TEKSCOPE

JANUARY 1972

The 7L12 Spectrum Analyzer Plug-In

Frequency Stabilization Techniques

Optimizing Mixer Performance Using the 7L12

Servicing the 1401A Spectrum Analyzer

A microwave spectrum analyzer for the 7000-Series Oscilloscopes

The authors, pictured above, are from left to right: Linley Gumm, Larry Lockwood, Morris Engelson and Al Huegli.

Cover: *The 7L12 Spectrum Analyzer plug-in brings state-of-the-art spectrum analysis to users of TEKTRONIX 7000-Series Oscilloscopes.*

The new 7L12 Spectrum Analyzer Plug-In for the 7000-Series Oscilloscope System features absolute amplitude and frequency calibration and complete freedom from unwanted responses. Covering the spectrum from 100 kHz to 1800 MHz, this unit has many unique design parameters that should bring it to the forefront in the range and ease of measurement. Some of the parameters not previously available are: a wide range of resolution bandwidths from 300 Hz to 3 MHz; automatic reference level computation with wider gain and/or attenuation settings; availability of both center and start frequency indication; CRT readout of measurement parameters; and, ability to make simultaneous time and frequency measurements.

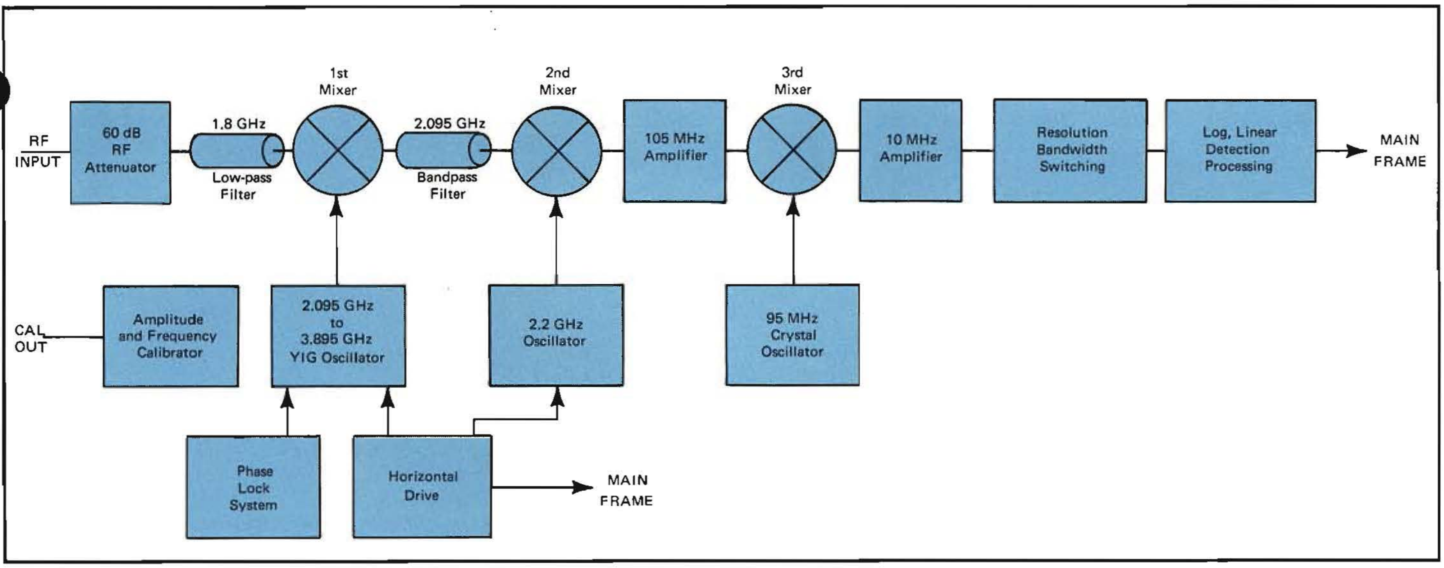


Fig. 1. Simplified block diagram of the 7L12 Spectrum Analyzer.

THE BASIC SYSTEM

Figure 1 is a simplified block diagram showing the overall system configuration. It will be observed that this is a straightforward front-end design with a first IF filter at 2095 MHz. The first local oscillator is phase locked at spans of 100 kHz/div and below, where the 2.2-GHz oscillator becomes the swept oscillator. System gain starts at 105 MHz with the majority of the gain at 10 MHz. The 10-MHz circuitry is also where all of the vertical mode display law shaping and the resolution bandwidth switching is done. Circuit and construction details are covered elsewhere in this issue.

PERFORMANCE CHARACTERISTICS

The capabilities of this versatile instrument are best illustrated by actual CRT displays. Here are some of the things that the 7L12 can do:

(a) Sensitivity—Figure 2 shows a —100 dBm signal displayed well above the noise level. The 7L12 can easily show signals less than —110 dBm.

(b) Resolution—Sensitivity alone is not enough. A good spectrum analyzer should be able to display the small signal in the presence of a large one. This is primarily determined by the resolution bandwidth and skirt selectivity shape factor. A flat-topped steep-sided filter gives the 7L12 unequalled resolution capabilities. This is illustrated by Figures 3, 4, and 5. Note that the 2-kHz sidebands in Figure 5 merge with the carrier almost 60 dB down. Note also that CRT readout obviates the need to describe separately the control settings for the photographs.

(c) Amplitude Differences—Sometimes the interest is in signals consisting of relatively equal amplitude components. Here the need is to measure small amplitude differences and for low intermodulation distortion to avoid generating spurious responses. Such measurements are illustrated in Figures 6 and 7. The former shows the ease with which one can measure the amplitudes of signals differing by only 1.5 dB, while the latter shows the absence of third order products for two —30 dBm signals.

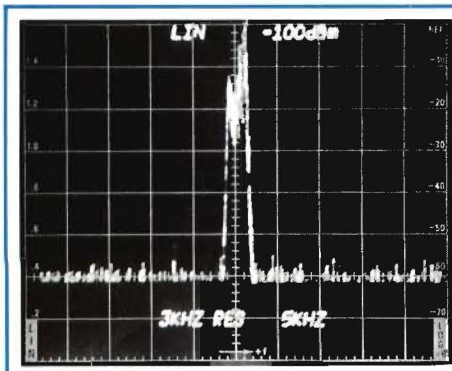
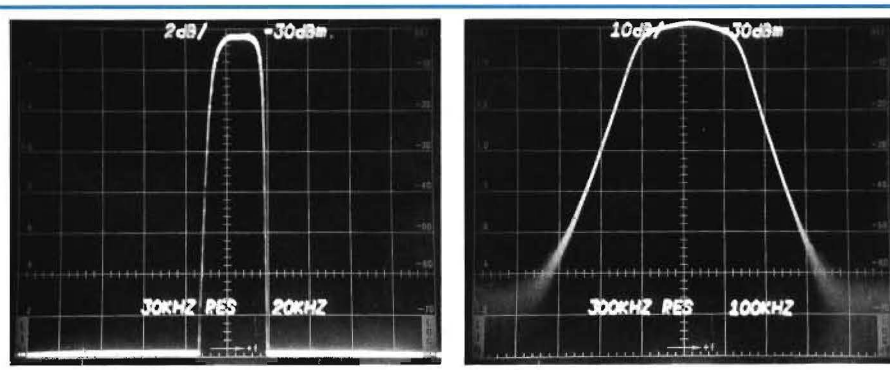


Fig. 2. A —100 dBm signal is displayed well above the noise level of the 7L12.



Figs. 3 & 4. Response curves of the 30 kHz and 300 kHz filters show the flat top and steep sides that give the 7L12 excellent resolution.

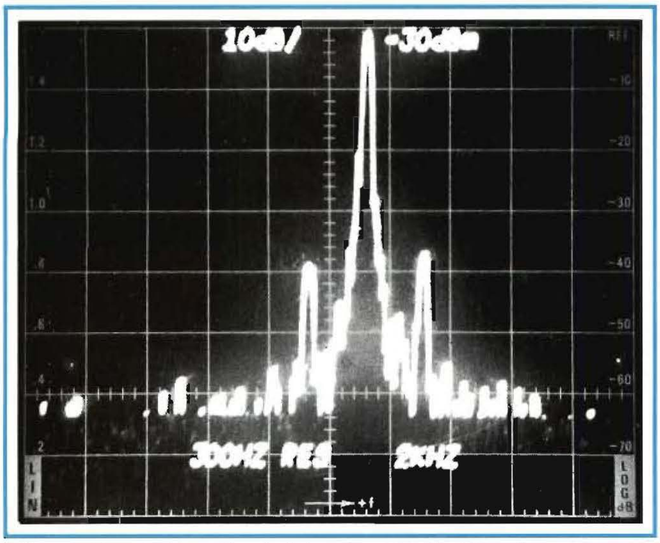


Fig. 5. Resolution afforded by the 300 Hz filter is evidenced in this photo showing 2 kHz sidebands merging with the carrier 60 dB down.

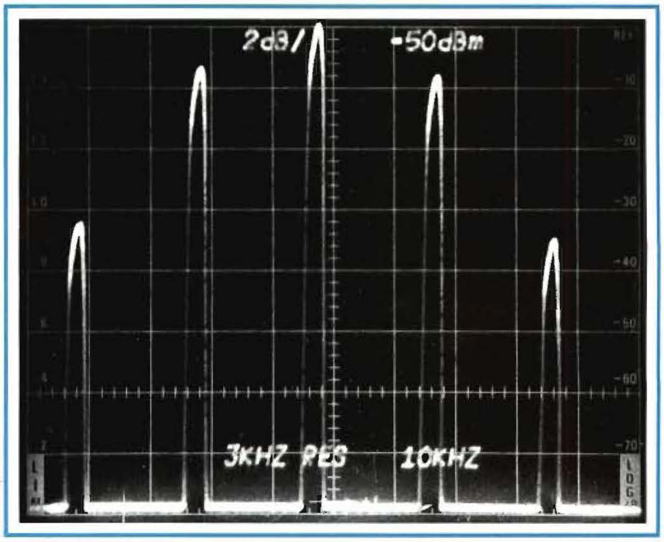


Fig. 6. Signals differing in amplitude by less than 2 dB are easily measured on the 7L12.

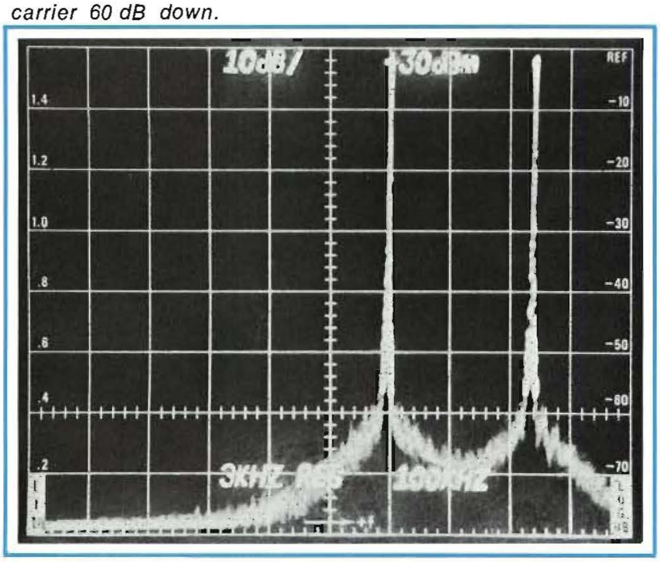


Fig. 7. Low intermodulation distortion is illustrated in this photo showing absence of third order products for two —30 dBm signals.

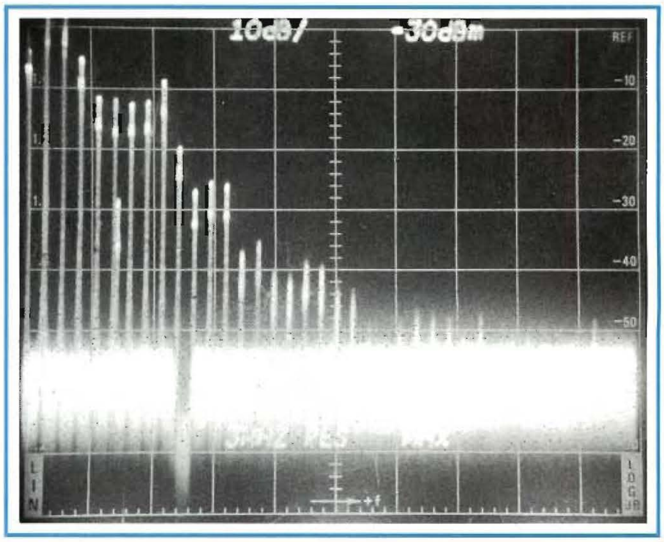


Fig. 8. Maximum frequency span of 1800 MHz is displayed with negative-going marker indicating frequency dial setting.

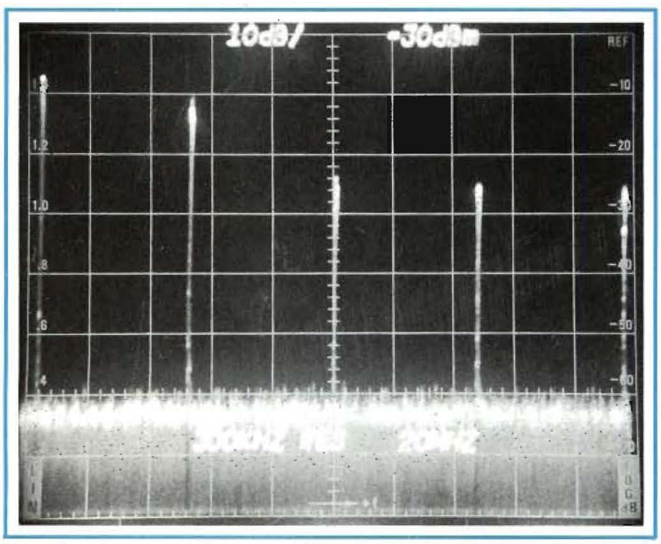


Fig. 9. Frequency span is reduced to 20 MHz/div showing a 200 MHz window of the marker area in Fig. 8.

(d) Finding the Signal—Finding your signal is easy with the 7L12. Figure 8 shows the maximum frequency span capability of 1800 MHz. Here the frequency dial selects the position of a negative-going marker which indicates the part of the spectrum to be selected. Figure 9 shows the details of the comb lines as the span is reduced to 20 MHz per division. The choice of center or start sweep capability is also of considerable convenience. Thus, Figure 10 shows the 0-Hz marker in the center with an approximately 10-MHz signal and its harmonics to either side. The left-hand edge of the screen conveys no information since it's a mirror image of the right-hand side. Setting the frequency control to the start rather than center sweep results

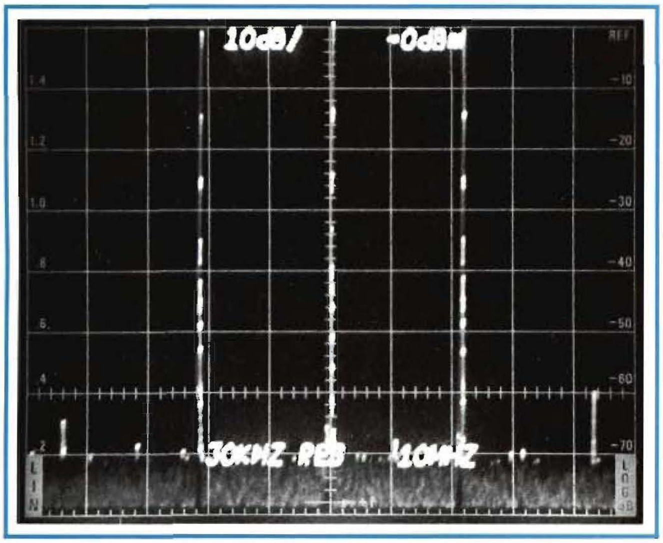


Fig. 10. *0-Hz marker is center screen with 10 MHz signal and its harmonics to either side.*

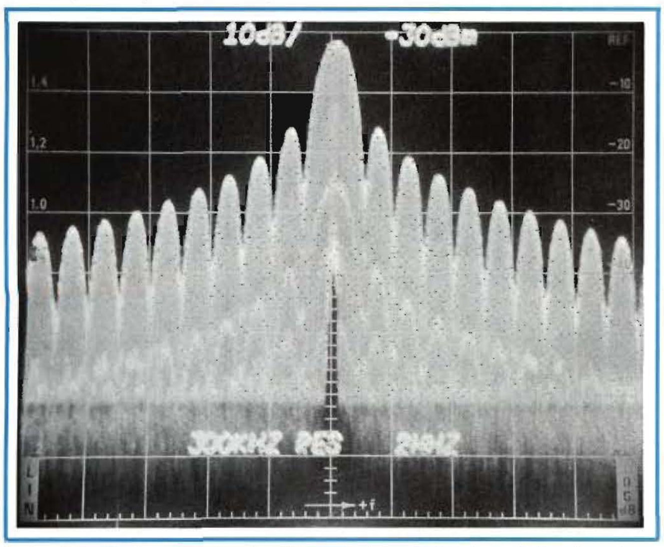


Fig. 12. *A 1-μs pulsed RF waveform displayed in the frequency domain.*

in Figure 11. Here we see the fundamental at about 0 dBm and the second, third and fourth harmonics at —56 dBm, —63 dBm, and —67 dBm, respectively.

(e) Time Domain Data—The wide (3 MHz) resolution capability of the 7L12 permits accurate reproduction of the modulating waveform by operating the analyzer in a non-sweeping mode. This is illustrated by two pairs of photographs. Figures 12 and 13 show a 1-μs pulsed RF waveform in the frequency domain and as a detected time domain pulse. Similarly, Figures 14 and 15 show the spectrum of amplitude modulation at a 1-MHz rate and the detected modulating waveform.

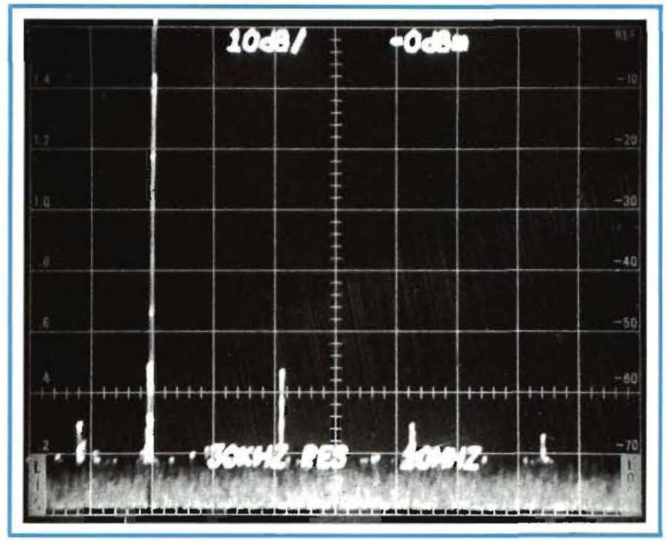


Fig. 11. *Same signal as in Fig. 10 with the frequency control set to "start" rather than "center" of sweep.*

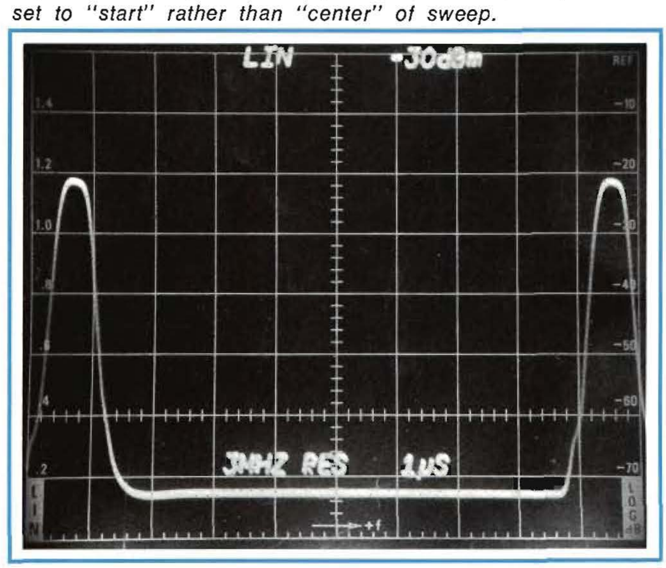


Fig. 13. *The same pulse displayed in Fig. 12 is detected and then displayed in the time domain using the 7L12.*

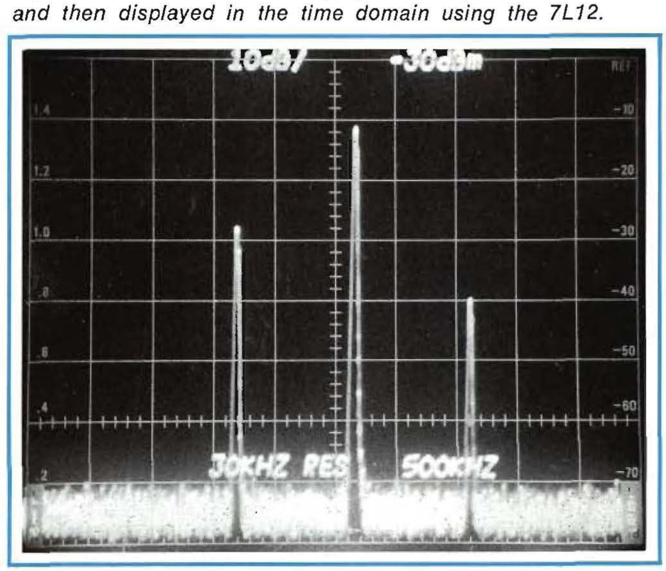


Fig. 14. *Frequency spectrum of amplitude modulation at a 1-MHz rate.*

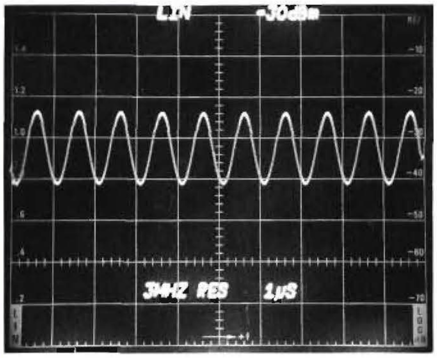


Fig. 15. The signal displayed in Fig. 14, detected and displayed in the time domain.

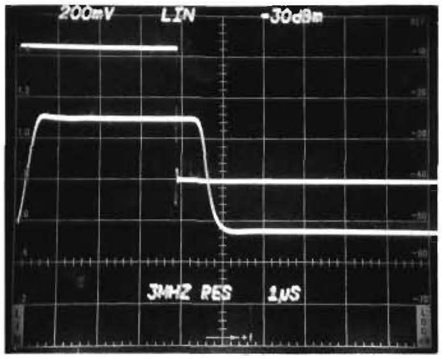


Fig. 16. Modulating pulse and the same pulse after demodulation displayed on the 7504 Oscilloscope.

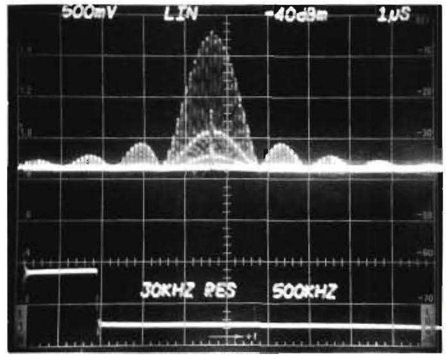


Fig. 17. Spectrum analysis and oscilloscope data displayed simultaneously on the 7504.

The availability of 7000-Series four-hole mainframes permits the simultaneous display of spectrum analyzer and oscilloscope data. This is shown in Figures 16 and 17. Figure 16 shows the original modulating pulse and the same pulse after demodulation. Figure 17 shows a square modulating pulse and the resulting (sin X)/X frequency spectrum.

Now let's look at some of the components and circuitry in the 7L12 in more detail.

THE RF COMPONENTS

The decision to make the 7L12 Spectrum Analyzer a plug-in unit dictated the use of thin film microwave integrated circuits. Previously used techniques would not have permitted components sufficiently small to fit in the available volume.

Design goals of this instrument centered around wide dynamic range and freedom from spurious responses. This called for components meeting some unusual requirements. Some of the needs were met with commercially available items. Others required in-house development of microwave circuits suited to the specific need. Following is a discussion of some of the unique microwave circuits developed especially for the 7L12.

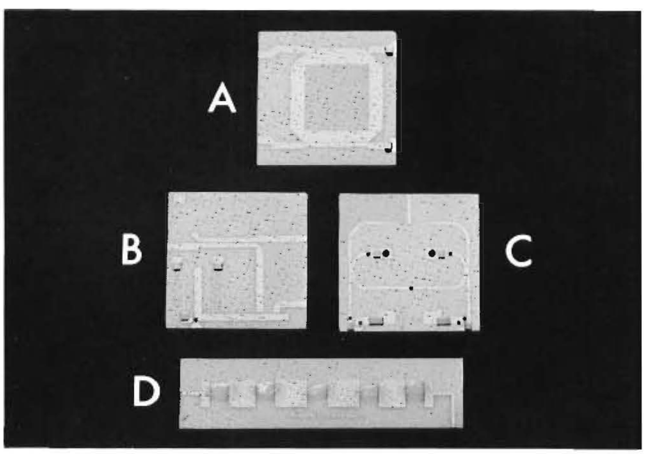


***Fig. 18. Some of the RF components developed for the 7L12:** **(a)** Travelling-wave filter, **(b)** 2.2 GHz oscillator, **(c)** phase detector, **(d)** 2.4 GHz low pass filter.*

The phase detector, Fig. 18(c), is used to stabilize the first voltage tuned oscillator (VTO). Its output is related to a harmonic of the 2.21 MHz crystal reference and the local oscillator in the 2.1 to 3.8-GHz range. Its operation is best understood by considering what happens to a step voltage applied to a directional coupler. (See Fig. 20) If port one receives a voltage step, port two has no output, port three has a rectangular pulse and port four has the remaining energy. In the phase detector this property is used to differentiate a step formed by a snap-off diode, while maintaining an impedance match at all frequencies. The rectangular pulse is applied to a diode detector along with the 2.1 to 3.8-GHz signal. The detector output charges to the amplitude of the rectangular pulse plus the applied input signal. Two of these devices are summed, one having reversed detector and pulse polarities. The summed output corresponds to the RF input at the time the step voltage is applied, and forms the phase detection process.

Because of the good dimensional tolerances that can be obtained using the photolithograph process, the output of the 2.21-MHz step into the 2.1 to 3.8-GHz input can be kept very small.

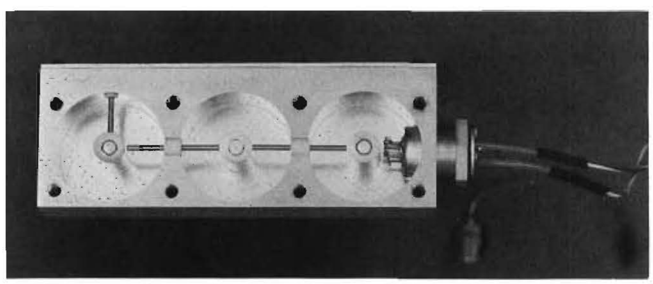


Fig. 19. The 2.1-GHz narrow bandpass filter and second mixer.

The 2.1-GHz narrow bandpass filter shown in Fig. 19 was machined from solid metal to minimize its insertion

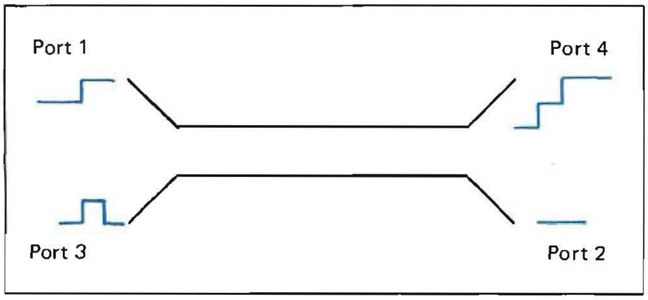


Fig. 20. Signal outputs of directional coupler with a step voltage applied to port 1.

loss. The filter is designed with relatively large capacitance loading which helps reduce the volume of the resonators without raising the insertion loss excessively. The coupling is done with capacitive probes as pictured in the photograph. A small single balanced mixer is placed inside the cavity and is magnetically coupled. It is used for the second conversion mixer.

During the development of the 7L12 it was learned that the impedance at the output of the first mixer, at the sum frequency of the first local oscillator and the input signal, was of special significance. A large reflection at this frequency affected both the flatness and the intermodulation performance. A traveling wave filter provides optimum transfer of energy between the first and second mixer at 2.1-GHz and serves as a termination for other frequencies. This improves the sensitivity and dynamic range by eliminating the need for a lossy attenuator to absorb the unwanted energy. The device is shown in Fig. 18(a).

Fig. 18(d) shows a 2.4-GHz low pass filter. Its function is to maintain the step band properties of the 2.1-GHz bandpass filter. This is of straightforward design. The 2.2-GHz oscillator in Fig. 18(b) is used with an external resonator similar to one section of the bandpass filter. This resonator improves the stability and noise performance of the oscillator by raising the effective Q of the oscillator.

THE IF SYSTEM

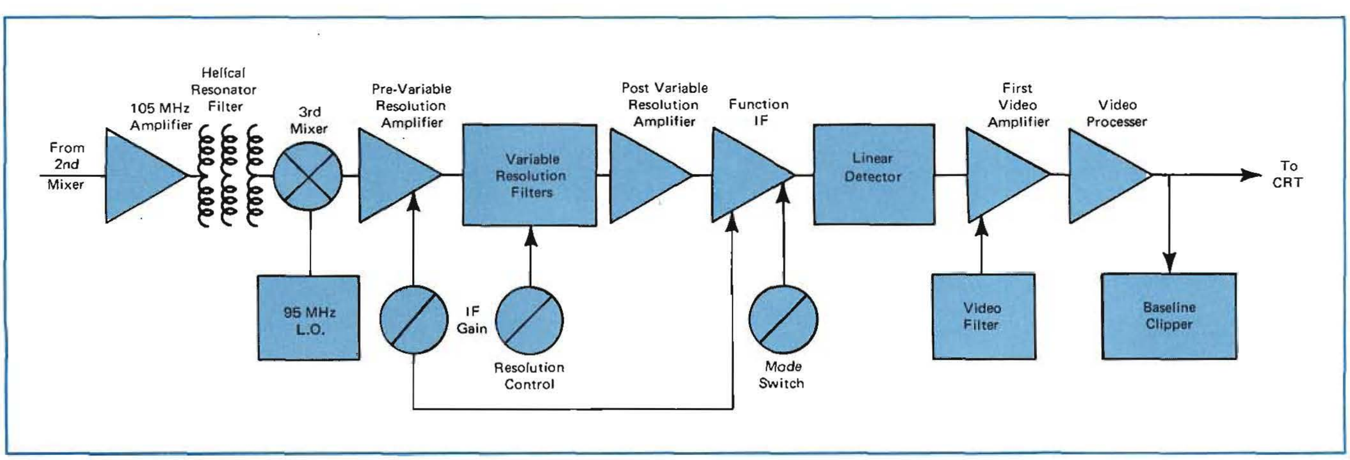
The high frequency IF System in the 7L12 is a low noise, wide dynamic range system incorporating advanced features. The block diagram depicts the design of the IF System. It consists of a first IF at 105 MHz, followed by a second IF and amplifier chain at 10 MHz.

The 105-MHz IF

The 105-MHz IF provides the first gain in the system, the microwave components ahead of this IF having no gain. It is important, therefore, for sensitivity considerations, that the 105-MHz IF have a good noise figure. Since low intermodulation is also important, a dual gate MOS-FET is used as the first amplifier stage.

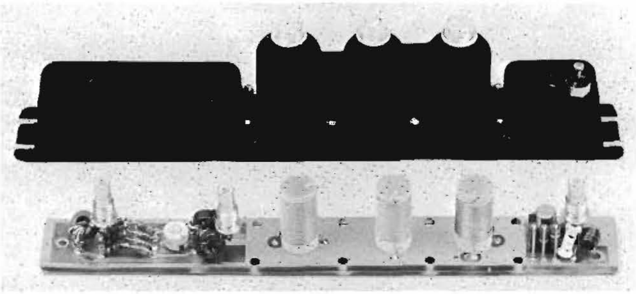
The MOS-FET amplifier is followed with a three-cavity helical resonator filter. A helical resonator is similar in concept to a quarter-wave transmission line filter, except that the center conductor of the transmission line is spirally wound inside the outer conductor. The spiral winding foreshortens the transmission line, making a quarter wavelength of line very compact. A quarter wave resonator at 105 MHz made of air line would be about 2.5-feet long. Because of this foreshortening, the 105-MHz helical resonator is only ¾-inches long! This makes the volume of the three-resonator filter very small.

The housing of the IF must provide the outer conductor of the helical resonator cavities. It is quite important that the cavities be uniform from unit to unit. To achieve uniformity and ease of production, it was



Block diagram of the 7L12 IF system and Video Amplifier and Processor.

decided to electroform the housing. The electroformed housing has a small compartment for the amplifier, three cavities to house the helical resonator filter, and a larger rear compartment to house the doubly balanced mixer that converts the 105-MHz signal to 10 MHz.



The 105-MHz three-cavity helical resonator filter and electroformed housing.

The 10-MHz IF

The 10-MHz IF is composed of four circuit blocks. The first block is the pre-variable resolution amplifier, followed by the second block containing the variable resolution filters. The third block is the post-variable resolution amplifier and noise filter. The final block is a function IF that generates logarithmic display functions at 10 dB/div and at 2 dB/div, as well as a linear display function.

Variable Resolution Filters

The bandwidths of the resolution filters in the 7L12 are in decade steps from 3-MHz to 300-Hz. A special feature of the 7L12 is that all of these filters have a narrow (4:1) 60 dB/6 dB aspect ratio.

The three narrowest bandwidths are obtained with crystal filters, while the 300-kHz position uses an L-C filter. The 3-MHz bandwidth is that of the 105-MHz helical filter, so in the maximum resolution postion, the 10-MHz IF is operated without a filter. After the variable resolution filters, the signal passes through another amplifier to raise its level before entering the function IF.

The Function IF

The function IF is designed to process the signal and feed the resulting video to the plug-in/mainframe interface for display on the CRT. In the 10-dB/div and 2-dB/div display modes, the function IF operates as a logarithmic amplifier. In the 2-dB/div and the Lin display modes, the funtion IF provides 40 dB of post-variable resolution gain as well.

The amplifier is followed by a detector utilizing feedback to attain a high degree of linearity and wide bandwidth. A 3-MHz low pass filter following the detector limits the video bandwidth to the maximum resolution bandwidth of the system.

Video Amplifier and Processor

The first video amplifier is also an active filter and baseline clamp. When the video filter switch is depressed, one of two video filters is turned on dependent on the position of the resolution switch. For resolutions of 300-kHz or greater, a 15-kHz video filter is chosen. For resolutions of 30-kHz and smaller a 30-Hz filter is selected. The concept of automatic selection of internal video filters simplifies the front panel and minimizes operator confusion.

Following the first video amplifier is the video processor. It was found that when viewing the spectrum of narrow RF pulses, the 3-MHz bandwidth of the 7L12 taxes the visual writing rate capabilities of even reasonably fast oscilloscopes. When looking at narrow RF pulses with a low repetition rate, the sweep speed may be as low as 1 sec/div. Normally all that would be seen on the display would be the baseline noise and a line representing the peak amplitude vs frequency of the pulses. The rise and fall times of the pulses would be invisible. The video processor slows the fall time of the beam so that the display shows a filled-in spectrum. The time constant of the display is short enough that under other conditions the display will be unaffected.

The Baseline Clipper

An adjustable baseline clipper is also provided. This circuit dims the trace when it is in the vicinity of the baseline. An added feature of the 7L12 is that the contrast between the clipped and unclipped areas of the screen is adjustable. This is particularly useful when one wishes to photograph the display, since one may overcome the baseline absence associated with conventional clippers.

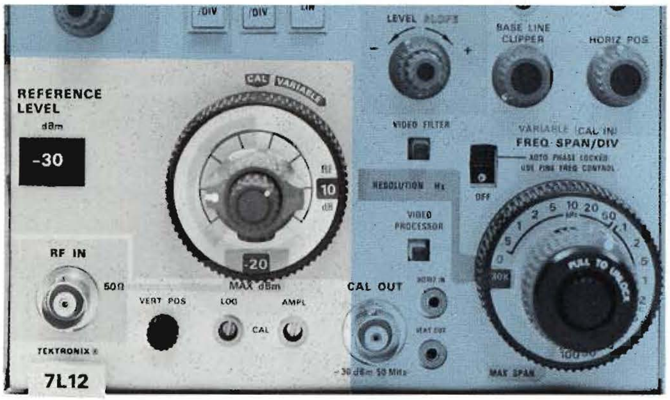
The design of the IF system was optimized for low intermodulation distortion and wide dynamic range. This, coupled with the low loss microwave front end of the 7L12, results in an instrument that typically achieves 70-dB dynamic range at 300-kHz resolution bandwidth. This permits the operator to sweep wide frequency spans at a high rate and still have 70-dB performance.

THE 7L12 MECHANICAL PACKAGE

Mechanical Design Objective

The goal was to provide a microwave spectrum analyzer in a two-plug-in width package offering all of the functions usually found in larger, stand-alone analyzers. Easy access to all active components and calibration adjustments for ease in servicing was a must. The efforts of many groups working in diverse disciplines combined to meet these challenging design goals.

Mechanically, the 7L12 is divided into three main sections: the front panel, designed for functionality and ease of operation; the RF section located directly behind the front panel; and the circuit board section containing the bulk of the active components.



Chance of measurement error is greatly reduced by automatic readout for various combinations of RF and IF gain and/or attenuation.

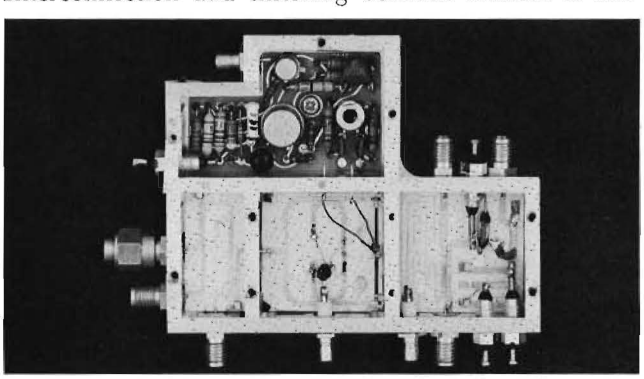
The Front Panel:

Use of lighted push buttons, color-coded grouping of associated controls, multifunction controls and easy-operating cam switches result in a control panel that is easy to understand and use.

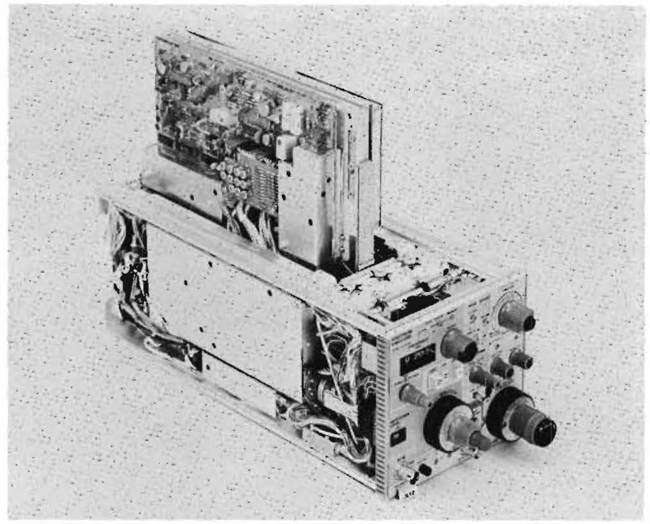
Switching of RF and IF attenuators and gain is accomplished by concentric controls. A unique summing arrangement provides direct readout of top-of-screen reference level, RF attenuation and maximum power input for linear operation.

Behind the Front Panel:

Immediately behind the front panel is the section containing the RF and IF attenuators, filters, and some of the oscillator and phase lock circuitry. Semi-rigid cables are used through this area to interconnect the various modules. These cables consist of a silver-plated solid center conductor, solid TFE fluorocarbon dielectric and tin-plated copper jacket. Using reasonable care the cables can be hand bent to aid in removing components. A multiple compartment enclosure houses the RF coupler, phase gate and 2.2 GHz oscillator hybrid circuits. Interconnection and shielding between sections is simplified and the space occupied by these components greatly reduced.



Multiple compartment enclosure housing the RF coupler, phase lock gate and 2.2 GHz hybrid circuits.



The two center circuit boards extend for easy servicing. The instrument can be operated with boards in the extended position.

The Circuit Board Section

This section contains four major etched circuit boards. The two center boards placed back-to-back, are mounted on miniature slides. The instrument can be operated with the slides locked in the extended position for ease in servicing.

Removal of the etched circuit boards and other components is simplified through extensive use of harmonica connectors.

The design objectives for the 7L12 posed a tremendous challenge from the mechanical standpoint. This challenge has been met with a unit that offers new operating ease and good serviceability, yet occupies only 5¼" of rack space when operated in a TEKTRONIX R7403 Oscilloscope.

ACKNOWLEDGEMENTS

Many talented people contributed to the successful completion of the 7L12—more than one can enumerate. Certainly a major portion of the credit belongs to the electrical, mechanical and integrated circuits design teams.

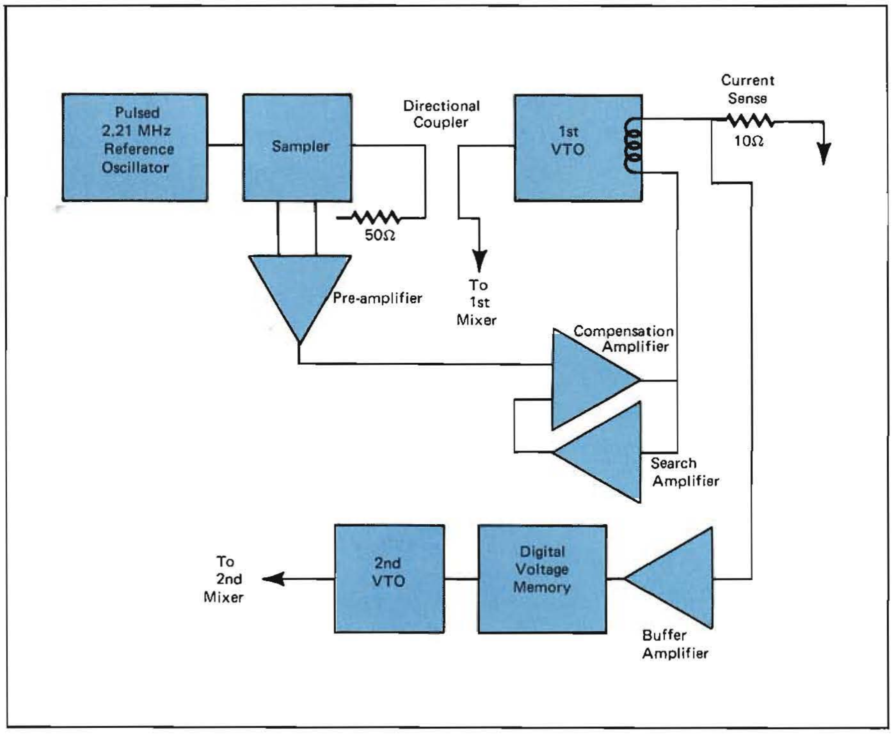
Here are some of the folks making up those teams: Electrical Engineering—Morris Engelson, Linley Gumm, Gene Kauffman, Larry Lockwood, Gordon Long, Steve Morton, Paul Parks, Fred Telewski.

Mechanical Engineering—Neal Broadbent, Jack Doyle, Al Huegli, Steve Skidmore, Leighton Whitsett.

Integrated Circuits—Judy Hanson, Robert Holmes, Carolyn Moore, Rena Randle.

Frequency Stabilization Techniques

by F. Telewski



Block diagram of the 7L12 phase lock system.

When spectrum analyzers were first conceived, designers soon became aware of the necessity of a circuit block referred to as the phase lock. The necessity for phase lock is determined by two parameters: the sensitivity of the first voltage tunable oscillator (VTO) and the narrowest span width which the instrument is to possess.

Let us assume that a VTO will respond with 100% integrity to its tuning command. Consider what stability may be achieved with good power supply regulation in today's swept front end spectrum analyzers. Typical VTOs have tuning sensitivities of 200 MHz/volt, or equivalently 200 Hz/μV. Since one normally does not like to live with a spec of less than 100 μV of noise on the sweep voltage, the oscillator will jitter 20 kHz at zero sweep. In modern analyzers with display spans of less than 20 kHz, this amount of instability is unacceptable.

This problem can be eliminated by stabilizing the first VTO with phase lock circuitry and sweeping the signal with a second VTO whose sensitivity is in the order of 1 MHz/volt, thereby providing stabilities in the order of 100 Hz.

Another advantage of the phase lock technique of oscillator stabilization is that the first VTO may be made as essentially pure as the reference which is used for the stabilization. This is important in reducing the phase noise on VTOs which use low Q resonators.

In general, the concept of phase lock involves the comparison of an oscillator (known as the locked oscillator) to a reference oscillator via a phase detector. The output of the phase detector is a voltage proportional to the phase difference ($\Delta\phi$) between the oscillators. This voltage is amplified, filtered, and fed back in a manner so as to tune the locked oscillator (first VTO) and maintain a constant $\Delta\phi$. As the gain increases, the $\Delta\phi$ becomes smaller and vice versa. It is important to note here that while we have mentioned a phase difference ($\Delta\phi$), there is no frequency error (ΔF). When the first VTO is locked, its long-term frequency stability is as good as that of the reference oscillator.

PHASE LOCK SYSTEMS

Phase detection is classically accomplished in two manners. IF mixing is a technique in which two signals (reference and locked oscillator) are fed into a mixer which yields a voltage related to the phase difference between them. This, of course, requires that we have a reference tone at each frequency at which we desire a lock. Circuitry for this type of system is somewhat more complex than the alternative.

Alternatively, a DC sampler may also be used as a phase detector. The sampler is a fast switch driven by a pulse generator which acts as the reference oscillator. The pulse generator supplies a short (typically < 100 ps) pulse which activates the switch, allowing a small portion of the locked oscillator waveform to pass through. These "samples" are integrated and form the voltage proportional to the phase difference between the generator and the locked oscillator. This system has an advantage in that it will yield outputs at discrete multiples of the pulse generator frequency.

Generally speaking, the DC sampler circuitry is less complex than the IF mixer system and therefore leads to a smaller and more economical package.

To date, the principal disadvantage of the sampling system was the very high output impedance of the sampling gate (typically 1 MΩ). This weakness has been overcome with development of a low impedance

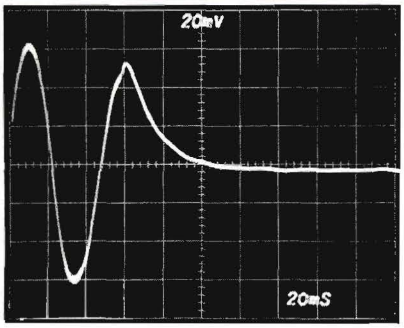
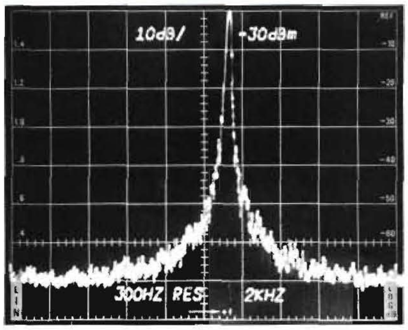
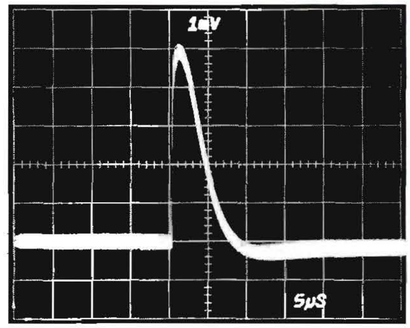


Photo above depicts the search and acquisition waveform in the 7L12 phase lock system. For the purpose of illustration, the loop was closed 20 ms after the start of the trace, thus the loop required 40 ms to acquire.



This photo demonstrates the spectral purity of the 7L12 phase lock system. The source is a 50-MHz crystal oscillator.



This photo of the impulse response of the 7L12 phase lock system depicts the wide band nature as well as the damping factor. These parameters contribute to the 7L12's spectral purity and resistance to shock.

(≈100 kΩ) balanced sampling gate. The balanced property also results in simplification of the phase lock circuitry.

ACQUISITION

When the frequency span is reduced, at some point the phase lock system must be engaged. When this happens, the locked oscillator (first VTO) must acquire on one of the harmonics of the pulse generator which, in the 7L12, operates at ≈2 MHz. The second VTO must be offset by an amount equal to, and opposite in direction to, the shift which the first VTO underwent during its acquisition, in order to keep the signal of interest on center screen.

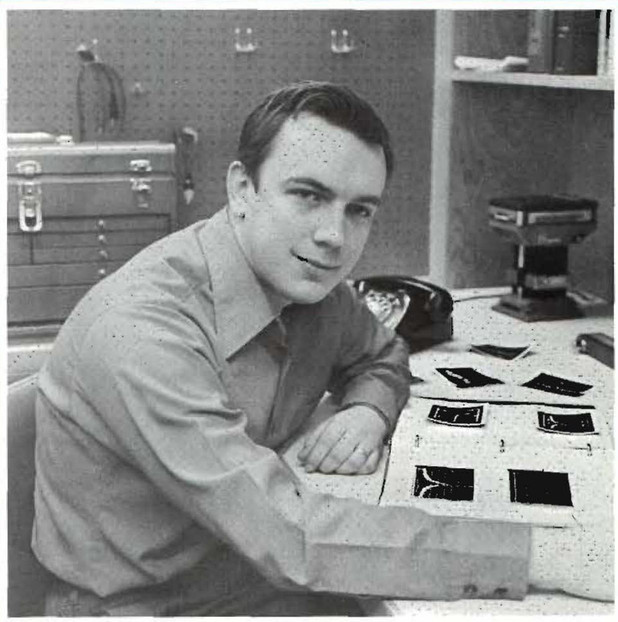
The acquisition is usually accomplished by adding a phase lock indicator which is used to turn off a search oscillator. The 7L12 eliminates this extra hardware through the use of a conditionally stable phase lock loop. The loop will oscillate at a 20-Hz rate until it intercepts a lock point. When this occurs, the oscillation ceases and the loop is locked.

While this takes place, a digital system measures the offset voltage on the first VTO before and after lock. It now generates a highly stable potential equal to this change, but of opposite polarity, for application to the second VTO.

PERFORMANCE CHARACTERISTICS AND FEATURES

The phase lock system of the 7L12 has been human engineered to operate automatically as a function of the frequency span control setting. This leaves the operator free to concentrate on his primary objective, spectrum analysis. Specifically, the 7L12 phase lock is energized automatically at frequency spans of 100 kHz or less without operator intervention. In order to provide versatility for other types of measurement, the operator may opt to disable this automatic feature with the phase lock on-off switch.

In addition to ease of use, the 7L12 provides excellent spectral purity and lock stability. The phase lock system incorporates a ≈40-kHz closed loop bandwidth damped to greater than 0.6. This damping factor yields a flat noise floor devoid of noise rises often seen in systems which are less damped. The wide loop bandwidth gives the 7L12 outstanding immunity to shock and vibration. It also permits the use of a 20-Hz search rate resulting in less than 50-ms acquisition time for the phase lock system. The 2-MHz reference generator typically reduces the phase noise ≈6 dB as compared to a 1-MHz reference generator used in previous instruments.



***Fred Telewski**—Fred is a newcomer to Tek and brings a good background in spectrum analyzer circuit design to the group. He received his BSEE in 1967 and his Master's in '69 from Newark College of Engineering in Newark, N.J. Fred is a cat fancier, has three Siamese, and also dabbles in photography and amateur radio.*

TEKNIQUE: OPTIMIZING MIXER PERFORMANCE USING THE 7L12 SPECTRUM ANALYZER

by Gene Kauffman

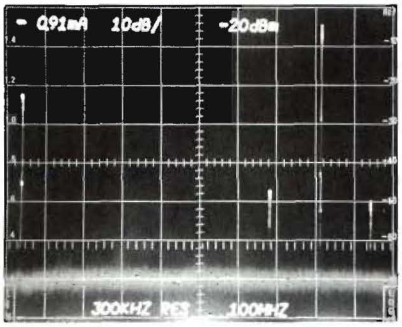


Fig. 1. Signals observed from IF port of mixer are from left to right: Signal feedthrough at 130 MHz, (LO-Signal) conversion at 770 MHz, LO feedthrough at 900 MHz and (LO + Signal) conversion at 1030 MHz.

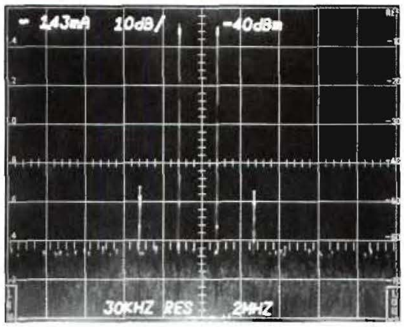


Fig. 2. Third order intermodulation products before mixer bias optimization.

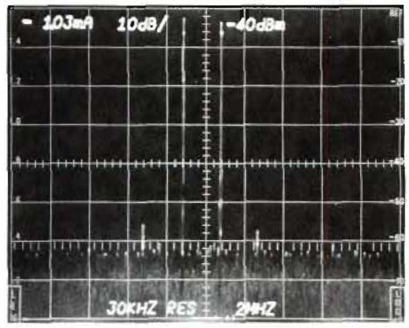


Fig. 3. Third order intermodulation is reduced by optimizing mixer bias. 7D13 readout of bias is at upper left corner of display.

"What can a spectrum analyzer do?", or, "What is an oscilloscope used for?" These questions are frequently asked by those outside of the electronics community. These are difficult questions to answer in a concise manner. Likewise, space here does not permit description of the broad domain of challenging RF measurement needs that the 7L12 is capable of fulfilling. However, one typical example will be outlined, showing a new facet of the TEKTRONIX 7000-Series measurement capability.

Here the 7L12 is combined with the 7D13 Digital Multimeter in a 7000-Series mainframe with readout (as shown in Figure 4). The following major parameters of an RF mixer can be determined using this setup:

1. Mixer conversion loss
2. Local oscillator feedthrough
3. Signal feedthrough
4. Mixer intermodulation products
5. Mixer bias

Figure 1 is a single exposure photograph showing, from left to right, the input signal feedthrough at 130 MHz. Next, we see displayed the mixer conversion (L.O. — signal), then the local oscillator feedthrough is observed at 900 MHz, and finally the (L.O. + signal) conversion. Thus, on one convenient setup, we can characterize or optimize the performance of this device.

Figure 2 shows the frequency span expanded around the (L.O. — signal) conversion; the center frequency on the spectrum analyzer is set at 770 MHz. Two signals 2 MHz apart are now applied to the input of the same mixer; third order intermodulation products[1] are displayed 42 dB below the converted signals. Figure 3 now shows that reducing the mixer bias current from 1.43 mA to 1.03 mA, reduces the intermodulation products by 10 dB while not substantially affecting the desired conversion efficiency.

To repeat, "What can a spectrum analyzer do?", perhaps you will be finding new and unique answers to that question as you discover the ease with which RF measurements can be made over the wide frequency range of 100 kHz to 1800 MHz, using the 7L12 Spectrum Analyzer along with the complementary 7000-Series Oscilloscope Systems.

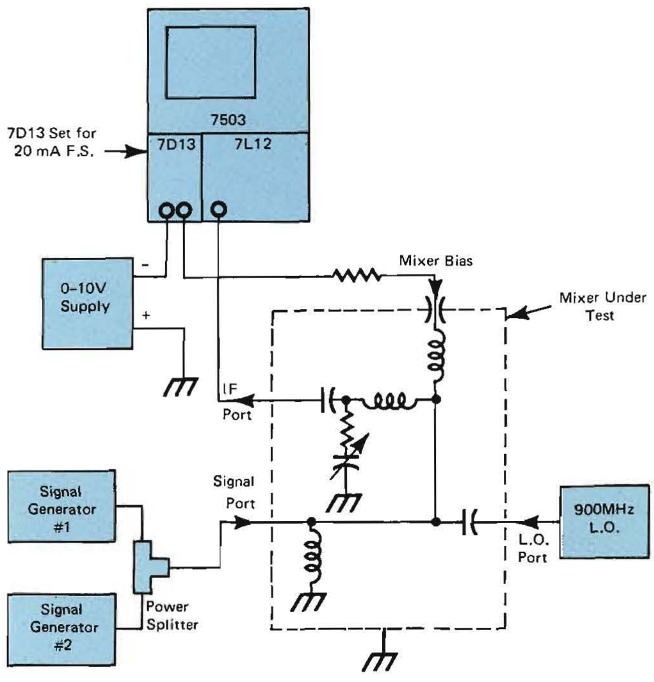


Fig. 4. Block diagram of test set up using 7L12 and 7D13 to measure RF mixer parameters.

[1]Engelson, M.; "Spectrum Analyzer Circuits;" Tektronix Circuit Concept Series.

***Gene Kauffman**—Gene is an old-timer at Tek (11 years) and an old-timer with the spectrum analyzer group. He has contributed to the development of most of our analyzer products and was project engineer for the popular 491 portable spectrum analyzer. Gene's offwork hours are filled with his family, church activities, ham radio and photography.*

INSTRUMENTS FOR SALE:

564B/3B3/3A6 w/probes $1800. John Clarke, 1531 Edinborough, Ann Arobr, Mi. 48104 (313) 971-7377

543/L $1500. Robert Healy. PO Box 2028, Dublin, Ca. 94566 (415) 828-6044

545B/1A6/53-54D/CA w/cart, 7 probes & acc. $1800. Dave Eppley, 988 Kingston Dr., Cherry Hill, NJ 08034 (609) 429-5957

321 exc. cond. $350. R. J. Jarnutowski, 1909 Forest Dr., Mount Propect, Il. 60056

585A/81. Marty Sperber, One Jake Brown Road, Old Bridge, NJ 08857 (201) 679-4000

502A; 2021; P6023 (2) Dr. Jane Denton or Ron Calvanio, Mass. Gen. Hosp. Fruit St., Anesthesia Rsch., Boston, Ma. 02114 (617) 726-3851

661/4S1/5T3 & Acc. Mr. Mawson, Scientific Measurement Sys., 351 New Albany Rd., Moorestown, NJ 08057 (609) 234-0200

531A/B $650. Robt. A. Stevens, 960 Hastings Ranch Dr., Pasadena, Ca. 91107 351-9141 or 246-6761, ext. 474

555. $895. L. A. Electronics, 23044 Crenshaw, Torrance, Ca. (714) 534-4456

3B4 $400. Craig Brougher, Hallmark Cards, Photo Res. Dept., 25th & McGee, Kansas City, Mo. 64141 (816) 274-4404

585A/82. $1870. Jim Leiby, Southwestern Industries, Inc., 5880 Centinela Av., Los Angeles, Ca. 90045 (213) 776-1125

532/53B $675. Dave Loder, 19511 N.E. Halsey St., Portland, Or. 97230 (503) 666-3440

D54, P6006, P6011 (2). $550. Richard Campbell, 766 Washington St., Marina del Rey, Ca. 90291 (213) 821-4958

310, 310A, 502. John Staples, University Computing Co. (214) 241-0551

3C66 Plug-in, 2 years old. $340. G. Rayber, Harrisburg Hospital. (717) 782-3152

134 Amp. Never used. Best offer. V. F. Meyers, P.O. Box 929, Minneapolis, Mn. 55440 (612) 377-8480, ext. 23

S54A, $425. Damien Appert, 1610 L St., Davis, Ca. 95616 (916) 756-4462 eves only

585A/82 $1000; 454, $1700; 422, $900; 567/6R1A/3S76/3T77, $2500; 561A/3S76/3T77, $1350. Brian Yamrone, LeCroy Rsch. Labs, 126 N. Route 303, West Nyack, NY 10994 (914) 358-7900

P6015. Never used. Best offer. John Zielinski, Spitz Labs, Chaddsford, Pa. 19317 (215) 459-5200, ext. 43

2A63, 502A. Elliot Geophysical Co., 4653 E. Pima, Tucson, Arizona 85712 (602) 793-2421

Will trade 162A for functional 126 Power Supply. Roger Pick, P.O. Box 1190, Berkeley, Ca. 94701

310. Jack Kidd, Honeywell, Inc., 275 Wyman St., Waltham, Ma. 02154 (617) 237-4150, ext, 441

561A, $300; 2A63, $100; Mod. D Scope Cart, $75; 1A5, $300; C-12, $250. Ron Jenkins, Scientific Advances, Inc., 4041 Roberts Rd., Columbus, Oh. 43228 (614) 876-2461

535A, 561A, 545B, 661, 545, 545A, 531A, 585A, 561. Wayne Coe, Univ. of Kansas, Center for Rsch., Lawrence, Ks. 66044

310A, Make offer. Interstate Business Equipment, Inc., 8264 Hascall, Omaha, Neb. 68124

502 w/electromyography machine attached. Mrs. Marie Spang, French Hosp., 4131 Geary Blvd., San Francisco, Ca. 94120 (415) 387-1400, Ext. 507

567/3S76/3T77/6R1, 262. Mr. Endean, Westinghouse Electric Corp., Computer & Instrument Div., 200 Beta Dr., Pittsburgh, Pa. 15238 (412) 782-1730, ext. 319

514D, $195 plus freight. Comm-well Sales & Engrg. Inc., RR 5, Box 761, Golden, Co. (303) 277-0807

561A/2A63/2B67 (5) $350 ea. Tom Coulter, Dept. of Physiology, Baylor College of Medicine, 1200 Moursund Av., Houston, Tx. 77025 (713) 529-4951, ext. 471

564B/2B67/3A6, C12. Best offer. George E. Leger, Dela Enterprises, Inc., P.O. Box 1407, Coolidge, Az. 85228 (602) 723-5491

P6046 w/acc. $500. Ed Paul, 4 Carlson Circle, Natick, Ma. 01760. (617) 653-4777

INSTRUMENTS WANTED:

P6032. Mr. McGaffy, Polara Engineering, 11208 Greenstone Av., Santa Fe Springs, Ca. 90670

Any scope of 500-Series accepting letter plug-ins, preferably defective or not serviceable. B. Kalab, 4712 Exeter St., Annandale, Va. 22003 (703) 941-4843

321A, D67, D54, S54A or S54U. Chuck J. Kolar, 5461 Vallecito Dr., Westminster, Ca. 92603 (714) 897-5874

T Plug-in for 536 Scope. Joe Konieczny, Jr., 5725 Edgepark Rd., Baltimore, Md. 21239 (301) 435-2529

611. Terry Keesey, P.O. Box 1008, State College, Pa. 16801

453. Charles Wallace, 3025 Palos Verdes, Dr. No., Palos Verdes, Ca. 90274 (213) 378-7002

516 Scope. Leonard Oursler, Ch. Engr., Staten-Oursler Broadcasting, 840 E. State St., Princeton, In. 47670

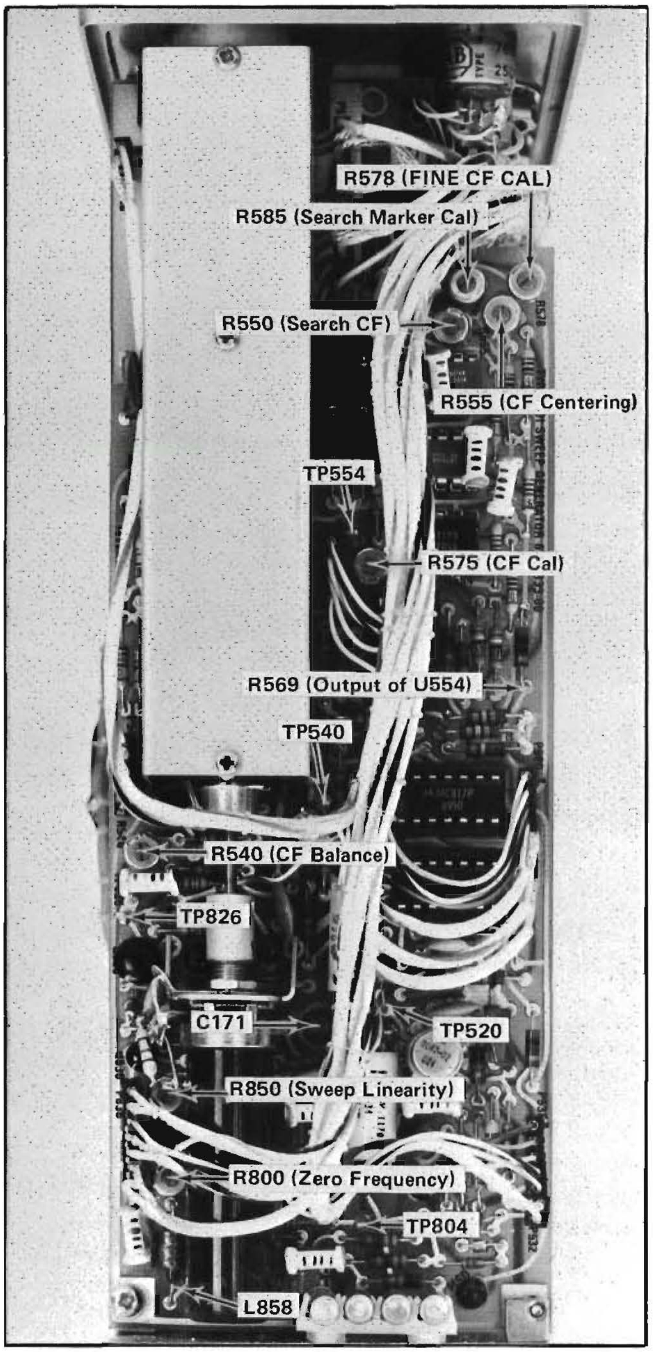
3B3. Fred Stuebner, Kuchler Dr., LaGrangeville, NY 12540 (914) 463-6092

P6021, P6013A, P6015. Richard Gilman, Box 3582, Hollywood Sta., Ruidoso, NM 88345

SERVICE SCOPE

Calibration and Troubleshooting Aids for the 1401A

by Bob Williams and John Ross, Production Test



Location of test points and adjustments on the 1401A Sweep Board.

Calibrating and troubleshooting the compact portable 1401A Spectrum Analyzer Module is a relatively easy job despite its small size. However, there are some aids that will help speed the job. Here are some items we've found helpful:

THE POWER REGULATOR

It is often difficult to determine which section of the power supply is faulty because of the feedback to the pre-regulator. The feedback can be disabled by removing Q708 and inserting a 100-KΩ, 1/8 watt carbon resistor in the socket between the emitter and collector terminals. This should permit the multivibrator in the pre-regulator to run and you can proceed from there.

Another area that sometimes causes concern is checking ripple on the supplies. A lead connected from the ground post on the side of the 1401A, to the test scope ground will reduce the apparent ripple.

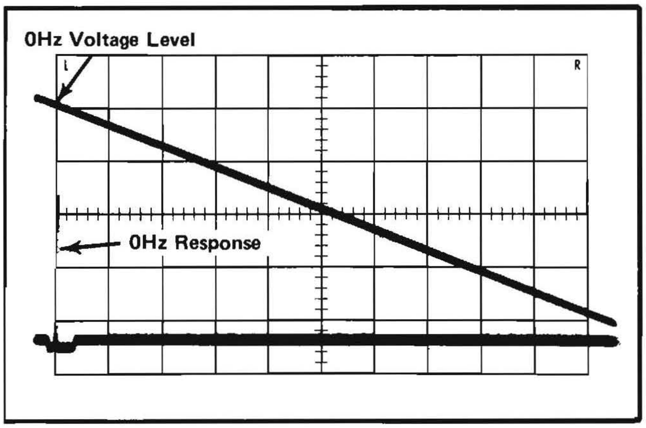
THE RF SECTION

If you are experiencing low sensitivity, the first step is to make sure the RF attenuator is switched out of the circuit. You can bypass the attenuator by feeding the signal directly into J141. If the sensitivity is quite low, check mixer diode CR167 in the second converter. It is physically located between two sections of the RF module and is easily broken if installed with leads that are too short. Failure of Q184 in the second converter will cause total loss of signal. If it is replaced you should check the 720-MHz oscillator adjustments as outlined in the manual.

Note that care should be taken when soldering parts or leads on the RF module printed circuit board. The board is made of material having low dielectric loss and is subject to damage from prolonged or excessive heat.

It is a characteristic of microwave RF components that they require special techniques and tools to properly service them. If you have problems in the RF attenuator, low-pass filter, voltage tuned oscillator or the wideband mixer, we suggest you return the unit to Tektronix for service.

If you have occasion to align the RF section of the analyzer, you will encounter a spurious that occurs at about 12.5 MHz. This can be tuned down by inserting an RF signal close to it in frequency. With both the signal and spurious displayed on screen, set the RF module adjustments for optimum signal response and minimum spurious amplitude. The spurious may be twice the noise in amplitude if the input of the 1401A is not properly terminated (50 Ω for the 1401A and 75 Ω for the 1401A-1).



Test scope display when setting R550, center frequency adjustment.

THE IF SECTION

While we're discussing alignment, you will find that T208 and T210 have considerable effect on sensitivity. These should be set for peak signal. Low amplitude when in the 3-kHz resolution position indicates that the 100-kHz filter is not aligned over the 3-kHz filter. If you have removed the power regulator board for servicing and inadvertently reversed the connector on P711 or P712 you will have a similar symptom.

IF gain is contributed by Q208, U240 and U260. Q208 is the most likely suspect if gain through the IF section is low.

The IF section also contains the circuitry for gated operation of the 1401A. If trouble is suspected in this area, you can bypass the gate by placing a jumper between Pin 1 and 4 of P208.

THE SWEEP CIRCUIT

Because the sweep adjustments interact, more difficulty with calibration has been experienced in this area than in any other. The following procedure will help set the sweep adjustments properly:

1. Set up the 1401A and test scope as detailed in step 5 of the manual calibration/adjustment procedure.
2. Set R575 (CF Cal) on the sweep circuit board about 1/3 turn from full CCW.
3. Connect the test scope probe to TP554 and adjust the test oscilloscope EXT HORIZONTAL GAIN for about 10.5 divisions centered horizontally.
4. Adjust R555 (CF Centering) for 0 V at TP554.
5. Switch FREQ SPAN MHz/div to 20 and adjust R540 (CF Balance) for 0 V at the center of the sweep.
6. Switch FREQ SPAN MHz/div to SEARCH and adjust R550 (Search CF) for 0 V at the left graticule line.
7. Continue as shown in the manual for the remaining sweep adjustment, commencing with step 8.

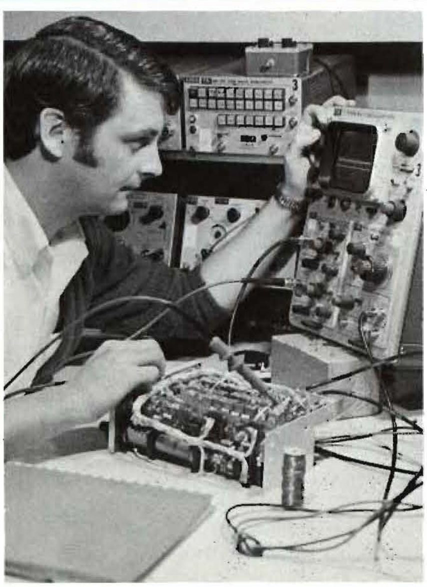
When adjusting the sweep shaper the following points may be noted:

a. Step 12 of the procedure calls for measuring the voltage across R108. This cannot be done without removing the gate-calibrator board. An alternate method is to measure the voltage at L858 on the sweep board. It should be approximately 1 V more negative than at TP826.

b. If the 0-Hz response moves appreciably ($\approx$0.5 cm) when adjusting R415 it usually indicates R800 will have to be set to a different voltage level and R850 readjusted.

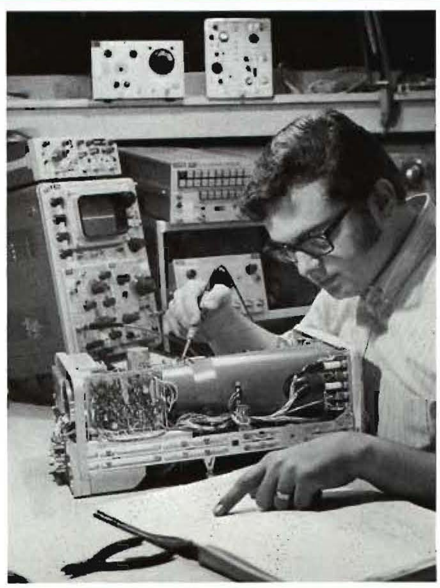
c. It is not always necessary to adjust R410 to R415 from their preset positions to achieve proper sweep shaper adjustment.

Using these service hints and the calibration and maintenance procedures outlined in the manual you should be able to keep your 1401A in good working order. If you have difficulty, don't hesitate to call your TEKTRONIX Field Engineer.



***Bob Williams**, pictured at left, is a staff engineer in Production Test. Bob has been with Tek six years, working primarily with spectrum analyzer products. He started his electronics career in the Navy as an Electronic Technician. Bob's leisure time is largely filled with his wife and three children; he does admit to an occasional stint at the bowling lanes.*

*Co-author **John Ross**, at right, also works in Production Test. He joined Tektronix nearly six years ago upon graduation from Spokane Community College. He, too, likes to bowl; however, electronics is John's main hobby as well as vocation. He has a charming wife and year-and-a-half old daughter.*



TEKSCOPE

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Editor: Gordon Allison Graphic Designer: Jim McGill For regular receipt of TEKSCOPE contact your local field engineer.

The 1401A/324 Portable Spectrum Analyzer System

Spectrum analysis from 1 MHz to 500 MHz with 60 dB dynamic range and absolute calibration.

Oscilloscope measurements from DC to 10 MHz at 10 mV/div and to 8 MHz at 2 mV/div.

System weight including batteries is less than 15 pounds.

The 1401A is tailored for use with the SONY/TEKTRONIX 323, 324 and 326 Oscilloscopes. It is compatible with any oscilloscope having 0.5 V/div horizontal deflection factor and 1.2 volt full-screen vertical deflection.