General Microwave Corporation has been a leader in the field of microwave PIN diode control components for more than 35 years. The design and manufacture of high performance, broadband phase shifters, frequency translators and I-Q Modulators have made General Microwave the undisputed leader for these devices.

Today's more demanding systems require the ability to control the phase and amplitude of RF/microwave signals with a repeatable, high degree of accuracy. General Microwave intends this section to not only inform you of our most popular products but also to provide insight into theory of operation, calibration and practical applications where they can be utilized.

General Microwave offers a complete line of broadband phase shifters and I-Q modulators which span the frequency range from 0.05 to 24.0 GHz. These devices are available in several different topologies that allow the designer to choose among various performance characteristics that best suit his system needs. This section describes only our standard line of broadband phase shifter and I-Q modulator models. In addition to these, there are numerous special designs, employing a variety of phase shifter circuits, which General Microwave has utilized in custom applications.

PHASE SHIFTER FUNDAMENTALS

A variable phase shifter can be characterized as a linear two port device which alters the phase of its output signal in response to an external electrical command. (Mechanical phase shifters are not considered here.) Expressing this mathematically, with an input signal $\sin(\omega t)$, the output will be $A(n)\sin(\omega t)\Theta(n))$, where n is the programmed phase and $A(n)$ is the insertion loss. The difference between the input phase and the output phase is the sum of the phase shift due to the propagation through the phase shifter plus the programmed phase shift.

The relative simplicity of the idea that any reactance placed in series or shunt with a transmission line will produce a phase shift has given rise to many different circuits over the years for use as phase shifters at microwave frequencies.

Usually, for high speed applications, the controlling elements have been semiconductor devices such as PIN, Schottky and varactor diodes, whereas for high power requirements, when slower switching speed can be tolerated, ferrites are frequently employed. The final choice of a phase shifter network and control element will depend on the required bandwidth, insertion loss, switching speed, power handling, accuracy and resolution. In addition, a choice between analog and digital control must also be made.

Analog phase shifters are devices whose phase shift changes continuously as the control input is varied and therefore offer almost unlimited resolution with monotonic performance. The most commonly used semiconductor control devices used in analog microwave phase shifters are varactor diodes, which act as current controlled variable resistors. Schottky diodes and ferrite devices are also used as variable elements in analog phase shifters but the former suffer from limited power handling capability and matching difficulty in broadband networks whereas the latter are generally larger, require more bias power, and are relatively slow compared to semiconductor designs.

Among the more useful topologies for analog phase shifters are the loaded line design using lumped or distributed elements and the reflective design employing quadrature hybrids. One of the variants of the reflective phase shifter is the vector modulator, which in the particular embodiment used by General Microwave shows excellent performance over 3:1 bandwidths. This capability is especially useful in the design of frequency translators[1] and high resolution phase shifters for EW systems as well as in broadband simulators as I-Q modulators, where separate control of the quadrature components of the signal allow for independent adjustment of both phase and amplitude.

Analog phase shifters are readily convertible to digital control by the addition of suitable D/A converters and appropriate linearizing circuits.

(1) *Phase shifters can be used to translate the frequency of an RF carrier by subjecting it to a linear time varying phase shift.*

Phase Shifters and I-Q Modulators

WHAT IS AN IQ VECTOR MODULATOR?

An IQ Vector Modulator is an RF or microwave circuit which has the ability to control both the amplitude and phase of the transmitted signal simultaneously. Any sinusoidal signal can be expressed as a vector having the properties of both amplitude and phase with respect to a reference signal. If a signal is thought of as a vector in a polar coordinate system with coordinates of amplitude and phase, it can also be defined in a rectangular coordinate system with coordinates of "I" and "Q". The term "IQ" does not represent anything about the intelligence of the design engineer, but rather that the user can control both the "In-Phase" and "Quadrature-Phase" components of the output signal.

WHAT IS A TYPICAL IQ MODULATOR CIRCUIT?

The circuit typically includes an input power divider which splits the incident signal into two paths, an amplitude and/or phase control element in each path, and an output signal summing circuit. In the simplest embodiment, the input signal is divided into two equal signals with a 90° phase difference; controlled by a phase invariant bi-phase attenuator in each path; and combined by an in phase power combiner as shown in figure 1 on page 59.

WHAT ACTIVE CONTROL COMPONENTS ARE USED IN IQ MODULATORS?

The control components in an IQ vector modulator are circuits that employ PIN diode, Schottky diode or FET devices. The simplest circuit uses a PIN diode attenuator in series with a PIN-diode bi-phase modulator, or a combination of the two devices in a single bi-phase attenuator. This device has the property of providing a continuous function which first attenuates the input signal with no phase shift, then shifts phase 180° at maximum attenuation, and then decreases attenuation while holding a constant 180° phase shift. Balanced or double balanced Schottky diode or FET mixers exhibit a similar function, but are limited in dynamic range of attenuation. PIN diode devices usually exhibit higher power handling, lower insertion loss and higher intercept points than Schottky diode or FET based devices. Schottky diode or FET devices are preferred for modulation rates higher than a few megahertz.

WHAT ARE SOME OF THE USES OF IQ VECTOR MODULATORS?

- Amplitude and Phase control for RF simulator systems
- Quadrature Amplitude Modulation
- Cancellation of unwanted jamming signals
- Cancellation of crosstalk between co-located communication systems
- Cross-Polarization Cancellation
- Doppler Simulation
- Nulling of antenna reflections in monostatic radar systems
- Complex weights for Phased Array Antennas
- Linear Filter Equalizer

HOW ARE IQ VECTOR MODULATORS CALIBRATED?

Calibration of the IQ vector modulator for controlled amplitude and phase response is often performed by generating a "look-up" table using a vector network analyzer. To obtain the highest degree of accuracy, the calibration should be performed in-situ. A discussion of calibration techniques is provided on page 58. When IQ vector modulators are used in a nulling system an algorithm can readily be developed to adjust the values of I and Q in a closed loop fashion to achieve the desired system performance.

CAN THE I-Q VECTOR MODULATOR BE CUSTOMIZED FOR SPECIAL APPLICATIONS?

General Microwave has customized many variations of the IQ vector modulator for numerous applications ranging from low cost designs to nuclear hardened radar systems. Our sales and engineering staff are available to help you maximize your system performance by incorporating IQ vector modulators to meet challenging system requirements

DEFINITION OF PARAMETERS

Phase Shift:

The difference in phase angle of the existing RF signal at a given frequency and phase shift setting referenced to the exiting signal at the same frequency with the phase shifter set to zero degree phase shift.

Accuracy:

The maximum deviation in phase shift from the programmed phase shift over the operating frequency range when measured at room temperature.

Temperature Coefficient:

The average rate of change in phase shift, as referenced to the zero degree phase state, over the full operating temperature range of the unit. Expressed in degrees phase shift/degrees C.

PM/AM:

The maximum peak-to-peak change in insertion loss of the phase shifter at any phase state over the full 360° phase range.

Switching Speed:

The time interval from the 50% point of the TTL control signal to within 10° of final phase shift. This applies to a change in either direction between any two phase states which differ by more than 22.5°.

Carrier Suppression:

When the phase shifter is operated as a frequency translator, the minimum ratio of carrier output power to the translated carrier output power.

Sideband Suppression:

When the phase shifter is operated as a frequency translator, the minimum ratio of any sideband output power to the translated carrier output power.

Translation Rate:

When the phase shifter is used as a frequency translator, the translation rate is determined by dividing the clock rate by the number of steps. Number of steps is equal to 2" where n equals number of bits.

TYPICAL PERFORMANCE CHARACTERISTICS

HARMONICS AND INTERMODULATION PRODUCTS

All PIN diode control devices will generate harmonics and intermodulation products to some degree since PIN diodes are non-linear devices. When compared to digital switched-bit designs, analog PIN diode phase shifters are more prone to generate spurious signals since the diodes function as current-variable resistors and are typically operated at resistance levels where significant RF power is absorbed by the diode.

The levels of harmonic and intermodulation products generated by a phase shifter or I-Q modulator are greatly dependent upon its design, the operating frequency, attenuation setting and input power level. Typical 2nd and 3rd order intercept performance for a moderately fast phase shifter, i.e. 500 nsec switching speed follows:

TYPICAL INTERCEPT POINTS		
Frequency	**2nd Order Intercept**	**3rd Order Intercept**
2.0 GHz	+35 dBm	+30 dBm
8.0 Ghz	+40 dBm	+35 dBm

PHASE NOISE

The phase shifters and I-Q modulators offered by General Microwave minimize the contribution of phase noise to system performance. This is accomplished by utilizing PIN diodes which are less sensitive to high frequency noise than Schottky diodes, limiting the noise bandwidth in driver control elements and the use of low noise buffer amplifiers to drive the PIN diodes.

Theory of Operation & Practical Applications

I-Q VECTOR MODULATOR— THE IDEAL CONTROL COMPONENT!

Microwave control components are used to vary signal amplitude and phase. Typically, they consist of two-port devices including amplifiers, attenuators, phase shifters, and switches. The I-Q vector modulator is a unique combination of active and passive devices that is, in theory, ideally suited for the simultaneous control of amplitude and phase.

THEORY OF OPERATION

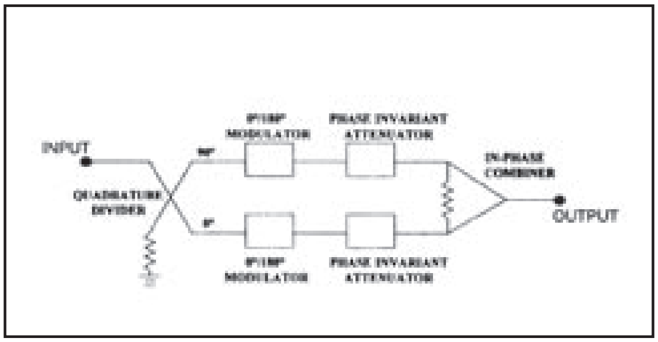


FIGURE 1
I-Q Vector Modulator Block diagram

The block diagram of the I-Q vector modulator is shown in Figure 1. An RF signal incident on a 3 dB quadrature hybrid is divided into two equal outputs, with a 90 degree phase difference between them. The in-phase or 0 degree channel is designated the I channel and the quadrature or 90 degree channel is designated the Q channel. Each signal passes through a biphase modulator which selects the 0 or 180 degree state for both the I and the Q paths. This defines the quadrant in which the resultant output signal resides (Figure 2). The attenuator in each path then varies the magnitude of each of the signals, which are combined in phase to yield the resultant vector. This vector will lie anywhere within the bounded area shown in Figure 2. Thus, any signal applied to the I-Q vector modulator can be shifted in phase and adjusted in amplitude by assuming the desired attenuation level = x dB and the desired phase shift = Θ degrees. The normalized output voltage magnitude is then given by:

$$R = 10^{-(x/20)}$$

The attenuation values of the I and Q attenuators are then given by:

$$\text{I attenuator (dB)} = 20 \log (R \cos \Theta)$$

$$\text{Q attenuator (dB)} = 20 \log (R \sin \Theta)$$

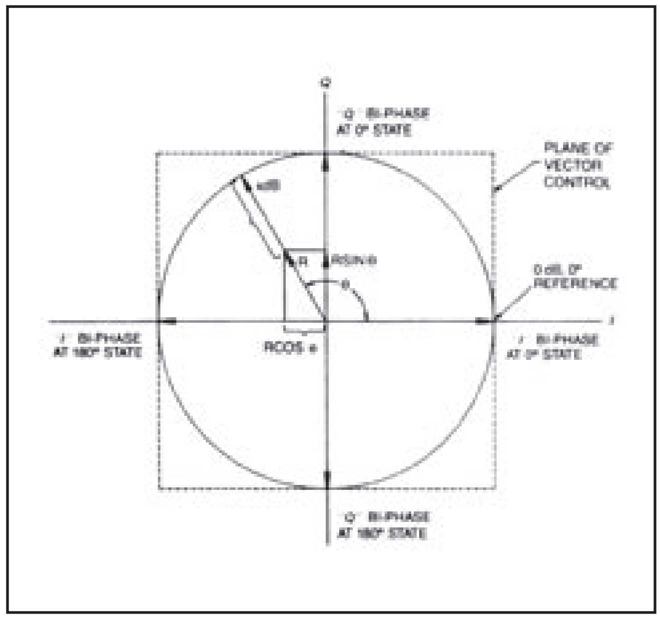


FIGURE 2
I-Q Phase Relationship

To achieve the desired phase shift, biphase modulator states must also be selected as shown in Table 1. In this way, the phase and amplitude of the output signal can be varied simultaneously in a controlled fashion.

TABLE 1

Biphase Modulator States I	Q	Desired Phase Shift
0°	0°	0°-90°
180°	0°	90°-180°
180°	180°	180°-270°
0°	180°	270°-360°

The theoretical model presupposes perfect amplitude and phase balance in the two signal paths, and ideal quadrature coupling in the 3 dB hybrid. To the extent that the conditions are not met in practice, the performance of the I-Q vector modulator will be limited.

PHASE BALANCE

The key element in determining the useful frequency range of the I-Q vector modulator is the 3 dB quadrature hybrid. Its most important characteristic is very low quadrature phase error (such as small deviation from 90 degree phase shift between outputs). To achieve this over a broad frequency range, we employ the Hopfer quadrature hybrid[(2)], which exhibits extremely wideband quadrature-phase properties (typically greater than 3 to 1 bandwidth with ±2-degree phase balance).

In addition to using an in-phase Wilkinson combiner (which, with proper design, exhibits excellent phase balance) the transmission-line length for the I and Q paths must also be carefully phase-matched.

(2) *S. Hoofer, "A Hybrid Coupler for Microstrip Configuration," IEEE MTT-S International Microwave Symposium Digest, 1979.*

AMPLITUDE BALANCE

The amplitude balance of the I and Q paths is a second source of performance limitation. Unequal power levels in these paths also produce errors in both the amplitude and phase of the transmitted signal. To minimize this source of error, the quadrature-hybrid coupling must be adjusted to provide minimum deviation from the nominal 3 dB across the frequency band. For an ideal hybrid, the amplitude unbalance will be ±0.31 dB over an octave band. The effect of amplitude and balance error on phase is shown in Figure 3.

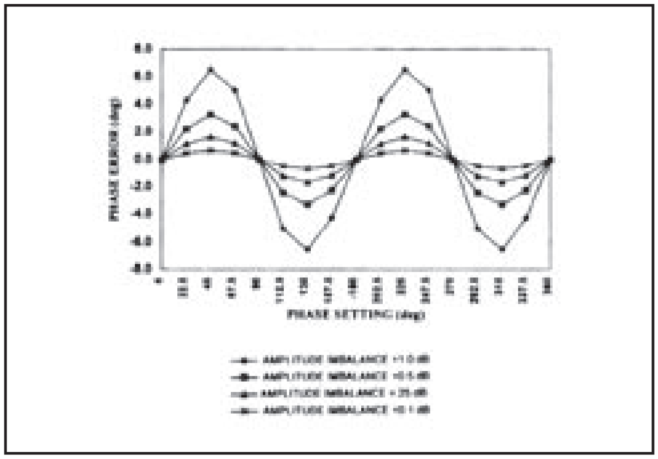


FIGURE 3
Phase Error Due to Amplitude Imbalance

NON-IDEAL BI-PHASE MODULATOR AND ATTENUATOR

Errors in amplitude and phase will occur if the biphase modulator deviates from the ideal, eg: changes state from 0 to 180 degrees with constant amplitude or if the attenuator has an associated phase shift as attenuation is varied. Not only do these components in practice exhibit such deviations, but their interacting reflections may increase the resultant errors significantly. The arrangement in Figure 4 minimizes the errors. As indicated, the tandem combination of a biphase modulator and attenuator in each path is replaced by a doubly-balanced biphase modulator. The doubly-balanced biphase modulator developed by General Microwave[3] has the ability to attenuate a signal by more than 20 dB with constant phase, then change the phase 180 degrees and return to the low-loss state. At insertion loss, it exhibits a maximum phase error of less than ±6 degrees and an amplitude balance of ±0.5 dB over a 3 to 1 bandwidth.

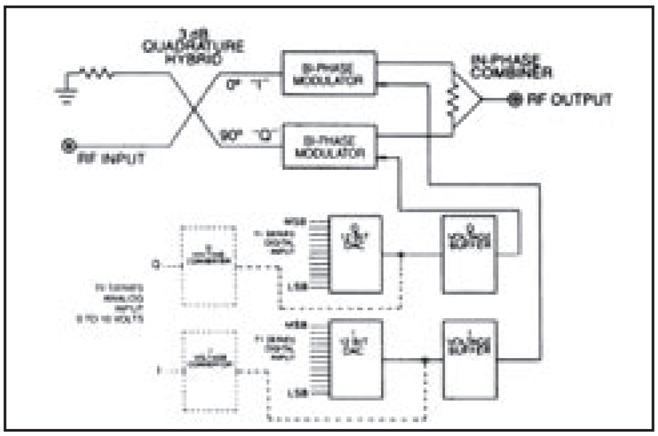


FIGURE 4
Series 71/71 Block Diagram

PRACTICAL APPLICATIONS

PHASE SHIFTERS

If the doubly-balanced biphase-modulator conditions are adjusted so that the magnitude of the resultant vector remains fixed, the I-Q vector modulator can behave as a constant-amplitude phase shifter. The relationships between the desired phase shift and the I and Q attenuation levels are given by:

$$|I|^2 + |Q|^2 = 1$$

$$I = \cos \Theta$$

$$Q = \sin \Theta$$

where I and Q are normalized voltages.

(3) *Z. Adler and B. Smilowitz, "Octave-Band High-Precision Balanced Modulator," IEEE MTT-S International Microwave Symposium Digest, 1984.*

The relationship between the I and Q drive circuitry can be generated in either analog or digital fashion. The analog circuit employs a broadband quadrature hybrid to generate the drive signals. In the digital drive circuit, PROMS are used to provide the required relationships between I and Q. See the Selection Guide on page 61 for the General Microwave phase shifter model numbers.

FREQUENCY TRANSLATORS

A signal-processing technique using a linear time-varying phase shifter is one method of frequency translation. One principal use is in velocity deception for ECM systems by providing false Doppler radar returns.

In a true Doppler radar situation, the reflected signal is translated in frequency in an amount proportional to the radial velocity of the target. As a rule, there are no harmonics or spurious signals accompanying the reflection. However, if the target is using velocity-deception techniques, spurious signals may be present in the radar return because of the non ideal performance of the frequency translator. The presence of these spurious signals will reveal that the Doppler radar is being jammed. Therefore, it is critical for optimum ECM system performance that the frequency translator suppress the carrier, harmonics and all unwanted sidebands to the greatest extent possible. For the linear phase shifter, the principal factors that contribute to imperfect carrier suppression and sideband generation are:

2π error

This is the deviation from 360 degrees when maximum phase shift is programmed.

PM/AM error

The amplitude change (AM) is a function of the phase change (PM).

Phase nonlinearity

It is the deviation from linear phase shift vs. time.

Quantization error

This term is usually negligible for phase resolution greater than 6 bits. It arises in a digital phase shifter, which only approximates linear phase shift with discrete phase steps.

Flyback time

This arises from the finite time required by the phase shifter to return from 360 to 0 degrees.

In the I-Q modulator, since the network operates as a constant-velocity rotating vector, the 0 and 360 degree phase states are exactly the same, and the 2π error and flyback error are eliminated. In addition, the General Microwave Series 77 provides 10 bits of digital phase control (sufficient to eliminate the quantization error), while phase linearity is optimized by the use of PROM correction in the drive circuitry. Finally, the PM/AM error is minimized by using matched doubly-balanced biphase modulators, thereby reducing this error essentially to the difference in amplitude of the 3 dB quadrature hybrid output ports. This amplitude imbalance varies with frequency and generates a unique spurious sideband during frequency translation. An additional PROM correction using RF operating frequency information can be employed to reduce this spurious sideband for customer requirements.

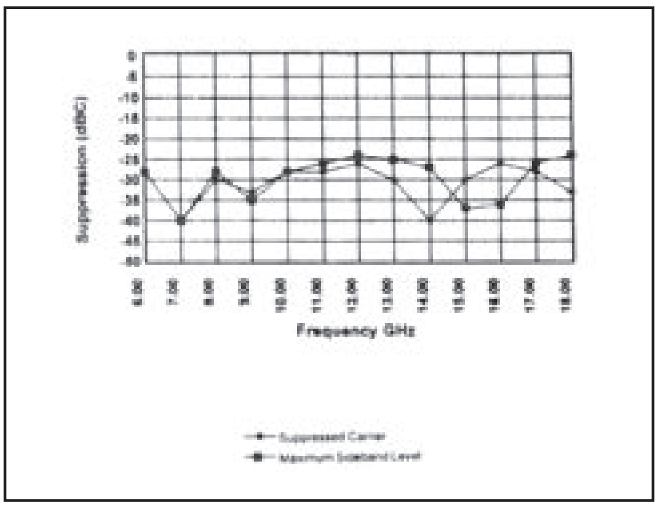


FIGURE 5–Typical Carrier and Sideband Suppression
General Microwave Model 7728A
Frequency Translator

The specifications of the General Microwave Series 77 Digitally Controlled and Series 78 Voltage Controlled Frequency Translators include 25 dB carrier suppression and 20 dB sideband suppression over a three-to-one frequency range. Typical performance data for carrier and sideband suppression, of the 6 to 18 GHz Model 7728A, are shown in Figure 5. Carrier and sideband suppression of greater than 34 dB for a frequency translator covering a 15-percent bandwidth at X band over the operating temperature range of –54°C to +100°C have been achieved in production quantities.

COMPLEX I-Q VECTOR MODULATORS

System requirements often call for a tandem connection of phase shifters and attenuators to provide independent control of magnitude and phase of an RF signal. If tight tolerances are required for the amplitude and phase accuracy, a look-up table is usually incorporated in the system software to calibrate the phase shift and attenuation across the frequency range. This is a tedious job that entails the generation of an extensive amount of error correction data, obtained by alternately varying the phase shifter and attenuator over the dynamic range for each narrow frequency band where optimization is required. The inclusion of an I-Q vector modulator in the system in place of a discrete phase shifter and attenuator offers several distinct advantages. A single RF component replaces two separate units, thus reducing cost and eliminating interacting VSWR. The relationship between the I and Q inputs and the desired amplitude and phase permits a tremendous reduction in the amount of data required for a look-up table. This is because the I and Q inputs are independent variables for the I-Q vector modulator, whereas the tandem connection of attenuator and phase shifter exhibit large AM to PM and PM to AM pushing, creating dependency between the amplitude and phase inputs. Depending on the frequency range and accuracy specifications, the RF circuitry of the I-Q vector modulator can be optimized to eliminate the need for a look-up table entirely.

The I-Q Vector Modulator is ideally suited for use in EW Simulators, Adaptive Equalizers or Automatic Test/Calibration Systems where extremely high accuracy and repeatability are essential.

See the Selection Guide on page 61 for the General Microwave I-Q Vector Modulator model numbers.

Amplitude and Phase Calibration

General Microwave I-Q Vector modulators can be calibrated to provide precision control on both amplitude and phase over their full rated dynamic range. The calibration is performed using a vector network analyzer and a customer generated test program to achieve the utmost in accuracy. The most frequently used algorithm to accomplish this calibration is described herein. This algorithm involves defining a unity circle and then employing an iterative technique to locate precise calibration values.

Many factors contribute to the overall accuracy that is achievable using any calibration routine for the I-Q vector modulator. It is important that the user fully understand the limitations of measurements in calibrating these units at microwave frequencies. For example, it is imperative that the desired calibration accuracy not exceed the accuracy and repeatability of the microwave test equipment. Another factor which must be included in the overall calibration accuracy is the effects of temperature on the I-Q modulator and the test equipment. Given that the user has a thorough understanding of vector network analyzer measurements, the following will be useful for generating a calibration program for a digitally controlled I-Q vector modulator. (Note that an analog controlled unit can be calibrated in the same fashion using the relationship that 000 hex equals zero volts and FFF hex equals ten volts on the I and Q controls.)

1.0 The calibration routine is performed at discrete frequencies in the band of interest. The calibration will be valid over an interval of frequencies centered at the calibration frequency and will be limited by the amplitude and phase errors that occur as frequency is varied. The highest calibration accuracy will occur with minimum frequency interval size. However this may require an excessive amount of calibration time and data storage. It is recommended that a calibration interval of 100 to 200 MHz be used in the center of the frequency range of the vector modulator and 25 to 50 MHz be used at the band edges. The optimum calibration interval for any user must be determined empirically by insuring that the maximum phase and amplitude error over the frequency calibration interval is within the desired limits.

2.0 Once the calibration interval and the calibration frequency have been chosen, the next step is to define the I and Q axes and the magnitude of the unit circle. For this example, the I axis is defined to be the horizontal axis on the I-Q plane with control word 000 (hex) being equivalent to a vector of approximate magnitude 1.0 at an angle of zero degrees. In the same fashion the Q axis is defined to be the vertical axis on the I-Q plane with control word 000 (hex) equivalent to a vector of approximately magnitude 1.0 at an angle of 90 degrees. Note that for both I and Q, the magnitude zero vector is approximately 7FF (hex) and the magnitude –1.0 vector occurs as FFF (hex). Following this procedure the definition of the I-Q plane is arrived at per the table below:

TABLE 2

I CONTROL (hex)	Q CONTROL (hex)	APPROX. VECTOR
000	7FF	1.0 ANG 0°
FFF	7FF	1.0 ANG 180°
7FF	000	1.0 ANG 90°
7FF	FFF	1.0 ANG 270°

3.0 The magnitude of the unit circle is determined by finding the maximum insertion loss at the calibration frequency in each of the four states in table 2 above. Since by nature the I-Q plane is a square and not a circle (see figure 6), the maximum insertion loss will occur at one of these four states. Once the maximum insertion loss is determined, the I or Q values of the other three states in table 2 are adjusted to meet the same maximum insertion loss level. Note that only either I or Q should be adjusted to increase insertion loss at any state, not both. The I or Q value that is initially set to 7FF (which is approximately the center of the IQ plane) is not varied during this part of the calibration since the amplitude of the unit circle is not affected by small changes in the control input.

4.0 Having thus defined the unit circle, the next step is to scale the I and Q axes to allow for computation of I and Q values given the desired amplitude and phase. If the I and Q axes were perfectly linear and each consisted of 4096 equal increments (for a 12 bit control), it would be possible to achieve the desired amplitude and phase shift using only the sine and cosine relationships given in figure 6. In order to approach the ideal case, the I and Q values for each of the four states given in table 2 must be scaled if they differ from 000 or FFF (note that the control input at 7FF is not varied in this step). The scaling entails taking the difference between 2048 digital counts (equal to one half of the 12 bit control) and the number of counts required to equalize the insertion loss of each of the four states required for the unit circle derived from step 3.0. For example, assume that the I value at zero degrees (I=000, Q=7FF), is the maximum insertion loss of the four states and that in order to achieve the same level of insertion loss at 180° (nominal value I=FFF, Q=7FF), I must be lowered by 127 counts such that the new value for 180° on the unity circle is I=F80, Q=7FF. In this case the I axis for 1<0 (in the second and third quadrants) is limited to 1921 counts instead of 2048. Thus, when the algorithm is determining the equivalent I value for a desired amplitude and phase occurring in the first or fourth quadrants, the calculated value for I=R*cos Θ is multiplied by 2048 and the result subtracted from 2048 (1=7FF, the origin). When, in the same example, this calculation is done for a vector that occurs in the second or third quadrants, the calculated value for I= R*cos Θ will be multiplied by 1921 and the result added to 2048 (I=7FF) to find the desired I value (reference the I scale at the bottom of figure 6). The scale value will be called SCALE in calculations given in step 5.2. While this scaling is not precise, it is sufficient to enable the algorithm to establish the boundary of the I-Q plane such that any desired amplitude and phase calibration point can be achieved with a minimum of iterations.

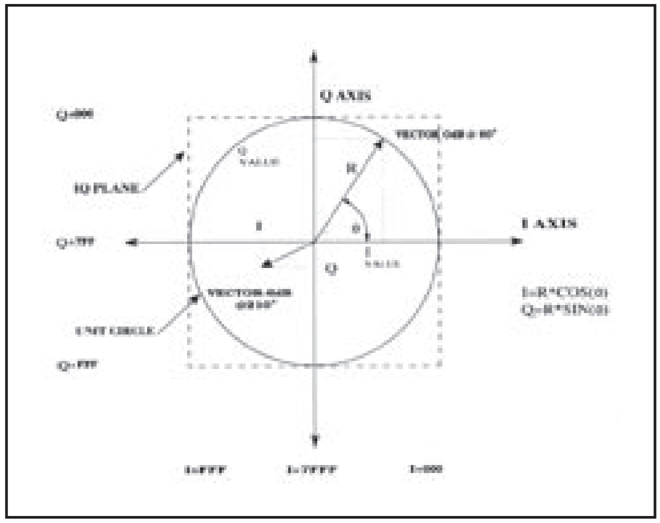


FIGURE 6
I-Q Vector Model

5.0 Once the scaling of the axes has been accomplished, the zero degree point on the unity circle is stored and normalized on the vector analyzer. The control word for this point will be approximately I=000, Q=7FF and all succeeding phase and amplitude values will be referenced to this point. Note that the I control word will differ from 000 if it is not the maximum insertion loss state of the four states listed in table 2. The Q control word will be equal to 7FF. An algorithm to find any desired amplitude and phase with respect to the normalized unit circle zero degree point can be constructed from the following procedure:

Amplitude and Phase Calibration

5.1 Convert the desired amplitude to a ratio such that the desired amplitude and phase can be expressed as a magnitude (R) and phase (Θ). This is the desired phase and amplitude change with respect to the normalized point obtained in step 5.0.

5.2 Solve for the required values of I and Q and multiply by appropriate scaling factor as outlined in step 4.0. I = (R*cos Θ)*SCALE, Q = (R*sin Θ)*SCALE. This process is essentially changing from polar coordinates (amplitude and phase) to rectangular coordinates I and Q.

5.3 Change I-Q modulator control word to the value obtained above and measure the resultant amplitude and phase. Compare the difference between the desired vector (at the calibration frequency) and the measured vector. This difference vector will be adjusted by successive iterations until its amplitude and phase error from the desired value is less than the desired calibration accuracy value. From experience, accuracy values of 0.1 dB and 1 degree are reasonable calibration limits for attenuation levels below 20 dB. However higher accuracy is achievable with careful measurements.

5.4 If the measured vector is within the error limits, store the I-Q value in the calibration table that is being set up. If the error is larger than the limit, calculate the I and Q change that is necessary to reach the desired vector. This is performed by changing both the desired vector and the error vector back into rectangular I-Q coordinates and calculating the difference in I and Q control word required to reach the desired vector. It is recommended that the I-Q steps taken be limited to one half of the calculated value in order to minimize hunting time. Repeat this process until the desired point is reached within the accuracy limits.

6.0 Complete calibration is usually performed by generating sets of constant amplitude circles on the I-Q plane. Data points can readily be interpolated over the plane and therefore only a limited number of actual calibration points are required. Our experience shows that calibration points taken every 22.5 degrees around a constant amplitude circle with a linear interpolation of I and Q values to find intermediate phase angles is sufficient to achieve high accuracy. Constant amplitude circles should be calibrated every 0.5 dB for the first two dB above insertion loss and 1.0 dB increments beyond that level. Interpolation between constant amplitude circles is also useful in minimizing data collection. For applications that require high speed (<1.0 µsec) variations between amplitude and phase states, the entire I-Q plane can be calibrated, interpolated and the results stored for each frequency interval. Where speed is not critical, an interpolation routine can be run in real time and thus the data storage can be minimized. Typical calibrations using this technique should provide amplitude accuracy of ±0.2 dB and phase accuracy of ±2.0 degrees over a 10 dB dynamic range for each frequency calibration interval.

Further improvements in accuracy can be obtained by the following:

- Tightening up the error limits at each calibration point
- Reducing the frequency interval
- Maintaining tight control of temperature (less than ±3 degrees C)

Phase Shifters and I-Q Modulators Selection Guide

PHASE SHIFTERS/FREQUENCY TRANSLATORS
BI-PHASE MODULATORS
I.Q. VECTOR MODULATORS

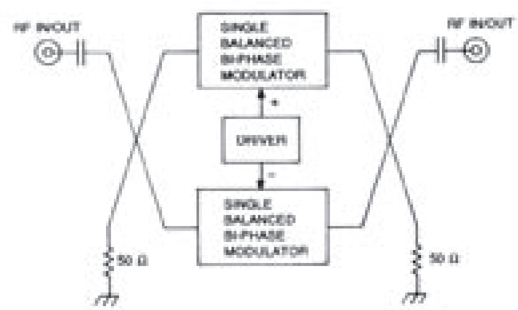
FREQUENCY RANGE (GHz) 0.5 – 2.0 – 4.0 – 6.0 – 8.0 – 12.0 – 18.0	MODEL	PAGE	COMMENTS
0.5 — 2.0	7720A/7820	77	Phase shifter/Frequency translator, digital/analog
2.0 — 6.0	7722A/7822		Phase shifter/Frequency translator, digital/analog
4.0 — 12.0	7724A/7824		Phase shifter/Frequency translator, digital/analog
6.0 — 18.0	7728A/7828		Phase shifter/Frequency translator, digital/analog
6.0 — 18.0	7928	81	Miniature Phase shifter/Frequency translator, Hermetically sealed,digital
6.0 — 18.0	F1938	62	I.Q. Vector modulator, digital/analog
0.5 — 2.0	7120/7220	65	I.Q. Vector modulator, digital/analog
2.0 — 6.0	7122/7222		I.Q. Vector modulator, digital/analog
4.0 — 12.0	7124/7224		I.Q. Vector modulator, digital/analog
6.0 — 18.0	7128/7228		I.Q. Vector modulator, digital/analog
2.0 — 6.0	7322/7422	70	I.Q. Vector modulator, digital/analog High Dynamic Range
6.0 — 18.0	7328/7428		I.Q. Vector modulator, digital/analog High Dynamic Range
16.0 — 24.0	7329/7429		I.Q. Vector modulator, digital/analog High Dynamic Range
6.0 — 18.0	7328H	75	I.Q. Vector modulator, High speed High Dynamic Range

Model F1938
Bi-Phase Modulator
With Integrated Driver

- **Frequency range: 6-18 GHz**
- **Differential phase shift: 180° ±10°**
- **High speed: 5 nsec (10-90% RF)**
- **Low VSWR and insertion loss**
- **Small size, light weight**

The Model F1938 is a high-speed 0° or 180° phase shifter that operates over the 6 to 18 GHz frequency range. It features a double-balanced design that provides excellent phase accuracy over its entire frequency range.

The RF design is shown below. The currents required to switch the unit between states are provided by the integrated driver, which is controlled by an external logic signal.



Model F1938, block diagram

PERFORMANCE CHARACTERISTICS

Frequency Range .... 6 to 18 GHz
Differential Phase Shift[(1)] .... 180° ±10°
Switching Characteristics[(2)]
ON Time .... 20 nsec max
OFF Time .... 20 nsec max
Rise Time .... 5 nsec max
Fall Time .... 5 nsec max
Insertion Loss[(1)] .... 6 to 16 GHz, 3 dB max
>16 to 18 GHz, 3.5 dB max
VSWR[(1)] .... 2.0 max
Change of Insertion Loss
with Phase Shift .... 1.0 dB max
Carrier Suppression .... 20 dB min
Modulation Rate .... 10 MHz max
Power Handling Capability
Without Performance
Degradation .... 1W cw or peak
Survival Power .... 2W average, 25W peak (1µsec max pulse width)
Power Supply Requirements .... +5V ±5%, 65mA
–12 to –15V, 20 mA

Control Characteristics

Control Input Impedance .... Schottky TTL, two-unit load. (A unit load is 2 mA sink current and 50 µA source current.)
Control Logic .... Alternate applications of logic “0” (–0.3 to +0.8V) and logic “1” (+2.0 to +5.0V) switches phase by 180°.

(1) With option 85, within Frequency Band of 16 to 18 GHz will be:
a. Insertion Loss: 4 dB max
b. Differential Phase Shift: 180° ±15°
c. VSWR: 2.2:1 max

(2) As measured with a phase bridge.

Model F1938 Specifications

ENVIRONMENTAL RATINGS

Operating Temperature
Range .... –65° to +110°C

Non-Operating Temperature
Range .... –65° to +125°C

Humidity .... MIL-STD-202F, Method 103B, Cond. B (96 hrs. at 95%)

Shock .... MIL-STD-202F, Method 213B, Cond. B (75G, 6 msec)

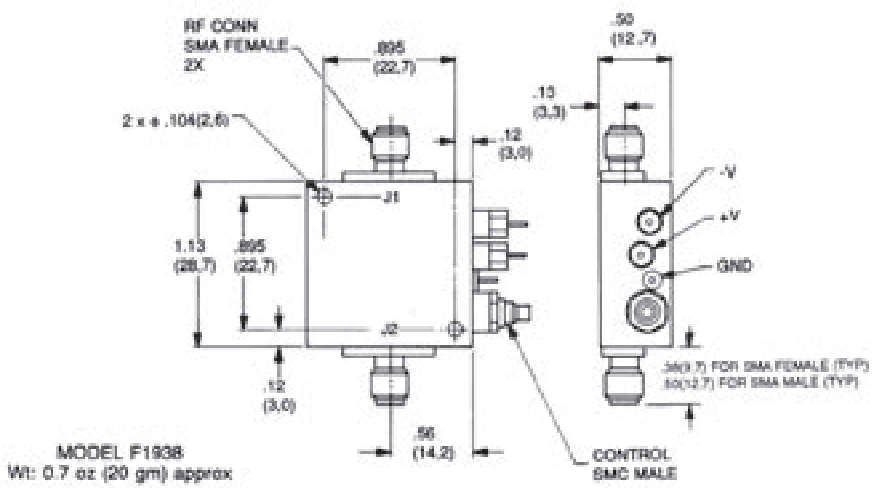
Vibration .... MIL-STD-202F, Method 204D, Cond. B (.06" double amplitude or 15G, whichever is less)

Altitude .... MIL-STD-202F, Method 105C, Cond. B (50,000 ft.)

Temp. Cycling .... MIL-STD-202F, Method 107D, Cond. A, 5 cycles

AVAILABLE OPTIONS

Option No.	Description
3	SMA female control connector
7	Two SMA male RF connectors
10	One SMA (J1) male and one SMA female (J2) RF connector
33	EMI filter solder-type control terminal
85	SMA RF connectors (see note (1) page 63 for specification change with this option)



Dimensional Tolerances, unless otherwise indicated: .XX ±.02; .XXX ±.005

Series 71, 12 Bit Digital and Series 72 Analog I-Q Vector Modulators

Both Series comprise a family of four solid-state PIN diode I-Q Vector Modulators covering the frequency range from 0.5 to 18 GHz in four bands: 0.5 to 2 GHz, 2 to 6 GHz, 4 to 12 GHz and 6 to 18 GHz. See Fig. 1.

All models provide a full 360° range of phase shift and a minimum of 20 dB attenuation range at any frequency.

- **Simultaneous control of amplitude and phase**
- **0.5 to 18 GHz in four bands: 0.5 to 2 GHz; 2 to 6 GHz; 4 to 12 GHz; 6 to 18 GHz**
- **12 Bit digitally programmable (Series 71)**
- **Analog control (Series 72)**
- **High speed**
- **Guaranteed monotonicity**

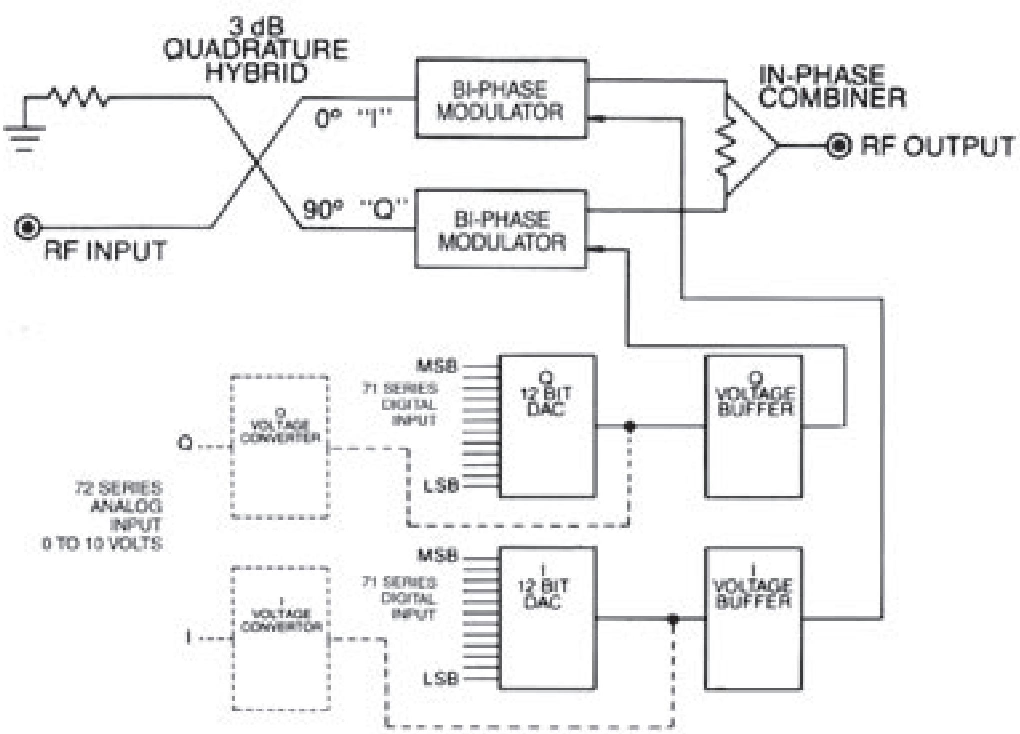


Fig. 1–Series 71, 72 Block Diagram

Series 71, 12 Bit Digital and Series 72 Analog I-Q Vector Modulations

THEORY OF OPERATION

The block diagram of the I-Q Vector Modulator is shown in Figure 1. An RF signal incident on a 3 dB quadrature hybrid is divided into two equal outputs, with a 90° phase difference between them. The in-phase, or 0°, channel is designated the I channel and the Quadrature, or 90°, channel is designated the Q channel. Each signal passes through a biphase modulator which sets the 0° or 180° state and the attenuation level for both the I and Q paths. The outputs of the I and Q path are combined to yield the resultant vector which may fall anywhere within the bounded area shown in Figure 2. Any signal applied to the I-Q Vector Modulator can be shifted in phase and adjusted in amplitude by applying the following relationships:

1. Let the desired attenuation level = X dB and the desired phase shift = θ° (with respect to 0 dB and 0° reference states).
2. The normalized output voltage magnitude is given by: $|V| = 10^{-(x/20)}$.
3. The values of the I and Q attenuator control inputs are then expressed as:

$$I = V \cos \theta$$

and

$$Q = V \sin \theta.$$

Figure 3 shows the nominal value of I and Q vs. either digital word (Series 71) or analog voltage (Series 72). Thus, to achieve an attenuation level of 3 dB with a phase offset of 112.5° (with respect to 0 dB and 0° reference states) the values of I and Q can be calculated as follows:

$$V = 10^{-(3/20)} = 0.707$$

$$I = 0.707 \cos (112.5°) -.027$$

$$Q = 0.707 \sin (112.5°) +0.65$$

From Figure 3, the control inputs to yield the desired amplitude and phase are approximately:

Analog Units (72 Series)	Digital Units (71 Series)
I = 5.78 volts	100101000000
Q = 2.84 volts	010010001011

While these values for I and Q will yield an output signal whose amplitude and phase are close to the nominal values over the entire operating frequency range of the vector modulator, the use of an iterative measurement procedure will determine the I and Q inputs which exactly define the desired parameter at any selected frequency.

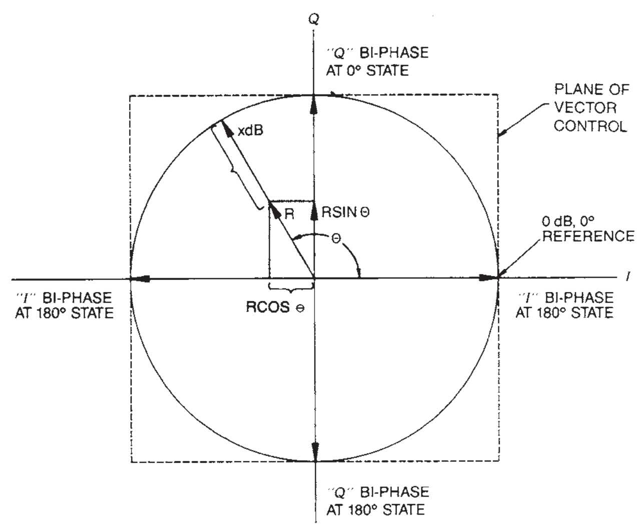


Fig. 2–I-Q Phase Relationship

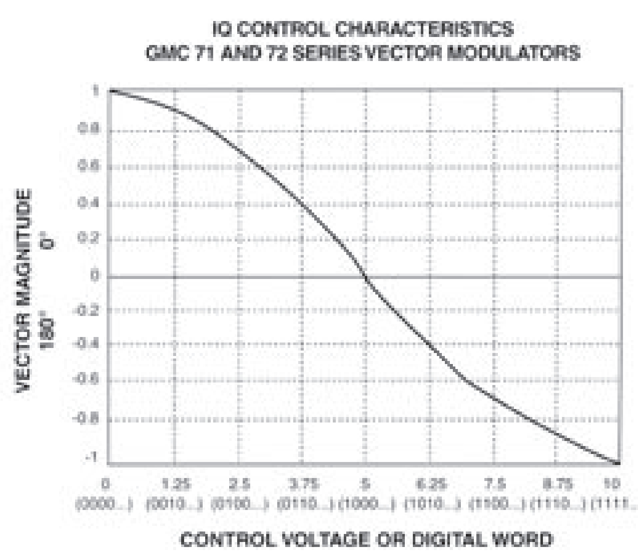


Fig. 3 – I-Q vs. Control Input (Typical)

PERFORMANCE CHARACTERISTICS

MODEL	7120/7220	7122/7222	7124/7224	7128/7228
FREQUENCY	0.5-2.0 GHz	2.0-6.0 GHz	4.0-12.0 GHz	6.0-18.0 GHz
INSERTION LOSS	13 dB	11 dB	12 dB	12 dB
VSWR (MAX)	1.6:1	1.8:1	1.8:1	2.0:1
POWER HANDLING WITHOUT PERFORMANCE DEGRADATION	+7 dBm	+20 dBm	+20 dBm	+20 dBm
SURVIVAL POWER (MAX)	1W			
ABSOLUTE INSERTION PHASE ACCURACY VS. FREQUENCY (MAX)	±15°			
FINE GRAIN PHASE RIPPLE (50 MHz) (MAX)	2° pk-pk			
VARIATION OF PHASE VS. TEMPERATURE (MAX)	±0.1 deg./ °C			
ATTENUATION RANGE (MIN)	20 dB			
VARIATION OF AMPLITUDE VS.TEMPERATURE (MAX)	0.02 dB/ °C			
RESPONSE TIME (MAX)	0.5 µsec			
POWER SUPPLY	–12 to –15V @ 70 mA +12 to +15V @ 70 mA			
CONTROL INPUT 71 SERIES 72 SERIES	12 bit TTL for both I and Q inputs 0 to +10V DC for both I and Q inputs			
CONTROL INPUT IMPEDANCE 71 SERIES 72 SERIES	40 µA max 10 K ohms			

ENVIRONMENTAL RATINGS

Operating Temperature Range .... –54°C to +100°C

Non-Operating Temperature Range .... –65°C to +125°C

Humidity .... MIL-STD-202F, Method 103B, Cond. B (96 hrs. at 95%)

Shock .... MIL-STD-202F, Method 213B, Cond. B (75G, 6 msec)

Vibration .... MIL-STD-202F, Method 204D, Cond. B (.06" double amplitude or 15G, whichever is less)

Altitude .... MIL-STD-202F, Method 105C, Cond. B (50,000 ft.)

Temp. Cycling .... MIL-STD-202F, Method 107D, Cond. A, 5 cycles

ACCESSORY FURNISHED

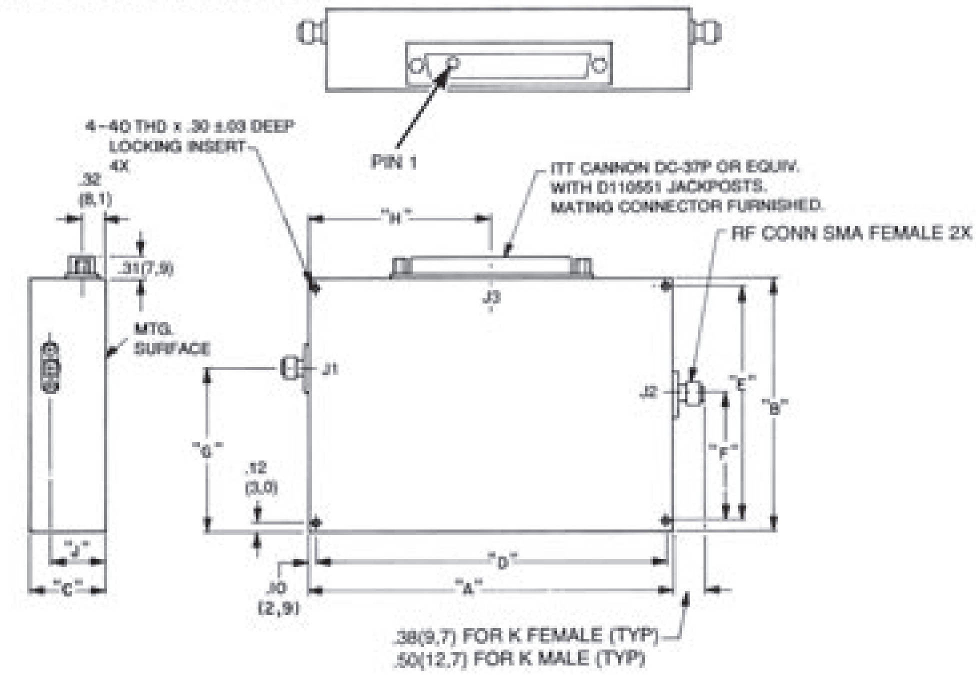
Mating power/control connector (Series 71 only)

AVAILABLE OPTIONS

Option No.	Description
7	Two SMA male RF connectors
10	One SMA male (J2) and one SMA female (J1) RF connector

Seeries 71/72
Specifications

DIMENSIONS AND WEIGHTS



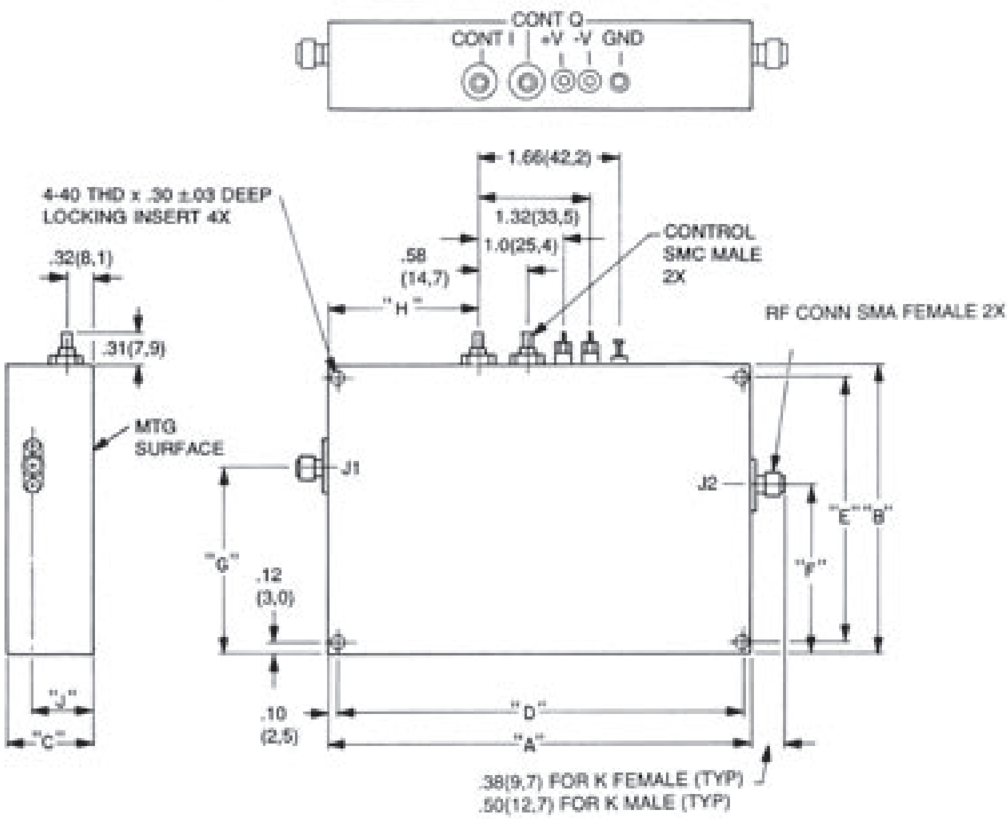
<table>
<tr><th>MODEL</th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th><th>G</th><th>H</th><th>J</th></tr>
<tr><td>7120</td><td>4.95±.03
(125,7)</td><td>3.38±.03
(85,9)</td><td>1.02
(25,9)</td><td>4.75±.01
(120,7)</td><td>3.12±.01
(79,2)</td><td>1.68
(42,7)</td><td>.75
(19,1)</td><td>2.48
(62,9)</td><td>.73
(18,5)</td></tr>
<tr><td>7122</td><td rowspan="2">3.25±.03
(82,6)</td><td rowspan="2">3.25±.03
(82,6)</td><td rowspan="2">.85
(21,6)</td><td rowspan="2">3.05±.01
(77,5)</td><td rowspan="2">3.00±.01
(76,2)</td><td rowspan="2">1.63
(41,4)</td><td>1.99
(50,5)</td><td rowspan="2">1.63
(41,4)</td><td rowspan="2">.64
(16,3)</td></tr>
<tr><td>7124</td><td>1.83
(46,5)</td></tr>
<tr><td>7128</td><td>3.00±.03
(76,2)</td><td>3.00±.03
(76,2)</td><td>.96
(24,4)</td><td>2.80±.01
(71,1)</td><td>2.75±.01
(69,9)</td><td>1.50
(38,1)</td><td>1.63
(41,4)</td><td>1.50
(38,1)</td><td>.76
(19,3)</td></tr>
</table>

J3 PIN FUNCTION			
PIN	FUNCTION	PIN	FUNCTION
1	I-5	20	I-4
2	I-6	21	I-7
3	I-8	22	I-3
4	I-9	23	I-2
5	I-10	24	I-1 (LSB)
6	I-11	25	I-12 (MSB)
7	N/C	26	N/C
8	+12 to +15V	27	N/C
9	GND	28	GND
10	GND	29	N/C
11	–12 to –15V	30	N/C
12	Q-3	31	N/C
13	Q-2	32	Q-4
14	Q-1 (LSB)	33	N/C
15	Q-5	34	N/C
16	Q-6	35	Q-12 (MSB)
17	Q-7	36	Q-11
18	Q-8	37	Q-10
19	Q-9		

MODEL	WEIGHT (APPROX)
7120	13 oz. (369 gm)
7122	10 oz. (284 gm)
7124	10 oz. (284 gm)
7128	9 oz. (255 gm)

Dimensional Tolerances, unless otherwise indicated: .XX ±.02; .XXX ±.005

DIMENSIONS AND WEIGHTS



<table>
<tr><th>MODEL</th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th><th>G</th><th>H</th><th>J</th></tr>
<tr><td>7220</td><td>4.95±.03
(125,7)</td><td>3.38±.03
(85,9)</td><td>1.02
(25,9)</td><td>4.75±.01
(120,6)</td><td>3.12±.01
(79,2)</td><td>1.68
(42,7)</td><td>.75
(19,1)</td><td>1.75
(44,5)</td><td>.73
(18,5)</td></tr>
<tr><td>7222</td><td rowspan="2">3.25±.03
(82,6)</td><td rowspan="2">3.25±.03
(82,6)</td><td rowspan="2">.85
(21,6)</td><td rowspan="2">3.05±.01
(77,5)</td><td rowspan="2">3.00±.01
(76,2)</td><td rowspan="2">1.63
(41,4)</td><td>1.99
(50,5)</td><td rowspan="2">.90
(22,9)</td><td rowspan="2">.64
(16,3)</td></tr>
<tr><td>7224</td><td>1.83
(46,5)</td></tr>
<tr><td>7228</td><td>3.00±.03
(76,2)</td><td>3.00±.03
(76,2)</td><td>.96
(24,4)</td><td>2.80±.01
(71,1)</td><td>2.75±.01
(69,9)</td><td>1.50
(38,1)</td><td>1.63
(41,4)</td><td>.78
(19,8)</td><td>.76
(19,3)</td></tr>
</table>

MODEL	WEIGHT (APPROX)
7220	13 oz. (369 gm)
7222	10 oz. (284 gm)
7224	10 oz. (284 gm)
7228	9 oz. (255 gm)

Dimensional Tolerances, unless otherwise indicated: .XX ±.02; .XXX ±.005

Series 73 12 Bit Digital and Series 74 Analog High Dynamic Range I-Q Vector Modulators

The new Series 73/74 represents the latest addition to General Microwave's existing line of PIN Diode I.Q. Vector Modulators. Their performance has been enhanced to provide a higher dynamic range of attenuation for today's more demanding system applications.

All models incorporate multiple bi-phase modulator sections to provide in excess of 60 dB attenuation range at any frequency. All models are also capable of a full 360° range of phase shift. The series covers a frequency range of 2 GHz to 24 GHz in three bands: 2 GHz to 6 GHz, 6 GHz to 18 GHz, and 16 GHz to 24 GHz. A simplified block diagram is shown in Fig. 1.

- **Simultaneous control of amplitude and phase over a 60 dB dynamic range**
- **2 to 24 GHz in three bands: 2 to 6 GHz; 6 to 18 GHz; 16 to 24 GHz**
- **12 Bit digitally programmable (Series 73)**
- **Analog control (Series 74)**
- **High speed**
- **Guaranteed monotonicity**

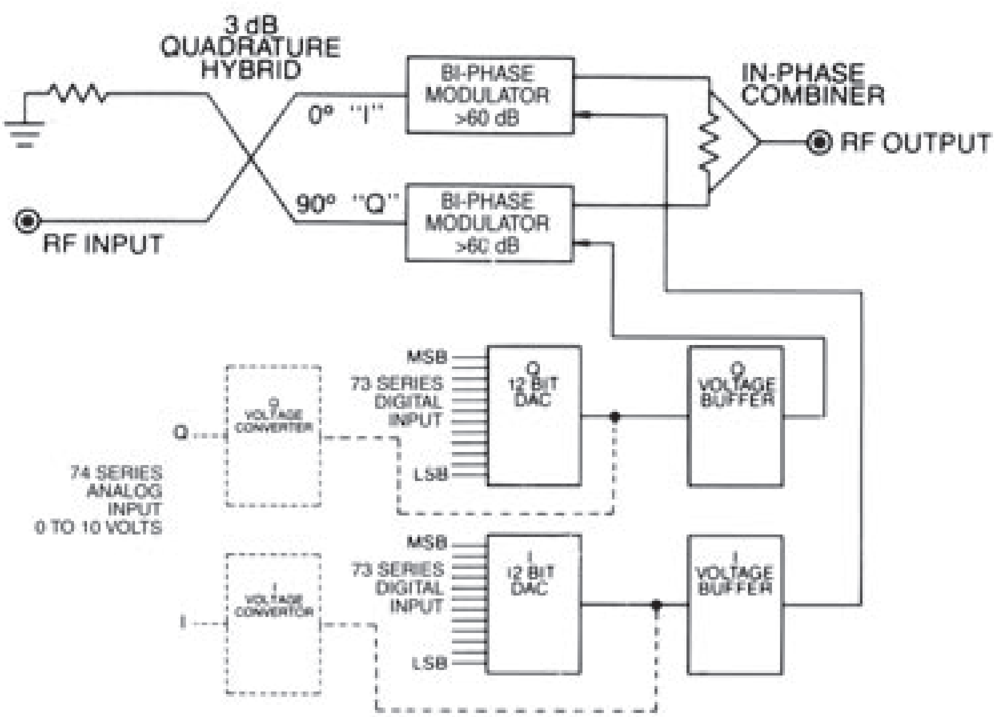


Fig. 1 – Series 73, 74 Block Diagram

Series 73 12 Bit Digital and Series 74 Analog High Dynamic Range I-Q Vector Modulators

THEORY OF OPERATION

The block diagram of the I-Q Vector Modulator is shown in Figure 1. An RF signal incident on a 3 dB quadrature hybrid is divided into two equal outputs, with a 90° phase difference between them. The in-phase, or 0°, channel is designated the I channel and the Quadrature, or 90°, channel is designated the Q channel. Each signal passes through a biphase modulator which sets the 0° or 180° state and the attenuation level for both the I and Q paths. The outputs of the I and Q path are combined to yield the resultant vector which may fall anywhere within the bounded area shown in Figure 2. Any signal applied to the I-Q Vector Modulator can be shifted in phase and adjusted in amplitude by applying the following relationships:

1. Let the desired attenuation level = X dB and the desired phase shift = θ° (with respect to 0 dB and 0° reference states).
2. The normalized output voltage magnitude is given by: $|V| = 10^{-(x/20)}$.
3. The values of the I and Q attenuator control inputs are then expressed as:

$$I = V \cos \theta$$

and

$$Q = V \sin \theta.$$

Figure 3 shows the nominal value of I and Q vs. either digital word (Series 73) or analog voltage (Series 74). Thus, to achieve an attenuation level of 3 dB with a phase offset of 112.5° (with respect to 0 dB and 0° reference states) the values of I and Q can be calculated as follows:

$$V = 10^{-(3/20)} = 0.707$$

$$I = 0.707 \cos (112.5°) -.027$$

$$Q = 0.707 \sin (112.5°) +0.65$$

From Figure 3, the control inputs to yield the desired amplitude and phase are approximately:

Analog Units (73 Series)	Digital Units (74 Series)
I = 7.81 volts	110010000000
Q = 1.50 volts	001010000000

While these values for I and Q will yield an output signal whose amplitude and phase are close to the nominal values over the entire operating frequency range of the vector modulator, the use of an iterative measurement procedure will determine the I and Q inputs which exactly define the desired parameter at any selected frequency.

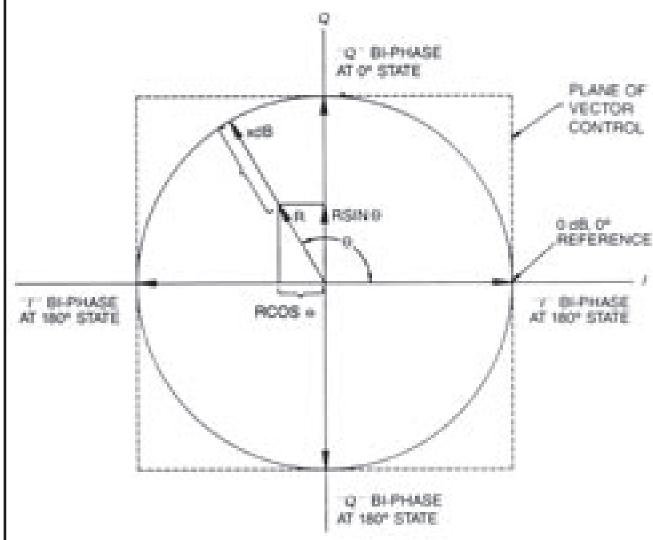


Fig. 2–I-Q Phase Relationship

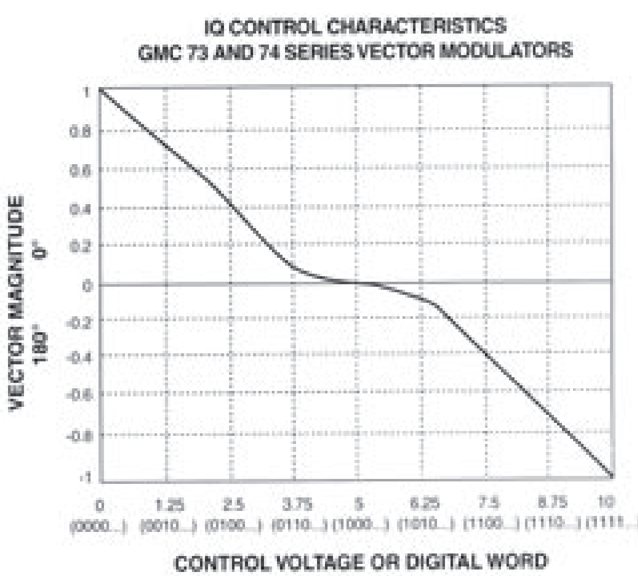


Fig. 3 – I-Q vs. Control Input (Typical)

Series 73/74 Specifications

PERFORMANCE CHARACTERISTICS

<table>
<tr><th>MODEL</th><th>7322/7422</th><th>7328/7428</th><th>7329/7429</th></tr>
<tr><td>FREQUENCY</td><td>2.0-6.0 GHz</td><td>6.0-18.0 GHz</td><td>16.0-24.0 GHz</td></tr>
<tr><td>INSERTION LOSS</td><td>14 dB</td><td>15 dB 6-16 GHz
16.5 dB >16-18 GHz</td><td>16 dB 16-22 GHz
18 dB >22-24 GHz</td></tr>
<tr><td>VSWR (MAX)</td><td>1.8:1</td><td>2.0:1</td><td>2.0:1 16-22 GHz
2.2:1 >22-24 GHz</td></tr>
<tr><td>POWER HANDLING WITHOUT PERFORMANCE DEGRADATION</td><td colspan="3">+20 dBm</td></tr>
<tr><td>SURVIVAL POWER (MAX)</td><td colspan="3">1W</td></tr>
<tr><td>ABSOLUTE INSERTION PHASE ACCURACY VS. FREQUENCY (MAX)</td><td colspan="2">±15°</td><td>±15° 16-22 GHz
±20° >22-24 GHz</td></tr>
<tr><td>FINE GRAIN PHASE RIPPLE (50 MHz) (MAX)</td><td colspan="3">2° pk-pk</td></tr>
<tr><td>VARIATION OF PHASE VS. TEMPERATURE (MAX)</td><td colspan="3">±0.2 deg./ °C</td></tr>
<tr><td>ATTENUATION RANGE (MIN)</td><td colspan="3">60 dB</td></tr>
<tr><td>VARIATION OF AMPLITUDE VS.TEMPERATURE (MAX)</td><td colspan="3">0.04 dB/ °C</td></tr>
<tr><td>RESPONSE TIME (MAX)</td><td colspan="3">1.0 µsec</td></tr>
<tr><td>POWER SUPPLY</td><td colspan="3">–12 to –15V @ 100 mA
+12 to +15V @ 100 mA</td></tr>
<tr><td>CONTROL INPUT
73 SERIES
74 SERIES</td><td colspan="3">
12 bit TTL for both I and Q inputs
0 to +10V DC for both I and Q inputs</td></tr>
<tr><td>CONTROL INPUT IMPEDANCE
73 SERIES
74 SERIES</td><td colspan="3">
40 µA max
10 K ohms</td></tr>
</table>

ENVIRONMENTAL RATINGS

Operating Temperature Range .... –54°C to +100°C

Non-Operating Temperature Range. –65°C to +125°C

Humidity .... MIL-STD-202F, Method 103B, Cond. B (96 hrs. at 95%)

Shock .... MIL-STD-202F, Method 213B, Cond. B (75G, 6 msec)

Vibration .... MIL-STD-202F, Method 204D, Cond. B (.06" double amplitude or 15G, whichever is less)

Altitude .... MIL-STD-202F, Method 105C, Cond. B (50,000 ft.)

Temp. Cycling .... MIL-STD-202F, Method 107D, Cond. A, 5 cycles

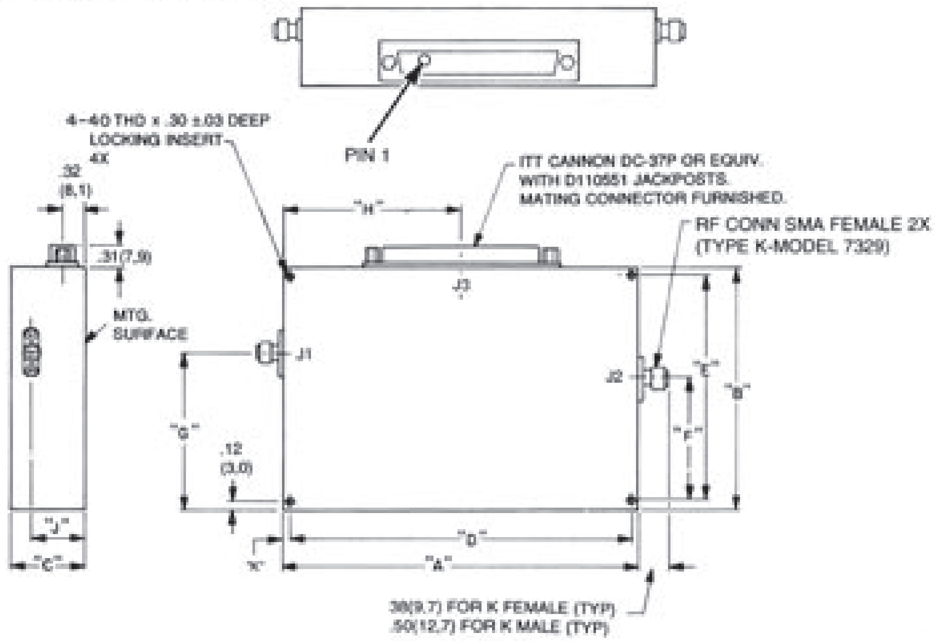
ACCESSORY FURNISHED

Mating power/control connector (Series 73 only)

AVAILABLE OPTIONS

Option No.	Description
7	Two SMA (Type K-Model 7X29) male RF connectors
10	One SMA (Type K-Model 7X29) male (J2) and one SMA (Type K-Model 7X29) female (J1) RF connector

DIMENSIONS AND WEIGHTS



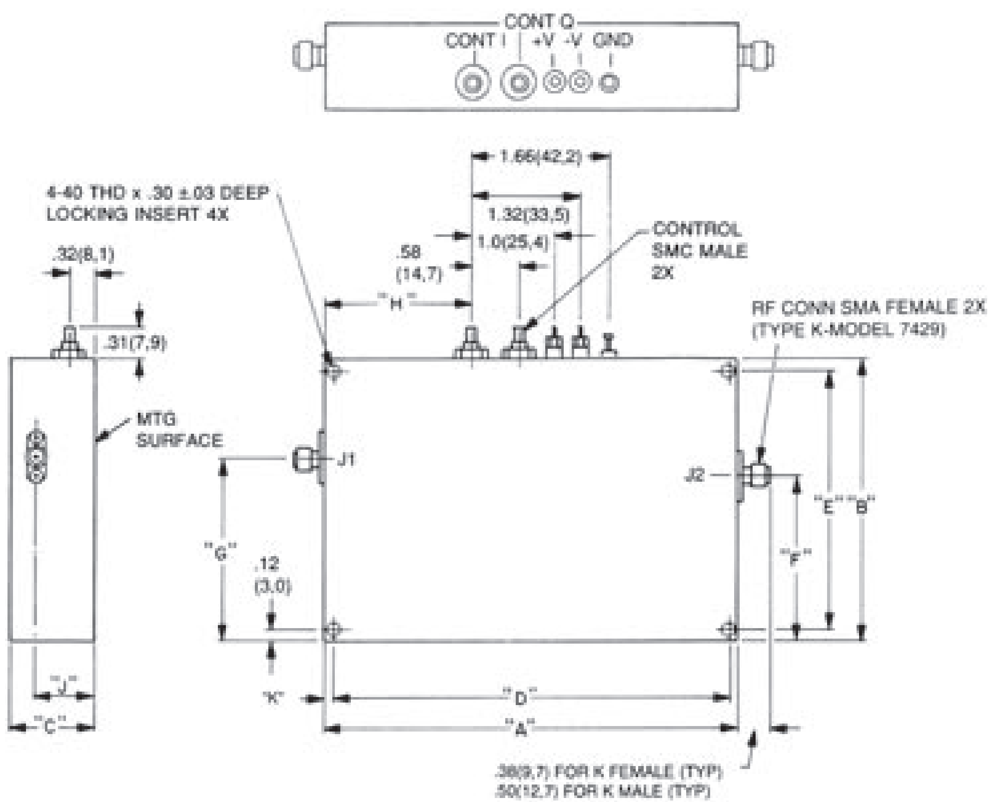
MODEL	A	B	C	D	E	F	G	H	J	K
7322	4.00±.03 (101,6)	3.00±.03 (76,2)	.88 (22,4)	3.80±.01 (96,5)	2.75±.01 (69,9)	1.50 (38,1)	1.90 (48,3)	2.00 (50,8)	.68 (17,3)	.10 (2,9)
7328	3.12±.03 (79,2)	3.00±.03 (76,2)	.88 (22,4)	2.92± .01 (74,2)	2.75±.01 (69,9)	1.50 (38,1)	1.82 (46,2)	1.56 (39,6)	.68 (17,3)	.10 (2,9)
7329	3.25±.03 (82,6)	3.00±.03 (76,2)	.82 (20,8)	3.00±.01 (76,2)	2.75±.01 (69,9)	1.50 (38,1)	1.69 (42,9)	1.69 (41,1)	.65 (16,5)	.12 (3,0)

J3 PIN FUNCTION			
PIN	FUNCTION	PIN	FUNCTION
1	I-5	20	I-4
2	I-6	21	I-7
3	I-8	22	I-3
4	I-9	23	I-2
5	I-10	24	I-1 (LSB)
6	I-11	25	I-12 (MSB)
7	N/C	26	N/C
8	+12 to +15V	27	N/C
9	GND	28	GND
10	GND	29	N/C
11	–12 to –15V	30	N/C
12	Q-3	31	N/C
13	Q-2	32	Q-4
14	Q-1 (LSB)	33	N/C
15	Q-5	34	N/C
16	Q-6	35	Q-12 (MSB)
17	Q-7	36	Q-11
18	Q-8	37	Q-10
19	Q-9		

MODEL	WEIGHT (APPROX)
7322	12 oz. (341 gm)
7328	11 oz. (312 gm)
7329	11 oz. (312 gm)

Dimensional Tolerances, unless otherwise indicated: .XX ±.02; .XXX ±.005

Series 73/74 Specifications



MODEL	A	B	C	D	E	F	G	H	J	K
7422	4.00±.03 (101,6)	3.00±.03 (76,2)	.88 (22,4)	3.80±.01 (96,5)	2.75±.01 (69,9)	1.50 (38,1)	1.90 (48,3)	1.28 (32,5)	.68 (17,3)	.10 (2,9)
7428	3.12±.03 (79,2)	3.00±.03 (76,2)	.88 (22,4)	2.92± .01 (74,2)	2.75±.01 (69,9)	1.50 (38,1)	1.82 (46,2)	.83 (21,1)	.68 (17,3)	.10 (2,9)
7429	3.25±.03 (82,6)	3.00±.03 (76,2)	.82 (20,8)	3.00±.01 (76,2)	2.75±.01 (69,9)	1.50 (38,1)	1.69 (42,9)	.90 (22,9)	.65 (16,5)	.12 (3,0)

MODEL	WEIGHT (APPROX)
7422	12 oz. (341 gm)
7428	11 oz. (312 gm)
7429	11 oz. (312 gm)

Dimensional Tolerances, unless otherwise indicated: .XX ±.02; .XXX ±.005

Model 7328H High Speed, High Dynamic Range I-Q Vector Modulator

The Model 7328H represents the latest advancement to General Microwave's comprehensive product line of PIN diode I-Q Vector Modulators. Its response time has been significantly reduced, resulting in an enhanced modulation rate performance of 50 MHz to better serve today's more demanding system applications.

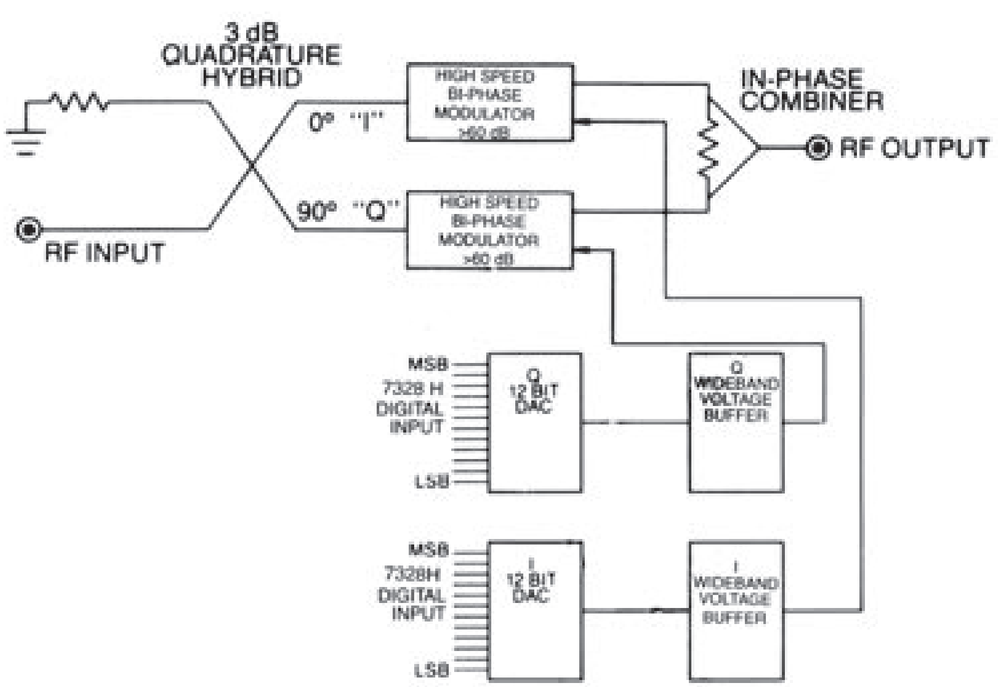
In addition to the high speed, the Model 7328H incorporates multiple bi-phase modulator sections to provide in excess of 60 dB attenuation through 16 GHz, and is capable of a full 360 degrees of phase shift. Thus, the unit will provide high speed and simultaneous control of amplitude and phase over the full frequency range of 6 to 18 GHz. A simplified block diagram is shown in Fig. 1.

THEORY

The Theory of Operation of the Model 7328H is the same as the Series 73 units. The RF and Driver portions of the IQ Modulator have been modified to enable modulation rates up to 50 MHz.

- **High Speed – Modulation Rate of better than 50 MHz**
- **Wide Frequency Range – 6 to 18 GHz**
- **Simultaneous control of amplitude and phase over a 60 dB dynamic range**
- **Digitally Programmable I&Q – 12 Bit ECL control**
- **Guaranteed monotonicity**

FIG. 1–SERIES 7328H BLOCK DIAGRAM



Model 7328H Specifications

PRELIMINARY PERFORMANCE CHARACTERISTICS

PARAMETER	SPECIFICATION
Frequency Range, min	6.0 to 18.0 GHz
Insertion Loss, max	16.0 dB
VSWR, max	2.0:1
Power Handling, max Without Performance Degradation	–5 dBm Typical
Survival	+27 dBm
Absolute Insertion Phase Accuracy vs Frequency	±15°
Variation of Phase vs Temperature, max	±0.2°/°C
Attenuation range, min 6 to 16 GHz	60dB
>16 to 18 GHz	50dB
Variation of Amplitude vs Temperature, max	0.04 dB/°C
Modulation Rate, min	50 MHz
Control Input	12 Bit ECL for both I&Q
Control Characteristics, I&Q, typ	See Figure 2
Control Input Impedance	100 ohms (to –2V supply)
Power Supply	+12V @ 350 mA –12V @ 130 mA –5.2V @ 340 mA –2V @ 280 mA

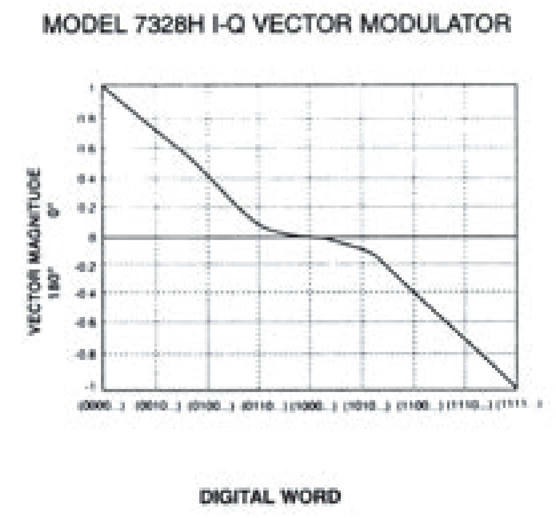
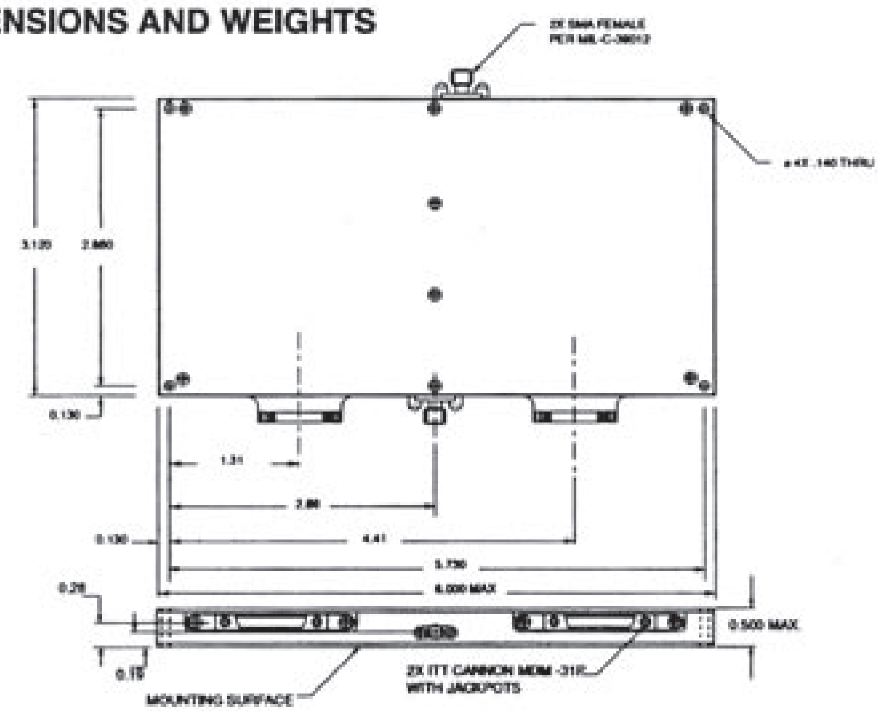


FIG. 2 TYPICAL IQ CONTROL CHARACTERISTICS

DIMENSIONS AND WEIGHTS

PIN DESIGNATIONS– J3(I) AND J4(Q)			
PIN NO.	SIGNAL	PIN NO.	SIGNAL
1	CLK+	17	CLK–
2	D0	18	GND
3	D1	19	GND
4	D2	20	GND
5	D3	21	GND
6	D4	22	GND
7	D5	23	GND
8	D6	24	GND
9	D7	25	GND
10	D8	26	GND
11	D9	27	GND
12	D10	28	GND
13	D11	29	GND
14	GND	30	+12V
15	–5.2V	31	–12V
16	–2V		



Dimensional Tolerances, unless otherwise indicated: .XX ±.02; .XXX ±.005

Series 77, 10 Bit Digital and Series 78 Analog 360° Phase Shifters & Frequency Translators

Both Series, 77 and 78, comprise a family of eight solid-state PIN diode phase shifters covering the frequency range from 0.5 to 18 GHz in four bands: 0.5 to 2 GHz, 2 to 6 GHz, 4 to 12 GHz and 6 to 18 GHz. All models provide a full 360° range of phase shift and may also be used for frequency translation applications.

Each unit is an integrated assembly of an RF vector modulator and a driver circuit, consisting of a 10-bit D/A converter and a voltage buffer in the Series 77 digital units (see Fig. 1A) and a voltage converter and buffer in the Series 78 analog configuration (see Fig. 1 B).

The voltage converter in the Series 78 consists of an A/D converter followed by a 10-bit D/A converter, and converts a continuous analog input voltage into discrete steps of 0.35°.

- **0.5 to 18 GHz in four bands: 0.5 to 2 GHz; 2 to 6 GHz; 4 to 12 GHz; 6 to 18 GHz**
- **10 Bit digitally programmable (Series 77)**
- **Analog control (Series 78)**
- **High speed**
- **Guaranteed monotonicity**

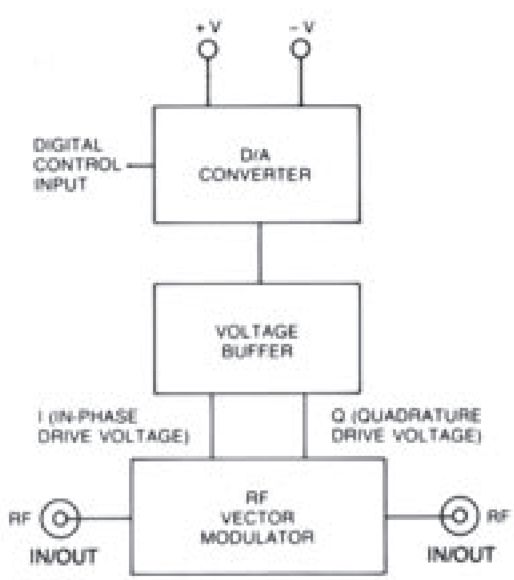


Fig. 1A—Series 77, Block Diagram

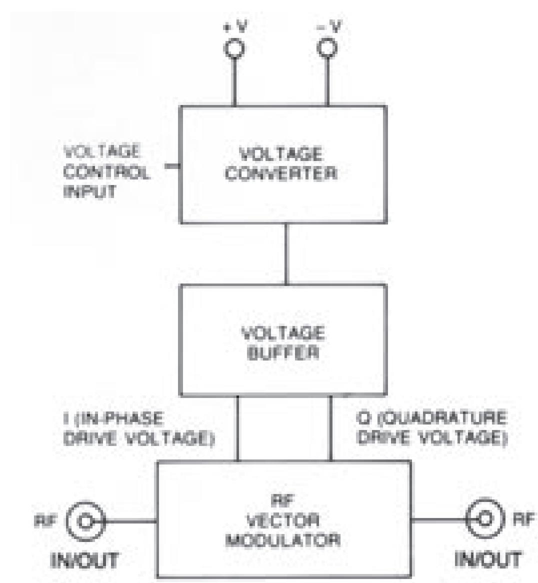


Fig. 1B—Series 78, Block Diagram

Series 77/78 Specifications

Phase Shift

Phase shift is achieved utilizing the RF vector modulator approach shown in Fig. 2. The 3 dB hybrid coupler divides the RF signal into two quadrature components which are then modulated in proportion to the sine and cosine of the desired phase shift. The signals are then combined in-phase to yield the phase-shifted output.

Excellent phase accuracy and PM/AM performance (see Figs. 4 and 5) are achieved by using linearized double balanced modulators. In their main operating bands, phase accuracy is better than ±10° up to 10 GHz and ±12° to 18 GHz. This phase accuracy can be extended to cover the band edges by using a built-in frequency correction circuit. Switching speed is better than 500 nsec.

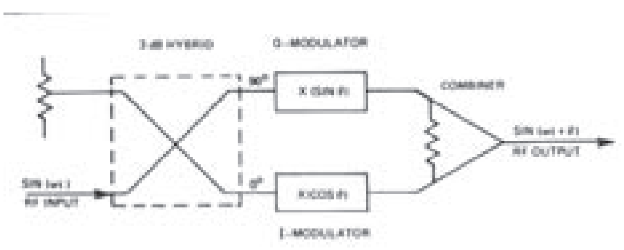


Fig. 2-RF vector modulator

Frequency Translation (Serrodyning)

Special attention in the design of the units has been paid to those characteristics which affect their performance as frequency translators. These include minimizing PM-to-AM conversion, use of high slew rate drivers, and optimizing phase shift linearity with applied signal. As a result, carrier and sideband suppression levels of over 25 and 20 dB, respectively, are obtained in the main bands. The same carrier and sideband performance can be realized over the full stretch band when the internal frequency correction circuit is employed.

See Fig. 3 for input voltage control requirements for Series 77 and 78 when used as a frequency translator.

On special order, frequency translators can be provided for operation over reduced bandwidths with suppression levels of up to 35 dB. Consult the factory for special requirements.

PERFORMANCE CHARACTERISTICS

SERIES 77

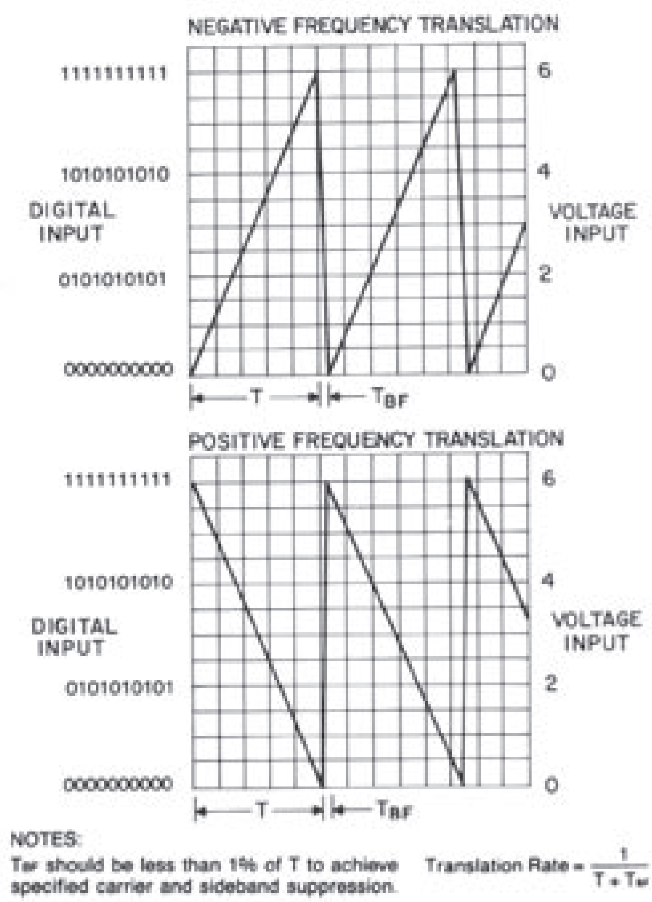
Control ....10 bit TTL

Logic Input

Logic "0" (Bit OFF)...–0.3 to +0.8V @ 500 µA max

Logic "1" (Bit ON).....+2.0 to +5.0V @ 100 µA max

Fig. 3-Series 77 and Series 78 input requirements



Power Supply ....+5V at 200 mA
+12 to +15V @ 100 mA max
–12 to –15V @ 90 mA max

SERIES 78

Control Voltage ....0 to +6V

Sensitivity.....................23.4 mV/LSB

Resolution ....1.41°

Step Uncertainty..........0.7° max, 0.3° typ.

Input Resistance..........2K ohms

Power Supply ....+5V at 300mA
+12 to +15V at 125 mA
–12 to –15V at 50 mA

COMMON TO BOTH SERIES 77 & 78

Power Handling Capability
Without Performance
Degradation ....+20 dBm (+7 dBm for 7720A, 7820)

Survival.........................+30 dBm

Harmonics ....–30 dBc

Phase Variation ....0.1°/°C

PHASE SHIFTER SPECIFICATIONS

MODEL NOS.	FREQUENCY RANGE (GHz)	INSERTION LOSS (Max.)	VSWR (Max.)	ACCURACY[1] (Max.)	PM/AM (Max.)
7720A & 7820	Main Band 0.7-1.85 Stretch Band 0.5-2.0	11.5 dB 13.0 dB	1.75	±10° ±15°	±1.1 dB ±2.5 dB
7722A & 7822	Main Band 2.6-5.2 Stretch Band 2.0-6.0	10.0 dB 11.0 dB	1.6	±10° ±15°	±1.1 dB ±1.5 dB
7724A & 7824	Main Band 4.5-10.5 Stretch Band 4.0-12.0	10.5 dB 12.0 dB	1.8	±10° ±15°	±1.1 dB ±2.0 dB
7728A & 7828	Main Band 8.0-18.0 Stretch Band 6.0-18.0	12.0 dB	2.0	±12° ±15°	±1.1 dB ±2.0 dB

OTHER SPECIFICATIONS

Switching Speed (50% TTL to within 10° of Final Phase Value); 500 nsec Max.
Minimum phase shift range:
Series 77: 360° in 1024 Steps (1o-bit)   Series 78: 360° @ 60°/Volt

FREQUENCY TRANSLATOR SPECIFICATIONS

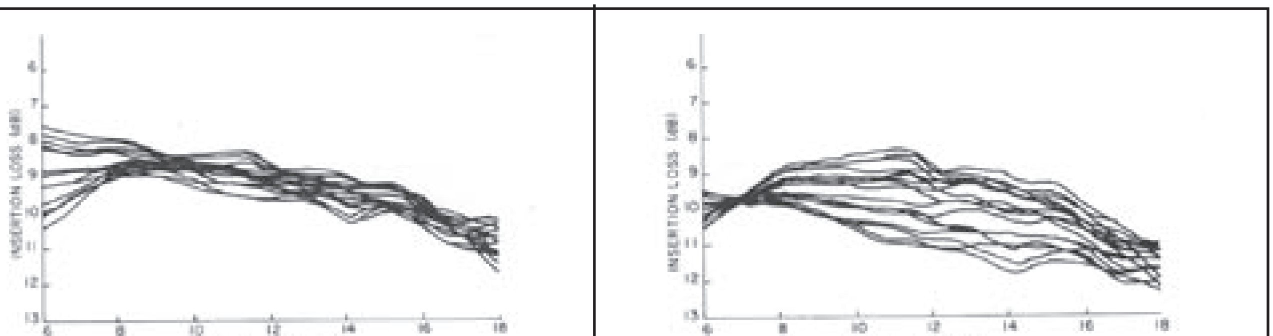
TRANSLATION RATE (Min.)	CARRIER[1] SUPPRESSION (Min.)	SIDEBAND[1] SUPPRESSION (Min.)	INSERTION LOSS VARIATION (Max.) with translation rate:
0 to 500 kHz[2]	Main Band: 25 dB Stretch Band: 18 dB	Main Band: 20 dB Stretch Band: 15 dB	200 kHz: 1 dB 500 kHz: 3 dB

NOTES:

(1) *When operating as a Phase Shifter outside the Main Band Frequency Range, a TTL Low (0) applied to the J3 Power/Control Connector Freq. Correction Pin (pin 3) will result in Stretch Band Frequencies exhibiting enhanced performance characteristics. The resultant Insertion Loss, Accuracy and PM/AM specifications will be the same as those shown for the Main Band Frequency Range. When using the unit as a Frequency Translator, similar enhanced performance can be achieved for Carrier & Sideband Suppression.*

(2) *All specifications are met using five or more most significant bits for 0 to 200 kHz translation rates. For 201-500 kHz translation rates, only the four most significant bits are used.*

TYPICAL PERFORMANCE



PM/AM over the full operating band with frequency correction set to Main Band (Logic "1").   *Figure 4*   *PM/AM with frequency correction set to Band Edge (Logic "0").*

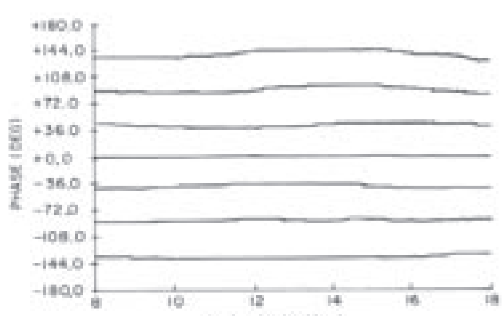


Fig. 5-Model 7728A-Phase accuracy vs. frequency.

Series 77/78 Specifications

ENVIRONMENTAL RATINGS

Operating Temperature Range ....–54°C to +100°C

Non-Operating Temperature Range......–65°C to +125°C

Humidity ....MIL-STD-202F, Method 103B, Cond. B (96 hrs. at 95%)

Shock................................MIL-STD-202F, Method 213B, Cond. B (75G, 6 msec)

Vibration...........................MIL-STD-202F, Method 204D, Cond. B (.06" double amplitude or 15G, whichever is less)

Altitude ....MIL-STD-202F, Method 105C, Cond. B (50,000 ft.)

Temp. Cycling ....MIL-STD-202F, Method 107D, Cond. A, 5 cycles

ACCESSORY FURNISHED

Mating power/control connector

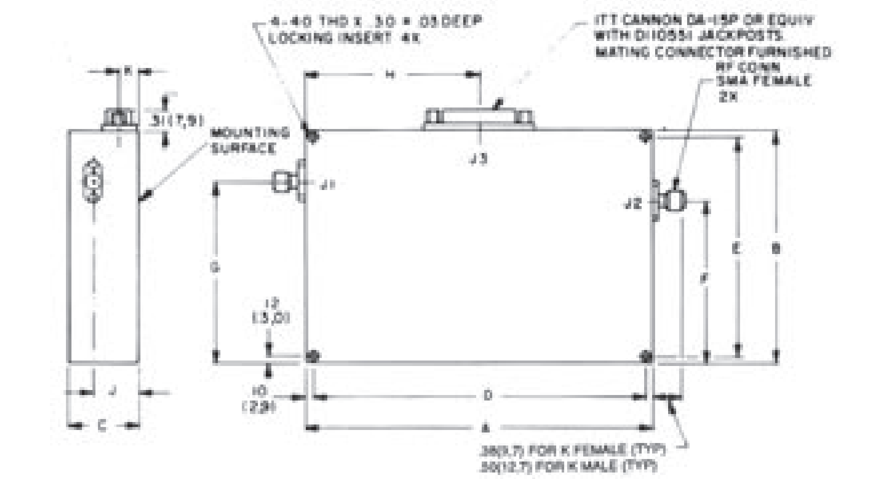
AVAILABLE OPTIONS

Option No.	Description
7	Two SMA male RF connectors
10	One SMA male (J2) and one SMA female (J1) RF connector

J3 PIN FUNCTIONS

Pin No.	Function: Series 77[1]	Function: Series 78
1	–12V to –15V	–12V to –15V
2	+12V to +15V	+12V to +15V
3	Freq. Correction Circuit Select[3] "0" = Band Edge	Freq. Correction Circuit Select "0" = Band Edge
4	1.4° [3]	Not Used
5	5.6° [3]	Not Used
6	45.0° [3]	Not Used
7	180.0° (MSB)[3]	Not Used
8	90.0° [3]	Not Used
9	Ground	Ground (Sig)
10	0.7° [3]	Ground (PWR)
11	22.5°	Not Used
12	2.8°	Not Used
13	11.3°	Not Used
14	.035° (LSB)	Control Voltage
15	+5V±0.5VDC[2]	+5V

DIMENSIONS AND WEIGHTS



NOTE:
(1) *Unused logic bits must be grounded.*
(2) *Must not exceed +7VDC. See footnote (3) below.*
(3) *Must not be greater than +0.3 VDC above voltage at pin 15.*

MODEL	A	B	C	D	E	F	G	H	J	K	WEIGHT (APPROX)
7720A	4.95±.03	3.38±.03	1.02 (25,9)	4.75±.01	3.12±.01	2.62	1.69	2.48	.73 (18,5)	.32 (8,1)	13 oz. (369 gm)
7820	(125,7)	(85,9)	1.48 (37,6)	(120,7)	(79,2)	(66,5)	(42,9)	(62,9)	1.18 (30,0)	.78 (19,8)	15 oz. (425 gm)
7722A			.84 (21,3)				1.99		.66 (16,8)	.32 (8,1)	9 oz. (255 gm)
7822	3.25±.03	3.25±.03	1.25 (31,8)	3.05±.01	3.00±.01	1.63	(50,5)	1.63	1.07 (27,2)	.72 (18,3)	10 oz. (284 gm)
7724A	(82,6)	(82,6)	.84 (21,3)	(77,5)	(76,2)	(41,4)	1.83	(41,4)	.66 (16,8)	.32 (8,1)	9 oz. (255 gm)
7824			1.25 (31,8)				(46,5)		1.07 (27,2)	.72 (18,3)	10 oz. (284 gm)
7728A	2.50±.03	3.00±.03	.88 (22,4)	2.30±.01	2.75±.01	1.50	1.63	1.25	.71 (18,0)	.39 (9,9)	6 oz. (170 gm)
7828	(63,5)	(76,2)	1.19 (30,2)	(58,4)	(69,9)	(38,1)	(41,4)	(31,8)	1.02 (25,9)	.69 (17,6)	8 oz. (227 gm)

Dimensional Tolerances, unless otherwise indicated: .XX ±.02; .XXX ±.005

Model 7928A Miniaturized 8 Bit 360° Phase Shifter/Frequency Translator

- 6 to 18 GHz
- 360° range
- High speed
- Digitally programmable (8 Bits)
- Guaranteed monotonicity
- Hermetically Sealed
- Miniaturized: less than 1.5 in^3

The Model 7928A is a miniaturized, hermetically sealed PIN diode phase shifter covering the frequency range from 6 to 18 GHz providing a full 360° range of variable phase shift. It can also be used to perform frequency translation.

The unit is an integrated assembly of an RF vector modulator and a driver circuit consisting of an 8-bit D/A converter and a voltage buffer. See Figure 1.

PHASE SHIFT

Phase shifting is achieved utilizing the RF vector modulator approach shown in Figure 2. The 3-dB hybrid coupler divides the RF signal into two quadrature components which are then biased in proportion to the sine and cosine of the desired phase shift. The signals are then combined in-phase to yield desired output.

ACCURACY

Improved phase accuracy and PM/AM performance are achieved by using double-balanced bi-phase linear amplitude modulators. In the main operating band, overall phase accuracy is better than 12°. The same phase accuracy can be achieved at the band edges by using a built-in frequency correction circuit.

Switching speed is better than 500 nsec.

FREQUENCY TRANSLATION (SERRODYNING)

In the design of the Model 7928A special attention has been paid to those characteristics which affect its performance as a frequency translator. These include minimizing PM-to-AM conversion, use of high slew rate drivers, and optimizing phase shift linearity with applied signal. As a result, carrier and sideband suppression levels of over 25 and 20 dB, respectively, are obtained in the main band. The same carrier and sideband performance can be realized over the full stretch band when the internal frequency correction circuit is employed. See Fig. 3 for input control requirements.

On special order, frequency translators can be provided for operation over reduced bandwidths with suppression levels of up to 40 dB. Consult the factory for such requirements.

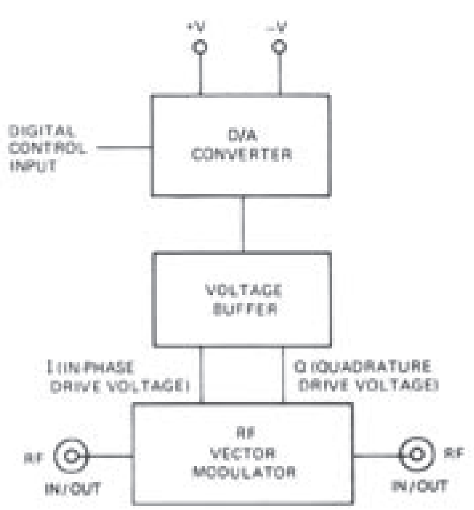


Fig. 1–Model 7928A, block diagram

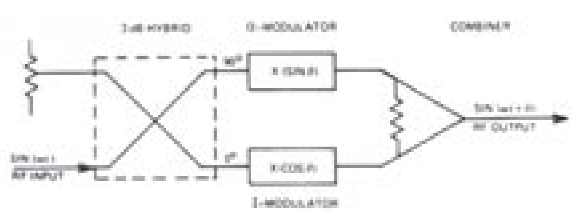


Fig. 2–RF Vector Modulator

Model 7928A Specifications

PHASE SHIFTER SPECIFICATIONS

FREQUENCY RANGE (GHz)	INSERTION LOSS (Max.)	VSWR (Max.)	ACCURACY[1] (Max.)	PM/AM[1] (Max.)
Main Band 8.0-18.0 Stretch Band 6.0-18.0	12.0 dB	2.0:1	±12° ±15°	±1.1 dB ±2.0 dB

FREQUENCY TRANSLATOR SPECIFICATIONS

TRANSLATION RATE (Min.)	CARRIER[1] SUPPRESSION (Min.)	SIDE BAND[1] SUPPRESSION (Min.)	INSERTION LOSS VARIATION (Max.) with translation rate:
0 to 500 kHz[2]	Main Band: 25 dB Stretch Band: 18 dB	Main Band: 20 dB Stretch Band: 15 dB	200 kHz: 1 dB 500 kHz: 3 dB

(1) *When operating as a Phase Shifter outside the Main Band Frequency Range, a TTL Low (0) applied to the J3 Power/Control Connector Freq. Correction Pin (pin R) will result in Stretch Band Frequencies exhibiting enhanced performance characteristics. The resultant Insertion Loss, Accuracy and PM/AM specifications will be the same as those shown for the Main Band Frequency Range. When using the unit as a Frequency Translator, similar enhanced performance can be achieved for Carrier & Sideband Suppression.*

(2) *All specifications are met using only the five most significant bits for translation rates of 0 to 200 kHz. For translation rates of 201 to 500 kHz, only 4 most significant bits are used.*

PERFORMANCE CHARACTERISTICS

Phase Shift
- **Range** .... 360° in 256 steps
- **Variation** .... 0.1°/°C

Control Input .... 8 Bit TTL

Switching Speed
(50% TTL to within 10° of Final Phase Value .... 500 nsec max

Harmonics .... –30 dBc

Power Handling Capability
- **Without Performance Degradation** .... +10 dBm (typically +13 dBm)
- **Survival power** .... +30 dBm

Power Supply
- **Requirements** .... +5V ±5%, 80 mA
  +12 to +15V, 10 mA
  –12 to –15V, 95 mA

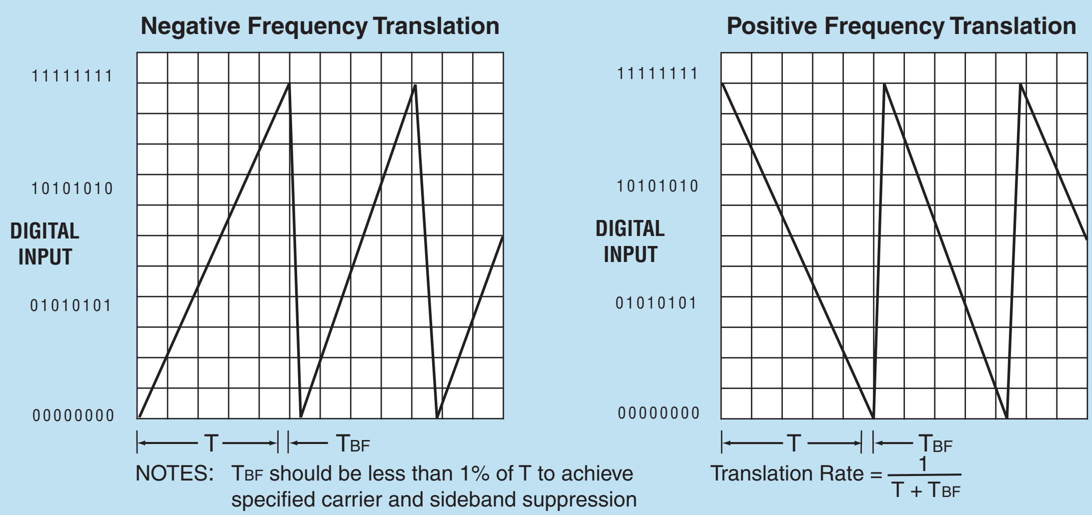


Fig. 3–Model 7928A Control input requirements.

ACCESSORY FURNISHED

Mating power/control connector

ENVIRONMENTAL RATINGS

Operating Temperature Range............................–54°C to +95°C

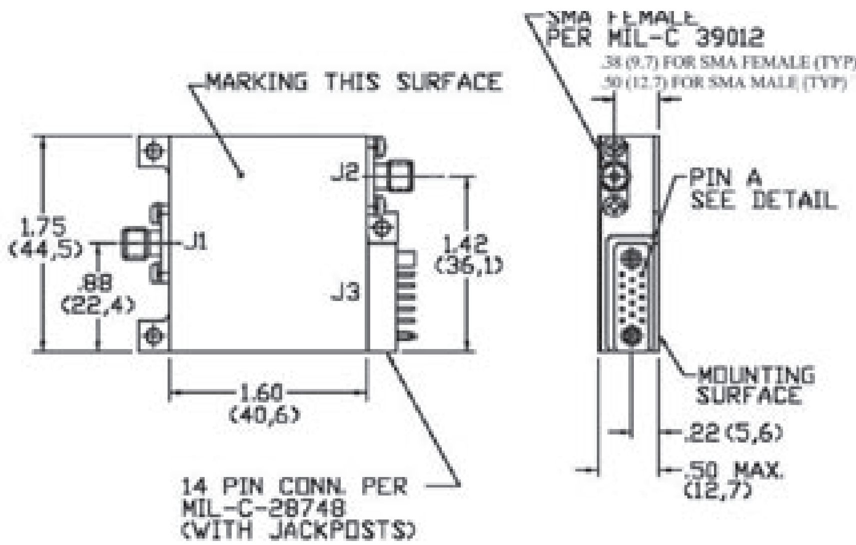
Non-Operating Temperature Range......–65°C to +125°C

AVAILABLE OPTIONS

Option No.	Description
7	Two SMA male RF connectors
10	One SMA male (J1), and one SMA female (J2) RF connector
49	High Rel screening (see table 1, page 43)

DIMENSIONS AND WEIGHT

MODEL 7928A	PIN FUNCTIONS
PIN	**FUNCTIONS**
A	Ground
B	+5V
C	–12 to –15V
D	1.4° (LSB)
E	2.8°
F	5.6°
H	22.5°
J	11.3°
K	90°
L	180° (MSB)
M	+12 to +15V
N	45°
P	GND
R	Freq. Correction Circuit Select “0” = Band Edge



Model 7928A Wt. 4.0 oz (113g) approx.

Dimensional Tolerances: unless otherwise indicated: .XX ±.02; .XXX ±.005

Switches

General Microwave switches cover the frequency range from 100 MHz to 40 GHz and are available in various topologies ranging from single-pole single-throw (SPST) to single-pole eight-throw (SP8T) in both reflective and non-reflective configurations, and a nonreflective SP16T unit.

SWITCH TOPOLOGY

There are two fundamental methods of connecting PIN diodes to a transmission line to provide a switching function: in series with the transmission line so that RF power is conducted when the PIN diode is forward biased and reflected when reverse biased; or in shunt with the transmission line so that the RF power is conducted when the diode is reverse biased and reflected when forward biased. A simple reflective SPST switch can be designed utilizing one or more PIN diodes in either configuration as shown in Fig. 1.

A multi-throw switch essentially consists of a combination of SPST switches connected to a common junction and biased so that each switch port can be enabled individually. The common junction of the switch must be designed to minimize the resistive and reactive loading presented by the OFF ports in order to obtain low insertion loss and VSWR for the ON port. There are two basic methods of realizing a multi-throw switch common junction for optimum performance over a broad frequency range. The first employs series mounted PIN diodes connected to the common junction. A path is selected by forward biasing its series diode and simultaneously reverse biasing all the other diodes. This provides the desired low-loss path for the ON port with a minimum of loading from the OFF ports. The second method utilizes shunt mounted PIN diodes located a quarter wavelength from the junction. The diode(s) of the selected ON port is reverse biased while the OFF ports are forward biased to create a short circuit across the transmission line. As a result of the quarter wavelength spacing, the short circuits are transformed to open circuits at the junction. By proper choice of transmission line impedances and minimization of stray reactance it is possible to construct a switch of this type with low insertion loss and VSWR over a three to one bandwidth. The schematic diagrams for both switches are shown in Fig. 2.

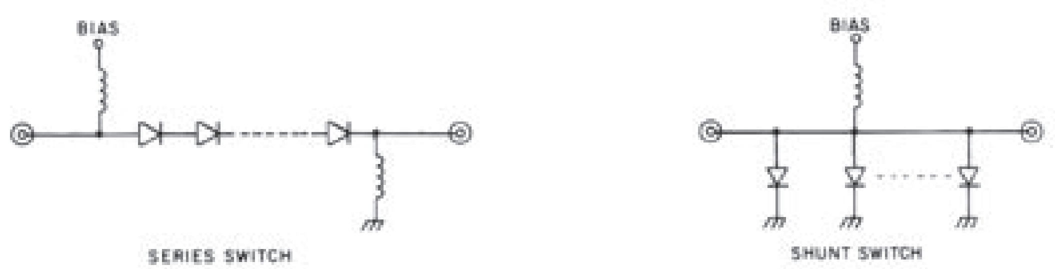


Fig. 1-Reflective SPST switch

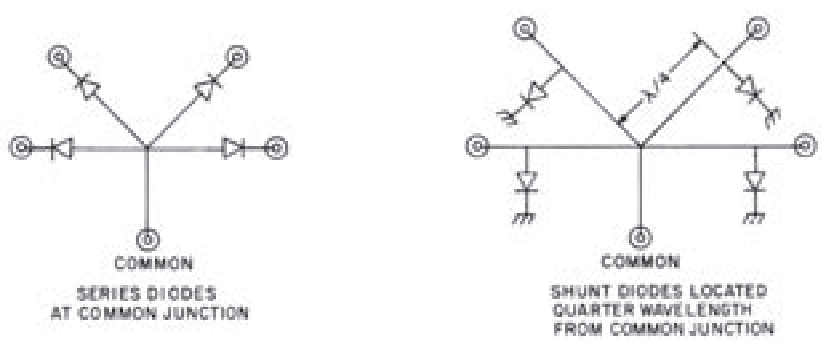


Fig. 2-Schematic diagrams of multi-throw switches

ABSORPTIVE SWITCHES

It is often desirable to have a PIN diode switch present a low VSWR in its OFF position as well as in its ON state in order to maintain desired system performance. General Microwave offers a complete line of single and multi-throw absorptive switches which incorporate 50Ω terminations in each of the output ports. Fig. 3 shows the schematic diagrams of the two versions of absorptive (also known as nonreflective or terminated) switches employed by GMC. The shunt termination is used in GMC's "all-series" configured absorptive switches which have a suffix ending in “T” or “W”. This style of absorptive switch offers the minimum penalty in insertion loss due to the addition of the terminating elements. The series termination is used in GMC's high speed “series-shunt” configured absorptive switches since it provides the optimum in switching performance.

The common port of the standard absorptive multi-throw switches in the GMC catalog will be reflective in the special circumstance when all ports are turned OFF. If there is a need for this port to remain matched under these conditions, this can be realized either by employing an additional port to which an external termination is connected or, in a custom design, by providing automatic connection of an internal termination to the common port.

DEFINITION OF PARAMETERS

INSERTION LOSS is the maximum loss measured in a 50 ohm system when only a single port of the switch is in the ON state.

ISOLATION is the ratio of the power level when the switch port is ON to the power level measured when the switch port is OFF. In a multi-throw switch the isolation is measured with one of the other ports turned ON and terminated in 50 ohms.

VSWR is defined for the input and output ports of the selected ON path. For those switches with a “T”, “W” or “HT” suffix, the VSWR is also defined for the OFF state.

VIDEO LEAKAGE

Video leakage refers to the spurious signals present at the RF ports of the switch when it is switched without an RF signal present. These signals arise from the waveforms generated by the switch driver and, in particular, from the leading edge voltage spike required for high speed switching of PIN diodes. When measured in a 50 ohm system, the magnitude of the video leakage can be as much as several volts. The frequency content is concentrated in the band below 200 MHz although measurable levels for high speed switches are observed as high as 6.0 GHz. The magnitude of the video leakage can be reduced significantly by the inclusion of high pass or “video filters”[1] in the switch, but the high frequency energy which falls within the passband of the switch can be eliminated only by using a slower speed switch.

HARMONIC AND INTERMODULATION PRODUCTS

All PIN diode switches generate harmonics and inter-modulation products since the PIN diodes are fundamentally non-linear devices. The magnitude of these spurious signals is typically small in a switch since the diodes are usually either in their saturated forward biased state or in their reversed biased state. The physics of the PIN diode cause a cut-off frequency phenomena such that the level of harmonics and intermods greatly increase at low frequencies. These levels will vary with the minority carrier lifetime of the diode. Thus, a high speed switch operating below 500 MHz may have a second order intercept point of 35 dBm, while a slow switch operating at 8 GHz will have a second order intercept point of 70 dBm. Typical performance is as follows:

TYPICAL SWITCH INTERCEPT POINTS

SWITCH	FREQUENCY	2nd Order INTERCEPT	3rd ORDER INTERCEPT
HIGH SPEED	2.0 GHz	+50 dBm	+40 dBm
LOW SPEED	2.0 GHz	+65 dBm	+50 dBm

Since these levels vary significantly with frequency, switching speed, and RF topology, please consult the factory for specific needs in this area.

(1) *For switches with internal video filters, specify Option 41, Option 42, or Option 43. These filters reduce the leakage as shown in the chart following the power handling discussion on page 87.*

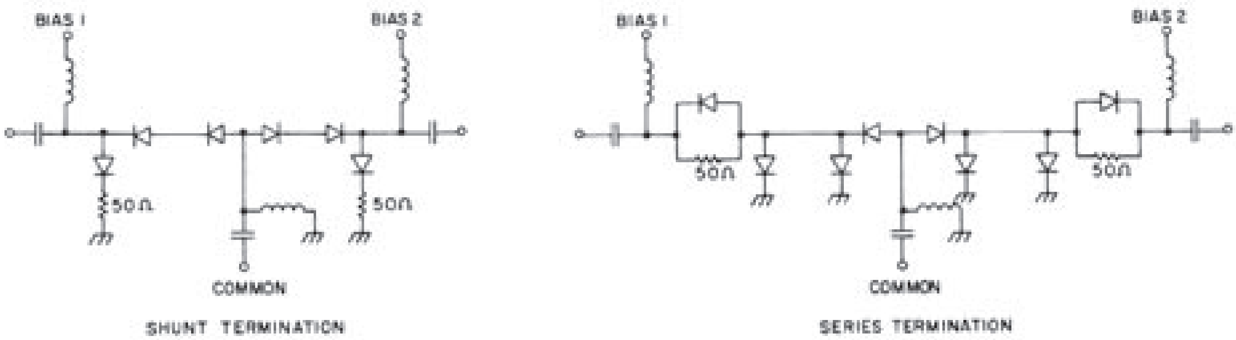


Fig. 3-Schematic diagrams of absorptive switches

SWITCHING SPEED[(2)]

Port-To-Port Switching is the interval from the time the RF power level at the off-going port drops to 90% of its original value to the time the RF power level in the on-going port rises to 90% of its final value. See Fig. 4.

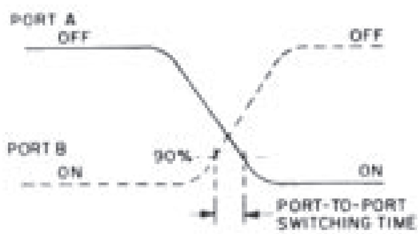


Fig. 4-Port-to-port switching speed definition

Rise Time is measured between the 10% and 90% points of the square-law detected RF power when the unit is switched from full OFF to full ON. See Fig. 5.

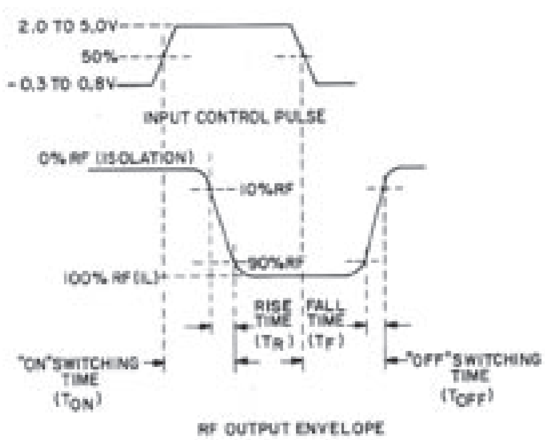


Fig. 5-Switching speed definition

Fall Time is the time between the 90% and 10% points of the square-law detected RF power when the unit is switched from full ON to full OFF.

On Time is measured from the 50% level of the input control signal to the 90% point of the square-law detected RF power when the unit is switched from full OFF to full ON.

Off Time is measured from the 50% level of the input control signal to the 10% point of the square-law detected RF power when the unit is switched from full ON to full OFF.

In addition to the above definitions, the following information about switching performance may be useful to the system designer.

Switching To Isolation – Although catalog switching speed specifications are usually defined to the 10% level of detected RF (equivalent to 10 dB isolation), the user of a switch may be more interested in the time the switch requires to reach rated isolation. This latter time is strongly dependent on the topology of the switch. For all-shunt mounted or combination series and shunt mounted topologies, the time to reach final isolation is usually less than twice the fall time. For an all-series topology, the time to reach final isolation may be as much as ten times the fall time.

Switching To Insertion Loss – For multi-throw switches, the ON time depends on whether the switch is being operated in a commutating or single port mode. In the former mode, switching speed is slower than in the latter due to the loading effect at the junction of the port turning OFF. All switching speed measurements at GMC are performed in the commutating mode.

(2) *For a unit without an integrated driver, the specifications apply to conditions when it is driven by an appropriately shaped switching waveform.*

PHASE AND AMPLITUDE MATCHING

Switches are available on a custom basis with phase and/or amplitude matching. Matching can be either between ports of a switch, between like ports on different switches, or a combination of the two. The uniformity of broadband catalog switches is quite good and is usually better than ±0.75 dB and ±15 degrees over the entire operating frequency of the switch. Please consult the factory for special requirements.

POWER HANDLING

The power handling of PIN diode switches is dependent on the RF topology, forward and reverse biasing levels, and speed of the switch. This catalog addresses both the maximum operating power levels and the survival limits of the components. Maximum operating limits are usually set at the power level which will cause the reversed biased diodes to begin conduction and thereby degrade the insertion loss, VSWR, or isolation of the switch. The survival power limits are based on the maximum ratings of the semiconductors in the switch. For special applications, significantly higher operational power levels can be provided, particularly for narrow band requirements. Please consult the factory for specific applications.

VIDEO FILTER OPTIONS			
Applicability: F91 and G91 Switch Series			
		Peak to Peak (mV)	**Bandwidth (MHz)**
Video Leakage with Video Filter Options:		50 max	100
INSERTION LOSS DEGRADATION			
Option	**Affected Ports**	**Frequency**	**Additional IL**
41	Common Port Only	1-12.4 GHz 12.4-18 GHz	0.1 dB 0.2 dB
42	Output Ports Only	1-12.4 GHz 12.4-18 GHz	0.1 dB 0.2 dB
43	All Ports	1-12.4 GHz 12.4-18 GHz	0.2 dB 0.4 dB
VSWR DEGRADATION			
Option	**Affected Ports**	**Frequency**	**VSWR**
41, 42, 43	All Ports	1-4 GHz 4-18 GHz	1.7:1* No Change

* As shown for switches whose VSWR specification from 1-4 GHz is less than 1.7.
No change for switches whose VSWR specification from 1-4 GHz is 1.7 or greater.

OPTION 55 – EXTENDED FREQUENCIES
Any switch in our catalog that covers 1-18 GHz can be modified to cover 0.5 to 18 GHz with following specification changes: 1. Specification for insertion loss and isolation from 0.5 to 1.0 GHz is the same as the 1-2 GHz specification. VSWR degrades to 2.0:1. 2. Insertion loss in the 12.4-18 GHz band increases by 0.3 dB, Consult factory for cost.