KRATOS | GENERAL MICROWAVE
Microwave Electronics Division

FREQUENCY TRANSLATORS
IQ VECTOR MODULATORS
PHASE SHIFTERS
ATTENUATORS

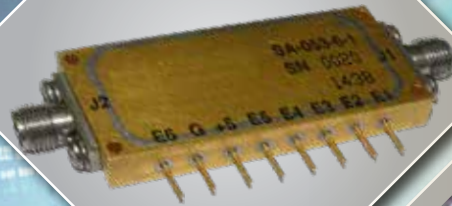# CONTROL COMPONENTS - 1

Table of Contents

The information contained in this short form brochure is basic marketing information and does not contain any export controlled information.

KRATOS | GENERAL MICROWAVE
Microwave Electronics Division

COMPANY PROFILE

ABOUT KRATOS GENERAL MICROWAVE

KRATOS General Microwave incorporates engineering innovation and excellence with high-quality design and production to deliver special requirements and mission critical needs.

Having built numerous products for the most rigid requirements and demanding environments, KRATOS General Microwave has become a leader in Innovative Microwave Solutions. Whether it is off-the-shelf, or custom made, KRATOS General Microwave designs provide top performance at a competitive price and uncompromised quality, while powering many military, governmental and commercial applications.

For more than 50 years, our multi-disciplinary expertise in RF technology, signal processing, hardware and firmware have been utilized worldwide in state-of-the-art microwave components and sub-assemblies for a wide range of defense and civil applications.

TYPICAL APPLICATIONS

Military and Defense - Electronic Warfare (EW) Systems, Radars, Missiles, UAVs, Smart Munition/Precision Guided Munition, GPS Immune/Navigation Warfare, Communications, Homeland Security (HLS), Simulators, Munition Proximity Sensors and Software Defined Radio (SDR).

Commercial - In-Flight Connectivity, Maritime and Train Connectivity, Airborne Weather Radars, IFF, Test Equipment, RF and Fiber Optic Communications, Industry Manufacturing Instrumentation, Research Laboratories and Medical Instruments.

PRODUCT LINES

MICROWAVE PRODUCT SOLUTIONS

Broadband Oscillators and Synthesizers - This product line covers 0.5 to 18 GHz band (and beyond) and includes Fast Indirect Synthesizers with less than 1 microsecond settling time with modulation, Direct Coherent Synthesizers with 40 nanosecond settling time, Digitally Tuned Oscillators (DTOs), Phase Locked Oscillator PLOs) and Voltage Controlled Oscillators (VCOs).

2

Solid State Power Amplifiers (SSPAs) - Up to 1KW in X, Ku and Ka-bands for missiles, airborne Radars and HLS radars. Up to 1 KW in VHF for military and non-military applications as well as for Pulse Power Amplifiers for IFF systems and Low Noise Amplifiers.

Data-Links - A variety of customized DATA-LINKS subsystems, from small, simple, low cost and low power to complex, high-end and high-power products that incorporate stat-of-the-art microwave technology, mixed signal processing, System on Chip (SoC) devices, high power FPGAs and other Digital technologies.

INTEGRATED MICROWAVE ASSEMBLIES (IMAS) AND SUB-SYSTEMS

Beam Forming Modules - A versatile line of complex, high-density modules, utilizing Surface Mount Technology for Phase Array Radars.

Transceivers and Receivers - Superior performance and cost-effective product line that includes both Narrowband and Broadband products and covers 0.5 – 18 GHz bands. A perfect fit for various applications, such as Direction Finder subsystem for ELINT and ESM airborne systems, Data Links for Missiles, Smart Munition, UAVs, Centric Network Warfare, JDAM/BDI and more.

Custom IMAs - Integrated Microwave Assemblies (IMA) built per specific requirements such as: RF Front-Ends, Complicated Switching Assemblies and Frequency Up and Down Converters.

CONTROL COMPONENTS

Control Components (0.1 – 40 GHz) - Based on PIN diode and proprietary coupler technology, this product line includes low, medium, and high-power switches (SPST up to SP16T), Switched Filter Banks, Attenuators, Limiters, Modulators, Phase Shifters, Frequency Translators. All control components are available with either digital or analog control.

STANDARDS AND CERTIFICATIONS

KRATOS General Microwave Quality Management has been certified to AS9100 and ISO9001. General Microwave Corporation US is certified to ISO 9001:2015. Certain companies within the Microwave Electronics Division are FAA certified to maintain microwave modules for commercial aircraft and is in process of being certified by the European Union Aviation Safety Agency (EASA). KRATOS Microwave Electronics Division shares the concern for a better world for all, and certain companies within the division are certified to ISO 14001. Our products can be ordered to be REACH or RoHS compliant.

Kratos General Microwave detailed product line catalog is available online at www.kratosmed.com/gmcatalog.

MICROWAVE ATTENUATORS

GENERAL

Kratos General Microwave PIN diode attenuators cover the frequency range from 200 MHz to 40 GHz and are available in numerous configurations to allow for system performance optimization. Most designs are available with either analog or digital control, operating over octave or multi-octave bands with high or moderate switching speed characteristics.

THE ATTENUATOR TOPOLOGY

Kratos General Microwave PIN diode attenuator designs include several different topologies, each of which has is optimized for certain performance characteristics. A brief discussion of these various topologies is presented below including performance trade-offs.

SHUNT-MOUNTED REFLECTIVE ATTENUATOR

The simplest version of a PIN diode attenuator consists of one or more PIN diodes in shunt with a transmission line as shown in Fig. 1. This design provides a broadband reflective attenuator that can reach very high levels of attenuation, depending upon the number and electrical spacing of the diodes. While it generally has very low insertion loss and can operate at high switching rates, its usefulness is limited by the very large mismatch it presents in the attenuation state.
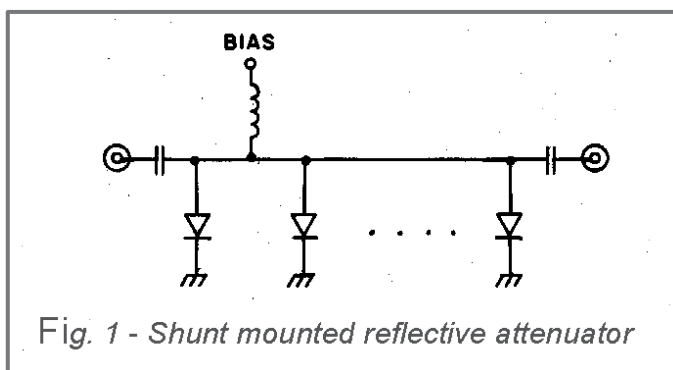
Fig. 1 - Shunt mounted reflective attenuator

BALANCED ATTENUATOR

By placing identical shunt-mounted reflective attenuators between an appropriately connected pair of 3 dB quadrature hybrid couplers, a balanced attenuator is realized (see Fig. 2). The balanced attenuator has all the simplicity of the shunt-mounted reflective attenuator with the added feature of providing low VSWR under all conditions of attenuation. In addition, power handling is improved by 3 dB due to the power split of the input hybrid. This style of PIN diode attenuator offers simplicity, up to 3 to 1 bandwidth, moderately fast speed, and excellent linearity. Kratos General Microwave balanced attenuators cover the frequency range of 0.5 to 40.0 GHz.

Fig. 2 - Balanced Attenuator

ARRAY ATTENUATOR

With the addition of terminating diode elements to the shunt-mounted reflective attenuators of Fig. 1, an attenuator can be realized with low VSWR that can operate over an octave band (see Fig. 3). By tapering the diode and transmission line impedance and adding multiple transformer sections it is possible to obtain good VSWR and attenuation characteristics over several octaves.
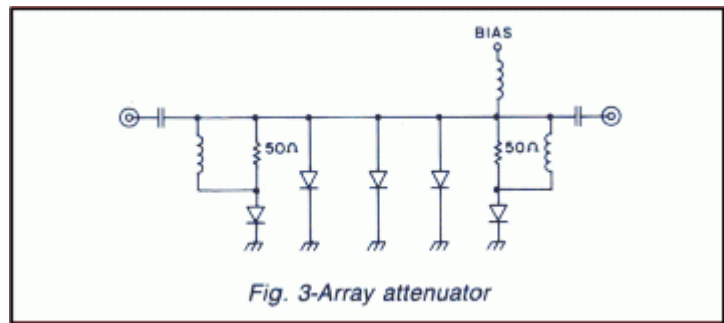
Fig. 3-Array attenuator

Kratos General Microwave employs array attenuators in a number of custom designs.
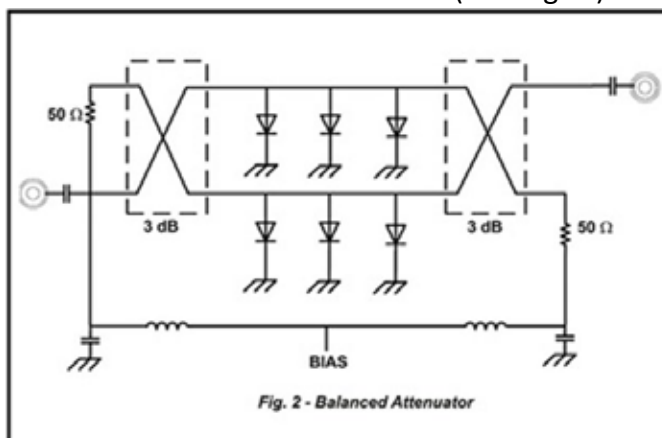
T-PAD AND π-PAD ATTENUATORS

The broadest frequency coverage available is obtained with some form of T-pad or π-pad attenuator. These are lumped element circuits which function in the microwave frequency range in essentially the same manner as they do at DC. Attenuation variation is obtained by simultaneously changing the bias current of the series and shunt diodes comprising the pads in a manner that assures constant impedance at all levels. Fig. 4 shows the basic configurations of both circuits. Only the T-pad configuration is used by GMC due to the difficulties in realizing sufficiently low stray reactance and short transmission line lengths in Π-pad circuits for operation at higher microwave frequencies. Models of these attenuators cover the full frequency range from 0.2 to 18.0 GHz with excellent attenuation lateness and moderate switching speed.
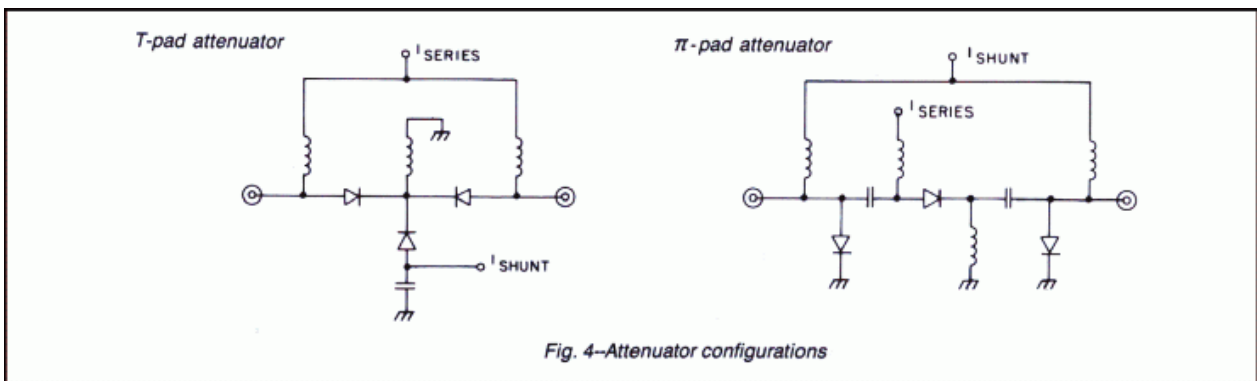
Fig. 4--Attenuator configurations

SWITCHED BIT ATTENUATORS

When an attenuator with a fast switching speed and high-power handling capacity is required, the only option is to utilize a switched-bit attenuator. This attenuator combines one or more tandem pairs of SP2T switches with a zero-loss connection between one pair of outputs and a fixed attenuator inserted in the other (see Fig. 5). In this configuration the PIN diodes are not used as variable resistors, but are switched between their forward and reversed biased states. This allows for much faster switching speed since high speed PIN diodes and drive circuitry can be used. In

addition, it offers higher power handling capacity since the RF power is absorbed in the fixed attenuator(s), and not in the PIN diodes.

There are some disadvantages to this approach that may limit its usefulness. First, the minimum practical attenuation step size at microwave frequencies is about 0.5 dB due to interacting VSWR's as the bits are switched. These interactions may lead to a non-monotonic response as the attenuation is changed in increments of one LSB, i.e., the attenuation level may actually decrease when an increasing attenuation step is called for. Second, because of the RF circuit complexity, the cost of this attenuator is usually higher than other approaches. Finally, the incorporation of high-speed switches may lead to excess video leakage.

Fig. 5-Switched bit attenuator
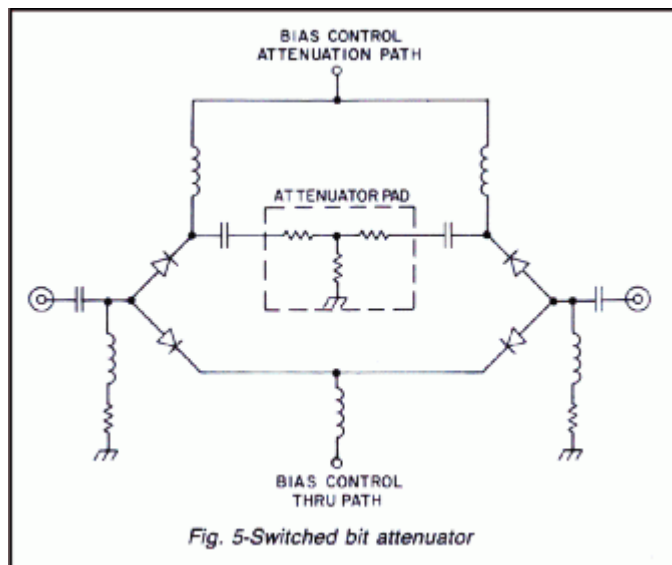
PHASE INVARIANT ATTENUATORS

In this specialized class of attenuators, the insertion phase variation is minimized as the attenuation level is changed. A unique topology is employed by Kratos General Microwave to obtain this performance which is described in detail in a separate technical paper*. In all other respects they perform in a manner similar to the balanced attenuators described above.

* "Broadband Phase Invariant Attenuator", D. Adler and P. Maritato; 1988 IEEE MTT-S Digest, pp. 673-676.

CATALOG ATTENUATORS

Kratos General Microwave comprehensive line of PIN diode Microwave and RF attenuators cover a wide frequency range, from 200 MHz to 50 GHz, and are available in numerous configurations to enable system performance optimization. Most designs are available with either analog or digital control, operating over octave or multi-octave bands with high or moderate switching speed characteristics. The RF and Microwave pin diode attenuators are available in various configurations:

- Microwave & RF Attenuators with Digital control
- Microwave & RF Attenuators with Analog Voltage control
- Microwave & RF Attenuators with Analog Current control
- Pulse Modulator

- Phase Invariant Attenuators (PIA)

- Microwave & RF Switch Bit Attenuators

Additional specifications and diagrams can be found in the online catalog at
www.kratosmed.com/gmcatalog.

CUSTOM ATTENUATORS

Kratos General Microwave is providing custom
meet specific customer's requirements, starting from minor
modifications to standard attenuators and up to a completely new
design.

Attenuators to

For more information, in the USA, contact the US team at

kratos-gmc@kratosdefense.com, for all other countries contact
sales@kratos-med.com.
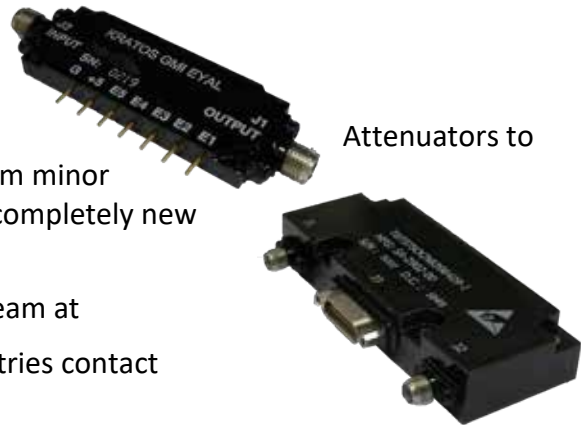
APPLICATIONS NOTES

DRIVER CONSIDERATIONS

All attenuators except for the switched bit variety are available with linearizing driver circuits with
either analog or digital control inputs. In addition, many attenuators are available without the
driver for those who choose to provide their own. Most digital attenuators are available with
eight-bit TTL control which, for an attenuator with a nominal attenuation range of 60 dB, will
provide a resolution of 0.25 dB. Some attenuators are available with a resolution of as low as 0.05
dB. Except for switched-bit designs, all PIN diode attenuators are analog in nature and thus their
resolution is essentially limited by the DAC used in the driver circuit.

The driver circuit includes compensating elements to minimize the variation of attenuator with
temperature. It also provides the proper source impedance and switching waveforms to optimize
switching speed.

MONOTONICITY

In most applications it is imperative that the attenuator displays monotonic behavior as a function
of the control input. Non-monotonic performance can occur in switched bit attenuators when
interacting VSWR's are not properly compensated, or in digitally controlled analog attenuators
when a non-monotonic condition exists in the MSB of the DAC. All GMC's attenuators are
guaranteed monotonic.

PHASE SHIFT VS. ATTENUATION

All attenuators exhibit a variation in phase shift with attenuation level (AM/PM modulation). Fig.
6 shows typical phase shift variation as a function of attenuation for a number of Kratos General
Microwave attenuator models. The phase shift is attributable to both the stray reactance of the
PIN diodes as well as the lengths of transmission line interconnecting the diodes. While it is
possible to minimize the AM/PM by careful design, it is not possible to eliminate it entirely. Where

minimum change of phase with attenuation is a critical parameter, the use the above described Phase Invariant Attenuators should be considered.
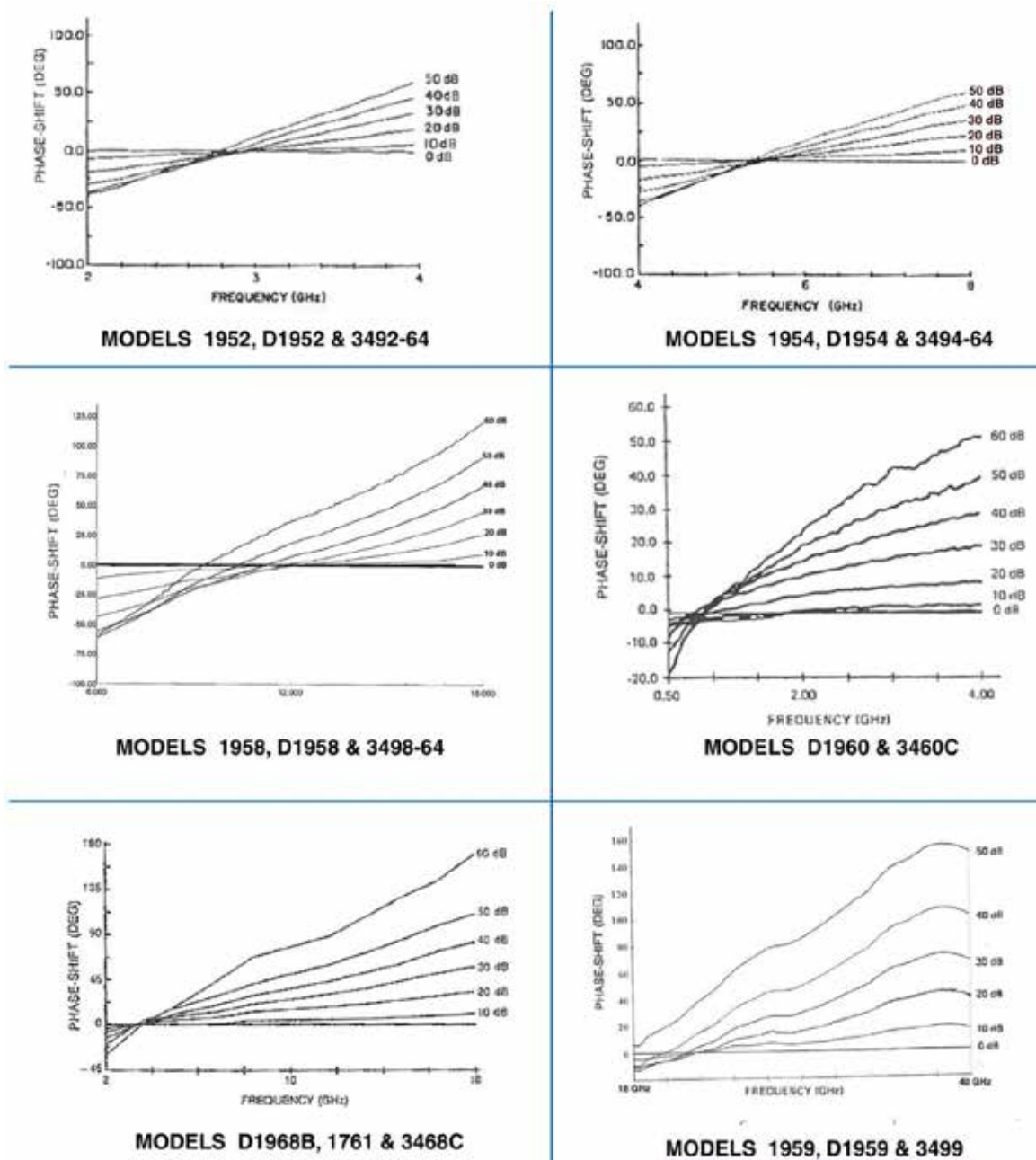
Fig. 6 – Typical Phase vs. Attenuation & Frequency

HARMONICS AND INTERMODULATION PRODUCTS

All PIN diode control devices (i.e. attenuators, switches and phase shifters) 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 attenuators 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 an attenuator are greatly dependent upon its design, the operating frequency, attenuation setting and input power level.

TYPICAL ATTENUATOR INTERCEPT POINTS

Typical performance for a moderately fast attenuator, i.e., 500 nsec switching speed.

Frequency	2nd Order Intercept	3rd Order Intercept
2.0 GHz	+35 dBm	+30 dBm
8.0 GHz	+40 dBm	+35 dBm

POWER HANDLING

The power handling of a PIN diode attenuator is dependent on its topology, biasing levels, and switching speed. The faster the attenuator, the lower the power handling capability. This catalog specifies both the maximum operating and the maximum survival levels. Maximum operating level is defined as the level which will cause an out of specification condition. The survival levels are generally dependent on the maximum ratings of the semiconductors in the attenuator. Please consult the factory for special applications requiring higher operational power levels than those listed in this catalog.

DEFINITION OF PARAMETERS

Mean Attenuation is the average of the maximum and minimum values of the attenuation over the specified frequency range for a given control signal.

Attenuation Flatness is the variation from the mean attenuation level over the specified frequency range. This is usually a function of the attenuation level, and is expressed in ± dB.

Attenuation Accuracy is the maximum deviation of the mean attenuation from the programmed attenuation value expressed in dB when measured at + 23 ± 5°C.

Total Accuracy is the sum of all the effects which contribute to the deviation from the programmed attenuation value. It includes the effects of attenuation accuracy, frequency variation and temperature, as shown in Fig. 7.

Fig. 7-Total accuracy
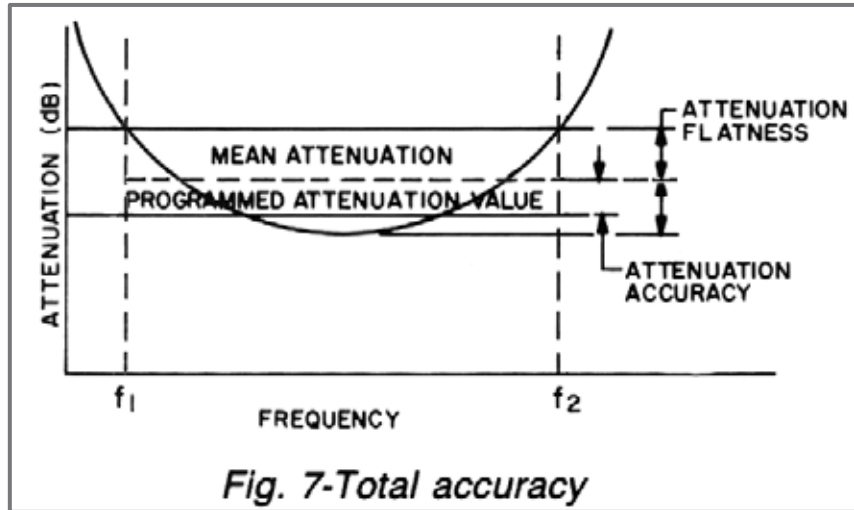
SWITCHING SPEED

The following are the standard definitions of switching speed, as shown in Fig. 8:

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

Fall Time is the transition 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 the transition time between 50% 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 the transition time between 50% 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.

Fig. 8-Switching speed
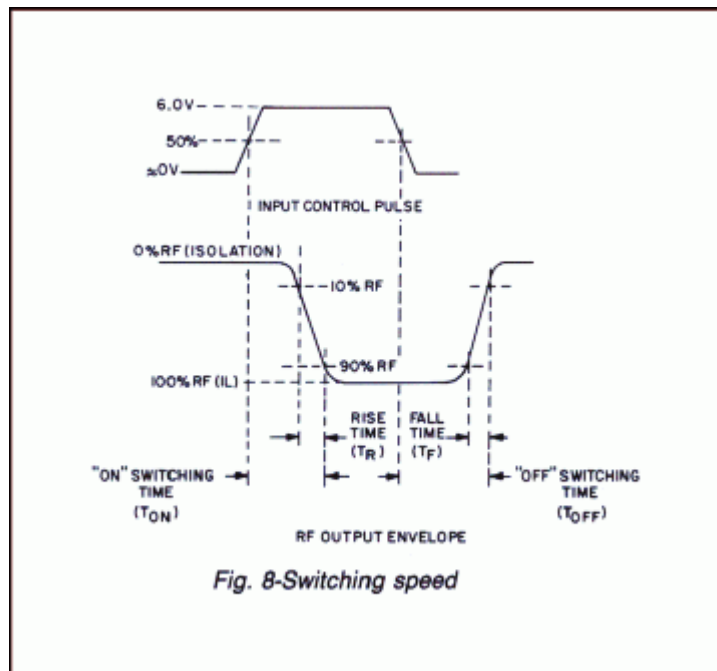
Notes:

- *For units without integrated drivers, the specifications apply to conditions when the attenuator is driven by an appropriately shaped switching waveform.*
- *Depending on the attenuator topology, there are differences in the behavior of the switching characteristics that may affect system performance. Switching speed is only specified to the 90% or 10% points of the detected RF signal, but the time the attenuator takes to reach final attenuation value or switch between different attenuation levels may be significantly longer.*

MODULATION BANDWIDTH

Small Signal Bandwidth: With reference to a modulation frequency of 100 Hz and a modulation depth of ±3 dB at a quiescent level of −6 dB, the frequency at which the modulation depth decreases by 50% as measured with a square-law detector.

Large Signal Bandwidth: With reference to a modulation frequency of 100 Hz and a 100% modulation depth at a quiescent level of −6 dB, the frequency at which the modulation depth decreases by 50% as measured with a square-law detector.

Temperature Coefficient is defined as the average rate of change of attenuation over the full operating temperature range of the unit under fixed bias conditions. It is expressed in dB/°C. Note that the attenuator temperature coefficient may vary with both temperature and programmed attenuation level.

GLITCH FREE DRIVER – Option G10

With a standard attenuator driver, while the attenuator is in transition from value X to value Y, it can go through any arbitrary value of attenuation. This is sometimes called a glitch, sometimes an undershoot and sometimes an overshot. The "glitch free" attenuator is designed in such a way that the transition is smooth as possible from X to Y.
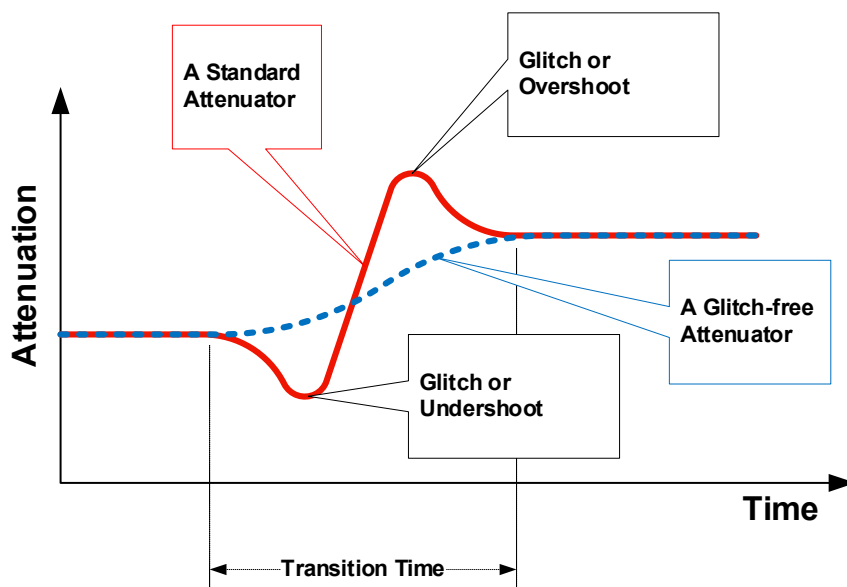
Fig. 9 – Glitch Free vs standard driver

This option is recommended as a default since it has only advantages and no penalties in performance or price.

KRΛTOS | GENERAL MICROWAVE
Microwave Electronics Division

SPECIFICATIONS TABLE NOTES

[1] SPECIAL ORDER PRODUCTS

For pricing and availability, in the USA, contact the US team at kratos-gmc@kratosdefense.com, for all other countries contact sales@kratos-med.com.

[2] ATTENUATION STEPS

For attenuation steps of 10 dB or more.

[3] EXTENDED FREQUENCY RANGE

Specifications for the extended frequency ranges are typical.

[4] PERFORMANCE OPTIMIZATION

Performance can be optimized for a narrower bandwidth.

[5] ATTENUATION RANGE

Attenuation range can be customized.

[6] NOT APPLICABILITY FOR UNITS WITHOUT DRIVERS

Not applicable for units without drivers.

[7] AVAILABLE OPTIONS FOR ATTENUATORS – MAIN SPECIFICATIONS TABLE PAGES 15 - 33

1 - BDC programming (Binary is standard).

2 - Complementary programming (logic "0" is Bit On).

3 - SMA female control connector.

4 - Strobe latch for data input. Attenuator responds to data input when logic "0" is applied. Attenuator latched to data input when logic "1" is applied.

It is recommended that when operating the Series 349/H Attenuators with the Strobe/Latch option 4 feature, the digital control inputs should be in place, with the Latch set to a low "(0)" level, before the Attenuator is powered up.

7 - Two SMA male RF connectors.

9 - Inverse control logic; "1" for switch ON, "0" for switch OFF.

10 - One SMA male (J1) and one SMA female (J2) RF connectors.

33 - EMI filter solder-type control terminal.

48 - +5V, -15V operation.

45 - Extended attenuation range to 45 dB.

48 - +5V, -15V operation.

49 - High Reliability Screening – MIL-STD 883, see following table:

TEST	METHOD	CODITION
Internal Visual	2017	—
Temperature Cycle	1010	A
Mechanical Shock	2002	B
Burn-In	1015	—
Leak	1014	A1

58 - Internally-generated reset to insertion loss.
Where the use of external reset pulse (Option 59) is not feasible, this option will automatically sense the slope and magnitude of the control signal and reset the unit to the insertion loss state within 200 nsec for a stop of 50 dB or more.

59 - Externally-triggered reset to insertion loss.
An external terminal is provided for the user to apply a fast (10 nsec, max rise time) positive-going 3-volt pulse at least 0.5 µsec wide to accelerate the return of the attenuator to the insertion loss state with the simultaneous lowering of the control signal to the zero-voltage level. This reset can be accomplished within 200 nsec.
The input impedance of units equipped with Option 59 is a circuit equivalent to approximately 50 pF in series with a parallel combination of 100 pF and 1,000 ohms.

61 - 20 dB/volt transfer function with 0 to +3V control signal input. +4V for the D1950A.

62 - ±15V operation.

64 - SMC male control connectors.

64A - SMB male control connectors.

65 - ±12V operation.

5002[1] - 8-Bit Resolution 1 µsec switching time.

C38 - 30 dB attenuation range. Consult factory for impact on specifications.

G06 - Switching speed for analog input is no longer than with a digital input.

G09 - Guaranteed to meet the Environmental Ratings.

G10 – Glitch free driver. Recommended option. See applications notes for more information.

G11 - 12V & +6 to +15V.

G12 - RoHS Compliant.

G18 – REACH Compliant.

Z06 - 1 to 18 GHz operation. I.L 4.8dB max.

ATTENUATORS - MAIN SPECIFICATIONS TABLE

For the complete specifications list please refer to the web catalog www.kratosmed.com/gmcatalog

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss (dB)	No. of Bits	LSB (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
Digitally Controlled Attenuators									
1761	2.0 - 18.0 GHz	**60**	**4.5**	7	0.5	1.0 µsec	+12 to +15V, 100 mA -12 to -15V, 100 mA	G09, G12, G18	Miniature
3250A	0.2 - 18 GHz	**60**	0.2-8 GHz: **3.5** 8-12.4 GHz: **4.0** 12.4-18 GHz: **5.0**	6	1	2 µsec	+5V ±5%, 250 mA +15V ±5%, 75 mA -15V ±5%, 75 mA	1, 2, 7, 10, 5002, G09, G12, G18	Ultra-Broad-band
3460C [1]	0.5 - 4 GHz	**60**	**2.5**	10	0.06	ON: 1.0 µsec OFF: 0.5 µsec	+12V ±5%, 90 mA -12V ±5%, 60 mA	2, 7, 10, 62, C38, G09, G12, G18	Multi-octave band
3461C	0.5 - 8 GHz	**60**	0.5-4 GHz: **2.5** 4-8 GHz: **3.2**	10	0.06	ON: 1.0 µsec OFF: 0.5 µsec	+12V ±5%, 90 mA -12V ±5%, 60 mA	2, 7, 10, 62, C38, G09, G12, G18	Multi-octave band

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss (dB)	No. of Bits	LSB (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
Digitally Controlled Attenuators *(continued)*									
3462C[1]	2.0 - 8.0 GHz	**60**	**3.2**	10	0.06	ON: 1.0 µsec OFF: 0.5 µsec	+12V ±5%, 90 mA -12V ±5%, 60 mA	2, 7, 10, 62, C38, G09, G12, G18	Multi-octave band
3468C	2.0 - 18.0 GHz	**60**	**4.5**	10	0.06	ON: 1.0 µsec OFF: 0.5 µsec	+12V ±5%, 90 mA -12V ±5%, 60 mA	2, 7, 10, 62, C38, G09, G12, G18, Z06	Multi-octave band
3482	2.0 - 4.0 GHz 1.5 - 4.5 GHz[3]	**60**	2.0-4 GHz: **1.8** 1.5-4.5 GHz: **1.9**	8	0.25	500 nsec	+12 to +15V, 120 mA -12 to -15V, 50 mA	7, 10, 49, G09, G12, G18	Miniature Octave band
3482H[1]	2.0 - 4.0 GHz 1.5 - 4.5 GHz[3]	**60**	2.0-4 GHz: **1.8** 1.5-4.5 GHz: **1.9**	8	0.25	200 nsec	+12 to +15V, 120 mA -12 to -15V, 50 mA	7, 10, 49, G09, G12, G18	Miniature Octave band
3483[1]	2.6 - 5.2 GHz 1.95 - 5.85 GHz[3]	**60**	2.6-5.2 GHz: **2.0** 1.95-5.85 GHz: **2.1**	8	0.25	500 nsec	+12 to +15V, 120 mA -12 to -15V, 50 mA	7, 10, 49, G09, G12, G18	Miniature Octave band

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss (dB)	No. of Bits	LSB (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
Digitally Controlled Attenuators *(continued)*									
3483H[1]	2.6 - 5.2 GHz 1.95 - 5.85 GHz[3]	**60**	2.6-5.2 GHz: **2.0** 1.95-5.85 GHz: **2.1**	8	0.25	200 nsec	+12 to +15V, 120 mA -12 to -15V, 50 mA	7, 10, 49, G09, G12, G18	Miniature Octave band
3484	4.0 - 8.0 GHz 3.0 - 9.0 GHz[3]	**60**	4.0-8.0 GHz: **2.4** 3.0-9.0 GHz: **2.5**	8	0.25	500 nsec	+12 to +15V, 120 mA -12 to -15V, 50 mA	7, 10, 49, G09, G12, G18	Miniature Octave band
3484H	4.0 - 8.0 GHz 3.0 - 9.0 GHz[3]	**60**	4.0-8.0 GHz: **2.4** 3.0-9.0 GHz: **2.5**	8	0.25	200 nsec	+12 to +15V, 120 mA -12 to -15V, 50 mA	7, 10, 49, G09, G12, G18	Miniature Octave band
3486	6.0 - 12.0 GHz 4.5 - 13.5 GHz[3]	**60**	6.0-12.0 GHz: **2.7** 4.5-13.5 GHz: **2.8**	8	0.25	500 nsec	+12 to +15V, 120 mA -12 to -15V, 50 mA	7, 10, 49, G09, G12, G18	Miniature Octave band
3486H	6.0 - 12.0 GHz 4.5 - 13.5 GHz[3]	**60**	6.0-12.0 GHz: **2.7** 4.5-13.5 GHz: **2.8**	8	0.25	200 nsec	+12 to +15V, 120 mA -12 to -15V, 50 mA	7, 10, 49, G09, G12, G18	Miniature Octave band

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss (dB)	No. of Bits	LSB (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
			Digitally Controlled Attenuators *(continued)*						
3488	8.0 - 18.0 GHz 6.0 - 18.0 GHz[3]	60	8.0-16.0 GHz: **3.0** 16.0-18.0 GHz: **4.0**	8	0.25	500 nsec	+12 to +15V, 120 mA -12 to -15V, 50 mA	7, 10, 49, G09, G12, G18	Miniature Octave band
3488H	8.0 - 18.0 GHz 6.0 - 18.0 GHz[3]	**60**	6.0-12.0 GHz: **3.0** 12.0-16.0 GHz: **3.5** 16.0-18.0 GHz: **4.0**	8	0.25	200 nsec	+12 to +15V, 120 mA -12 to -15V, 50 mA	7, 10, 49, G09, G12, G18	Miniature Octave band
3491-64	1.0 - 2.0 GHz 0.75 -2.25 GHz[3]	**64**	1.0-2.0 GHz: **1.6** 0.75-2.25 GHz: **1.7**	11	0.03	550 nsec	+12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3491H-64	1.0 - 2.0 GHz 0.75 - 2.25 GHz[3]	**64**	1.0-2.0 GHz: **1.6** 0.75-2.25 GHz: **1.7**	11	0.03	300 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band Fast Switching

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss (dB)	No. of Bits	LSB (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
Digitally Controlled Attenuators *(continued)*									
3491-80	1.0 - 2.0 GHz 0.75 - 2.25 GHz[3]	**80**	1.0-2.0 GHz: **1.6** 0.75-2.25 GHz: **1.7**	11	0.04	2 µsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3492-64	2.0 - 4.0 GHz 1.5 - 4.5 GHz[3]	**64**	2.0-4.0 GHz: **1.8** 1.5-4.5 GHz: **1.9**	11	0.03	550 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3492H-64	2.0 - 4.0 GHz 1.5 - 4.5 GHz[3]	**64**	2.0-4.0 GHz: **1.8** 1.5-4.5 GHz: **1.9**	11	0.03	300 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band Fast Switching
3492-80	2.0 - 4.0 GHz 1.5 - 4.5 GHz[3]	**80**	2.0-4.0 GHz: **1.8** 1.5-4.5 GHz: **1.9**	11	0.04	2 µsec	12 to +15V, 120mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3493-64	2.6 - 5.2 GHz 1.95 - 5.85 GHz[3]	**64**	2.6–5.2 GHz: **2.0** 1.95-5.85 GHz: **2.1**	11	0.03	550 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G12, G18G10,	Octave band

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss (dB)	No. of Bits	LSB (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
Digitally Controlled Attenuators *(continued)*									
3493H-64	2.6 - 5.2 GHz 1.95 - 5.85 GHz[3]	**64**	2.6-5.4 GHz: **2.0** 1.95-5.85 GHz: **2.1**	11	0.03	300 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3493-80	2.6 - 5.2 GHz 1.95 - 5.85 GHz[3]	**80**	2.6-5.2 GHz: **2.0** 1.95-5.85 GHz: **2.1**	11	0.04	2 µsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3494-64	4.0 - 8.0 GHz 3.0 - 9.0 GHz[3]	**64**	4.0-8.0 GHz: **2.4** 3.0-9.0 GHz: **2.5**	11	0.03	550 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3494H-64	4.0 - 8.0 GHz 3.0 - 9.0 GHz[3]	**64**	4.0-8.0 GHz: **2.4** 3.0-9.0 GHz: **2.5**	11	0.03	300 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3494-80	4.0 - 8.0 GHz 3.0 - 9.0 GHz[3]	**80**	4.0-8.0 GHz: **2.4** 3.0-9.0 GHz: **2.5**	11	0.04	2 µsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band

ATTENUATORS

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss (dB)	No. of Bits	LSB (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
Digitally Controlled Attenuators *(continued)*									
3495-64	5.0 - 10.0 GHz 3.75 - 11.25 GHz[3]	64	5.0-10.0 GHz: 2.6 3.75-11.25 GHz: 2.7	11	0.05	550 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3495H-64	5.0 - 10.0 GHz 3.75 - 11.25 GHz[3]	64	5.0-10.0 GHz: 2.6 3.75-11.25 GHz: 2.7	11	0.05	300 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3495-80	5.0 - 10.0 GHz 3.75 - 11.25 GHz[3]	80	5.0-10.0 GHz: 2.6 3.75-11.25 GHz: 2.7	11	0.04	2 µsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3496-64	6.0 - 12.0 GHz 4.5 - 13.5 GHz[3]	64	6.0 - 12.0 GHz: 2.7 4.5 - 13.5 GHz: 2.8	11	0.05	550 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3496H-64	6.0 - 12.0 GHz 4.5 - 13.5 GHz[3]	64	6.0-12.0 GHz: 2.7 4.5-13.5 GHz: 2.8	11	0.03	300 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss (dB)	No. of Bits	LSB (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
			Digitally Controlled Attenuators *(continued)*						
3496-80	6.0 - 12.0 GHz 4.5 - 13.5 GHz[3]	**80**	6.0 - 12.0 GHz: **2.7** 4.5 -13.5 GHz: **2.8**	11	0.04	2 µsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3498-64	8.0 - 18.0 GHz 6.0 - 18.0 GHz[3]	**64**	6-16 GHz: **3.0** 16-18 GHz: **4.2**	11	0.03	550 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3498H-64	8.0 - 18.0 GHz 6.0 - 18.0 GHz[3]	**64**	6-16 GHz: **3.0** 16-18 GHz: **4.2**	11	0.03	300 nsec	12 to +15V, 120 mA -12 to -15V, 50 mA	1, 2, 4, 7, 10, G06, G09, G10, G12, G18	Octave band
3499	18.0 - 40.0 GHz	**50**	18-26.5 GHz: **4.1** 26.5-36 GHz: **4.6** 36-40 GHz: **5.2**	11	0.03	0.5 µsec	12V to +15V, 120 mA -12V to -15V, 50 mA	2, 4, 7, 10, G09, G10	Octave band

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss (dB)	No. of Bits	LSB (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
Digitally Controlled Attenuators (continued)									
3499-60	18.0 - 40.0 GHz	**60**	18-26.5 GHz: **4.3** 26.5-36 GHz: **4.9** 36-40 GHz: **5.8**	11	0.03	0.5 µsec	12V to +15V, 120 mA -12V to -15V, 50 mA	2, 4, 7, 10, G09, G10	Octave band

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss(dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
Voltage Controlled Attenuators							
D1950A[1]	0.5 - 1.0 GHz	**80**	**1.5**	ON: 10 µsec OFF: 600 nsec	+12V ±5%, 100 mA -12V ±5%, 50 mA	3, 7, 10, 61 62, 64, 64A, G09, G12, G18	Absorptive Linearized
D1951	1.0 - 2.0 GHz 0.75 - 2.25 GHz[3]	**60**	1.0-2.0 GHz: **1.7** 0.75-2.25 GHz: **1.8**	ON: 1.6 µsec OFF: 100 nsec	+12V ±5%, 100 mA -12V ±5%, 50 mA	3, 7, 10, 58, 59, 61, 62, 64, 64A, G09, G12, G18	Absorptive Linearized
D1952	2.0 - 4.0 GHz 1.5 - 4.5 GHz[3]	**60**	2.0-4.0 GHz: **2.0** 1.5-4.5 GHz: **2.1**	ON: 1.6 µsec OFF: 100 nsec	+12V ±5%, 100 mA -12V ±5%, 50 mA	3, 7, 10, 58, 59, 61, 62, 64, 64A, G09, G12, G18	Absorptive Linearized
D1953	2.6 - 5.2 GHz 1.95 - 5.85 GHz[3]	**60**	2.6-5.2 GHz: **2.2** 1.95-5.85 GHz: **2.3**	ON: 1.6 µsec OFF: 100 nsec	+12V ±5%, 100 mA -12V ±5%, 50 mA	3, 7, 10, 58, 59, 61, 62, 64, 64A, G09, G12, G18	Absorptive Linearized

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss(dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
Voltage Controlled Attenuators *(continued)*							
D1954	4.0 - 8.0 GHz 3.0 - 9.0 GHz[3]	**60**	4.0-8.0 GHz: **2.6** 3.0-9.0 GHz: **2.7**	ON: 1.6 µsec OFF: 100 nsec	+12V ±5%, 100 mA -12V ±5%, 50 mA	3, 7, 10, 58, 59, 61, 62, 64, 64A, G09, G12, G18	Absorptive Linearized
D1955	5.0 - 10.0 GHz 3.75 - 11.25 GHz[3]	**60**	5.0-10.0 GHz: **2.8** 3.75-11.25 GHz: **2.9**	ON: 1.6 µsec OFF: 100 nsec	+12V ±5%, 100 mA -12V ±5%, 50 mA	3, 7, 10, 58, 59, 61, 62, 64, 64A, G09, G12, G18	Absorptive Linearized
D1956	6.0 - 12.0 GHz 4.5 - 13.5 GHz[3]	**60**	6.0-12.0 GHz: **2.9** 4.5-13.5 GHz: **3.0**	ON: 1.6 µsec OFF: 100 nsec	+12V ±5%, 100 mA -12V ±5%, 50 mA	3, 7, 10, 58, 59, 61, 62, 64, 64A, G09, G12, G18	Absorptive Linearized
D1958	8.0 - 18.0 GHz 6.0 - 18.0 GHz[3]	**60**	6-16 GHz: **3.0** 16-18 GHz: **4.0**	ON: 1.6 µsec OFF: 100 nsec	+12V ±5%, 100 mA -12V ±5%, 50 mA	3, 7, 10, 58, 59, 61, 62, 64, 64A, G09, G12, G18	Absorptive Linearized

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss(dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
Voltage Controlled Attenuators *(continued)*							
D1959	18 - 40 GHz	**50**	18-26.5 GHz: **4.1** 26.5-36 GHz: **4.6** 36-40 GHz: **5.2**	ON: 1.6 µsec OFF: 100 nsec	+12V ±5%, 120 mA -12V ±5%, 50 mA	3, 7, 10, 61[6], 62[6], 64, 64A	Absorptive Linearized
D1960B[1]	0.5 - 4.0 GHz	**60**	**2.7**	ON: 1.0 µsec OFF: 0.5 µsec	+12V ±5%, 80 mA -12V ±5%, 50 mA	3, 7, 10, 33, 61, 62, 64A, G09, G12, G18	Multi-Octave Non-reflective
D1961B	0.5 - 8.0 GHz	**60**	0.5-4 GHZ: **2.5** 4-8 GHz: **3.2**	ON: 1.0 µsec OFF: 0.5 µsec	+12V ±5%, 80 mA -12V ±5%, 50 mA	3, 7, 10, 33, 61, 62, 64A, G09, G12, G18	Multi-Octave Non-reflective
D1962B[1]	2.0 - 8.0 GHz	**60**	**3.2**	ON: 1.0 µsec OFF: 0.5 µsec	+12V ±5%, 80 mA -12V ±5%, 50 mA	3, 7, 10, 33, 61, 62, 64A, G09, G12, G18	Multi-Octave Non-reflective
D1968B	1.0 - 18.0 GHz	**60**	**4.5**	ON: 1.0 µsec OFF Time: 0.5 µsec	+12V ±5%, 80 mA -12V ±5%, 50 mA	3, 7, 10, 33, ,61, 62, 64A, G09, G12, G18	Multi-Octave Non-reflective

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss(dB)	Max Switching Speed	Bias Current for Maximum Attenuation	Available Options [7]	Notes
Current Controlled Attenuators							
1950A[1]	0.5 - 1.0 GHz	**80**	**1.4**	Fall Time: 50 nsec[3] Rise Time: 250 nsec[3]	35 mA	3, 7, 10, 64, 64A, G09, G12, G18	Absorptive High speed
1951	1.0 - 2.0 GHz 0.75 - 2.25 GHz[3]	**60**	1.0-2.0 GHz: **1.3** 0.75-2.25[x]: **1.4**	Fall Time: 20 nsec[3] Rise Time: 125 nsec[3]	70 mA	3, 7, 10, 64, 64A, G09, G12, G18	Multi-Octave Non-reflective
1952	2.0 – 2.4 GHz 1.5 – 4.5 GHz[3]	**60**	2.0-2.4 GHz: **1.5** 1.5-4.5 GHz: **1.6**	Fall Time: 20 nsec[3] Rise Time: 125 nsec[3]	70 mA	3, 7, 10, 64, 64A, G09, G12, G18	Multi-Octave Non-reflective
1953	2.6 - 5.2 GHz 1.95 - 5.85 GHz[3]	**60**	2.6-5.2 GHz: **1.7** 1.95-5.85 GHz: **1.8**	Fall Time: 20 nsec[3] Rise Time: 125 nsec[3]	70 mA	3, 7, 10, 64, 64A, G09, G12, G18	Multi-Octave Non-reflective
1954	4.0 - 8.0 GHz 3.0 - 9.0 GHz[3]	**60**	4.0-8.0 GHz: **2.0** 3.0-9.0 GHz: **2.1**	Fall Time: 20 nsec[3] Rise Time: 125 nsec[3]	70 mA	3, 7, 10, 64, 64A, G09, G12, G18	Multi-Octave Non-reflective

Model	Frequency Range	Mean Attenuation (dB)	Max Insertion Loss(dB)	Max Switching Speed	Bias Current for Maximum Attenuation	Available Options [7]	Notes
			Current Controlled Attenuators *(continued)*				
1955	5.0 - 10.0 GHz 3.75 - 11.25 GHz[3]	**60**	5.0-10.0 GHz: **2.2** 3.75-11.25 GHz: **2.3**	Fall Time: 20 nsec[3] Rise Time: 125 nsec[3]	70 mA	3, 7, 10, 64, 64A, G09, G12, G18	Multi-Octave Non-reflective
1956	6.0 - 12.0 GHz 4.5 - 13.5 GHz [3]	**60**	6.0-12.0 GHz: **2.3** 4.5-13.5 GHz: **2.4**	Fall Time: 20 nsec[3] Rise Time: 125 nsec[3]	70 mA	3, 7, 10, 64, 64A, G09, G12, G18	Multi-Octave Non-reflective
1958	8.0 - 18.0 GHz 6.0 - 18.0 GHz [3]	**60**	6.0-16.0 GHz: **2.5** 16.0-18.0 GHz: **3.5**	Fall Time: 20 nsec[3] Rise Time: 125 nsec[3]	70 mA	3, 7, 10, 64, 64A, G09, G12, G18	Multi-Octave Non-reflective
1959	18.0 - 40.0 GHz	**50**	18-26.5 GHz: **3.6** 26.5-36 GHz: **4.1** 36-40 GHz: **4.7**	ON: 1.6 µsec OFF: 100 nsec	70 mA	3, 7, 10, 61[2], 62[2], 64, 64A	Single Control Absorptive High speed

PULSE MODULATOR - MAIN SPECIFICATIONS TABLE

For the complete specifications list please refer to the web catalog www.kratosmed.com/gmcatalog

Model	Frequency Range	Min Isolation (dB)	Max Insertion Loss (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
F192A	0.2 - 18.0 GHz	0.2-0.5 GHz: **70** 0.5-18.0 GHz: **80**	0.2-2.0 GHz: **2.0** 2.0-8.0 GHz: **2.5** 8.0-12.4 GHz: **3.0** 12.4-18.0 GHz: **3.5**	ON: 30 nsec OFF: 15 nsec	+15V ±5% @ 90 mA -12V ±5% @ 75 mA	3, 7, 9, 10, 33, 48, 64A, G09, G12, G18	Non-reflective High speed

PHASE INVARIANT ATTENUATORS (PIA) - MAIN SPECIFICATIONS TABLE

For the complete specifications list please refer to the web catalog www.kratosmed.com/gmcatalog

Model	Frequency Range	Max Phase Shift	Min Isolation (dB)	Max Insertion Loss (dB)	LSB (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
Digitally Controlled PIA									
3472[1]	2 - 6 GHz	0-20 dB: ±4 ° 20-32 dB: ±8 °	0.125	**4**	0.125	350 nsec	+5V ± 5% @ 325 mA +15V ± 5% @ 15 mA -15V ± 5% @ 70 mA	7, 10, 45, 65, G09, G12, G18	Multi-octave band Non-reflective High Speed
3474[1]	4 - 11 GHz	0-20 dB: ±4 ° 20-32 dB: ±8 °	0.125	**5**	0.125	350 nsec	+5V ± 5% @ 325 mA +15V ± 5% @ 15 mA -15V ± 5% @ 70 mA	7, 10, 45, 65, G09, G12, G18	Multi-octave band Non-reflective High Speed
3478[1]	6 - 18 GHz	0-20 dB: ±5 ° 20-32 dB: ±10°	0.125	**7**	0.125	350 nsec	+5V ± 5% @ 325 mA +15V ± 5% @ 15 mA -15V ± 5% @ 70 mA	7, 10, 45, 65, G09, G12, G18	Multi-octave band Non-reflective High Speed

Model	Frequency Range	Max Phase Shift	Mean Attenuation (dB)	Max Insertion Loss (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]	Notes
Voltage Controlled PIA								
D1972[1]	2.0 - 6.0 GHz	0-20 dB: **±4º** 20-32 dB: **±8º**	**32**	**4**	250 nsec	+15V ±5% @ 200 mA -15V ±5% @ 120 mA	7, 10, 45, 65, G09, G12, G18	Integrated driver and RF Low phase shift Non-reflective High speed
D1974[1]	4.0 - 11.0 GHz	0-20 dB: **±4º** 20-32 dB: **±8º**	**32**	**5**	250 nsec	+15V ±5% @ 200 mA -15V ±5% @ 120 mA	7, 10, 45, 65, G09, G12, G18	Integrated driver and RF Low phase shift Non-reflective High speed
D1978[1]	6.0 - 18.0 GHz	0-20 dB: **±5º** 20-32 dB: **±10º**	**32**	**7**	250 nsec	+15V ±5% @ 200 mA -15V ±5% @ 120 mA	7, 10, 45, 65, G09, G12, G18	Integrated driver and RF Low phase shift Non-reflective High speed

SWITCHED BIT ATTENUATORS - MAIN SPECIFICATIONS TABLE

For the complete specifications list please refer to the web catalog www.kratosmed.com/gmcatalog

Model	Frequency Range	Min Attenuation (dB)	Max Insertion Loss (dB)	No. of Bits	LSB (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]
SA-26-1-25[1]	2.0 - 6.0 GHz[4]	25 [5]	2.0	1	25	30 nsec	+5V ± 2% @ 60 mA -12V ± 2% @ 60 mA	G09
SA-26-2-5[1]	2.0 - 6.0 GHz[4]	15 [5]	2.5	2	5	30 nsec	+5V ± 2% @ 110 mA -12V ± 2% @ 75 mA	G09
SA-26-3-1[1]	2.0 - 6.0 GHz[4]	7 [5]	3.2	3	1	30 nsec	+5V ± 2% @ 180 mA -12V ± 2% @ 130 mA	G09
SA-26-6-1[1]	2.0 - 6.0 GHz[4]	63 [5]	5.0	6	1	30 nsec	+5V ± 2% @ 350 mA	G09
SA-26-7-1[1]	2.0 - 6.0 GHz[4]	81[5]	5.5	7	1	100 nsec	+5V ± 2% @ 400 mA	G09
SA-26-8-0.25[1]	2.0 - 6.0 GHz[4]	63.75[5]	6.5	8	0.25	100 nsec	+5V ± 2% @ 450 mA	G09
SA-218-1-25[1]	2.0 - 18.0 GHz[4]	25[5]	2.6	1	25	30 nsec	+5V ± 2% @ 60 mA -12V ± 2% @ 60 mA	G09
SA-335-5-1-60[1]	2.0 - 3.5 GHz[4]	31[5]	3.8	5	1	100 nsec	+5V ± 2% @ 300 mA	G09
SA-618-2-5[1]	6.0 - 18.0 GHz[4]	15[5]	4.5	2	5	30 nsec	+5V ± 2% @ 110 mA -12V ± 2% @ 75 mA	G09

Model	Frequency Range	Min Attenuation (dB)	Max Insertion Loss (dB)	No. of Bits	LSB (dB)	Max Switching Speed	Power Supply Requirements	Available Options [7]
Switched Bit Attenuators (continued)								
SA-618-3-1[1]	6.0 - 18.0 GHz[4]	**7**[5]	**6.5**	3	1	30 nsec	+5V ± 2% @ 200 mA -12V ± 5% @ 150 mA	G09
SA-618-6-1[1]	6.0 - 18.0 GHz[4]	**63**[5]	**13**	6	1	30 nsec	+5V ± 2% @ 450 mA -12V ± 2% @ 250 mA	G09

IQ VECTOR MODULATORS, PHASE SHIFTERS AND FREQUENCY TRANSLATORS

INTRODUCTION

Kratos General Microwave Corporation has been a leader in microwave PIN diode control components for more than 35 years, designing and manufacturing high performance, broadband phase shifters, frequency translators and I-Q Modulators.

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. This section provides insight into the theory of operation, calibration and practical applications.

Kratos General Microwave offers a complete line of broadband phase shifters and I-Q modulators which span the frequency range from 0.05 to 40.0 GHz. These devices are available in several different topologies, allowing 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 Kratos General Microwave has utilized in custom applications.

CUSTOM PRODUCTS

In addition to the standard line of broadband phase shifters, frequency translators and I-Q Modulators, Kratos manufacturers numerous special design products for special applications. Such custom-made products, are designed per specific customer's requirements and are considered as customer's proprietary information.

High Power Phase Shifter

For more information, in the USA contact the US team at kratos-gmc@kratosdefense.com, for all other countries contact sales@kratos-med.com.

CATALOG PRODUCTS

Kratos General Microwave offers a complete line of broadband microwave and RF Phase Shifters, Frequency Translators and IQ Vector Modulators, which span the frequency range from 0.05 to 40.0 GHz. These products are available in several different topologies that allow the designer to choose among various performance characteristics that best suit his system needs. The catalog includes the following products, which are available in various configurations:

- Microwave Phase Shifters

- Microwave Frequency Translators Pulse Modulators

- Microwave IQ Vector Modulators

Additional specifications and diagrams can be found in the online catalog at **www.kratosmed.com/gmcatalog.**

IQ VECTOR 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.
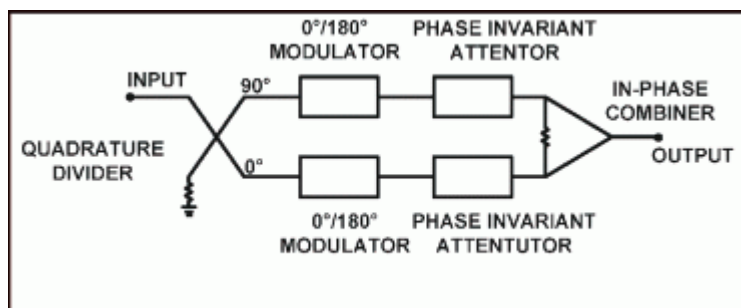

Figure 1: I-Q Vector Modulator Block diagram

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.

TYPICAL APPLICATIONS 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. 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?

Kratos General Microwave has customized many variations of the IQ vector modulators 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.

THEORY OF OPERATION & PRACTICAL APPLICATIONS

I-Q vector modulator is 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

The block diagram of the I-Q vector modulator is shown in Figure 5. 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 as the I channel and the quadrature or 90-degree channel is designated as the Q channel. Each signal passes through a biphase modulator, which selects the 0- or 180-degree state for both the

Figure 2: I-Q Vector Modulator Block diagram

I and the Q paths. This defines the quadrant in which the resultant output signal resides (Figure 6). 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 6. Thus, any signal applied to the l-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:
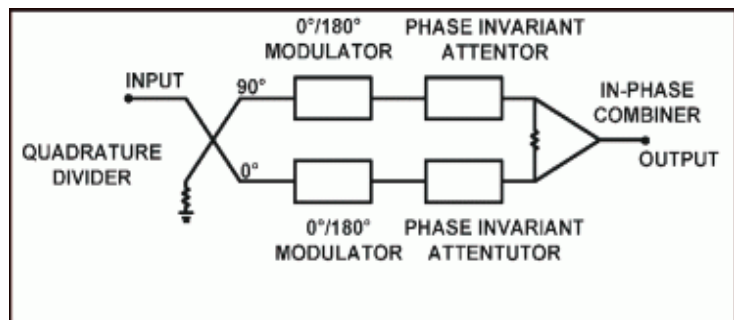
R = 10–(x/20)

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

I attenuator (dB) = 20 log (R cos Θ)
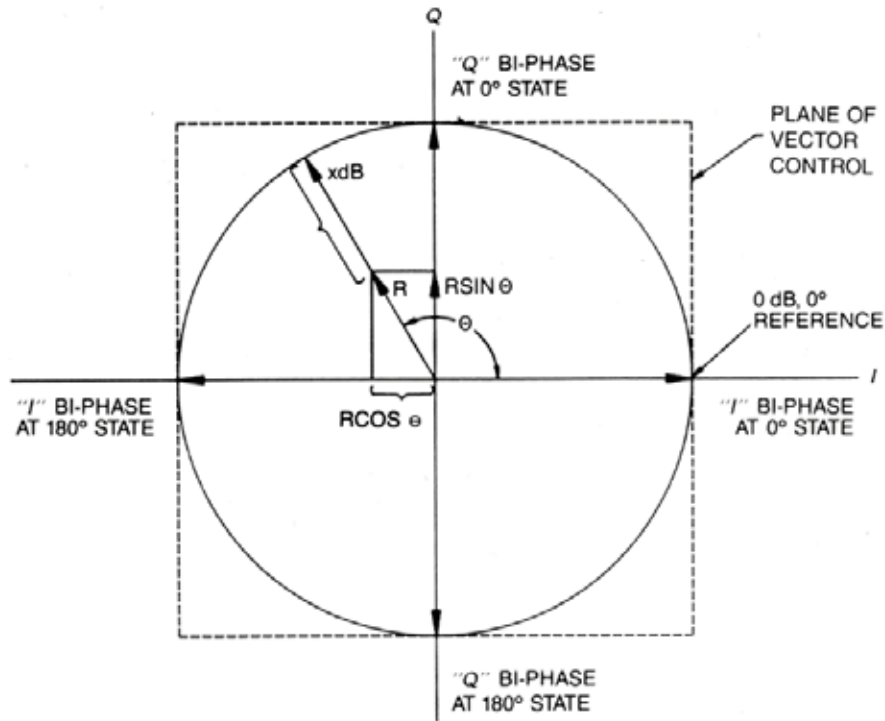Q attenuator (dB) = 20 log (R sin Θ)

Figure 3: I-Q Phase Relationship

To achieve the desired phase shift, bi-phase 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		
Bi-phase Modulator States		Desired Phase Shift
I	Q	
0°	0°	0°-90°
180°	0°	0°-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 Hoofer quadrature hybrid*, 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.

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 7.
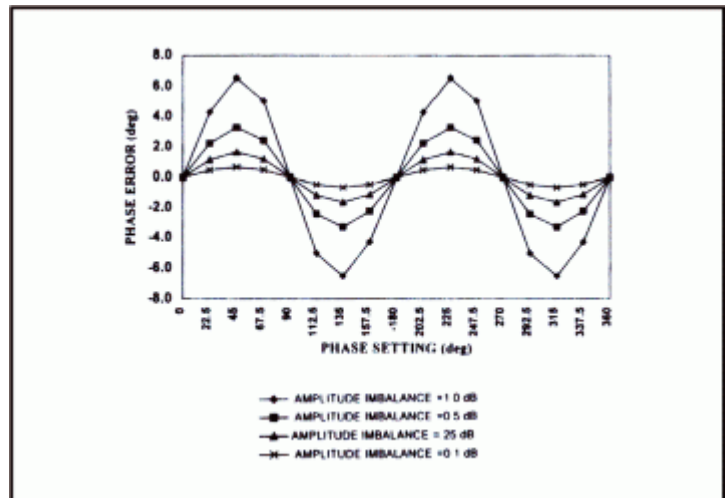

Figure 4: Phase Error Due to Amplitude Imbalance

NON-IDEAL BI-PHASE MODULATOR AND ATTENUATOR

Errors in amplitude and phase will occur if the biphase modulator deviates from the ideal, e.g.: 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 8 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 Kratos General Microwave* 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.
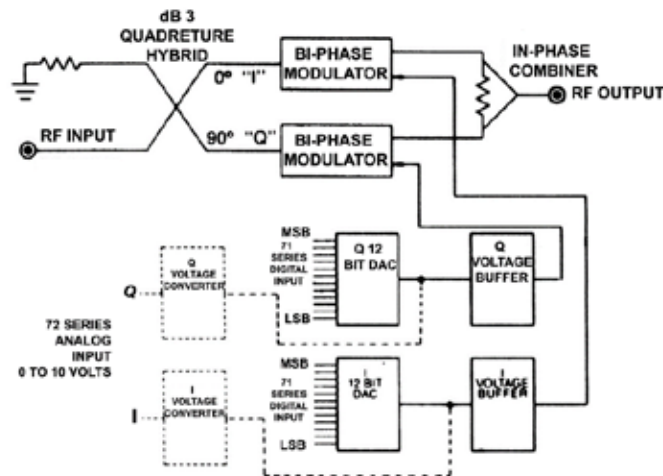
Figure 5: Series 71/71 Block Diagram

* Z. Adler and B. Smilowitz, "Octave-Band High-Precision Balanced Modulator," IEEE MTT-S International Microwave Symposium Digest, 1984. Theory of Operation & Practical Applications

PRACTICAL APPLICATIONS

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:

$I = \cos \Theta$

$Q = \sin \Theta$

where I and Q are normalized voltages.

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.

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.

AMPLITUDE AND PHASE CALIBRATION

Kratos 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 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 will fully understand the limitations of measurements in calibrating these units at microwave frequencies. For example, it is imperative that the desired calibration accuracy will 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. 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 ensuring that the maximum phase and amplitude error over the frequency calibration interval is within the desired limits.

2. 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 derived at per the table 2 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. 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. 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 10. 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. 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 I<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 10). The scale value will be called SCALE in calculations given in step 5. 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.
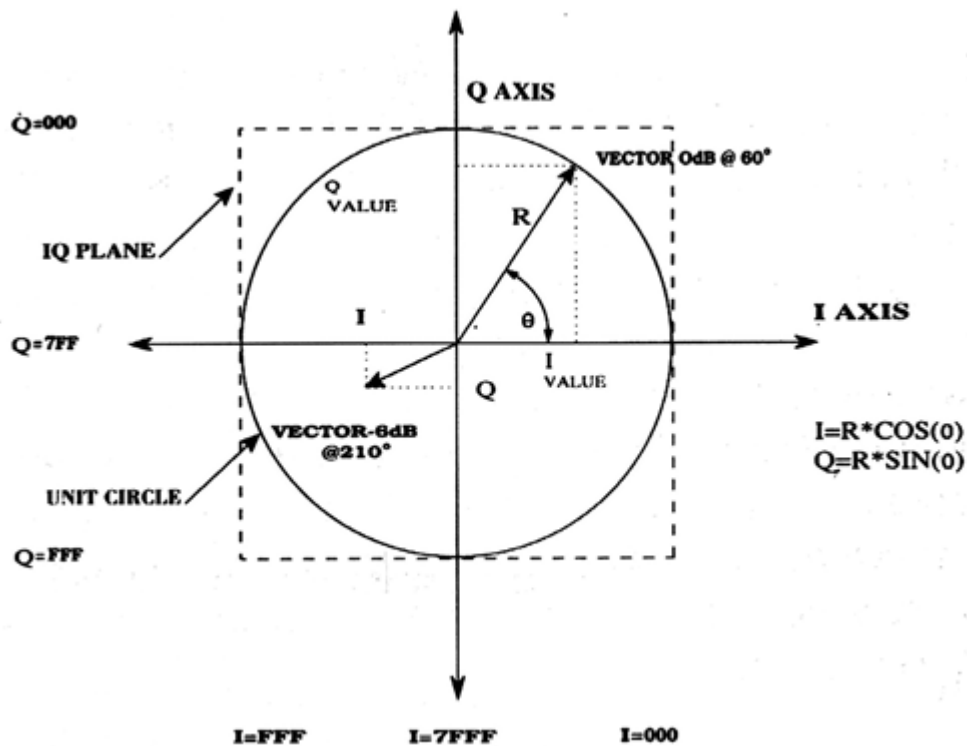
Figure 6: I-Q Vector Model

5. 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:

- 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.

- 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.

- 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.

- 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. 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)

SPECIFICATIONS TABLE NOTES

[1] AVAILABLE OPTIONS FOR IQ VECTOR MODULATORS – MAIN SPECIFICATION TABLE PAGES 44 - 46

7 - Two SMA male RF connectors.

Note: For 18 to 40 GHz Attenuators – K type male connectors are used.

10 - One SMA male and one SMA female RF connector. See details in the web.

Note: For 18 to 40 GHz Attenuators – K type male connectors are used.

G09 - Guaranteed to meet the Environmental Ratings.

G12 - RoHS Compliant

G18 – REACH Compliant

IQ VECTOR MODULATORS – MAIN SPECIFICATIONS TABLE

For the complete specifications list please refer to the web catalog www.kratosmed.com/gmcatalog

Model	Frequency Range	Max Insertion Loss (dB)	Attenuation Range (dB)	Power Handling (dBm)	Accuracy Vs. Frequency	Power Supply Requirements	Available Options [1]	Notes
7120	0.5-2.0 GHz	13	20	+7	±15°	-12 to -15V @ 70 mA +12 to +15V @ 70 mA	7, 10, G09, G12, G18	Digitally Programmable (12-Bit)
7122	2.0-6.0 GHz	11	20	+20	±15°	-12 to -15V @ 70 mA +12 to +15V @ 70 mA	7, 10, G09, G12, G18	Digitally Programmable (12-Bit)
7124	4.0-12.0 GHz	12	20	+20	±15°	-12 to -15V @ 70 mA +12 to +15V @ 70 mA	7, 10, G09, G12, G18	Digitally Programmable (12-Bit)
7128	6.0-18.0 GHz	12	20	+20	±15°	-12 to -15V @ 70 mA +12 to +15V @ 70 mA	7, 10, G09, G12, G18	Digitally Programmable (12-Bit)
7218	1.0-18.0 GHz Band 1: 2-6 GHz Band 2: 6-18 GHz	16	20	+20	±15°	+5V ±2% @ 200 mA, max. +12 to +15V @ 150 mA, max. -5.2 V ±2% @ 400 mA, max. -12 to -15V @ 150 mA, max	G09, G12, G18	Broadband Digitally Programmable (12-Bit)

IQ VECTOR MODULATOR

Model	Frequency Range	Max Insertion Loss (dB)	Attenuation Range (dB)	Power Handling (dBm)	Accuracy Vs. Frequency	Power Supply Requirements	Available Options [1]	Notes
					IQ Vector Modulators *(continued)*			
7220	0.5-2.0 GHz	13	20	+7	±15°	-12 to -15V @ 70 mA +12 to +15V @ 70 mA	7, 10, G09, G12, G18	Analog control
7222	2.0-6.0 GHz	11	20	+20	±15°	-12 to -15V @ 70 mA +12 to +15V @ 70 mA	7, 10, G09, G12, G18	Analog control
7224	4.0-12.0 GHz	12	20	+20	±15°	-12 to -15V @ 70 mA +12 to +15V @ 70 mA	7, 10, G09, G12, G18	Analog control
7228	6.0-18.0 GHz	12	20	+20	±15°	-12 to -15V @ 70 mA +12 to +15V @ 70 mA	7, 10, G09, G12, G18	Analog control
7322	2.0-6.0 GHz	16	50	+20	±25°	-12 to -15V @ 100 mA +12 to +15V @ 100 mA	7, 10, G09, G12, G18	High Dynamic Range
7328	6.0-18.0 GHz	6-16 GHz: 20 16-18 GHz: 23	50	+20	±25°	-12 to -15V @ 100 mA +12 to +15V @ 100 mA	7, 10, G09, G12, G18	High Dynamic Range
7329	16.0-24.0	18	50	+20	16-22 GHz: ±15° 22-24 GHz: ±20°	-12 to -15V @ 100 mA +12 to +15V @ 100 mA	7, 10, G09, G1, G182	High Dynamic Range

Model	Frequency Range	Max Insertion Loss (dB)	Attenuation Range (dB)	Power Handling (dBm)	Accuracy Vs. Frequency	Power Supply Requirements	Available Options [1]	Notes
IQ Vector Modulators *(continued)*								
7328H	6.0- 18.0 GHz	6-10 GHz: 18.5 10-12 GHz: 20 12-18 GHz: 27	6-16 GHz: 60 16-18 GHz: 50	-5	6-12 GHz: ±25° 12-18 GHz: ±35	+12V @ 350 mA -12V @ 130 mA -5.2V @ 340 mA -2V @ 280 mA	G09, G12, G18	High Speed High Dynamic Range
7422	2.0-6.0 GHz	16	50	+20	±25°	-12 to -15V @ 100 mA +12 to +15V @ 100 mA	7, 10, G09, G12, G18	High Dynamic Range Analog control
7428	6.0-18.0 GHz	18	50	+20	±25°	-12 to -15V @ 100 mA +12 to +15V @ 100 mA	7, 10, G09, G12, G18	High Dynamic Range Analog control
7429	16.0-24.0 GHz	18	50	+20	16-22 GHz: ±15° 22-24 GHz: ±20°	-12 to -15V @ 100 mA +12 to +15V @ 100 mA	7, 10, G09, G12, G18	High Dynamic Range Analog control

PHASE SHIFTERS

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 (ωt), the output will be A(n)*sin[(ωt+Θ(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 are 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 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 suffers 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 Kratos General Microwave, shows excellent performance over 3:1 bandwidth. This capability is especially useful in the design of frequency translators* 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 allows 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.

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

PHASE NOISE

The phase shifters and I-Q modulators offered by Kratos 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.

SPECIFICATIONS TABLE NOTES

7 - Two SMA male RF connectors.

Note: For 18 to 40 GHz Attenuators – K type male connectors are used.

10 - One SMA male and one SMA female RF connector. See details in the web.

Note: For 18 to 40 GHz Attenuators – K type male connectors are used.

G09 - Guaranteed to meet the Environmental Ratings.

G12 - RoHS Compliant

G18 – REACH Compliant

(2) Specifications in Stretch Band are typical

PHASE SHIFTERS – MAIN SPECIFICATIONS TABLE

For the complete specifications list please refer to the web catalog www.kratosmed.com/gmcatalog

Model	Frequency Range	Max Insertion Loss (dB)	Max Accuracy	Max PM/AM (dB)	Min Phase Shift Range	Power Handling (dBm)	Power Supply Requirements	Available Options [1]	Notes
7720A	Main Band 0.7-1.85 GHz Stretch Band 0.5-2.0 GHz Band Edges 0.5-0.7 & 1.9-2.0 GHz	11.5 13.0 13.0	±10° ±15° ±10°	±1.1 ±2.5 ±1.1	360° in 1024 Steps	+7	+5V to +5.5V @ 100mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18,	Digitally programmable (10-bit) Stretch Band specifications is typical Refer to the web catalog for optimized operation at the various bands
7722A	Main Band 2.6-5.2 GHz Stretch Band 2.0-6.0 GHz [2] Band Edges 2.0-2.6 & 5.2-6.0 GHz	10.0 11.0 11.0	±10° ±15° ±10°	±1.1 ±1.5 ±1.1	360° in 1024 Steps	+20	+5V to +5.5V @ 100mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18,	Digitally programmable (10-bit) Stretch Band specifications is typical Refer to the web catalog for optimized operation at the various bands

KRATOS | GENERAL MICROWAVE Microwave Electronics Division

Model	Frequency Range	Max Insertion Loss (dB)	Max Accuracy	Max PM/AM (dB)	Min Phase Shift Range	Power Handling (dBm)	Power Supply Requirements	Available Options [1]	Notes
					Phase Shifters *(continued)*				
7724A	Main Band 4.5-10.5 GHz Stretch Band 4.0-12.0 GHz [2] Band Edges 4.0-4.5 & 10.5-12.0 GHz	10.5 12.0 12.0	±10° ±15° ±10°	±1.1 ±2.0 ±1.1	360° in 1024 Steps	+20	+5V to +5.5V @ 100mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18,	Digitally programmable (10-bit) Refer to the web catalog for optimized operation at the various bands
7728A	Main Band 8.0-18.0 GHz Stretch Band 6.0-18.0 GHz [2] Band Edges 6.0-8.0 GHz	12.0 12.0 12.0	±12° ±15° ±12°	±1.25 ±2.0 ±1.25	360° in 1024 Steps	+20	+5V to +5.5V @ 100mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18,	Digitally programmable (10-bit) Refer to the web catalog for optimized operation at the various bands
7820	Main Band 0.7-1.85 GHz Stretch Band 0.5-2.0 GHz [2] Band Edges 0.5-0.7 & 1.9-2.0 GHz	11.5 13.0 13.0	±10° ±15° ±10°	±1.1 ±2.**5** ±1.**1**	360° @ 60°/volt	+7	+5V to +5.5V @ 200mA max +12 to +15V @ 100mA max 012 to -15V @ 90mA ma	7, 10, G09, G12, G18,	Analog control Refer to the web catalog for optimized operation at the various bands

Model	Frequency Range	Max Insertion Loss (dB)	Max Accuracy	Max PM/AM (dB)	Min Phase Shift Range	Power Handling (dBm)	Power Supply Requirements	Available Options [1]	Notes
Phase Shifters *(continued)*									
7822	Main Band 2.6-5.2 GHz Stretch Band 2.0-6.0 GHz [2] Band Edges 2.0-2.6 & 5.2-6.0 GHz	10.0 11.0 11.0	±10° ±15° ±10°	±1.1 ±1.5 ±1.1	360° @ 60°/volt	+20	+5V to +5.5V @ 200mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18,	Analog control Refer to the web catalog for optimized operation at the various bands
7824	Main Band 4.5-10.5 GHz Stretch Band 4.0-12.0 GHz [2] Band Edges 4.0-4.5 & 10.5-12.0 GHz	10.5 12.0 12.0	±10° ±15° ±10°	±1.1 ±2.0 ±1.1	360° @ 60°/volt	+20	+5V to +5.5V @ 200mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18,	Analog control Refer to the web catalog for optimized operation at the various bands
7828	Main Band 8.0-18.0 GHz Stretch Band 6.0-18.0 GHz [2] Band Edges 6.0-8.0 GHz	12.0 12.0 12.0	±12° ±15° ±12°	±1.25 ±2.0 ±1.25	360° @ 60°/volt	+20	+5V to +5.5V @ 200mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18,	Analog control Refer to the web catalog for optimized operation at the various bands

Model	Frequency Range	Max Insertion Loss (dB)	Max Accuracy	Max PM/AM (dB)	Min Phase Shift Range	Power Handling (dBm)	Power Supply Requirements	Available Options [1]	Notes
Phase Shifters (continued)									
7929	18.0-40.0	15.0	±15°	±2.0	360° in 1024 steps	+20	+5V ± 5%, 125 mA max +12 to +15V, 10 mA max -12 to -15, 95 mA max	7, 10, 49, G09, G12, G18,	Digitally programmable (10-bit) Hermetically Sealed Refer to the web catalog for optimized operation at the various bands

Model	Frequency Range	Max Insertion Loss (dB)	Max Accuracy	Max PM/AM (dB)	Min Phase Shift Range	Power Handling (dBm)	Power Supply Requirements	Available Options [1]	Notes
Narrow Band Phase Shifters									
7728-NB-0812	8.0 to 12.4 GHz	12.0	± 8°	± 0.75	360° in 1024 Steps	+20	+5V to +5.5V @ 100mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18,	Digitally programmable (10-bit)
7728-NB-1214	12.0 to 14.5 GHz	12.0	± 8°	± 0.75	360° in 1024 Steps	+20	+5V to +5.5V @ 100mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18,	Digitally programmable (10-bit)
7929-NB-1821	18.0 to 21.4 GHz	13.0	± 6°	± 1.0	360° in 1024 steps	+20	+5V ± 5%, 125 mA max +12 to +15V, 10 mA max -12 to -15, 95 mA max	7, 10, 49, G09, G12, G18,	Digitally programmable (10-bit) Hermetically Sealed

Model	Frequency Range	Max Insertion Loss (dB)	Max Accuracy	Max PM/AM (dB)	Min Phase Shift Range	Power Handling (dBm)	Power Supply Requirements	Available Options [1]	Notes
Narrow Band Phase Shifters *(continued)*									
7929-NB-2731	27.0 to 31.0 GHz	13.0	± 6°	± 1.0	360° in 1024 steps	+20	+5V ± 5%, 125 mA max +12 to +15V, 10 mA max -12 to -15, 95 mA max	7, 10, 49, G09, G12, G18,	Digitally programmable (10-bit) Hermetically Sealed
7929-NB-3336	33.0 to 36.0 GHz	13.0	± 6°	± 1.0	360° in 1024 steps	+20	+5V ± 5%, 125 mA max +12 to +15V, 10 mA max -12 to -15, 95 mA max	7, 10, 49, G09, G12, G18,	Digitally programmable (10-bit) Hermetically Sealed
7929-NB-3740	37.0 to 40.0 GHz	13.5	± 10°	± 1.0	360° in 1024 steps	+20	+5V ± 5%, 125 mA max +12 to +15V, 10 mA max -12 to -15, 95 mA max	7, 10, 49, G09, G12, G18,	Digitally programmable (10-bit) Hermetically Sealed

PHASE SHIFTERS

Model	Frequency Range	Max Insertion Loss (dB)	Max Accuracy	Max PM/AM (dB)	Min Phase Shift Range	Power Handling (dBm)	Power Supply Requirements	Available Options [1]	Notes
Miniaturized Phase Shifters									
7928A	Main Band 8.0-18.0 GHz Stretch Band 6.0-18.0 GHz [2]	12.0 12.0	±12° ±15°	±1.1 ±2.0	360° in 256 steps	+20	+5V ± 5%, 80 mA max + 12 to 15V, 10 mA max -12 to -15, 95 mA max	7, 10, 49, G09, G12, G18,	Digitally programmable (8-Bit)

FREQUENCY TRANSLATORS

GENERAL

WHAT IS FREQUENCY TRANSLATION?

A Frequency Translator is a Phase Shifter that is being operated in a different method, as described in the following.

Translation is shifting the frequency of a signal by a user-controlled delta. This frequency delta, also known as Translation Rate, is usually notated by "Fm".

If you want to translate the signal by 1 Hz, you need to apply a ramp (counter) that sweeps the phase control of the phase shifter (translator), starting from zero phase shift and ending at 360° in a cyclic manner.

Each cycle should take exactly 1 second in order to achieve a shift of 1 Hz. Using 10-bit counter, the clock of the counter would be 1/1024 Hz. Using only 5-bit counter, the clock of the counter would be 1/32 Hz. So using less bits will enable lower clock rates. However, too low number of bits will cause poor sidebands and carrier suppression.

Let us assume that we have a pure sine-wave signal as a carrier at Fc that appears at the output of the phase shifter with a nominal amplitude of 0 dBm. Now, when introducing an Fm [Hz] translation (covering the 360º once every 1/Fm [seconds]) using the 5 Most Significant Bits. With a perfect phase shifter we expect that the spectrum will look like this:
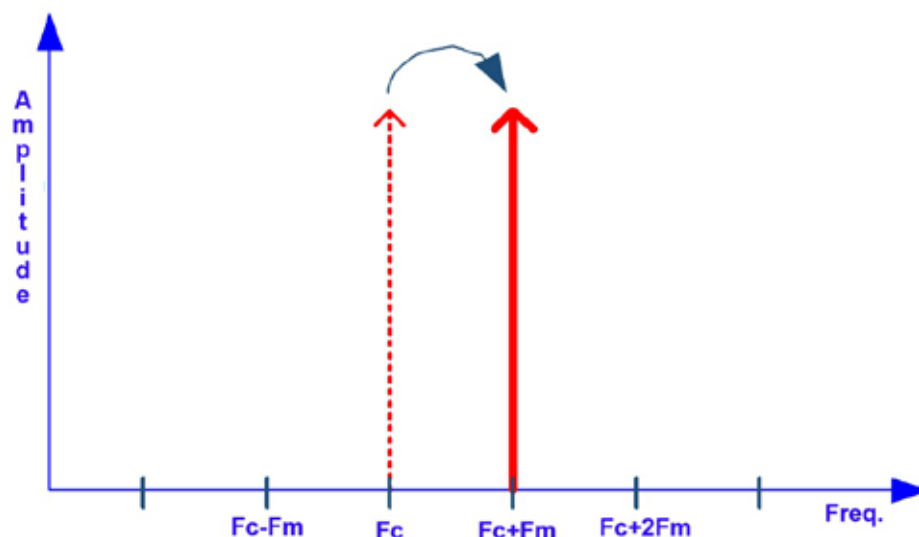

Figure 1: Ideal Frequency Translation of CW Signal

However, with a practical phase shifter the spectrum will look like this:
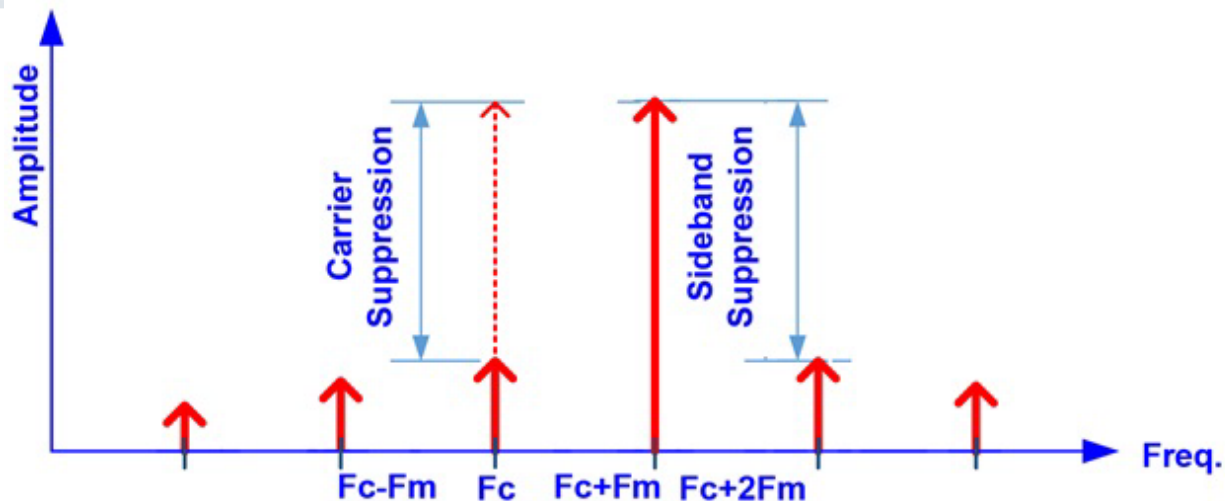
Figure 2: Practical Frequency Translation

Where:

Carrier Suppression: The amplitude difference between the translated signal and the original carrier. Sideband Suppression: The amplitude difference between the translated signal and the strongest sideband (could be at Fc-n*Fm or Fc+n*Fm, but usually is the Fc+2*Fm product).

IL Variation: Reduction of the Translated Carrier amplitude relative to an amplitude at low translation rate (50 kHz)."
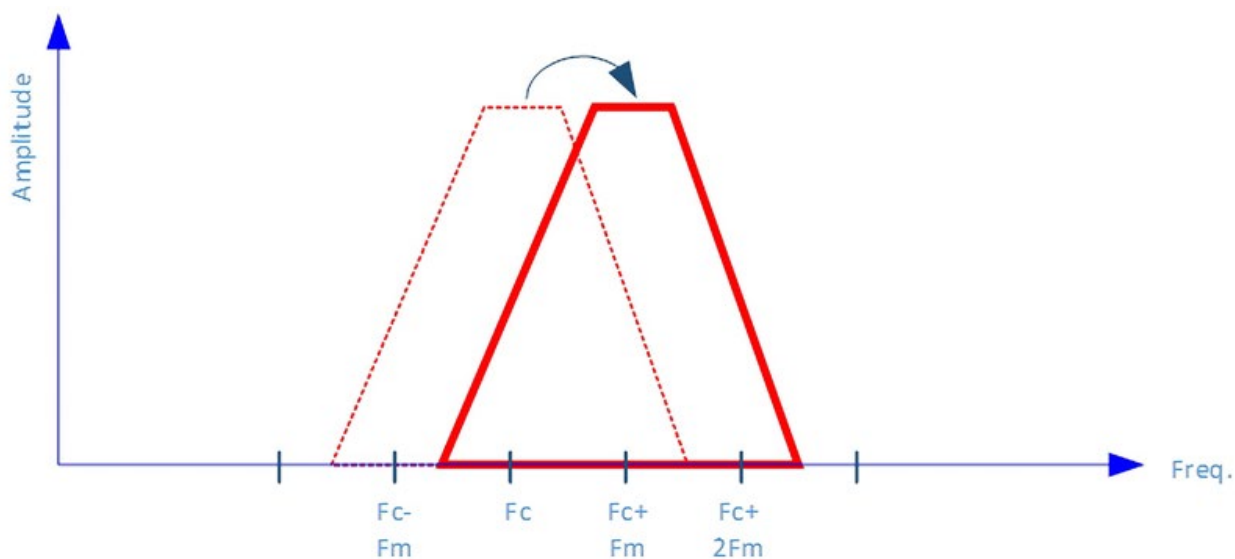

Figure 3: Ideal Frequency Translation of a Wide-Band Signal

PRACTICAL APPLICATIONS

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 Kratos 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.

KRATOS GENERAL MICROWAVE FREQUENCY TRANSLATOR

The specifications of the Kratos General Microwave 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 9. 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.
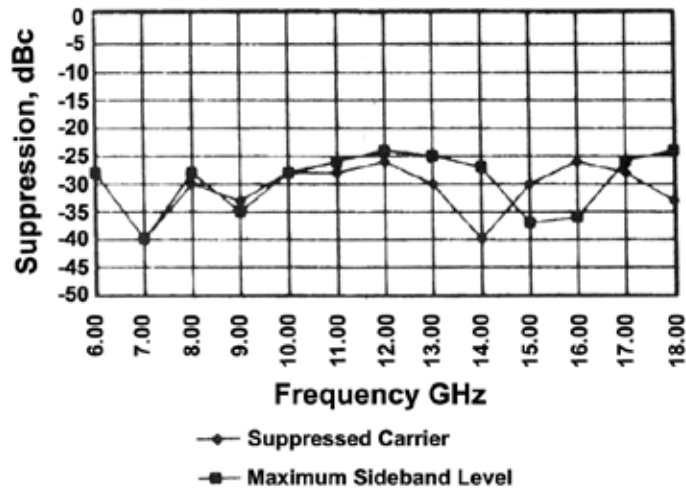
Figure 4: Typical Carrier and Sideband Suppression

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 2n, where n equals number of bits.

Frequency Range: Phase Shifters/Frequency Translators are specified to operate over a very broad frequency range. In order to optimize performance, the total frequency range has been broken into a Main Band and a Stretch Band. The Stretch Band frequency range segments are typically above and below the Main Band frequency range.

Main Band: Phase Shifters/Frequency Translators are factory set to meet the more accurate performance shown in the Main Band specifications. If operated at factory setting, but outside the Main Band frequency limits, the performance will me more typical of that shown for the Stretch Band specifications.

Stretch Band: Phase Shifters/Frequency Translators performance, outside the Main Band frequency limits, can be improved by utilizing the Frequency Correction Bit. This is done by the application of a TTL Low (0) at Pin 3 of the Power/Control Connector J3. Once done, the performance in the Stretch Band frequency segments will be enhanced to meet the specifications shown for the Main Band of operation.

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 8.0 GHz	+35 dBm +40 dBm	+30 dBm +35 dBm

PHASE NOISE

The phase shifters and I-Q modulators offered by Kratos 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.

KRATOS | GENERAL MICROWAVE
Microwave Electronics Division

SPECIFICATIONS TABLE NOTES

(1) AVAILABLE OPTIONS FOR FREQUENCY TRANSLATORS – MAIN SPECIFICATION TABLE PAGE 62 -65

7 - Two SMA male RF connectors.

Note: For 18 to 40 GHz Attenuators – K type male connectors are used.

10 - One SMA male and one SMA female RF connector. See details in the web.

Note: For 18 to 40 GHz Attenuators – K type male connectors are used.

49 - High Reliability Screening

Kratos General Microwave's hermetically-sealed products utilize rugged construction techniques and hermetic sealing to meet stringent military requirements for shock, vibration, temperature, altitude, humidity, and salt atmosphere. All hermetically-sealed parts may be ordered, if desired, with 100% screening in accordance with the following MIL-STD 883:

TEST	METHOD	CODITION
Internal Visual	2017	—
Temperature Cycle	1010	A
Mechanical Shock	2002	B
Burn-In	1015	—
Leak	1014	A1

G09 - Guaranteed to meet the Environmental Ratings.

G12 - RoHS Compliant

G18 - REACH Compliant

(2) Specifications in Stretch Band are typical

FREQUENCY TRANSLATORS – MAIN SPECIFICATIONS TABLE

For the complete specifications list please refer to the web catalog www.kratosmed.com/gmcatalog

Model	Frequency Range	Min Translation Rate[2]	Min Carrier Suppression (dB) [2]	Min Side Band Suppression (dB) [2]	Max Insertion Loss Variation (dB) With Translation Rate:	Power Supply Requirements	Available Options [1]	Notes
7720A	Main Band: 0.7-1.85 GHz Stretch Band: 0.5-2.0 GHz[2]	0 to 50 kHz	Main Band: 25 Stretch Band: 18	Main Band: 20 Stretch Band: 15	1	+5V to +5.5V @ 100mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA max	7, 10, G09, G12, G18	Digitally programmable (10-bit)
		>50 to 500 kHz	Main Band: 20 Stretch Band: 15	Main Band: 18 Stretch Band: 12	3			
7722A	Main Band: 2.6-5.2 GHz Stretch Band: 2.0-6.0 GHz[2]	0 to 50 kHz	Main Band: 25 Stretch Band: 18	Main Band: 20 Stretch Band: 15	1	+5V to +5.5V @ 100mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18	Digitally programmable (10-bit)
		>50 to 500 kHz	Main Band: 20 Stretch Band: 15	Main Band: 18 Stretch Band: 12	3			
7724A	Main Band: 4.5-10.5 GHz Stretch Band: 4.0-12.0 GHz[2]	0 to 50 kHz	Main Band: 25 Stretch Band: 18	Main Band: 20 Stretch Band: 15	1	+5V to +5.5V @ 200mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18	Digitally programmable (10-bit)
		>50 to 500 kHz	Main Band: 20 Stretch Band: 15	Main Band: 18 Stretch Band: 12	3			

Model	Frequency Range	Min Translation Rate[2]	Min Carrier Suppression (dB) [2]	Min Side Band Suppression (dB) [2]	Max Insertion Loss Variation (dB) With Translation Rate:	Power Supply Requirements	Available Options [1]	Notes
Frequency Translators *(continued)*								
7728A	Main Band: 8.0-18.0 GHz Stretch Band: 6.0-18.0 GHz[2]	0 to 50 kHz	Main Band: 25 Stretch Band: 18	Main Band: 20 Stretch Band: 15	1	+5V to +5.5V @ 200mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18	Digitally programmable (10-bit)
		>50 to 500 kHz	Main Band: 20 Stretch Band: 15	Main Band: 18 Stretch Band: 12	3			
7820	Main Band: 0.7-1.85 GHz Stretch Band: 0.5-2.0 GHz[2]	0 to 50 kHz	Main Band: 25 Stretch Band: 18	Main Band: 20 Stretch Band: 15	1	+5V to +5.5V @ 200mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18	Analog control
		>50 to 500 kHz	Main Band: 20 Stretch Band: 15	Main Band: 18 Stretch Band: 12	3			
7822	Main Band: 2.6-5.2 GHz Stretch Band: 2.0-6.0 GHz[2]	0 to 50 kHz	Main Band: 25 Stretch Band: 18	Main Band: 20 Stretch Band: 15	1	+5V to +5.5V @ 200mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18	Analog control
		>50 to 500 kHz	Main Band: 20 Stretch Band: 15	Main Band: 18 Stretch Band: 12	3			

| Model	Frequency Range	Min Translation Rate[2]	Min Carrier Suppression (dB) [2]	Min Side Band Suppression (dB) [2]	Max Insertion Loss Variation (dB) With Translation Rate:	Power Supply Requirements	Available Options [1]	Notes
Frequency Translators (continued)							
7824	Main Band: 4.5-10.5 GHz Stretch Band: 4.0-12.0 GHz[2]	0 to 50 kHz	Main Band: 25 Stretch Band: 18	Main Band: 20 Stretch Band: 15	1	+5V to +5.5V @ 100mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18	Analog control
		>50 to 500 kHz	Main Band: 20 Stretch Band: 15	Main Band: 18 Stretch Band: 12	3			
7828	Main Band: 8.0-18.0 GHz Stretch Band: 6.0-18.0 GHz[2]	0 to 50 kHz	Main Band: 25 Stretch Band: 18	Main Band: 20 Stretch Band: 15	1	+5V to +5.5V @ 200mA max +12 to +15V @ 100mA max -12 to -15V @ 90mA ma	7, 10, G09, G12, G18	Analog control
		>50 to 500 kHz	Main Band: 20 Stretch Band: 15	Main Band: 18 Stretch Band: 12	3			

Model	Frequency Range	Min Translation Rate	Min Carrier Suppression (dB)	Min Side Band Suppression (dB)	Max Insertion Loss Variation (dB) with translation rate of	Power Supply Requirements	Available Options [5]	Notes
Miniaturized Frequency Translators								
7928A	Main Band 8.0-18.0 GHz Stretch Band 6.0-18.0 GHz[2]	0 to 500 kHz	Main Band: 25 Stretch Band: 18	Main Band: 20 Stretch Band: 15	200kHz: 1 500kHz: 3	+5V ± 5%, 80 mA max + 12 to 15V, 10 mA max -12 to -15, 95 mA max	7, 10, 49, G09, G12, G18	Digitally programmable (8-Bit) Hermetically Sealed

BI PHASE MODULATORS

GENERAL

Bi Phase Modulator is a high-speed 0_o or 180° phase shifter. 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.
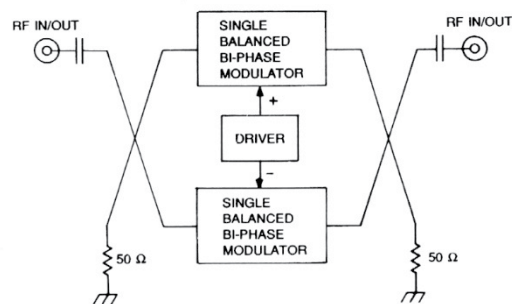
Model F1938, block diagram

SPECIFICATIONS TABLE NOTES

[1] AVAILABLE OPTIONS FOR PHASE MODULATORS – MAIN SPECIFICATION TABLE PAGES 67

3 - SMA female control connector.

7 - Two SMA male RF connectors.

   Note: For 18 to 40 GHz Attenuators – K type male connectors are used.

10 - One SMA male (J1) and one SMA female (J2) RF connector.

   Note: For 18 to 40 GHz Attenuators – K type male connectors are used.

33 - EMI filter solder-type control terminal**.**

85 - SMA RF connectors, see in the full catalog in the web, the specifications impact on model F1938.

G09 - Guaranteed to meet the Environmental Ratings.

G12 - RoHS Compliant.

G18 - REACH Compliant.

BI PHASE MODULATORS – MAIN SPECIFICATIONS TABLE

For the complete specifications list please refer to the web catalog www.kratosmed.com/gmcatalog

Model	Frequency Range	Max Insertion Loss (dB)	Power Handling (W)	Carrier Suppression	Power Supply Requirements	Available Options [1]
F1938	6.0-18.0 GHz	6-16 GH: **3** 16-18 GHz: **3.5**	1W cw or peak	20 dB min.	+5V ±5%, 65 mA -12V to -15V, 20 mA	3, 7,10, 33, 85, G09, G12, G18

Kratos | GENERAL MICROWAVE
Microwave Electronics Division

CONTROL COMPONENTS - 1

KRATOS | GENERAL MICROWAVE
Microwave Electronics Division
www.kratosmed.com

ISRAEL	**ISRAEL**	**USA**
JERUSALEM SITE:	**EYAL SITE:**	**NEW YORK SITE:**
20 Pierre Koenig	Kibbutz Eyal	227A Michael Drive
Jerusalem 9153102	D.N.Hasharon Hatichon 4584000	Syosset, New York 11791
Tel: +972-2-568-9444	Tel: +972-9-749-9100	Tel: + 1-516-802-0900
kratos-gmi@kratosdefense.com	kratos-eyal@kratosdefense.com	kratos-gmc@kratosdefense.com