APPLICATION NOTE 58

THE PIN DIODE AS A MICROWAVE MODULATOR

INTRODUCTION

The PIN diode has opened the way to a new method of modulating microwave signals. Placed across a transmission line, the PIN diode becomes an absorption-type attenuator which permits sine-wave, square-wave, and pulse modulation without frequency pulling.

The limitations of present amplitude modulation methods are becoming more evident with the advance of microwave technology. For example, it has been nearly impossible to amplitude modulate a klystron oscillator directly with anything but a square wave or pulse. Sine-wave modulation traditionally results in significant frequency shifts with changes in amplitude. In addition, conventional klystron oscillators have relatively slow rise and decay times and poor frequency stability, and jitter in the rf pulse is too high for precise pulse measurements. Modulators for lower-frequency triode master-oscillator-power-amplifier (MOPA) generators have low on-off ratios, and speed of rise and decay of the modulated signal is limited by the Q of the modulated stage.

A high-speed absorption-type attenuator that can be placed in series with the output of any signal generator can be made using PIN diodes. As diode bias is changed in accordance with the modulating signal, greater or lesser amounts of power are absorbed from the signal source, effectively amplitude modulating the output. Frequency band and power limits must be observed.

THEORY

An intrinsic silicon wafer is used to make PIN diodes. This slice of high-purity silicon has nearly equal p and n traces, but additional p type impurities are diffused from one side and additional n type impurities from the other. The middle intrinsic layer is left, which accounts for the name PIN. The wafer is sliced into diode chips which are placed into appropriate mounting configurations.

At frequencies below 100 Mc, the PIN diode assembly rectifies as any other junction diode. Because the intrinsic layer acts as a dielectric barrier separating the p and n regions, capacitance is low. However, rectification efficiency drops rapidly as frequency increases above 100 Mc because of carrier storage in the intrinsic layer.

When forward bias current is flowing through the PIN diode, holes and electrons are stored in the i layer. The number of stored charge carriers increases with bias current. Before a back bias can be applied to the diode, all these charge carriers must be removed. Above several hundred megacycles, currents do not flow in the reverse direction long enough to remove these charge carriers. Thus microwave currents do not significantly change the instantaneous number of charge carriers stored, and there is negligible rectification.

However, there is a resistance to microwave current flow in the PIN diode. This resistance is inversely proportional to the number of charge carriers stored in the i layer, which in turn is proportional to forward bias current. By varying the bias from back bias (no stored charge) to about 1/2 ma forward bias, resistance to microwave currents varies from about 5000 ohms to 30 ohms.

This concept can be demonstrated by assuming that the PIN diode has been mounted across a transmission line with a characteristic impedance of 50 ohms. When the diode is back biased to about 5,000 ohms, the microwave signal on the transmission line is not attenuated because 5,000 ohms compared to a 50-ohm line impedance has little effect. However, when the diode is forward biased to about 30 ohms, most of the microwave current flows through the 30-ohm diode instead of propagating down the 50-ohm line. Since this diode current represents microwave energy dissipated as heat, the diode actually absorbs microwave energy.

Negligible rectification means that resistance of the PIN diode is about the same throughout a microwave cycle, and the diode behaves essentially as a linear microwave resistor. On the other hand, operating of the diode harmonic generator is based on the change in its resistance during the cycle. If resistance of the PIN diode is constant throughout the microwave cycle, harmonic content of the modulated output must be low compared to other diode devices.

MODULATOR BOX

To use the microscopic PIN diode, it must be mounted on a metal post. Reactance of the post is compensated by selecting dimensions that give proper values of capacitance and inductance, leaving only the resistive component. After assembling the diodes on the posts, they are placed at quarter-wave length (at midband) intervals along a 50-ohm strip transmission line. A series of diode-post elements is used to achieve the required maximum attenuation. Higher resistance

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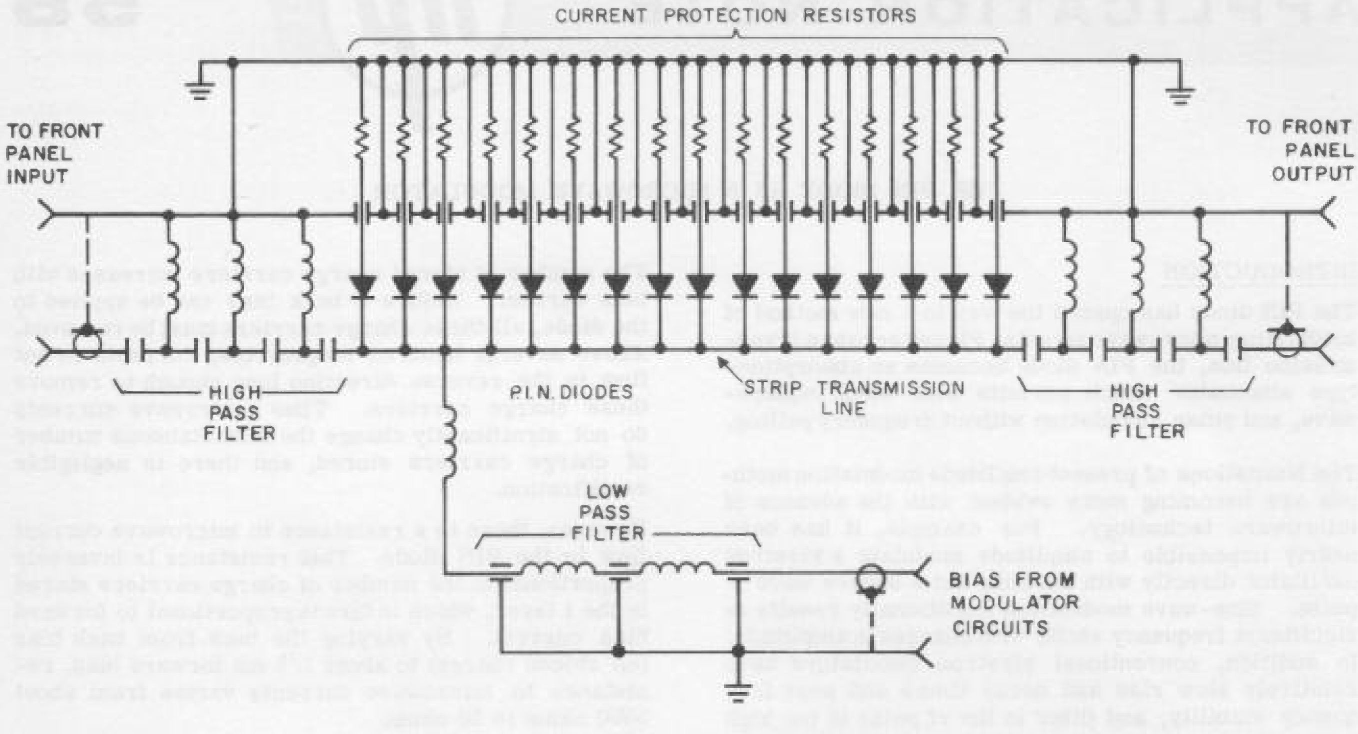

Figure 1. Modulator Schematic Diagram

elements are used at each end of the stripline to improve attenuator match and reduce reflections. Loss characteristics of the modulator box are shaped like those of a resistance card in a waveguide flap attenuator.

The typical modulator box in Figure 1 has 16 PIN diodes, although any number may be used depending on required attenuation. The quarter-wavelength spacing is not critical since the attenuator works well over a 3:1 frequency range. However, quarter-wavelength spacing at midband produces the lowest average SWR because reflections from each element tend to be absorbed and cancelled by adjacent diodes. This internal reduction of reflections is important in achieving low overall SWR. Diode series resistors give equal current distribution. Modulation circuits external to the box are protected by the low-pass filter in Figure 1, which prevents rf leakage. If leakage were present, it could cause erratic action in the driving circuits and objectionable rf interference. The high-pass filters permit rf energy to enter and leave the stripline while keeping the low-frequency modulating signals from entering the rf circuits preceding or following the modulator.

In constructing the PIN diode box, care must be taken to assure good rf matches for maximum power transfer. Not only does each PIN diode represent a possible mismatch or reflection point but the filters and connectors also contribute to mismatch. Mechanical tolerances of the box and the stripline are also important. A typical 16-diode box for 800 to 2400 Mc has a minimum insertion loss of 1 to 2 db and maximum attenuation oi at least 80 db. Maximum SWR may range from 1.5 to 2, and a response time of about 20 nsec is typical. Power handling capabilities are about 1 watt, and rf harmonic content is low.

DRIVING CIRCUITS

The PIN diode box can be modulated with any desired amplitude-time function. When modulating with sine waves, minimum distortion is obtained by setting dc bias so that it is centered on the most linear portion of the PIN diode characteristic curve. For normal modulation values (such as 50%), this bias level is about 7 db down from no attenuation bias. Nonlinear distortion can be decreased even more by using diode shaping circuits to approximate the inverse of the PIN diode characteristic curve. A feedback arrangement of the detected output would also be useful in reducing distortion in sine-wave systems. However, even without shaping circuits or feedback, harmonic distortion of less than 8% can be achieved with over 50% modulation as shown in Figure 2.

For maximum speed in pulse and square-wave modulation, enough energy must be supplied to the intrinsic layer to sweep charge carriers rapidly into and out of each diode. Therefore, a spiked driving front is applied to the modulator during changes of state. The energy levels required are readily obtained with transistors.

In the typical square-wave modulator in Figure 3, a square-wave rate multivibrator initiates the modulating circuits. Care is taken to design a symmetrical square-wave device and to maintain this symmetry through the rf output. In fact, the ratio of the

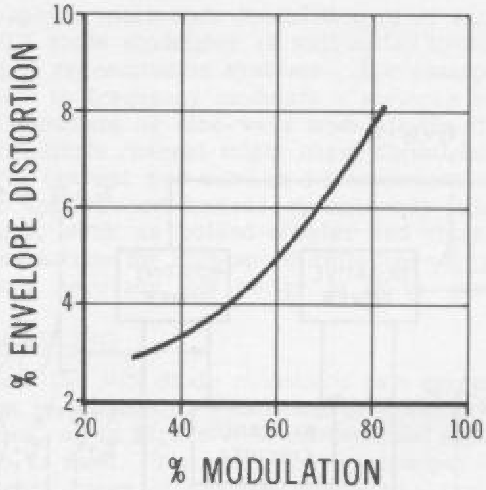

Figure 2. Typical Envelope Distortion on Sine-Wave Modulation

integrated square wave to cw power should be exactly 3 db. This 3-db figure can also be useful when measuring degradation in microwave systems.

The bistable circuits driving the PIN diodes have a holding characteristic and provide a back bias of several volts for no attenuation. For maximum attenuation, the bistable circuits provide the required bias current. The diodes are held at minimum microwave resistance by bias current throughout the off period of the rf pulse.

In the pulse modulator in Figure 4, modulation is again initiated by the rate multivibrator. Output of the rate multivibrator is symmetrical, and a width multivibrator provides the required pulse width. The delay multivibrator is useful for oscilloscope synchronization, target simulation or other instrumentation. The delay feature is particularly desirable when the modulator is operated with a sampling oscilloscope. All three functions-pulse rate, width, and delay - are front panel controls. Time sequences are indicated in Figures 3 and 4. The ⓗ Models 8714A and 8716A Modulators, covering the 800-Mc to 2400-Mc and 1800-Mc to 4500-Mc ranges respectively, utilize the PIN diode modulator box. Each instrument provides adjustable internal square-wave and pulse repetition rates from 50 cps to 50 kc. Pulse length and pulse delay are adjustable from 0.1 to 100 microseconds.

To permit external pulse modulation or synchronization, an externally actuated Schmitt trigger is substituted for the rate multivibrator. In the ⓗ Models 8714A and 8716A repetition rates have been extended up to 2 Mc with the Schmitt circuit. Pulse length and pulse delay are also adjustable from 0.1 to 100 microseconds for external synchronization. In external modulation, the modulating pulse determines length.

AMPLITUDE MODULATION

In conventional amplitude modulation, power output from the signal generator is usually varied by changing the dc power supplied to one of the oscillating or amplifying elements. However, this method may introduce extraneous FM and spectral impurities. Frequency characteristics are not always the same at all generator amplitudes. For example, klystron oscillator frequency depends heavily on klystron amplitude control, so that the klystron cannot be

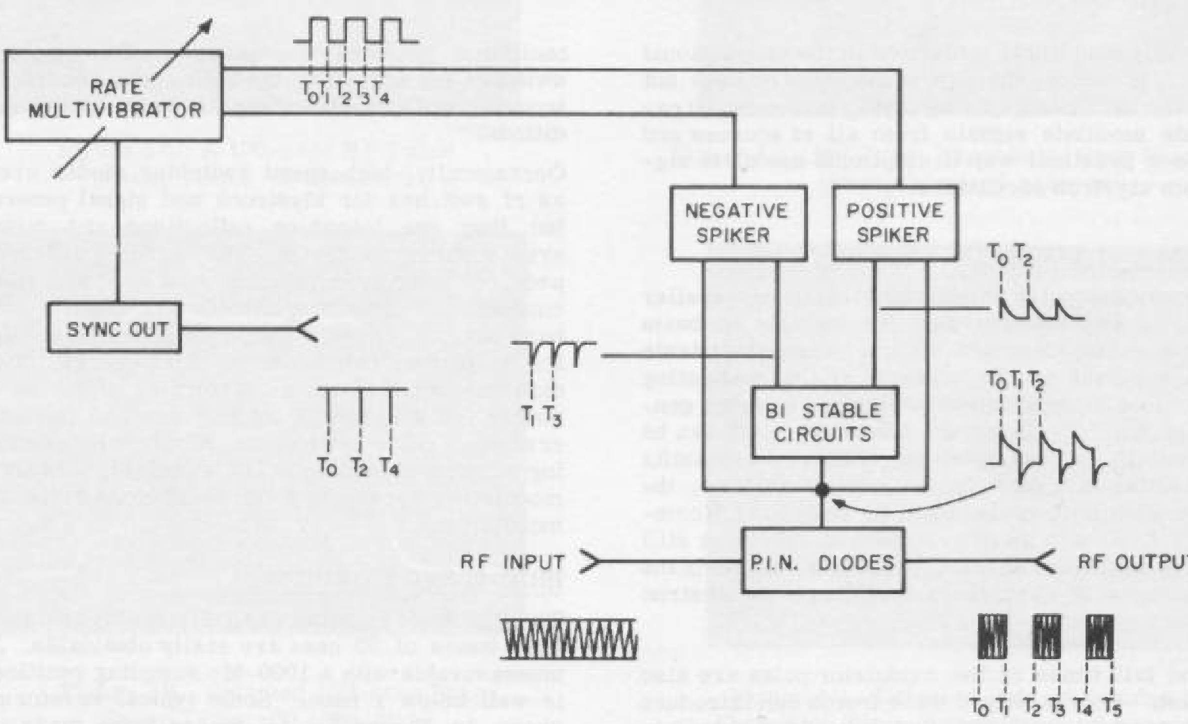

Figure 3. Square-Wave Modulator

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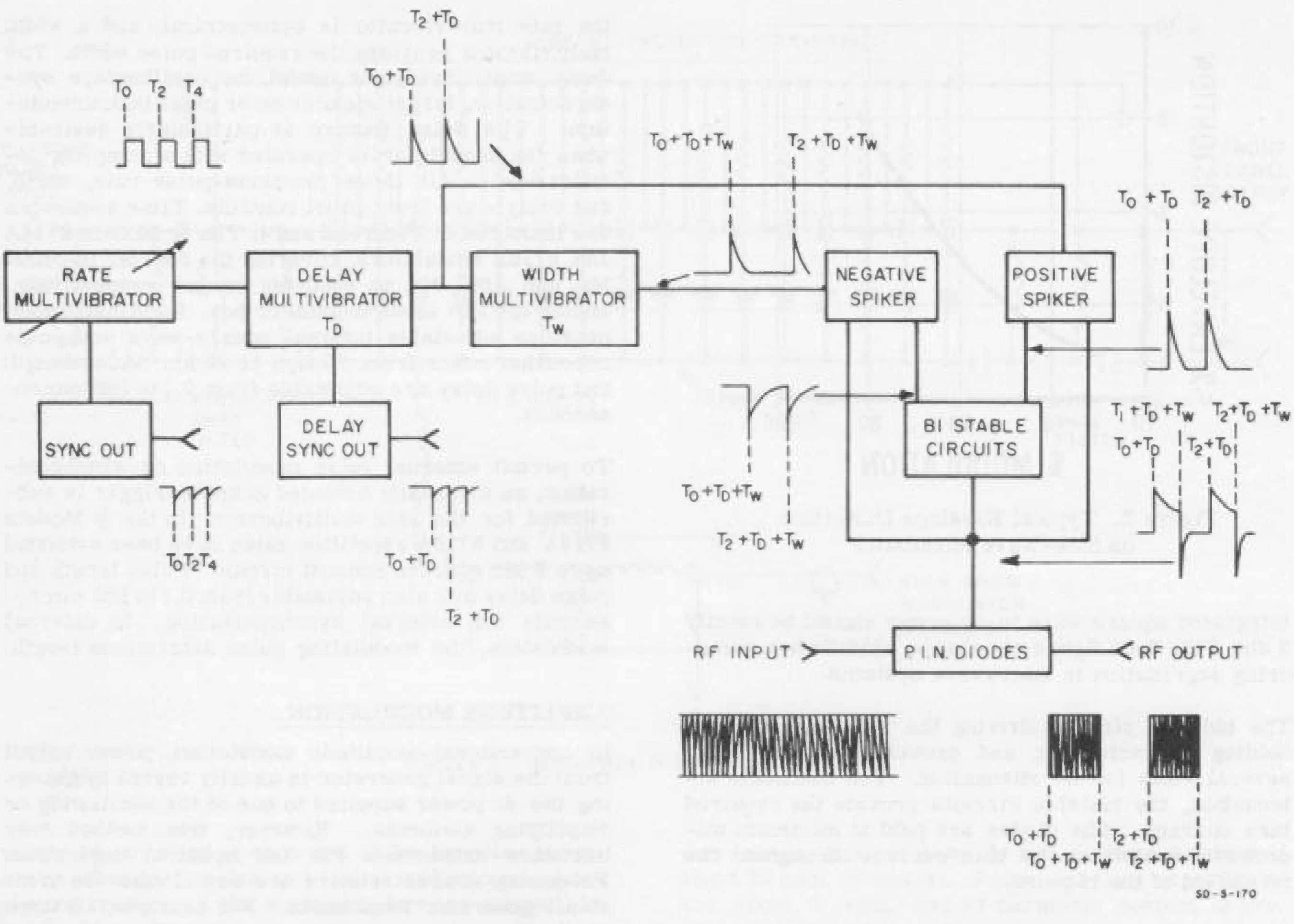


Figure 4. Pulse Modulator

successfully amplitude modulated in the conventional manner. However, the PIN diode system does not disturb the oscillating or amplifying elements. It can amplitude modulate signals from all rf sources and provides a practical way to amplitude modulate signals from klystron oscillators.

PULSE MODULATION

In conventional pulse modulation, klystron repeller potential is switched between two voltages or beam current is switched on and off. A reasonably stable frequency output can be achieved if the modulating pulse applied to the klystron is clamped when the generator is full on. However, frequency shift can be introduced if, for example, the clamp voltage shifts with modulation rate. In the full-off position, the klystron modulation pulse must be switched off completely. Even with these precautions, there are still frequency shifts and spectral problems because of the start-up and shut-down characteristics of the klystron oscillator.

Rise and fall times of the modulator pulse are also important. Poorly shaped wave fronts can introduce serious spectral problems that can cause errors in slotted-line and reflectometer measurements. With the PIN diode modulator, however, the klystron oscillator operates continuously. The output rf is switched on and off by the high-speed absorptive attenuator without disturbing klystron operating conditions.

Occasionally, high-speed switching diodes are used as rf switches for klystrons and signal generators, but they can introduce reflections and mismatch errors during switching. They present different impedances to the generator for maximum and minimum conduction. Switching diodes are usually narrow-band devices, and this technique provides no filtering for control or transmission of rf energy. The PIN diode modulator has no disturbing effect on the rf source as a result of loading and can introduce no erroneous pulse reflections. Klystron frequency pulling because of loading is not a problem because these modulators present a constant impedance during modulation.

HIGH-SPEED SWITCHING

The PIN diode modulator is useful for high pulse rates. Rise times of 20 nsec are easily obtainable. Jitter, unmeasurable with a 1000-Mc sampling oscilloscope, is well below 1 nsec. Some typical waveforms are shown in Figure 5. All traces were made using a 1000-Mc carrier frequency, a 0.1-μsec pulse width, and a 2-Mc repetition rate.

High-speed, pulse-code modulation of rf signals by the PIN diode modulator is well suited to telemetry and data transmission systems. For example, it is possible to frequency modulate a klystron and also pulse modulate or sine-wave modulate the rf output. The amplitude channel might carry digital data while the FM channel was used as a communications link. Other applications include synchronous pulsed FM systems, such as pulsed-doppler and chirp radar. The modulator for high-speed switching provides increased accuracy and better rf pulse resolution.

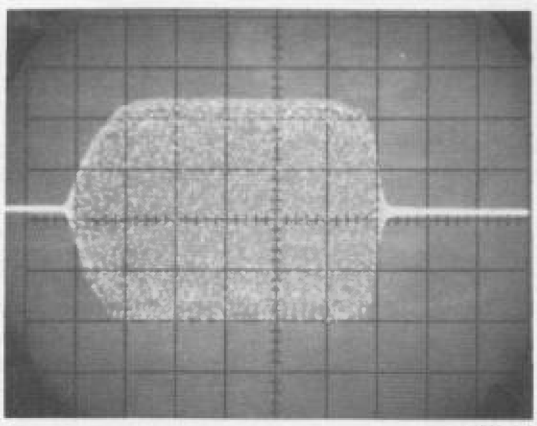
RF LEVELING

Because the PIN diode modulator is a current-controlled rf attenuator, it can control power level in rf systems, as in Figure 6. A conventional signal generator is used. The variation in rf output over the frequency range of a typical unleveled signal generator can be from 1/2 to 5 mw or 10 db, but it is possible to level within 1/2 db. The signal generator power that flows through the modulator is sampled from the directional coupler and fed to a temperature-compensated thermistor-type power meter. Power meter output is amplified and fed back to the modulator to control PIN diode bias. System response time, which is limited by gain in the feedback loop and thermal lag of the thermistor, may be a fraction of a second. Accuracy is limited by the thermistor mount and characteristics of the directional coupler.

If faster response is required, a crystal detector with negative output voltage could be used in place of the power meter. The hp Model 423A Crystal Detector is excellent for leveling systems. Because variations caused by this detector (±0.5 db, 10 Mc to 12.4 Gc) are small compared to those caused by most coaxial directional couplers, the degree of leveling is usually determined by the coupler.

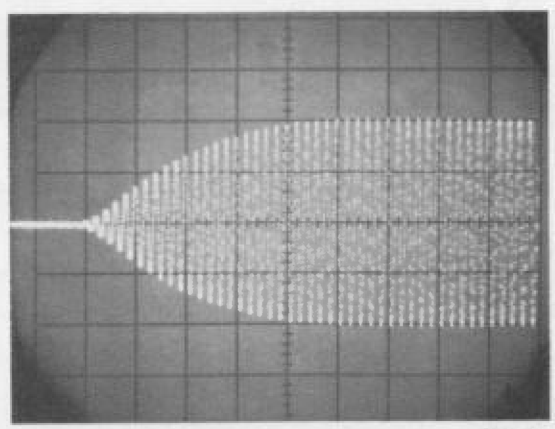
SIGNAL SOURCES

The hp Model 8614A Signal Generator (800 to 2400 Mc) uses an internal diode modulating system. The klystron operates continuously and output is leveled within ±0.5 db across the band. Output as plotted with a temperature-compensated thermistor power meter and recorded by an X-Y recorder is shown in Figure 7.



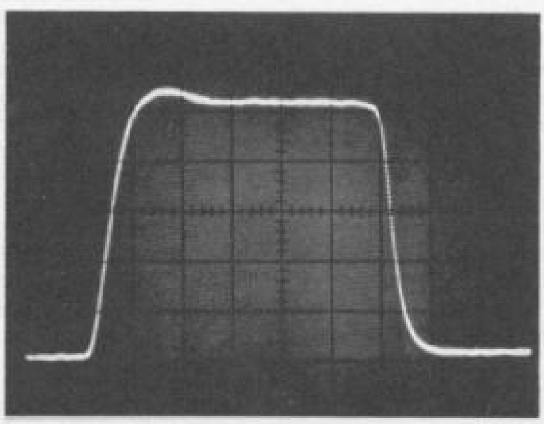
4000-A-I

Figure 5A. A 100-nsec RF Pulse
(Sweep Time: 20 nsec/div)



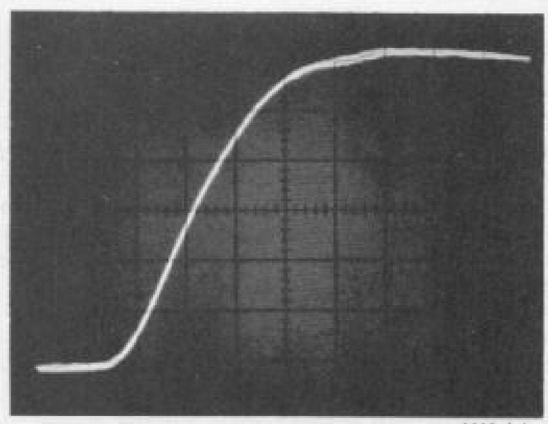
4000-A-I

Figure 5C. RF Pulse Expanded to Show Rise Time
(Sweep Time: 5 nsec/div)



4000-A-I

Figure 5B. Detected 100-nsec Pulse
(Sweep Time: 20 nsec/div)



4000-A-I

Figure 5D. Detected Pulse Expanded to
Show Rise Time (Sweep Time: 5 nsec/div)

Figure 5. Typical Waveforms (viewed on hp Model 185A Oscilloscope)

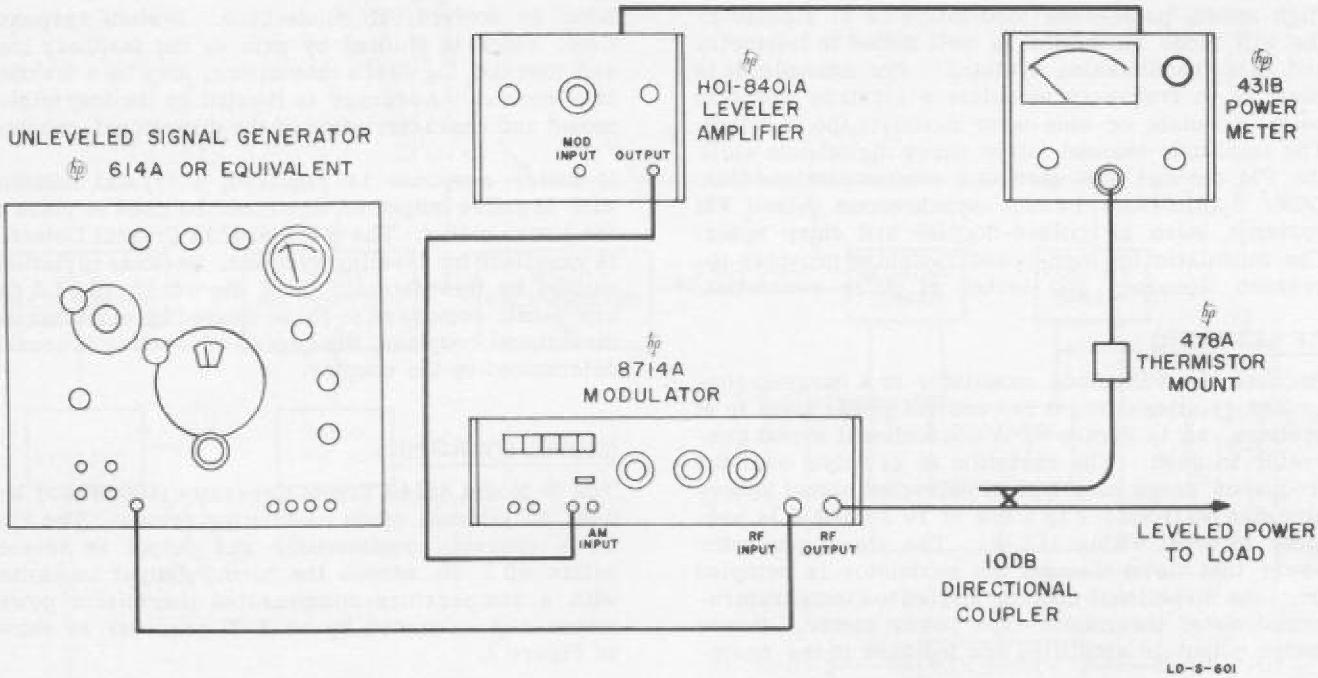


Figure 6. RF Leveling System

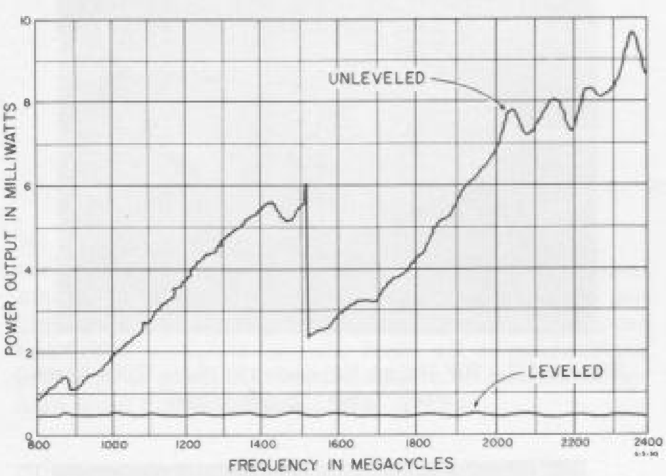


Figure 7. Leveled and Unleveled Klystron Output vs Frequency

Weight and size of this compact signal generator have been reduced by using the PIN diode modulator. Amplitude modulation is a standard feature. Performance has been improved by eliminating spurious FM during square-wave modulation, increasing power output and providing uniform power output at all frequencies by PIN diode leveling.

The hp Models 691A (1 to 2 Gc) and 692A (2 to 4 Gc) Sweep Oscillators also utilize the PIN diode modulator, which greatly improves the spectral purity of the output signal during amplitude modulation and provides a means for leveling. In both units, the leveling signal is derived at a point external to the oscillator where constant power is desired, and then applied to the modulator. Thus leveled power is available at any point in a system and is not necessarily restricted to the output connector of the oscillator.

CONCLUSION

The PIN diode as a microwave modulator overcomes many of the drawbacks of present modulation systems. The diode reduces reflections by absorbing power and improves spectral purity by permitting the source to operate continuously. Thus the PIN diode is the heart of a true advance in the technique of microwave modulation.

Acknowledgement

Portions of this Application Note first appeared under the title "The PIN Diode: Versatile Microwave Component", by Robert E. Heller, in the March 8, 1963 issue of Electronics.

6/1/63

TECHNICAL DATA

8614A SIGNAL GENERATOR

800 to 2400 mc

Revised 1/24/64

Advantages:

- Digital frequency and attenuator dials
- At least 10 mw output
- Automatic power output control
- AM modulation capability
- Easily carried with one hand
- Only 5¼ inches high
- Rugged and reliable

Use To Measure:

- Receiver sensitivity
- Signal-noise ratio
- Conversion gain
- Standing wave ratios
- Transmission line characteristics
- Antenna characteristics

Operator-oriented Signal Generator

hp Model 8614A Signal Generator is a particularly convenient source for stable, accurate signals from 800 to 2400 mc. Operator error and fatigue are reduced because frequency and attenuation are set on direct reading digital dials. In addition, function (cw, leveled output, square wave modulation, or external amplitude or pulse frequency modulation) is quickly selected by push buttons. Amplitude, frequency, or square wave modulation—with or without leveling—can be accomplished concurrently.

Two power output connectors are furnished which supply rf power simultaneously. One output provides at least 10 mw or a leveled output from 0 dbm to − 127 dbm which is flat within ± ½ db across the band without resetting the attenuator or power monitor. The other provides an uncalibrated output of at least ½ mw.

Operation of Model 8614A is simple because function is push-button selected, frequency and output are read from in-line digital dials, and oscillator-repeller voltage is automatically tracked to frequency.

Pin Modulator

Model 8614A contains a unique PIN diode modulator which allows you to amplitude modulate from dc to 1 mc, or to obtain rf pulses with a 2.0 μsec rise time. Such a broad modulation bandwidth allows remote control of output level or precise leveling using external equipment. The internal leveling, which holds rf output constant within ± 0.5 db, is also obtained by using a PIN modulator.

hp 8614 EEM 2900

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1-Watt Output/High Speed Modulation--With Accessories

When up to one watt output is required above 1000 mc the ⓗⓟ 489A (1 gc to 2 gc) or ⓗⓟ 491C (2 gc to 4 gc) Microwave Amplifiers serve as ideal power boosters. The ⓗⓟ 8714 high speed modulator is also available for use with the 8614A Signal Generator when a sophisticated high-speed, low-jitter modulation system is needed. The 8714A Modulator also offers a wide selection of pulse and square wave modulation.

General

Because of its wide range and great stability, the ⓗⓟ 8614A Signal Generator is ideal for the most precise UHF applications. Its compact design and light weight are such that the instrument may be carried with one hand. It not only saves bench space, but the 5¼-in. panel height is a real space saver to those interested in rack mounting. Ruggedly built of the finest components, the ⓗⓟ 8614A is designed for many years of trouble-free service and in-specification accuracy.

Figure 1. ⓗⓟ Models 8614A, 8714A, and 489A form a sophisticated 1-watt source for frequencies from 1 to 2 gc.

Specifications

Output

Frequency Range: 800 to 2400 mc; single, linearly calibrated control; direct reading within 2 mc.

Vernier: Δ F control has range of 2 mc for fine tuning.

Frequency Calibration Accuracy: ± 5 mc.

► **Frequency Stability:** Approximately 0.005%/°C change in ambient temperature, less than 2500 cps peak residual fm, negligible incidental fm in pulse and AM operation for attenuator settings below — 10 db, less than 0.003% change with line voltage variation of ± 10%.

RF Output Power: + 10 dbm (10 mw) to — 127 dbm (0.1 μvolt) into a 50-ohm load. Output attenuator dial directly calibrated in dbm from 0 to — 127 dbm. A second uncalibrated rf output (approximately 0.5 mw minimum) is provided on the front panel.

RF Output Power Accuracy *(with respect to attenuator dial):* ± 0.75 db + attenuator accuracy (— 10 to — 127 dbm); + 0, — 3 db (0 to — 10 dbm); uncalibrated above 0 dbm. (Includes leveled output variations.)

Attenuator Accuracy: ± 0.06 db/10 db from — 10 db to — 127 db; direct reading linear dial, 0.2 db increments.

Leveled Output: Constant within ± 0.5 db across entire frequency range at any attenuator setting below 0 db. Output power can be adjusted from — 4 to + 4 dbm of the normal calibrated level with the Automatic Level Control.

Internal Impedance: 50 ohms, swr less than 2.0.

Modulation

Internal Square Wave: 800 to 1200 cps. Other frequencies available on special order. On-off ratio at least 20 db.

► **External Pulse:** 50 cps to 50 kc, 2.0 μsec rise time. + 20 to + 100 v peak input. On-off ratio at least 20 db.

External AM: DC to 1 mc.

External FM: Mode width between 3 db points varies from a minimum of approximately 4 mc at a frequency of 800 mc to a maximum of approximately 15 mc at a frequency of 2000 mc. Sensitivity is approximately 100 kc/volt between 800 and 1600 mc and 200 kc/volt between 1600 and 2400 mc.

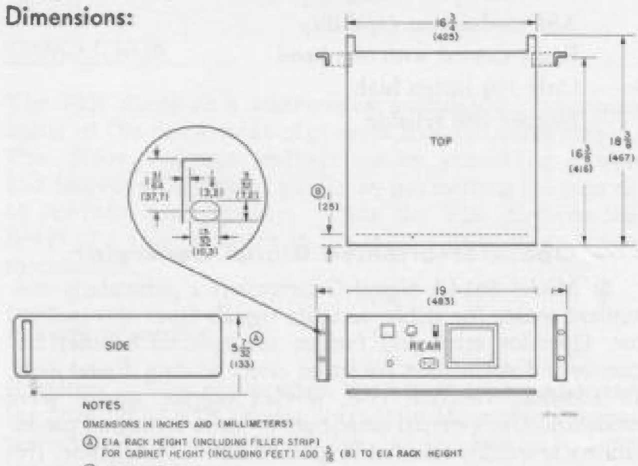
(a) Front-panel connector capacitively coupled to the repeller of the klystron.

(b) Rear-panel connector is dc-coupled to the repeller of the klystron.

General

Power Source: 115 or 230 volts ± 10%, 50 to 60 cps, approximately 125 watts.

Dimensions:



Weight: Net, 48 lbs. *(22 kg)*. Shipping, approximately 63 lbs. *(28 kg)*.

► **Price:** ⓗⓟ Model 8614A, $2,100.00.

► **Option 01.** External modulation input connectors on rear panel in parallel with front-panel connectors; rf connectors on rear panel only. Add $25.00.

TECHNICAL DATA

8714A 8716A MODULATORS

800 to 4500 mc

(Revised 2/10/64)

Ⓗ Model 8714A, 800 to 2400 mc

Advantages:

- Direct modulation of signal generator rf output
- High pulse resolution
- Low-jitter modulation
- Easily synchronized with other equipment

Uses:

- Fast rf attenuator
- Pulse modulate or level signal source output
- Amplitude modulate klystrons

Description

With an Ⓗ Model 8714A or 8716A Modulator you can obtain extremely fast, low jitter rf pulses from your signal source or generator. When using pulse modulation, rf pulses with 0.03 μs rise and fall times, 0.1 μs minimum duration and less than 1 ns jitter are obtained. Such fast rise and fall times result from using an absorption modulator composed of electrically controlled PIN diodes. The PIN modulator, in addition to fast pulse and square wave modulation characteristics, has sinusoidal modulation capabilities of dc to 10 mc. Model 8714A will modulate any cw signal of 800 to 2400 mc; the 8716A, 1800 to 4500 mc. Either unit can accept rf power up to 1 watt, peak or CW. These modulators, incorporating internal square wave and pulse generators with jitter-free synchronizing circuits, may be readily installed in elaborate test systems.

PIN Modulation

The PIN modulator, consisting of electrically controlled diodes mounted in a strip transmission line, sidesteps the bandwidth limitations imposed by high-Q rf output circuits. Since modulation is accomplished by varying the attenuation of the strip-line, rise and fall times are essentially as fast as the PIN diode switching speed.

Minimum insertion loss of these modulators is low, while maximum attenuation is greater than 80 db. Hence, rf pulses which have a large on-off ratio may be generated. In addition, an external AM input permits remote control of attenuation or sinusoidal modulation from dc to 10 mc. The PIN modulator is an absorption device and does not reflect the attenuated energy as does the crystal switch type of modulator; thus the load presented to the driving source remains virtually constant and is not dependent on the degree of attenuation.

Internal and External Modulation

Control circuitry associated with the PIN diode modulator makes these modulators extremely easy to use. An internal square wave and pulse generator is provided, which may be synchronized with external signals. Free-running, this generator has a prf continuously variable from 50 cps to 50 kc for either square wave or pulse modulation. In pulse modulation both pulse width and pulse delay are adjustable from 0.1 μsec to 100 μsec. Jitter with respect to the sync pulse and pulse width is less than 1.0 nsec. Even with the Ⓗ 185B 1000 mc Sampling Oscilloscope, jitter is virtually undetectable. Regular and delayed sync signals are available for synchronizing external equipment.

Versatile and Easy To Use

Because of their wide range, high stability, and low harmonic content, the 8714A and 8716A are ideal companion units for any high-quality signal sources such as the Ⓗ 8614A, *800 to 2400 mc,* or the 8616A, *1800 to 4500 mc,* Signal Generators. Using either the flexible internal modulation generators or external controlling voltages, they can produce precise pulses of microwave energy with rise and decay times of less than 30 nsec and on-off ratios greater than 80 db. Their compact construction makes them ideal for either bench or rack mounted use, and their simple controls and rugged construction will give you years of useful, trouble-free service.

Ⓗ 8714 EEM 2900

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Specifications

RF Characteristics

Frequency Range:
8714A, 800 to 2400 mc.
8716A, 1800 to 4500 mc.

On-Off Ratio: More than 80 db.

Insertion Loss:
8714A, 2 db max., less than 1 db variation across the band.
8716A, 3.5 db maximum, less than 1.5 db variation 1800 to 4000 mc; 4.0 db maximum, less than 2 db variation 4000 to 4500 mc.

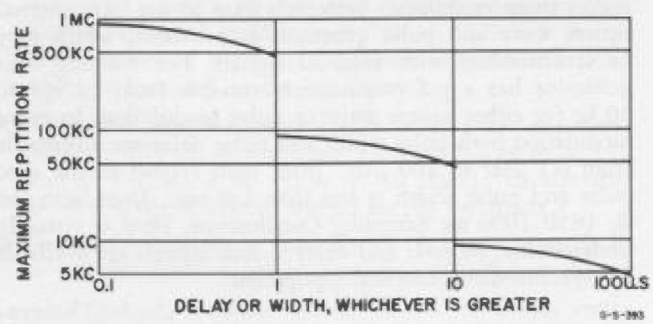
RF Input Power: Maximum 1 watt, peak or CW.

SWR:
8714A, 1.6 maximum at minimum attenuation. 2.0 maximum at 80 db attenuation.
8716A, 1.6 maximum at minimum attenuation 1800 to 4000 mc; 2.0 maximum at minimum attenuation 4000 to 4500 mc. 2.0 maximum at 80 db attenuation.

Internal Modulation

Square Wave:
Frequency: Continuously variable from 50 cps to 50 kc, 3 decade ranges.
Symmetry: Better than 45/55%.
►RF Output: Rise Time, less than 30 nsec.
Decay Time, less than 20 nsec.

Pulse:
Repetition Rate: Continuously variable from 50 cps to 50 kc, 3 decade ranges.
Delay: Continuously variable from 0.1 μsec to 100 μsec, in 3 decade ranges between sync out pulse and rf output pulse.
Width: Continuously variable from 0.1 μsec to 100 μsec in 3 decade ranges.
►RF Output: Rise Time, less than 30 nsec.
Decay Time, less than 20 nsec.
Maximum duty cycle: See graph.



External Sync:
Amplitude: 5 volts to 15 volts peak.
Waveform: Pulse or sine wave.
Polarity: Either positive or negative.
Input Impedance: Approx. 2000 ohms, dc coupled.
Rate: Subject to internal recovery time considerations; see graph.

Trigger Out:
Sync Out: 0.1 μsec to 100 μsec in advance of rf pulse, as set by DELAY control.
Delayed Sync Out: Simultaneous with rf pulse.
Amplitude: Approximately −2.0 volts.
Source Impedance: Approximately 330 ohms.

External Modulation

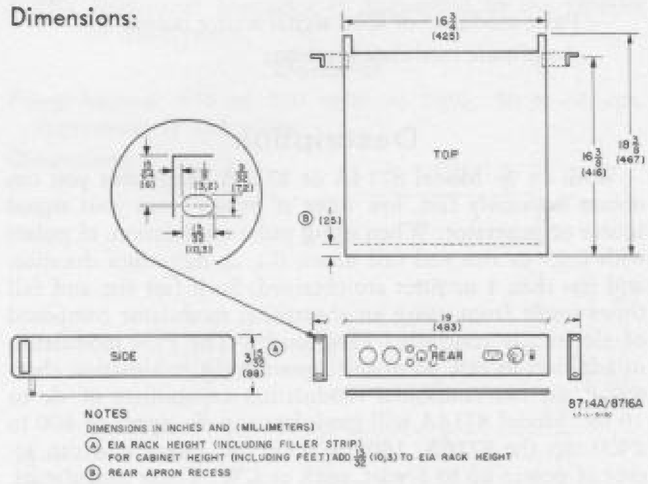
Pulse Input:
Amplitude and Polarity: 5 volts to 15 volts peak, either positive or negative.
Repetition Rate: Maximum average prf, 1 mc/sec. Maximum peak prf, 2 mc/sec.
Input Impedance: Approx. 2000 ohms, dc coupled.
Minimum Width: 0.1 μsec.
Maximum Width: $\frac{1}{\text{prf}} - 0.4$ μsec.
►RF Output: Rise Time, less than 30 nsec.
Decay Time, less than 20 nsec.

Continuous Amplitude Modulation:
Maximum Frequency: 10 mc, sinusoidal.
Sensitivity: Approximately 5 db to 20 db per volt, for attenuations from zero to 30 db.
Input Impedance: Approximately 1000 ohms.
Level Control: AM input is dc coupled, permitting control by bias of AM input; rear panel control for use with ac coupled modulation.

General

Power Requirements: 115 or 230 volts ± 10%, 50 to 1000 cps, approximately 10 watts.

Dimensions:



Weight: Net, 23 lbs. *(10 kg)*. Shipping, 26 lbs. *(11.5 kg)*.

Price:
8714A *(800 to 2400 mc)*, $1,300.00.
8716A *(1800 to 4500 mc)*, $1,300.00.

Option 01: Sync output and external modulation input connectors mounted on rear panel and front panel, in parallel; rf input and output connectors rear mounted only. Add $25.00.