the lower frequency to achieve an amplifier gain that is relatively flat with frequency.



In order to achieve sufficient power over the broadrange of frequencies, it is necessary to combine the outputs of two or more devices. This is normally achieved by using hybrids as shown here.

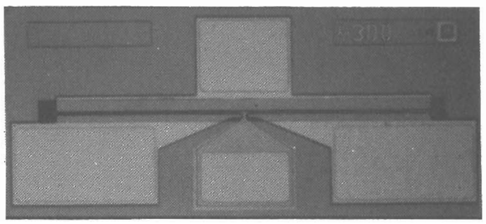
An example of a 2 to 7 GHz 0.5 watt MESFET amplifier for use in swept sources is shown here. It has a gain of 18 dB @ 0.5 watt output with harmonics typically 20 dB below the fundamental.



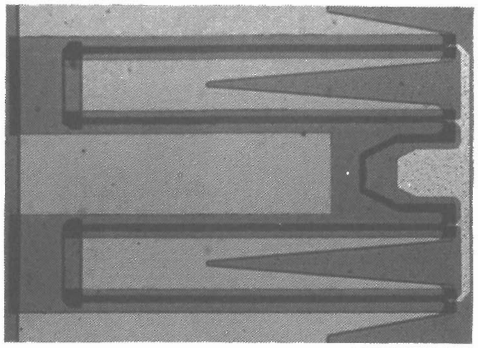
To achieve this performance, two specially designed FET's were utilized. The 1 micron x 500 micron device shown here was designed to have a high fmax which simplifies broadband amplifier designs.

For references purposes, a human hair is approximately 100 microns in diameter.

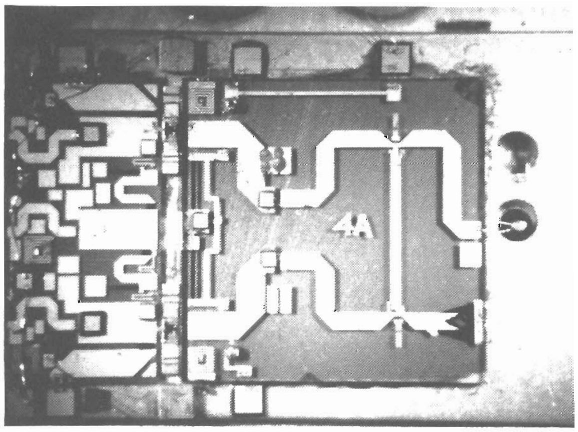
1 MICRON x 500 MICRON X-BAND FET



1.5 MICRON x 1500 MICRON LINEAR FET



This 1.5 x 1500 micron device was designed to achieve high output power with low distortion. It can deliver 300 mw @ 6 GHz.



The 500 micron device is used to drive the 1500 micron device as shown here.

Two 1500 devices re combined with a quadrature hybrid to achieve the 0.5 watt output.

Frequency multilpliers can be categorized as shown in this slide. Passive multiplers have no gain mechanism while an active multiplier has the ability to provide more output RF power at the multiplied frequency than is provided at the input of the multiplier. Passive multiplication is normally achieved by using rectifier type diodes or step recovery diodes. Active multiplication is achieved using field effect transistors.

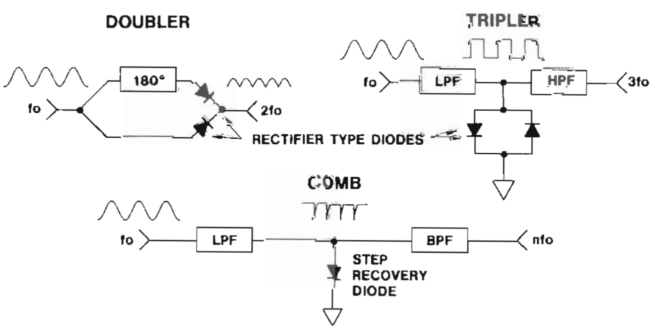
FREQUENCY MULTIPLIER CATEGORIES

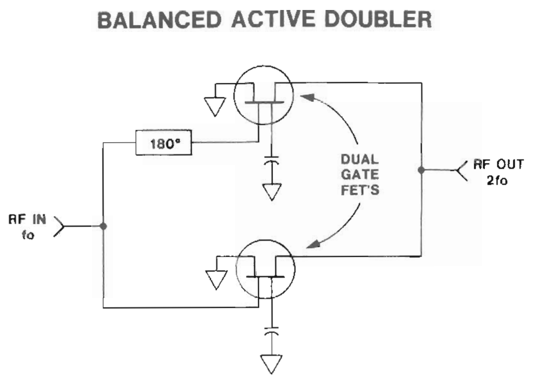
1. PASSIVE
   (a) RECTIFIER DIODE
   (b) STEP RECOVERY DIODE
2. ACTIVE
   (a) FET

Typical passive multipliers are shown here. The passive doubler is essentially a full wave rectifier which is rich in even order harmonics. The passive tripler is a diode limiter which is rich in odd order harmonics.

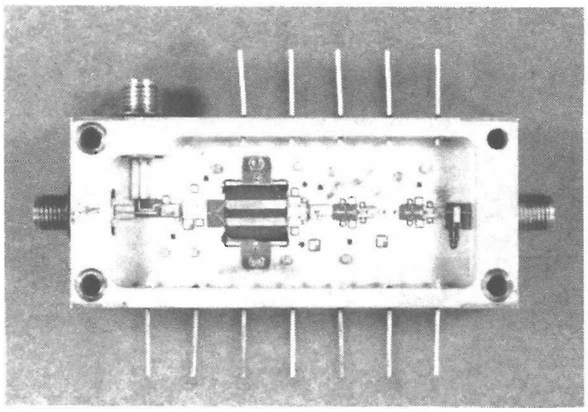
The comb multipler using a step recovery diode has an output wave shape that is essentially an impulse and therefore generates a comb of frequencies of both odd and even order.

PASSIVE MULTIPLIERS





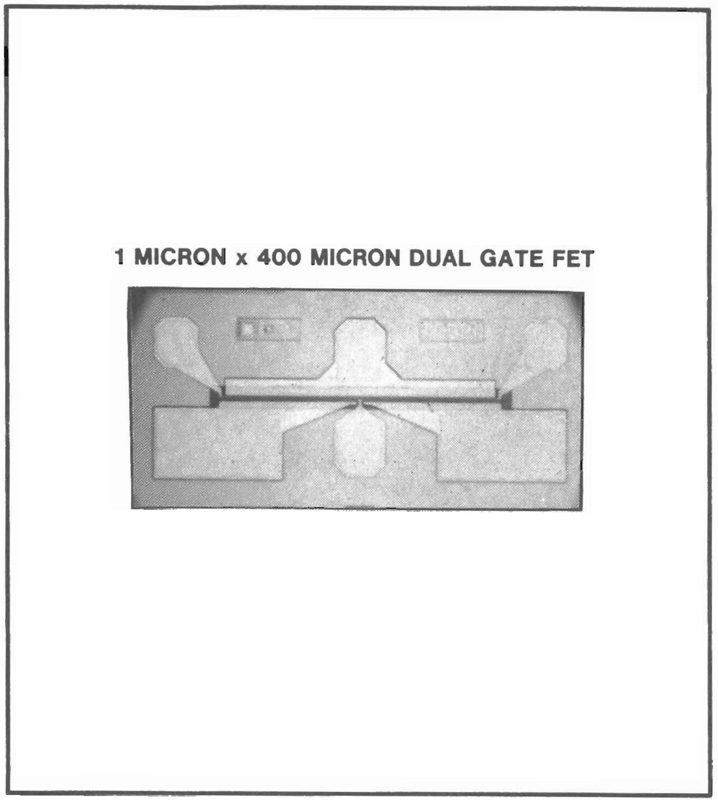
The active doubler is a FET device which is biased to rectify the input signal. Since the device has gain, the output signal can be larger in magnitude than the input signal.



An example of a single band active doubler is shown in this slide. The input power of the doubler is +13 dBm as is its output.

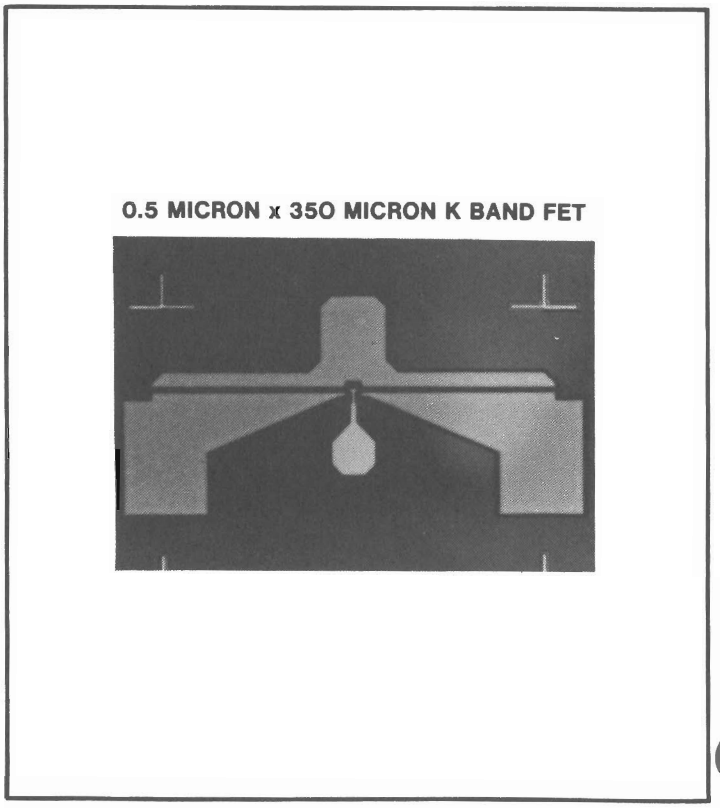
This design has the modulator following the multiplier and also utilizes an 18 to 26.5 GHz post amplifier. The amplification compensates for all circuit losses.

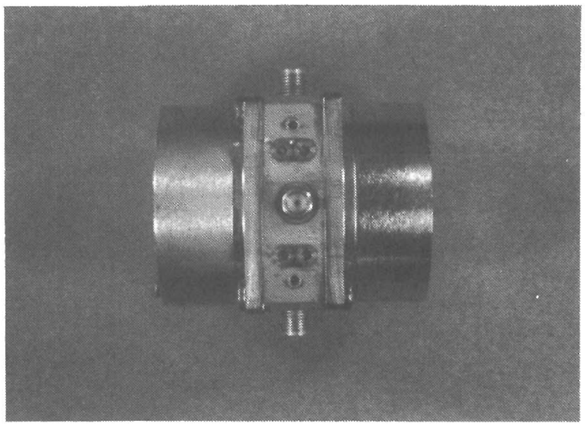
The devices used in this doubler are two dual gate FET's and a 0.5 x 350 micron gate device is used in the amplifier. The pattern of the dual gate FET is shown here.



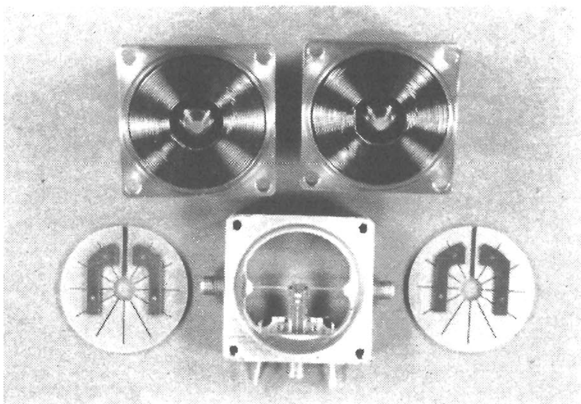
The 0.5 x 350 micron FET used for the amplifier has an fmax of 60 GHz and is capable of delivering 40 mw @ 26 GHz.

These two devices are also special HP designs.





An example of a frequency multiplier using a step recovery diode is shown here. The input frequency is 2 to 7 GHz and the YIG filtered output frequency is 2 to 26.5 GHz using multiplication numbers of 2, 3, and 4.



The magnetic structure was designed using two different magnetic materials.

The center body and pole tips are made of a low saturation material while the end pieces are made of a low hysteresis material. The shape of the pole and package was optimized to minimize flux leakage paths.

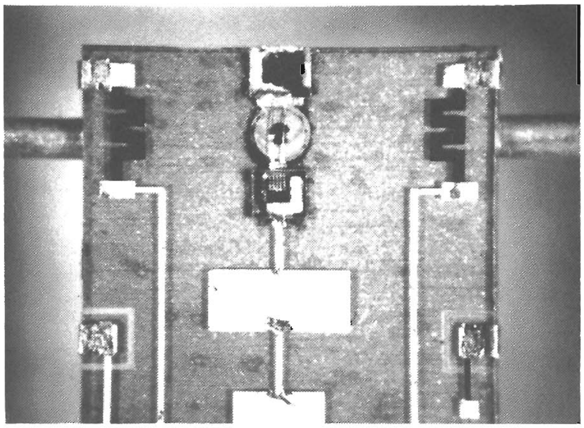
Thermal shorts were designed to carry heat away from the pole tips. The magnet saturates at frequencies in excess of 30 GHz.

The 680 micron (27 mil) YIG sphere is mounted in a 254 micron (10 mil) thick sapphire substrate. The YIG sphere is kept at a constant temperature by a thermostatically controlled heater.

The HP designed step recovery diode has a transition time less than 30 ps.

Typical conversion losses on the order of 10 dB are achieved to 20 GHz and 15 dB at 26 GHz. Fractional and subharmonics are typically 35 dB below the desired signal and harmonics are typically 50 dB below the desired desired signal.

This particular multiplier also has provisions for a multiplexed 10 MHz - 2.4 GHz signal so that the assembly can deliver a 10 MHz to 26.5 GHz swept signal from a single port.

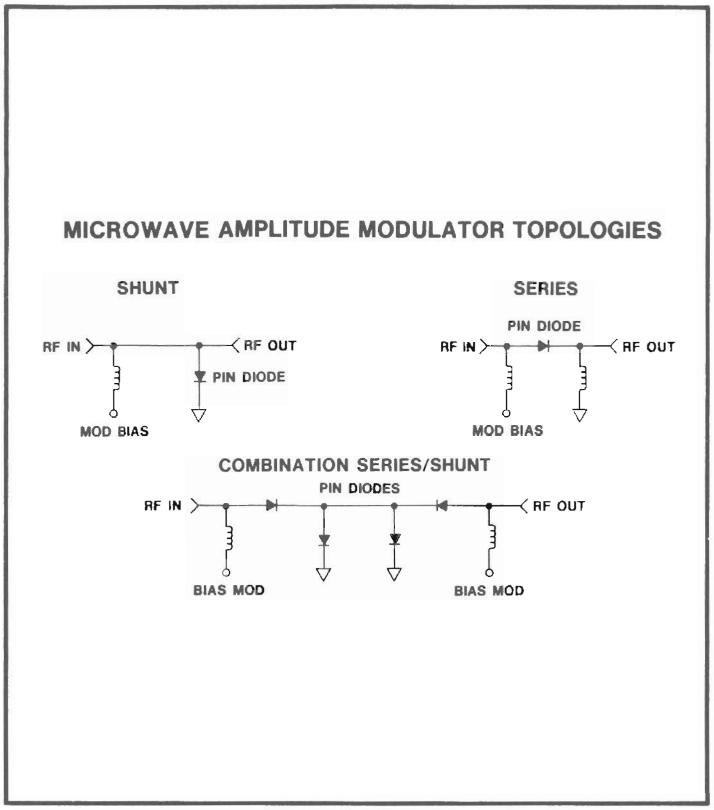


The functions of the Amplitude Modulator are shown here.

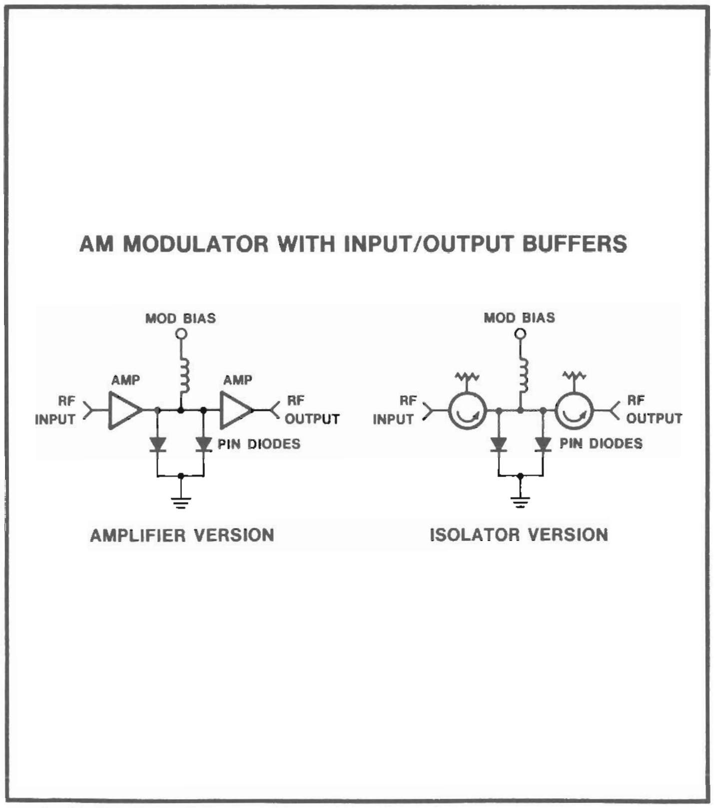
Items 1 and 2 are virtually essential for all modern swept sources. Items 3 and 4 are normally designed to meet the performance objectives of the source.

FUNCTIONS PROVIDED BY AM MODULATOR

1. RF LOSS CONTROL MECHANISM FOR AUTOMATIC LEVEL CONTROL AS A FUNCTION OF FREQUENCY.
2. SETS THE LEVEL OF RF OUTPUT POWER.
3. BLANKS RF OUTPUT ON RETRACE OF SWEEP OSCILLATOR.
4. PROVIDES MEANS OF AMPLITUDE MODULATING THE RF SIGNAL.
   (a) SINUSOIDAL AND SQUARE WAVE
   (b) PULSE



Most microwave modulators today utilize the PIN diode in either a series or shunt configuration or a combination of the two to provide the desired performance. The series and shunt versions are completely reflective while the combination circuit can be designed to have reasonable input and output match specifications.



In order to minimize problems associated with modulator input and output match changes as a function of frequency and RF output level, it is good design to include an input and output amplifier or isolator as shown here.

The directional coupler/detector has two primary functions:

1. to provide a DC output that is proportional to the RF output power.

2. to improve the source output match.

The output is amplified and fed back to the amplitude modulator to achieve leveled output power as a function of frequency.

FUNCTIONS PROVIDED BY DIRECTIONAL COUPLER AND DETECTOR

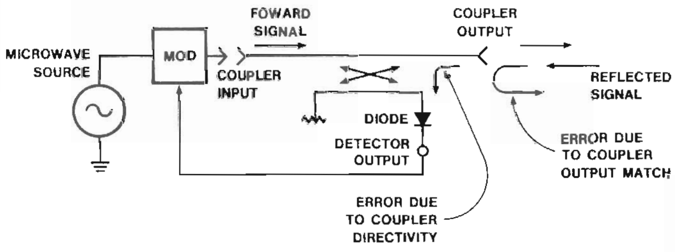
1. PROVIDE A DC OUTPUT SIGNAL THAT IS PROPORTIONAL TO THE RF OUTPUT POWER.

2. IMPROVE OUTPUT SOURCE MATCH.

To achieve good levelling, the combination of coupling loss and detector response together need to provide a DC output that does not vary as a function of frequency for a given output power level.

Good source match is achieved when the output connector has a good VSWR and the coupler has high directivity.

LEVELLING AND SOURCE MATCH DEGRADATION CAUSED BY OUTPUT COUPLER PARAMETERS



TYPICAL PERFORMANCE
OF THE
HP 86260A SWEPT SOURCE
(12.4-18.0 GHz)

BLOCK DIAGRAM CATEGORY	A
OSC. TUNING DEVICE	YIG
OSC. ACTIVE DEVICE	BULK GaAs DIODE
OSC. MAGNETIC STRUCT.	DOUBLE ENDED
TYPE OF HARMONIC FILTERING	NONE
AUX. OUTPUT FOR COUNTER OR PHASE-LOCK	NO
OUTPUT POWER (mw)	12
FREQUENCY ACCURACY (MHz)	30
HYSTERESIS (MHz)	10
RESIDUAL FM (KHz PEAK IN 10 KHz BANDWIDTH)	15
HARMONICS (dB BELOW FUNDAMENTAL)	30
INTERNAL LEVELED POWER VARIATION (dB)	+-0.5

In concluding, we will identify, by block diagram category type, some current Hewlett-Packard designs of swept sources to determine what performance is achievable using the concepts presented in this paper and state-of-the-art microwave devices and designs.

For Category A, the HP 86260A is a single band swept source using a bulk GaAs diode. Output power is 12 mw. Frequency accuracy is 30 MHz with a hysteresis of 10 MHz.

TYPICAL PERFORMANCE
OF THE
HP 83545A SWEPT SOURCE
(5.9 TO 12.4 GHz)

BLOCK DIAGRAM CATEGORY	A
OSC. TUNING DEVICE	YIG
OSC. ACTIVE DEVICE	FET
OSC. MAGNETIC STRUCT.	SINGLE END
TYPE OF HARMONIC FILTERING	FIXED LOW-PASS
AUX. OUTPUT FOR COUNTER OR PHASE-LOCK	NO
OUTPUT POWER (mw)	60
FREQUENCY ACCURACY (MHz)	15
HYSTERESIS (MHz)	20
RESIDUAL FM (KHz PEAK IN 10 KHz BANDWIDTH)	10
HARMONICS (dB BELOW FUNDAMENTAL)	>40 (7-12GHz)
INTERNAL LEVELED POWER VARIATION (dB)	+-0.4

Another Category A unit, the HP 83545A, is a single band unit designed for high output power. It uses a FET transistor oscillator and typically provides 60 mw leveled output between 5.9 and 12.4 GHz.

Still another example of Category A is the HP 83540B, a product designed for high power, good harmonics and frequency accuracy. It utilized a double-ended oscillator structure with a tracking YIG filter to achieve very low output harmonics over its double-octave frequency range.

TYPICAL PERFORMANCE
OF THE
HP 83540B SWEPT SOURCE
(2 TO 8.4 GHz)

BLOCK DIAGRAM CATEGORY	A
OSC. TUNING DEVICE	YIG
OSC. ACTIVE DEVICE	BI-POLAR
OSC. MAGNETIC STRUCT.	DOUBLE ENDED
TYPE OF HARMONIC FILTERING	YIG TUNED
AUX. OUTPUT FOR COUNTER OR PHASE-LOCK	NO
OUTPUT POWER (mw)	30
FREQUENCY ACCURACY (MHz)	3.5
HYSTERESIS (MHz)	1.2
RESIDUAL FM (KHz PEAK IN 10 KHz BANDWIDTH)	5
HARMONICS (dB BELOW FUNDAMENTAL)	50
INTERNAL LEVELED POWER VARIATION (dB)	+-0.8

For Category B, the HP 83570A is an 18 - 26.5 GHz doubler type source with 11 mw output power. The output of the fundamental oscillator, 9.0 - 13.25 GHz, is made available as an auxiliary output. This signal can be used as the RF sample for phase-locking or can be applied to a microwave counter.

TYPICAL PERFORMANCE
OF THE
HP 83570A SWEPT SOURCE
(18 TO 26.5 GHz)

BLOCK DIAGRAM CATEGORY	B
OSC. TUNING DEVICE	YIG
OSC. ACTIVE DEVICE	FET
OSC. MAGNETIC STRUCT.	SINGLE ENDED
TYPE OF HARMONIC FILTERING	FIXED HIGH-PASS
AUX. OUTPUT FOR COUNTER OR PHASE-LOCK	YES
OUTPUT POWER (mw)	11
FREQUENCY ACCURACY (MHz)	20
HYSTERESIS (MHz)	12
RESIDUAL FM (KHz PEAK IN 10 KHz BANDWIDTH)	20
HARMONICS (dB BELOW FUNDAMENTAL)	30
INTERNAL LEVELED POWER VARIATION (dB)	+-1.2

TYPICAL PERFORMANCE
OF THE
HP 83592B AND HP 83595A
SWEPT SOURCES

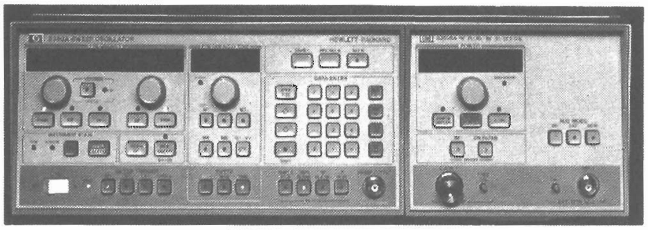
	83592B	83595A
BLOCK DIAGRAM CATEGORY	D	D
OSC. TUNING DEVICE	YIG	YIG
OSC. ACTIVE DEVICE	BI-POLAR	BI-POLAR
OSC. MAGNETIC STRUCT.	DOUBLE ENDED	DOUBLE ENDED
TYPE OF HARMONIC FILTERING	YIG TUNED	YIG TUNED
FREQUENCY RANGE (GHz)	.01 TO 20	.01 TO 26.5
OUTPUT POWER (mw)	25 mw	25 TO 20 GHz 4 TO 26.5 GHz
FREQUENCY ACCURACY (MHz)	4	5
HYSTERESIS (MHz)	1.2	1.2
RESIDUAL FM (KHz PEAK IN 10 KHz BANDWIDTH)	3 @ 6 GHz 10 @ 20 GHz	3 @ 6 GHz 12 @ 26.5 GHz
HARMONICS (dB BELOW FUNDAMENTAL)	25 BELOW 2.4 GHz 50 ABOVE 2.4 GHz	25 BELOW 2.4 GHz 50 ABOVE 2.4 GHz
HARMONICALLY RELATED (dB BELOW FUNDAMENTAL)	35	35
INTERNAL LEVELED POWER VARIATION (dB)	+-0.7	+-0.7

For Category D, the HP 83592B and 83595A are multi-band sources designed to span the .01 to 20GHz and .01 to 26.5GHz bands with good power and excellent frequency accuracy and residual FM. Output power is typically 25 mw at 20 GHz with frequency accuracy of 4 MHz. In order to achieve this type of accuracy you will notice that the hysteresis in all bands is typically 1.2 MHz. This is achieved because the oscillator operates over narrower ranges as the source is tuned to higher frequencies.

The residual FM performance of this product at high frequencies is superior to many of the single band units because the residual FM of the 2 - 8.4 GHz oscillator is only 3 KHz at 6 GHz. This noise multiplied by four yields a residual FM performance of 12 KHz at 26.5 GHz.

The auxiliary output from this unit's fundamental oscillator covers 2 to 6.7 GHz, yet it can be counted or phase-locked as if it were a 26 GHz signal.

SUMMARY



Drive & Control Circuity

Microwave Circuitry & Interface Circuitry

- IMPORTANCE OF DRIVE AND CONTROL CIRCUITRY
- RELIABILITY

In summary then, we have reviewed several design criteria necessary to achieve superior performance in swept sources.

Most of the focus has been on the microwave block diagrams and microwave components. However, in all system designs it is essential that the drive and control circuitry is carefully designed so that it does not degrade the inherent performance of the microwave components.

As in all system designs, many compromises have to be considered in order to have a cost effective product. These compromises require good judgment and proper evaluation of the important parameters. However, these decisions should not jeopardize the reliability of the product.

In order to achieve a reliable product, it is essential that the basic building blocks have been designed and chosen with reliability in mind and that design margins are considered in each area of design.

MAY 1982

PRINTED IN U.S.A.