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Plug-in Oscilloscope

A New Calibration Fixture for the  
7000-Series

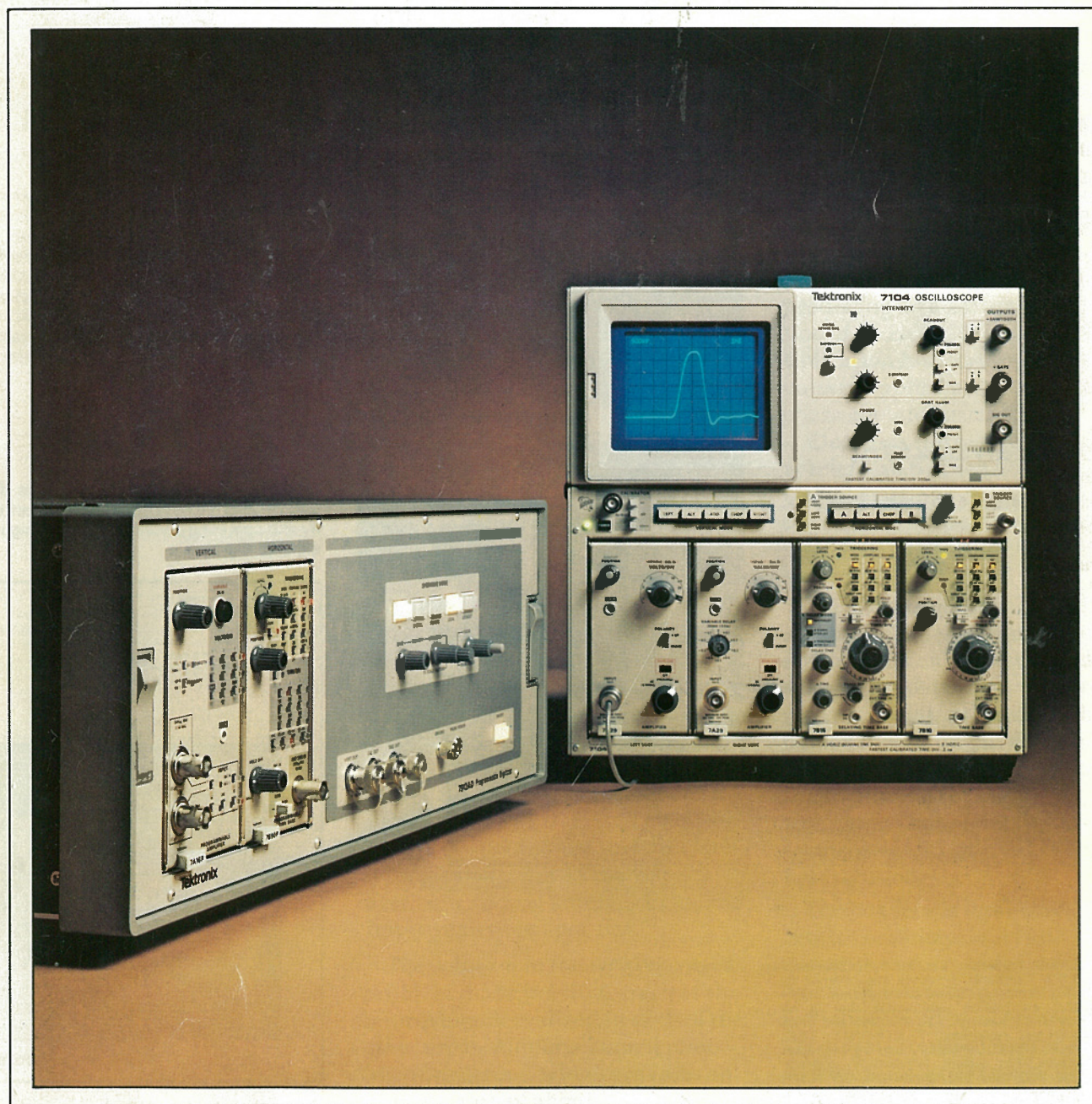
An Intelligent, Programmable  
Transient Digitizer

New Products

Volume 11  
Number 1

1979

# Tekscope



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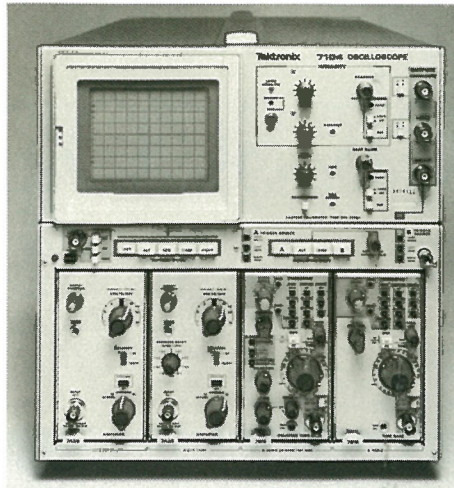
# Tekscope

Customer information from  
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Beaverton, Oregon 97077

Editor: Gordon Allison

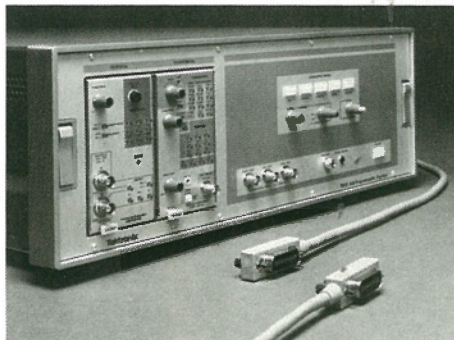
## 1 GHz at 1 mV in a General Purpose Plug-in Oscilloscope

The 7104 with its microchannel plate crt lets you view subnanosecond single-shot events directly from the crt screen.



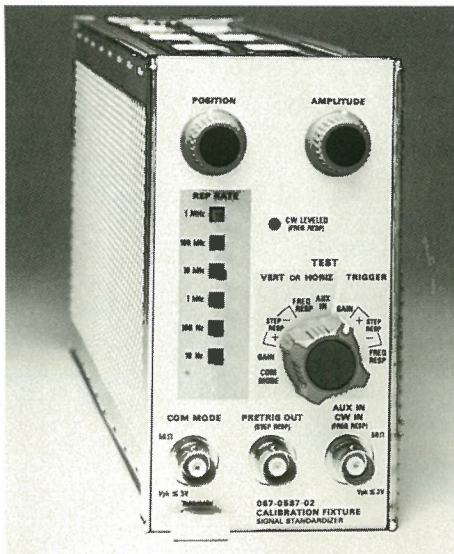
## An Intelligent, Programmable Transient Digitizer

The 7912AD is a fully programmable waveform acquisition and digitizing instrument compatible with GPIB.



## A New Calibration Fixture for the 7000-Series

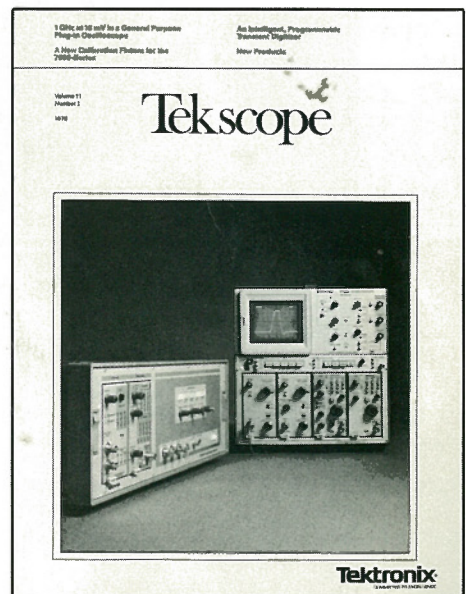
A new calibration fixture for the 7000-Series features 150 picosecond rise time, gigahertz sinewave leveling, and digitally generated staircase for amplitude and linearity checks.



Tekscope is a bimonthly publication of Tektronix, Inc. In it you will find articles covering the entire scope of Tektronix' products. Technical articles discuss what's new in circuit and component design, measurement capability, and measurement technique. A new products section gives a brief description of products recently introduced and provides an opportunity to request further information.

**COVER:** Two state-of-the-art products, the 7104 and 7912AD, provide new measurement capability and operating ease for analyzing high-speed signals.

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Cover photo by Jason Kinch



## 1 GHz at 10mV in a General Purpose Plug-in Oscilloscope



*Hans Springer was Project Engineer for the 7104 program. He came to Tek in 1962 from Enschede, Holland following graduation from the Higher Technical School and a brief period of military service. He received his MSEE in 1966 from Stanford University. Hans has contributed to many 7000-Series projects including the 7A14, 7503, and 7904. He also designed the 134 Current Probe Amplifier.*

Subnanosecond, single-shot events have been difficult, if not impossible, to view. They required use of a camera with a fast lens, 10,000 speed film, enhancement techniques such as film fogging, P11 phosphor for the crt screen, and a limited-scan display. Such events, thus recorded, left a dim trace at best.

The new TEKTRONIX 7104 changes all of that. Using a microchannel plate cathode ray tube, the 7104 achieves about a thousand-fold increase in single-shot trace brightness over conventional crt's. Individual subnanosecond events can now be viewed directly from the crt screen. Photographic writing speed, rated at 20 cm/ns (6.4 cm amplitude at 1 GHz), is measured using 3000 speed film without film fogging, an f1.9 camera lens with 1 to 0.85 reduction, and standard P31 phosphor. A fine trace width is maintained throughout the intensity range. For example, at full single-shot intensity no trace widening occurs.

Three new plug-ins have been developed to complement the 7104 Mainframe. The 7A29 Vertical Amplifier provides a system bandwidth of 1 GHz at a sensitivity of 10 mV per division. Two new time bases, the 7B15 and 7B10, provide normal or delayed sweep speeds up to 200 picoseconds per division, with triggering to 1 GHz and beyond.

The 7104 incorporates several new technologies to achieve this greatly improved performance. The key element in the system is the new T7100 cathode ray tube. A formidable set of specifications for the new tube called for a bandwidth at least twice that of previous designs, a three-times improvement in deflection sensitivity (over the T7904), writing speed sufficient to view subnanosecond single-occurrence events in normal ambient light, and improvement in spot size.

The solution to the writing-speed problem made possible much of the improvement realized in each of the other areas. A microchannel plate (mcp) structure, which provides an electron gain of about 10,000, is

placed just back of the phosphor screen in the crt. Some of this large gain potential in brightness is traded for the improvements in bandwidth, resolution, and sensitivity.

The microchannel plate is an electron multiplier device. Closely spaced across the plate are parallel, 1-millimeter length channels 25 microns in diameter, offset at a slight angle to the electron beam. The channel walls are coated with a material which exhibits secondary emission. Both sides of the plate are metallized so that an accelerating potential (mcp bias) can be established down the length of the channels.

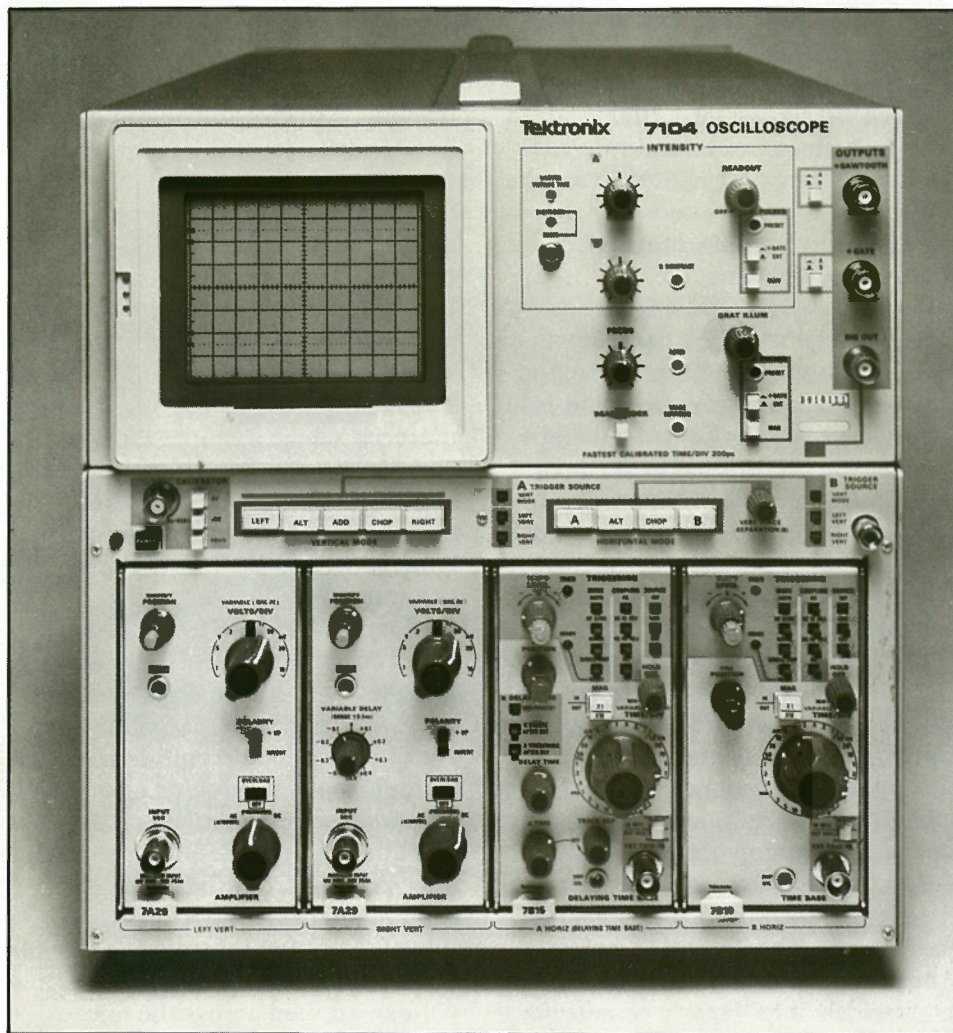
When an electron from the crt beam enters a channel, it strikes the channel wall, dislodging secondary electrons. The secondary electrons are accelerated and collide with the channel walls producing additional secondary electrons. The process cascades down each channel receiving electrons from the crt beam, producing an electron multiplication of about ten thousand. The multiplication is determined by the bias voltage applied across the microchannel plate structure.

Electrons exiting the channels are accelerated by the 12.5 kilovolt potential existing between the mcp structure and the aluminized phosphor screen, resulting in a bright, sharp trace.

The gun structure of the T7100 also includes several innovations. A scan expansion lens was needed to achieve the deflection sensitivity goal of 0.9 volt/division. Both the domed mesh and quadripole lens were considered and found to be less than optimum for our needs. A box lens, which functions similarly to a quadripole lens, proved to be the best solution.

The box lens is less critical with respect to dimensional and alignment tolerances, and also provides a means of correcting geometrical distortions caused by other elements in the gun structure. The lens provides an expansion of 4½ times in the vertical scan and four times in the hori-





**Fig. 1.** The 1 GHz 7104 Oscilloscope brings the versatility and operating ease of the 7000-Series to the measurement of single-shot or recurring subnanosecond rise time signals.

zontal scan. It is the last element the electron beam encounters before reaching the microchannel plate.

Both the horizontal and vertical deflectors in the crt are helical transmission line deflectors. The vertical deflector has an internal ground plane structure that yields an extremely rugged, precision design. Vertical deflection sensitivity is  $\leq 1$  volt per division (0.85 cm) and bandpass is about 2.5 gigahertz.

The horizontal deflector employs much the same construction as the vertical deflector in the T7904. The deflection sensitivity is  $\leq 2$  volts per division and bandpass greater than 1.5 gigahertz, allowing 350 megahertz operation in the X-Y mode of the 7104.

Most of the remaining elements in the crt gun structure are dedicated to minimizing spot size. A crossover demagnification lens serves to shorten the crt. It is interesting to

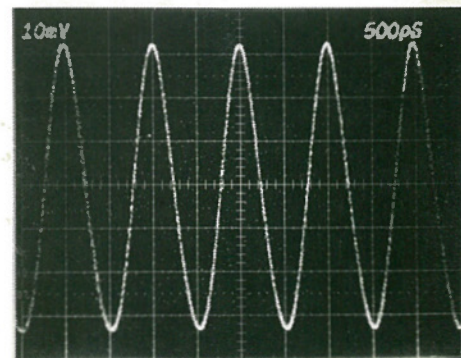
note that a crt using conventional techniques to achieve the same specifications would be over seven feet long.

### The vertical system

While design work was proceeding on the cathode ray tube, a parallel effort was under way to develop the high speed circuitry needed to complement the new display capability. Wider bandwidth amplifiers, channel switches, and attenuators, and faster sweep and triggering circuits, were needed. Also, the standard plug-in hybrid package had been pushed to its limit in the 500 MHz 7904. A new packaging and interconnecting system which would allow easy insertion and removal of wide-bandwidth devices was needed.

The answer to this need was development of a hybrid-to-printed-circuit connector system we

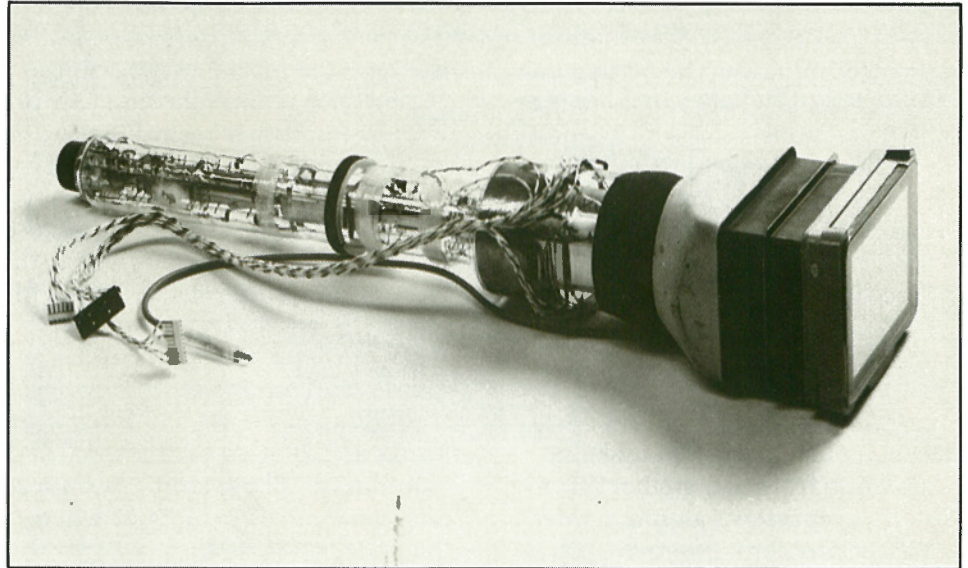
call HYPCON. The system uses a thin-film hybrid substrate to which integrated circuits are attached, and on which nichrome resistors and precision conductors are deposited. The precision conductors form transmission lines to carry signals from the edge of the substrate to the integrated circuits. The HYPCON is used to mount the substrate to the



**Fig. 2.** This single-sweep display of a 1 GHz sine wave shows the high writing rate capability of the 7104.



**Fig. 3.** The T7104 microchannel plate crt is the key to the 7104's performance. A portion of the box lens is visible just to the rear of the large black ring adjoining the funnel section.



printed circuit board and make the necessary connections for signals, control, and power.

The HYPCON connector consists of a plastic frame and an elastomer with gold contacts. The elastomer makes contact between the printed-circuit board and the substrate, and the plastic frame provides contact pressure and assures precise alignment (see Figure 4).

Two different types of HYPCON connectors — the flush and the stepped HYPCON — are used. The flush HYPCON provides better heat sinking since the hybrid substrate rests on a metal plate. This requires a hole in the circuit board. With the stepped HYPCON, the hybrid substrate rests on the groundplane of the circuit board. For most hybrids we use the stepped HYPCON, when the ground plane on the printed circuit board provides adequate heat sinking.

The circuit board material used for high-frequency signal transmission is glass-impregnated Teflon. This material gives lower losses than the standard G-10 glass-impregnated epoxy.

The HYPCON provides a practically reflection-free connection (as viewed on a 5 GHz TDR system), is inexpensive, and permits the hybrid to be replaced in only minutes.

### 6.5 GHz integrated circuits

To achieve a 1 GHz system bandwidth, the individual components in the system must, of course, have considerably greater bandwidth. The integrated circuit transistors used in the 7104 have a unity gain-bandwidth product in excess of 6 GHz.

A new high-frequency linear IC process we call super high frequency III (SHFIII) was developed specifically for the 7104. The Tek-developed  $f_T$  doubler cascode circuit and bridged-T coil peaking are used to achieve the high current gain-bandwidth needed. A novel approach we call "feedbeside" is used to match the low frequency gain to the high-frequency gain, rather than vice versa. Laser trimming with the circuit under power is used to set gain and input impedance to their nominal values.

### Wideband delay lines

The delay line in the 7104 provided its share of design challenges. At the frequencies involved, skin-effect losses become a major concern.

Such losses can be minimized by using larger cables; however, there is a practical limit to cable size, especially since the signal delivered to the 7104 Mainframe is differential,

requiring two delay lines. As large a cable size as feasible is used to minimize losses and still achieve the required 50 nanosecond delay. (Each cable is 32.5 feet in length). Even so, a passive, frequency-dependent hybrid equalizer is needed to compensate for skin-effect losses. This is accomplished by attenuating the low frequencies to match the high-frequency attenuation. The compensated line is flat within 0.25 dB to 1.5 GHz and has a 3 dB bandwidth of nearly 3 gigahertz. *1.53846 ns/ft.*

### Smoothering the signal paths

The gigahertz frequencies involved also required special attention be given to the signal and trigger interfaces between the plug-ins and the mainframe. A special "follower board" was developed for that portion of the interface connector which carries high-speed signals.

Precision 50-ohm strip lines are etched on the follower board; then the 50-ohm coaxial cables from the mainframe are soldered to the strip lines. Special contact fingers are soldered to the other end of the strip lines to make contact with the plug-in printed circuit board.

The follower board is held in place by a spring so that it can move lengthwise in the connector. When the plug-in is inserted into the 7104



Mainframe, the plug-in circuit board pushes against the follower board, eliminating the air gap between boards which causes inductive reflections.

As the input signal traverses the forty feet of signal path in the 7104 vertical system, it encounters several kinds of transmission lines — three types of coaxial cable, printed circuit microstrip lines, hybrid microstrip lines, coplanar flexible printed circuit lines, and the crt helical deflector.

Each place the signal makes a transition from one kind of line to another represents a unique interconnect problem. Extensive physical modeling and TDR testing was used to produce a very clean system. The largest single discontinuity occurs at the carefully spaced crt neck pins which provide access to the horizontal and vertical deflectors.

### The horizontal system

Handling the fast sweeps needed to display subnanosecond rise times requires a wide bandwidth horizon-

tal system. The T7100 horizontal deflector is a helical deflector similar to that used for the vertical in the T7904. The scan expansion lens provides a four times magnification on the horizontal axis for a sensitivity of 2 volts/division at the crt.

The 7104 horizontal amplifier uses many of the same techniques as the vertical amplifier. Bandwidth with the 7A29 is 350 MHz.

An optional delay line allows phase matching to be obtained at any frequency up to 250 MHz when using a 7A29 with variable delay (Option 04). Phase shift is within 2 degrees from dc to 50 MHz when balanced at 35 MHz.

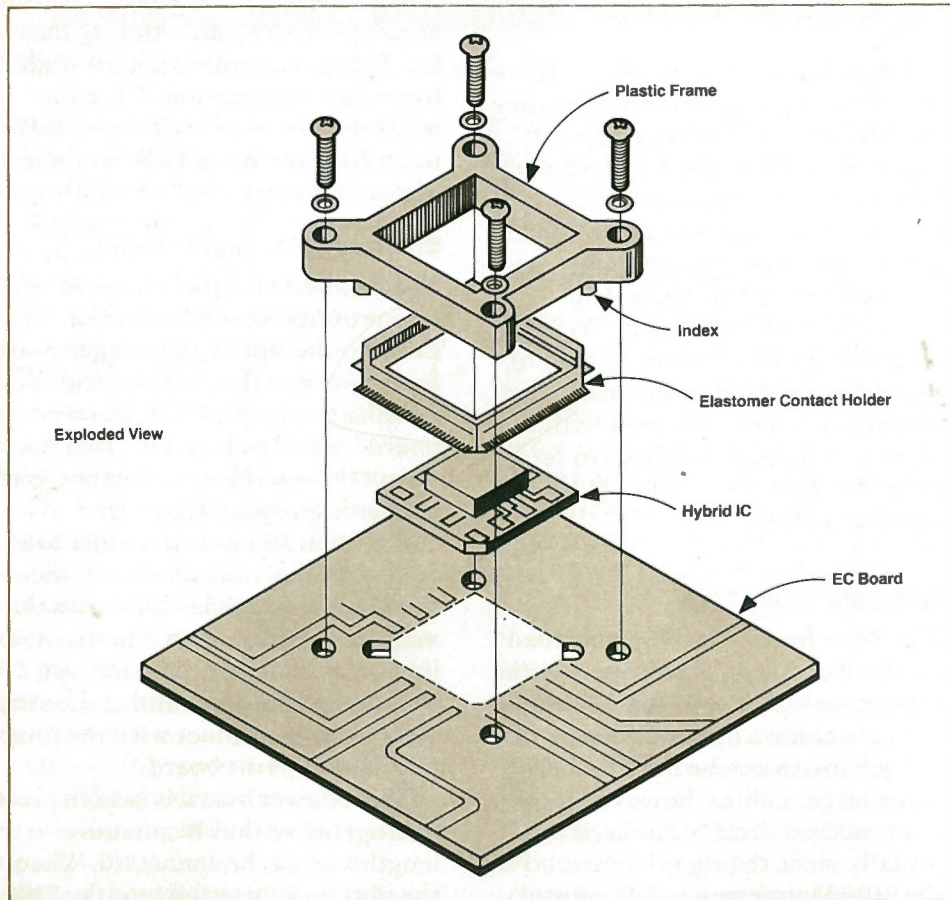
The 7B10 and 7B15 Time Base Plug-ins feature the same versatile delta delay measurement capabilities introduced in the 7B80 Series. They also use the new sweep circuit developed to replace the traditional Miller integrator. A sweep start gating circuit and a selectable timing current source are used to charge a grounded timing capacitor.

This configuration yields fast sweep speeds with very clean sweep start characteristics, while maintaining good accuracy and linearity. Top sweep speed has been extended to 200 picoseconds per division.

### Triggering to 1 GHz

Wide bandwidths, fast sweeps, and a high writing rate crt allow you to see signal jitter that is normally masked in a lower performance system. This places severe requirements on the trigger circuitry of the 7104.

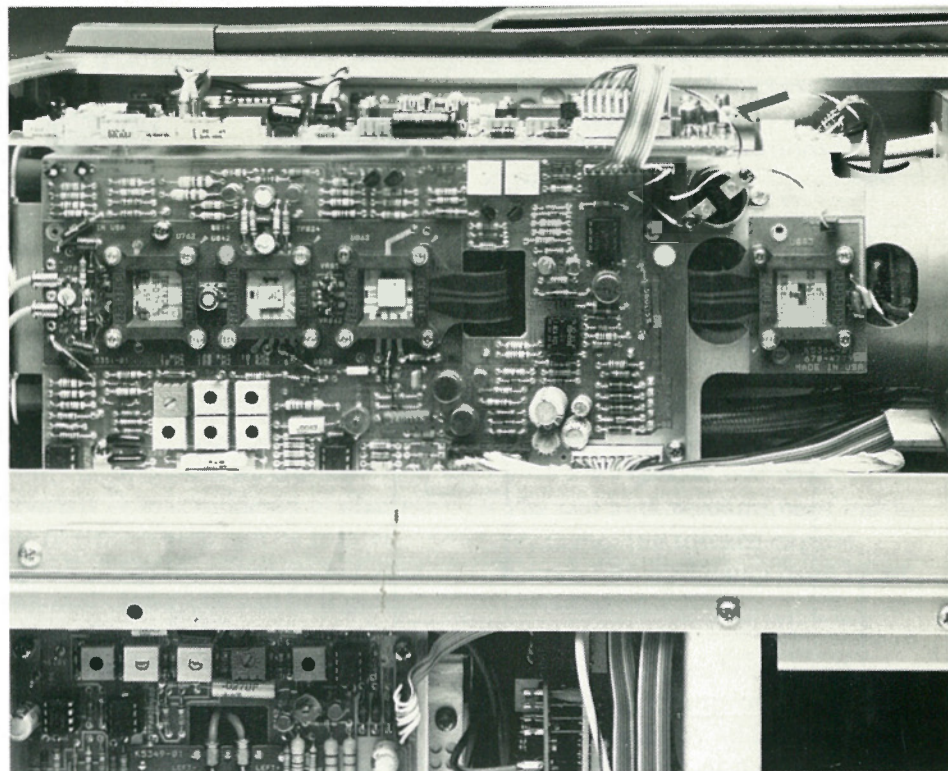
Two new integrated circuits were developed for the trigger using the SHFIII process. The first serves as a trigger amplifier, selects internal or external trigger source, selects the trigger coupling mode, and processes the trigger level input. The second serves as the trigger generator. It contains a trigger amplifier and two ECL latches. The amplifier is switchable to provide slope selection. The two latches operate in series, one arming or enabling the other, to provide a fast,



**Fig. 4.** The HYPCON connector system provides a fast, electrically clean method of mounting high-speed hybrids.



**Fig. 5.** Photo of vertical amplifier shows clean, open construction afforded by the HYPCON connector system.



clean trigger for gating on the sweep generator.

The latches are also used to produce stable high-frequency synchronization (see Figure 6). In the HF SYNC triggering mode, feedback is applied to the trigger amplifier to force the signals to the latches to be centered regardless of the dc component of the trigger input signal.

The trigger LEVEL control is switched to allow control of the hysteresis width (the voltage difference between the arm level and trigger level of the arm latch and trigger latch, respectively). With the LEVEL control, the hysteresis can be adjusted to zero and below. If the hysteresis is negative and no input signal is present, the dc-centered input at the latches exceeds both the arm and trigger levels and both latches are set when the holdoff signal goes LO. The sweep thus free runs at a frequency determined by the sweep and holdoff times.

When a trigger signal is present and the LEVEL control is used to control the hysteresis width, the trigger level of the trigger latch is moved up and down the signal until a locked or synchronized display is

obtained. The characteristics of the circuit have a tendency to "pull" making it easy to produce an exceptionally stable display, even at a gigahertz.

### Mechanical design

Many of the challenges facing the 7104 mechanical design team involved creating electrically clean interfaces between hybrids and circuit boards, between circuit boards themselves, and between the mainframe and plug-ins.

Implementing the HYPCON concept for making a low cost, fast, clean, interconnection between high-frequency hybrids and circuit boards was a major contribution to the 7104 project.

The follower board, which provides a clean interface for trigger and signal paths from the plug-ins to the mainframe, while not as extensive an undertaking, was an important one.

A refinement to the Tek-developed Peltola high-frequency connector was made to provide a more precise connection between small coaxial cables and the circuit boards.

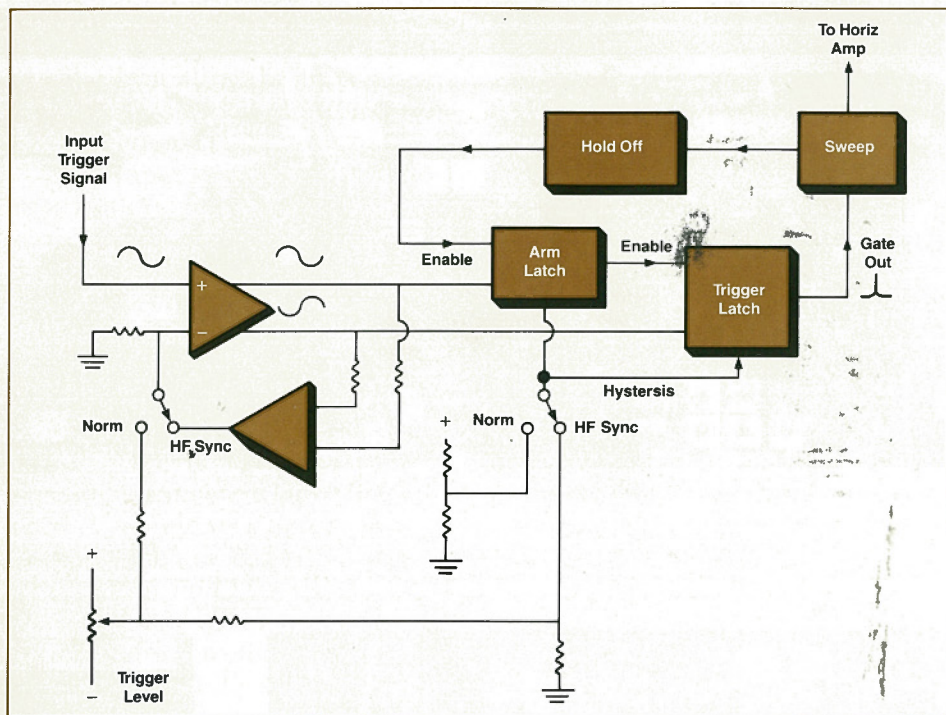
Another task involved making a

clean transition from the bulky delay lines, to small 50-ohm coaxial lines for connection to the circuit board. This was solved by drilling a small hole in the center conductor of the larger delay line and inserting a small socket to receive the center conductor of the smaller line. A four-piece clamp couples the two outer conductors and provides a secure mechanical bond.

Proper cooling provided its share of challenges. A plenum chamber at the rear of the instrument is used to produce a smooth flow of air across the vertical and horizontal amplifier sections to the exhaust fan.

Ease of maintenance is an important factor in mechanical design and received its share of attention in the 7104. The upper and lower sections of the instrument are hinged at the rear, with a built-in tilt bail provided near the front to keep the sections apart. Access to all of the circuitry is unusually good for an instrument of this complexity. For example, the substantial high-voltage circuitry is just behind a clear cover along the upper right-hand side of the instrument.





**Fig. 6.** Dual latch triggering system eliminates traditional multivibrator used as a count-down device. The trigger level adjusts hysteresis between latches to achieve "lock-on" at frequencies to 1 GHz.

## Summary

The 7104 and its associated plug-ins are designed to let you view and measure low-amplitude gigahertz signals with the same ease as those in the 1 MHz range. Short pulses and fast rise times occurring at low repetition rates can be viewed directly from the crt. Delta delayed sweeps, crt readout, and other operating features common to the 7000 Series have been retained.

From the operational viewpoint you might say the 7104 is "just another 7000 Series Oscilloscope." But from the measurement capability viewpoint it is a giant leap forward.

## Acknowledgements

The 7104 project, spanning some seven years, has been one of the most extensive undertaken by Tektronix. Val Garuts was the original Project Manager, with Gene Andrews taking over about mid-stream. Joel Davis did the early mechanical design with Neal Broadbent taking over the reins and completing the work.

John Addis, Project Engineer on the 7A29, worked out the vertical system design, assisted by Winthrop Gross. Dave Morgan did the main-

frame horizontal amplifier, and Art Metz the Z-axis design. The 7B10 and 7B15 Time Base Plug-ins are the work of Art Metz and Bruce Hofer. Art did the trigger design and Bruce the sweep circuit design. Chuck Davis and Ed Wolf are responsible for the 7A29 and 7B10/7B15 mechanical designs, respectively. Bill Berg, Chuck Davis, and John Addis each contributed to the development and implementation of the HYPCON connector system.

Much credit is due Walt Ainsworth, Binoy Rosario, and others in IC Engineering; and Doug Ritchie, Jon Schultz, and the folks in IC Processing, for their contributions.

Dennis Hall was Project Leader for the team that did the outstanding job on crt design.

The 7104 Mainframe prototypes were built by Lois Davis, with Jan Bowden performing a similar function for the plug-ins. Gary Bohms was the technician for the project.

Many others should be included in this list but time doesn't allow. Each can take personal pride for their part in a seemingly impossible task well done.



## An Intelligent, Programmable Transient Digitizer



Dale Aufrecht has been with Tek since 1961 and during most of this time has been involved with technical writing in one capacity or another. Following a period as a manuals writer, Dale joined the staff of Tekscope and authored several fine articles for both Tekscope and external publications. He is currently Documentations Manager for the Signal Processing Systems business unit. Dale has an Associate degree in Applied Science from Oregon Institute of Technology and is working on a degree in Business Administration at the University of Portland.

### Intelligence!

What is intelligence? Can an inanimate object have intelligence? Whatever your views on this subject, the world around us is changing — the toys that fill our leisure time, the microwave ovens that cook our food, the cars that we drive. Pseudo-intelligence is the “in” thing. And the key to this onslaught is the microprocessor — the do-all miracle chip.

How about another controversial subject? Is the world a continuum of events as proposed by analog theorists or is it made up of discrete bits of time which can be treated digitally? Again, regardless of your personal views, the world is going digital. Digital techniques make the microprocessor tick. And even the ubiquitous telephone is being converted to digital.

Now onto this stage comes a new entrant into the test and measurement field — the TEKTRONIX 7912AD Programmable Digitizer — combining the intelligence of the microprocessor with digital signal-processing techniques. The 7912AD bears a strong family resemblance to its forerunner, the R7912 Transient Digitizer. However, much of the resemblance ends at the outside covers. Using the proven concept and analog circuitry of the R7912, the 7912AD adds several significant capabilities:

- Full programmability of the measurement parameters.
- Full implementation of the IEEE 488-1975 interface standard (commonly called the GPIB) in a test and measurement instrument.
- On-board signal processing to ease the load on the external computer and software.
- Use of several microprocessors as a “team.”

### Why Build A “New” Model?

The R7912 Transient Digitizer was the world’s fastest digitizer when introduced five years ago. In the ensuing years, there have been no serious pretenders to this title and the R7912 is still considered the ulti-

mate measurement instrument within many industries.

So why fool with success? The answer can be found by examining R7912/7912AD applications in detail:

- Multiple-instrument systems are used.
- Large volumes of data are collected from each test.
- Tests often are expensive or can only be made once.
- Test area environment is hostile to both man and instrument.
- The test and measurement industry is moving toward capital investment and away from labor investment.

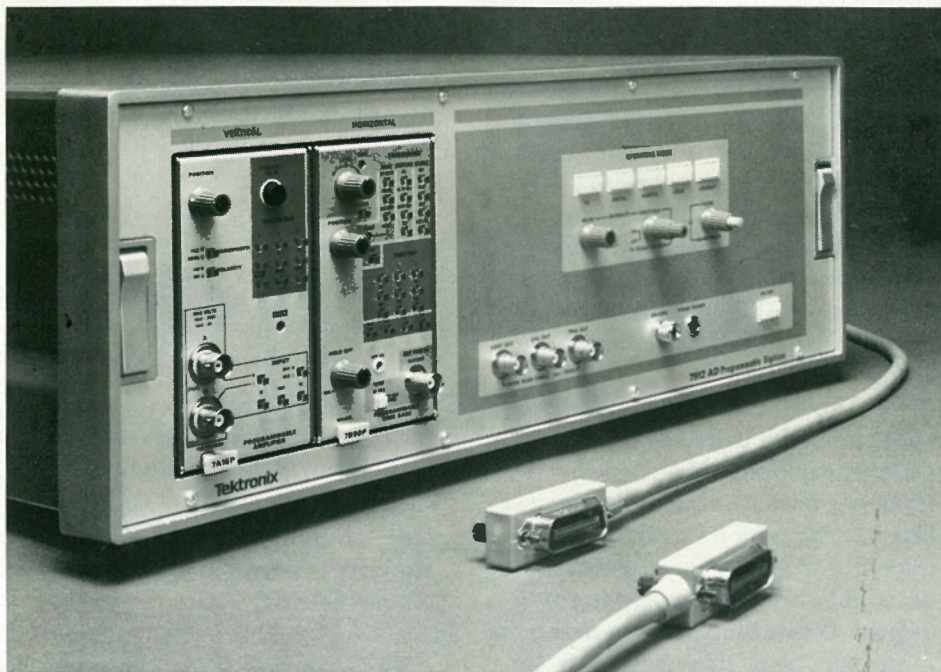
These and other factors influenced the decision to improve upon the R7912 concept by adding new, advanced features. As a result, Tektronix introduced the 7912AD Programmable Digitizer, 7A16P Programmable Amplifier, and 7B90P Programmable Time Base to the real world of measurements. Let’s characterize each of these instruments.

The 7912AD Programmable Digitizer is a fully programmable waveform acquisition and digitizing instrument. It features a digitized writing rate of 8,000 equivalent divisions per microsecond, or up to 30,000 equivalent divisions per microsecond in the TV mode. The 7912AD can digitize a time window from 10 milliseconds to 5 nanoseconds, which is equivalent to sampling rates between 50 kilohertz and 100 gigahertz.

While the vertical bandwidth depends upon the TEKTRONIX 7000-Series Plug-in selected, the following benchmarks can be noted: 7A16P Programmable Amplifier, dc to 200 megahertz with full programmability; 7A19 Amplifier, dc to 500 megahertz; 7A21N Direct Access Plug-in, dc to 1 gigahertz with an uncalibrated deflection factor of less than 4 volts/division.

The 7A16P Programmable Amplifier features bandwidth of dc to 200 megahertz (in 7912AD) and





**Fig. 1.** The 7912AD Programmable Digitizer uses the IEEE 488 (GPIB) for control and signal interfacing with a variety of instrumentation controllers.

calibrated deflection factors from 5 millivolts/division to 5 volts/division. Input impedance is switchable between 50 ohms and 1 megohm and the input coupling may be ac, dc, or ground reference. All of these features can be selected under program control.

The 7B90P Programmable Time Base provides calibrated sweep rates from 500 picoseconds/division to 500 milliseconds/division, triggering to 400 megahertz, and single-sweep operation. These features can be selected under program control.

The 7912AD, 7A16P, and 7B90P are largely adapted from field-proven instruments. The heart of the 7912AD is the Tektronix-developed T7910 scan-converter tube (see Figure 2). The vertical and horizontal deflection systems are virtually unchanged from the R7912. Likewise, the analog circuits of the 7A16P and the 7B90P are nearly identical to the TEKTRONIX 7A16A Amplifier and the 7B80 Time Base.

While the scan-converter technique used in the 7912AD has been discussed before, it warrants a quick review. Scan conversion transforms a signal from one data rate to another. In the 7912AD, high-speed analog input signals are converted to one of two output formats. In the

TV format, the high-speed input signal can be viewed on a relatively low-frequency video monitor. In the digital format, the resultant data can be processed using digital signal-processing techniques.

The 7912AD uses two scanning systems to convert the input signal to the desired output signal. The scan-converter tube consists of two facing electron guns with a scan-converter target positioned between them. The target is an array of diodes with a density of 2000 diodes per inch, formed on a thin silicon wafer. The low-speed reading beam continuously scans this target, reverse biasing each of the diodes in the array.

When a high-speed input signal is applied to the 7912AD, the writing beam writes the resultant waveform on the target by forward-biasing the target diodes. When the reading gun scans a "written" diode, more beam current is required to return the written diode to a reverse-biased state. Circuitry in the 7912AD senses this change in beam current and reconstructs a facsimile of the high-speed signal in a more usable, low-speed format.

#### **A Microprocessor Team**

The 7912AD uses two microprocessors to control the instrument, pre-

process data, and direct storage of measurement data in local memory. Figure 3 shows a block diagram of this multiple microprocessor system.

The first microprocessor, a 6800, serves as the Master Controller. It decodes IEEE 488 bus commands, delegates tasks to other blocks, controls signal processing, and runs power-up tests at turn-on. Each of the plug-ins also has a 6800 microprocessor which is addressed by the Master Controller for communications such as scale-factor readout or control-setting queries.

The second microprocessor in the mainframe, a 2900, operates in a slave mode to unscramble the data pouring out of the scan converter. Using firmware algorithms, the 2900 acquires data in response to a digitize command, stores the raw data in memory, performs signal processing on this raw data, and outputs data either to the IEEE 488 bus or to the X-Y-Z signal outputs (refreshed mode).

The 2900 microprocessor deserves a closer look. This device (actually a seven-chip set) is a bipolar bit-slice microprocessor which uses a pipeline register to shorten cycle time. The 2900 was chosen because it allows designers to tailor the instruction set for an optimum design.



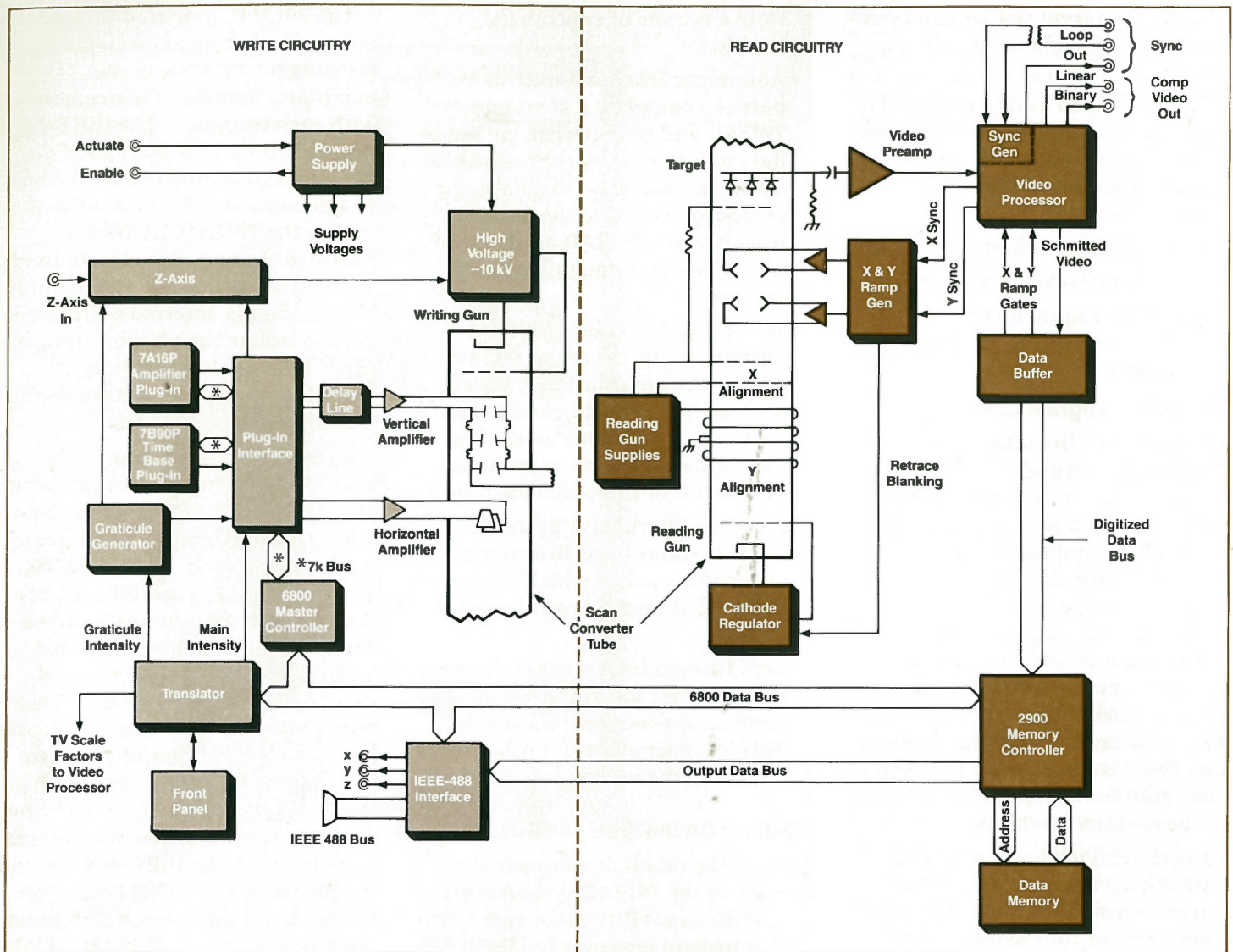


Fig. 2. Block diagram of the 7912AD showing the read and write section of the scan converter.

As a result, the 2900 performs its assigned functions much faster than if a microprocessor with a predefined instruction set were used. In fact, the 2900 is even faster at its assigned signal-processing tasks than many minicomputers.

A DMA (Direct Memory Access) type of data transfer over the IEEE 488 bus is available upon command. The IEEE Interface sets up bus handshakes for a maximum data transfer rate of 500k bytes/second. This is faster than most listeners presently operating on the IEEE 488 bus.

Fast transfer is accomplished by taking advantage of the 2900's speed and employing pipeline data transfer techniques between the 2900 Memory Controller and the IEEE

488 Interface. As the IEEE 488 Interface processes and outputs the data into the pipeline, the 2900 Memory Controller can simultaneously fetch more data to refill the pipeline.

### Data Handling Eases the Computer Load

One of the major challenges of interfacing the R7912 was the data format (or rather, the lack of format) at the output connector. As a result, any software designed to process this data had to first decode the data and then put it into some semblance of order — not a trivial task by any means.

Another problem was the way the scan-converter tube detected signals. Normally, the tube outputs two digital values for each location of the

vertical trace — one for the top edge and another for the bottom. To provide meaningful information for signal processing, these two edge values must be reduced to a single value representing their average.

In designing the 7912AD, the task of data formatting was turned over to the 2900 microprocessor in the mainframe. Using firmware algorithms, the 2900 formats and preprocesses the data to ease the load on the external computer. Among the data formatting and signal-processing tasks accomplished by this microprocessor are:

- Reformatting the data so the first data value output corresponds to the left side of the target.
- Flagging any defects in the scan-



converter target so they can later be removed from the waveform data.

- Performing an average-to-center-of-trace computation so that only one vertical output per horizontal point is produced regardless of beam width.
- Interpolating missing data points.
- Identifying waveform edges.
- Signal averaging up to 64 times (only 1.5 seconds required for 64 averages).

### All Under Program Control

Programmability allows the 7912AD, 7A16P, and 7B90P to perform complex tasks according to a predetermined plan (a program stored in a computer). Programmability also allows instruments to be operated from a remote location by an operator at a computer terminal (often a Tektronix graphic terminal). The test and measurement industry is moving toward programmable instruments, and there is strong early interest in the 7912AD, 7A16P, and 7B90P. Some of the reasons for this are:

- Hostile Environments. Test instruments are often located in areas where human control is undesirable or impossible — for example, near a large laser system.
- Remote Locations. Test instruments are often located great distances from the control console. With programmability, these instruments can be set or checked

from a remote or centralized location.

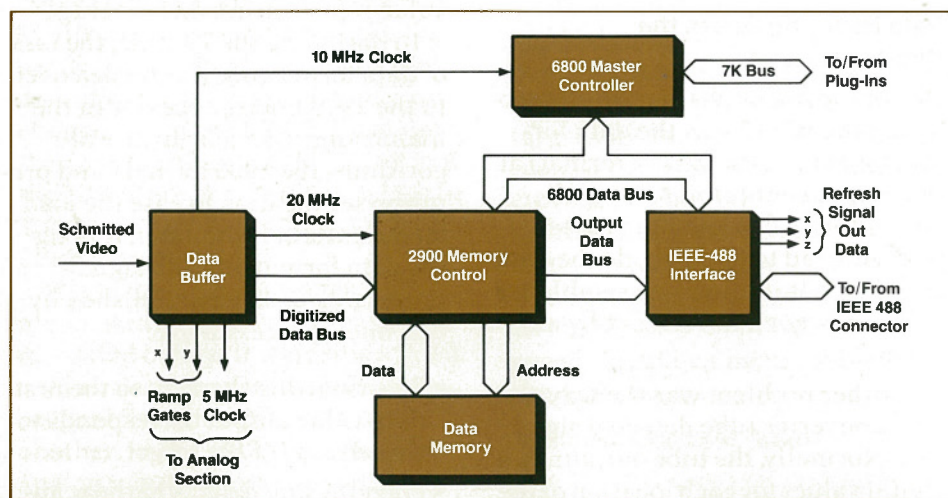
- Automatic Test and Control. As part of a complete test system, the 7912AD and plug-ins can gather data for analysis by the central computer. Based on this data, the computer can issue control commands to the 7912AD and plug-ins or to other equipment in the system.
- Pre-Test Calibration. With programmability, the entire test system can be automatically tested and readjusted just before the experiment is run. This saves time and money since many tests may be difficult or impossible to repeat.
- Multiple Instrument Systems. Some systems have 30 or more instruments, each of which can be set or checked from a central control console.
- Less Human Intervention. A single operator can control many instruments from one control console. This frees personnel for other tasks requiring the human touch.

### Getting On the IEEE 488 Bus.

One of the major advances in the design of the 7912AD system is giving it the capability to converse with other instruments over the IEEE 488 bus (commonly called the GPIB). The 7912AD system is compatible with the protocol defined in IEEE STD 488-1975 — IEEE Standard Digital Interface for Programmable Instrumentation.

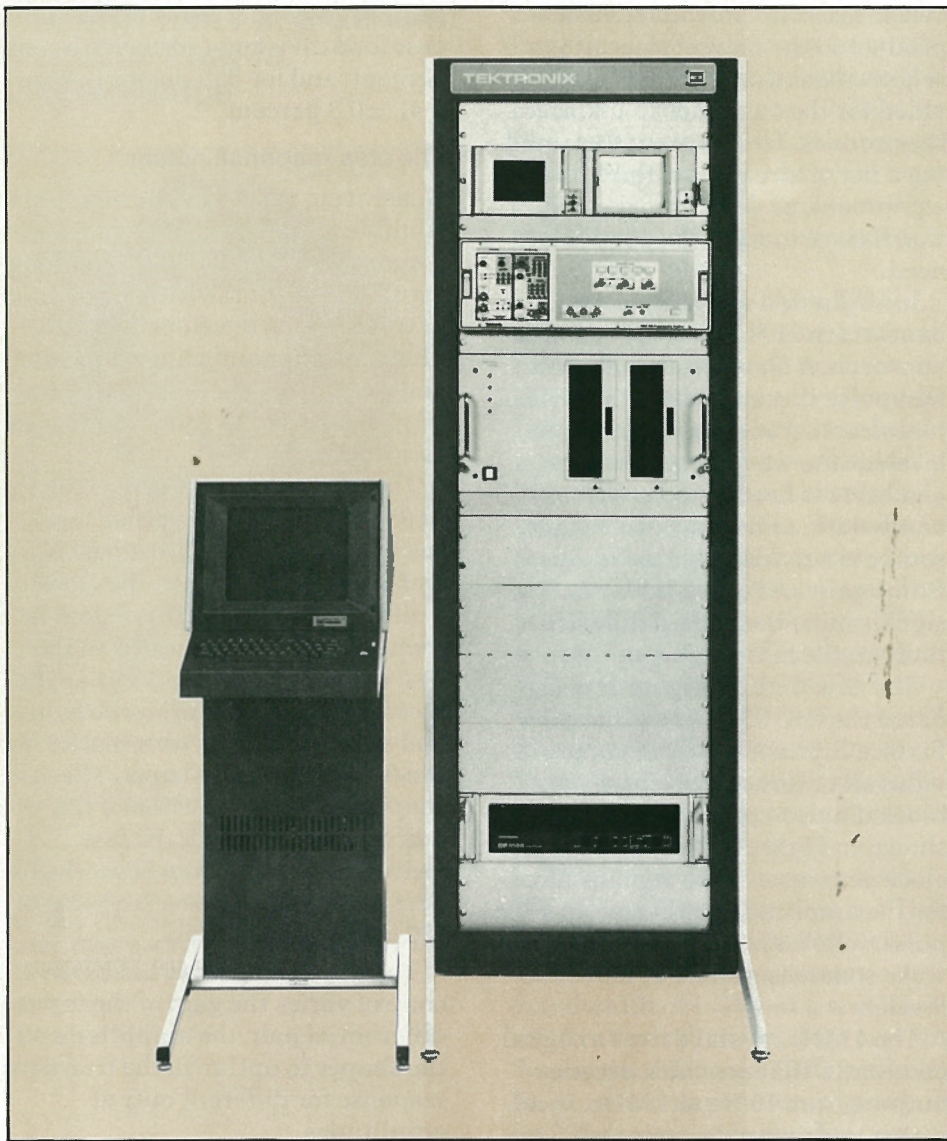
The 7912AD system combines internal buffering and extended addressing to allow use of the maximum number of instruments with each computer. The IEEE 488 standard limits the number of device loads (instruments) on the bus to a maximum of 15. Instead of allowing the 7912AD, 7A16P, and 7B90P to each represent an individual load on the bus for a maximum of five systems, internal buffering is used to isolate the plug-ins from the IEEE 488 bus. As a result, each 7912AD system represents only one load on the bus.

Extended addressing provides similar expansion of the addressing capabilities. The IEEE 488 standard allows only 30 individual addresses on the bus. If each 7912AD, 7A16P, and 7B90P had a separate address, only ten 7912AD systems could be connected to each bus. Extended addressing assigns a primary address to each 7912AD system. Then, a secondary address is used to access either the 7912AD mainframe programmable functions, the 7A16P, or the 7B90P. However, the mainframe appears transparent to communications between the IEEE 488 bus and the plug-ins. The 6800 Master Controller determines which commands are intended for the 7912AD, 7A16P, or the 7B90P and directs them to the correct unit. Extended addressing can be compared to the concept of apartment house addressing where a primary street address refers to the apartment building and secondary



**Fig. 3.** A microprocessor team controls the instrument, preprocesses data, and directs storage of data in local memory.





**Fig. 4.** The WP2250 Programmable Digitizer System is a self-contained signal acquisition and data processing system with CP4165 Instrument Controller and TEK SPS BASIC. Up to three additional 7912ADs can be added to the WP2250.

addresses refer to each apartment unit. As a result of this addressing scheme, more 7912AD systems can be connected to, and controlled by, each computer.

As an added bonus, use of the IEEE 488 interface bus allows the 7912AD, 7A16P, and 7B90P to be on talking terms with the many instruments presently available with a similar interface. And the number of IEEE 488 bus compatible instruments is growing every day, making compatibility an even more important concept for the future.

#### **Applying the 7912AD**

With an industry standard interface, programmability, and on-board signal preprocessing, the 7912AD system is ready for action. How you put it to work depends upon your mea-

surement needs and intended applications. The easiest way to get into measurement action is with complete measurement systems from Tektronix (see Figure 4). These high-performance systems combine signal acquisition, data storage, and signal processing with a powerful minicomputer. System parameters may be tailored to measurement needs through selection of minicomputer, peripherals, and the number of acquisition channels.

Combining the 7912AD and the TEKTRONIX 4051 Graphic System Controller provides a low-cost, yet powerful measurement system. In this configuration, the user must write system software using 4051 BASIC. However, the job is made easier by the 4050 Series R07 Signal

Processing ROM Pack No. 1. This ROM pack allows the 4051 to perform signal-processing functions on waveforms or other data stored in single-dimensioned arrays with a single command. Functions provided are maximum, minimum, cross, two-point differentiation, three-point differentiation, integration, and graphic display of the array.

Another choice is to build a system around your present controller, the 7912AD, and its plug-ins. The IEEE-488 bus interface and on-board signal processing help you get started. And the reference information provided in the instruction manuals will also prove helpful in your task.

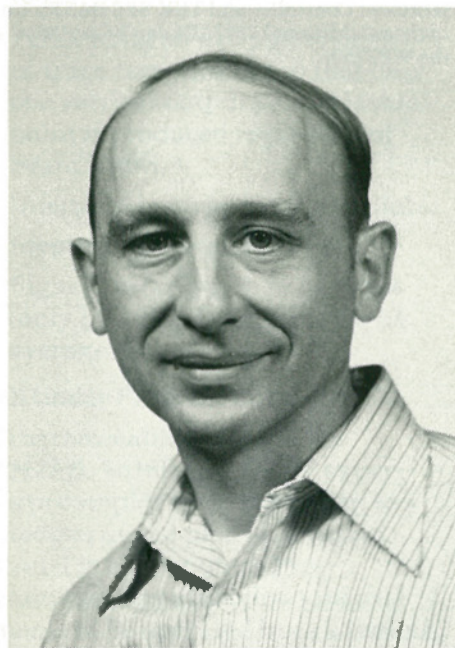
#### **Acknowledgements**

The 7912AD, 7A16P, and 7B90P were the result of a true team effort. Many people from a variety of disciplines throughout Tektronix contributed to the success of this project. Project development was guided by Stu McNaughton, 7912AD Project Manager. Bob Bretl headed the Firmware Design team.

I would like to thank Stu McNaughton and Steve Tuttle, SPS Engineering, for their significant contributions to this article.



## A New Calibration Fixture for the 7000 Series



Art Metz joined Tek in 1969 following a 7-year stint at Argonne National Labs. He has contributed to several 7000-Series Plug-in projects. Art designed the 7000-Series Calibration Fixture Plug-in. In addition, he designed the high-speed front ends for the 7D14 and 7D15, the peak-to-peak automatic triggering for the 7B80 Series, and the 7B10/7B15 trigger system, including the IC trigger amplifier and trigger generator. He also designed the Z-axis circuitry for the 7104.

When Tektronix introduces a new product to the marketplace, it is a requirement that a means be provided for the customer to maintain the product. This may entail providing a list of already-available test equipment, or developing a calibration fixture to meet the particular need.

Introduction of the gigahertz bandwidth 7104 dictated the latter approach. A fast-rise, low-aberration pulse is required to adjust the mainframe transient response, a leveled sine wave to beyond one gigahertz is needed to verify bandwidth, and an accurate signal source is needed to set the mainframe gain and check linearity. The signals must be applied differentially to the mainframe inputs.

The new fixture (Figure 1) designated the 067-0587-02 Calibration Fixture Signal Standardizer, provides all of these capabilities. A block diagram of the fixture is shown in Figure 2. A crystal-based clock generator is the signal source for the amplitude calibrator and the pulser, while an external leveled sine wave source is needed to drive the leveler.

The 1 MHz crystal drives a digital counter IC that provides decade outputs from 10 Hz to 1 MHz. In addition to driving the staircase generator and pulser, this signal is brought to the front panel as a pre-trigger output. Repetition rate accuracy is 0.1 percent making it suitable as a timing reference.

### The staircase generator

The signal used to set the gain of the mainframe amplifier is an eleven-step staircase. This type of signal provides a convenient means of checking linearity while setting the gain. The sweep is usually free run to provide a display as shown in Figure 3.

The staircase generator uses a 16-count counter and a multiplexer to give eleven discrete levels. The digital signal for level six (0 volts) is maintained for five counts producing a bright trace useful as a reference in adjusting the staircase to

center screen. Accuracy of the staircase for 6 divisions ( $-3$  to  $+3$ ) is  $\pm 0.3$  percent, and for 8 divisions ( $-4$  to  $+4$ ),  $\pm 0.5$  percent.

### The step response pulser

Generating a fast-rise, flat-top pulse suitable for checking the transient response of the 7104 was a challenging task. Two of the wide-band integrated circuits developed for the 7104 amplifier and trigger circuits, and a Schottky-diode hybrid shaper (Fig. 4) are used to generate the fast rise signal.

The clock signal is delayed for 55 to 95 nanoseconds (internally adjustable) and applied to a pair of transistors that convert the clock to a differential signal. This signal is then amplified and limited in the first of the two high-speed ICs. The second IC supplies still more gain and serves as a back termination for the Schottky-diode shaper. The shaper clips out a portion of the amplified pulse, with the fast switching action of the Schottky diodes producing a pulse rise time of 150 picoseconds or less.

The front-panel AMPLITUDE control varies the gain of the input differential pair, the amplifier, and the shaper to optimize the transient response for different output amplitudes.

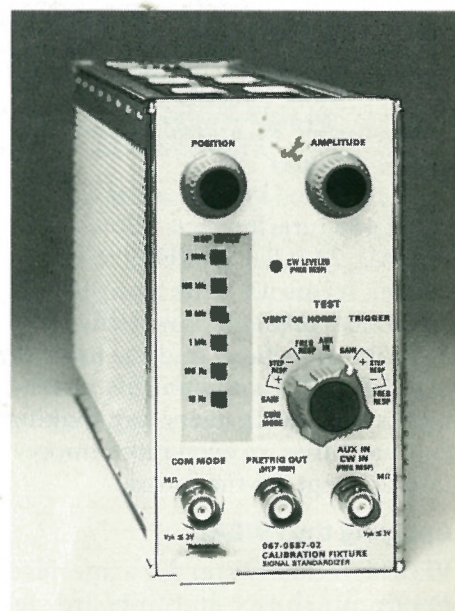
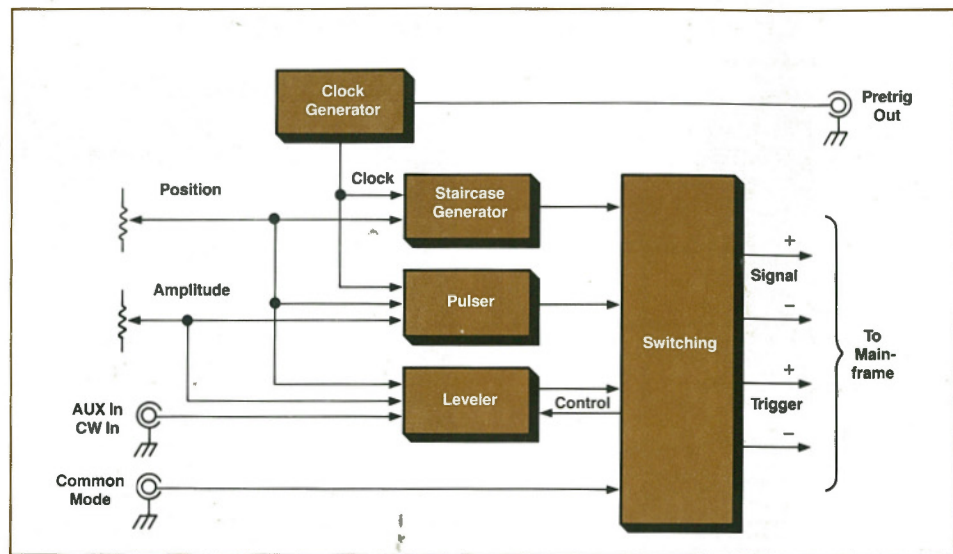


Fig. 1. The New Calibration Fixture Signal Standardizer is a calibration aid for all 7000-Series Mainframes.



**Fig. 2.** Simplified block diagram of the calibration fixture. Outputs to the mainframe must be applied differentially in a clean 50 $\Omega$  environment.



### The leveler

To check the bandpass of the 7104 Mainframe a leveled sine wave signal to one gigahertz and beyond is needed. Here, again, a differential signal is required. An external leveled sine wave generator capable of putting out 0.4 to 1.0 volt peak-to-peak is needed to drive the leveler circuit. A front-panel indicator is supplied to alert the operator should the input signal exceed these limits.

The single-ended input signal is converted to a differential signal by passing through a balun. It is then amplified using the same wide-band hybrid amplifier developed for the 7104. The amplifier drives a differential diode detector which is unique in that it detects from rail to rail rather than from rail to ground. This provides proper leveling even though the signal contains common-mode elements.

The output of the detector adjusts the gain of the amplifier, through an automatic gain control (agc) loop. A temperature-compensating reference diode (mounted on the differential detector hybrid) provides a correction signal to the agc loop to compensate for temperature variation in the detector diodes.

The leveler circuit provides an output signal at least 10 divisions in amplitude and maintains the amplitude within  $\pm 3$  percent over a frequency range of 3 MHz to 1 GHz.

### Switching the output

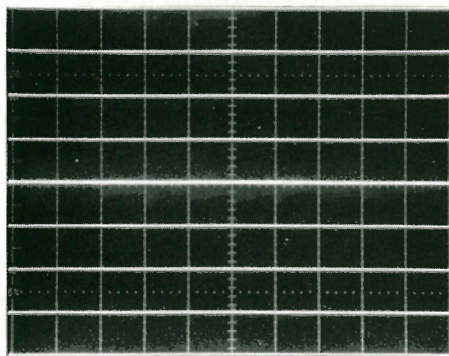
Switching the various calibration signals to the outputs of the fixture provided another design challenge. A 10-position, 18-section cam-operated elastomer switch was developed which maintains a 50-ohm environment for the signal and trigger inputs to the 7000-Series Mainframes.

### Summary

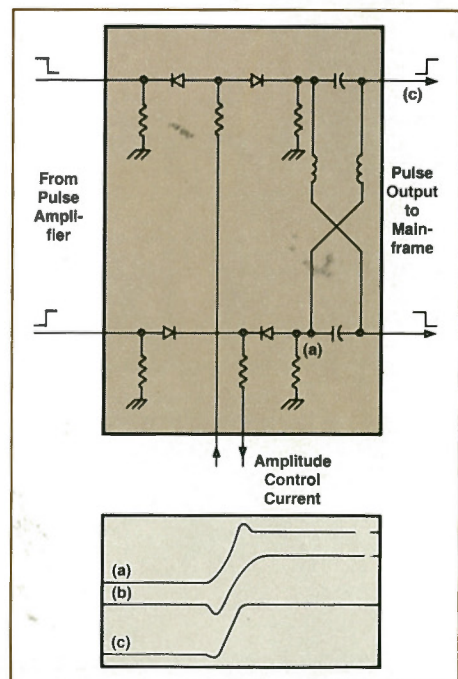
State-of-the-art components and circuit design are employed to develop a calibration fixture suitable for all 7000-Series Mainframes including the new 7104. A crystal-based digital clock drives a staircase generator useful for setting gain and checking linearity. A selectable rep rate pulse with 150 picosecond rise time and  $<2$  percent aberrations is available for adjusting transient re-

sponse. And a leveler circuit that maintains a constant amplitude sine wave output within  $\pm 3$  percent over a frequency range of 3 MHz to 1 GHz provides a means of verifying bandwidth.

All of these capabilities, and more, are included in the new 067-0587-02 Calibration Fixture Signal Standardizer. It is representative of our continuing commitment to assist

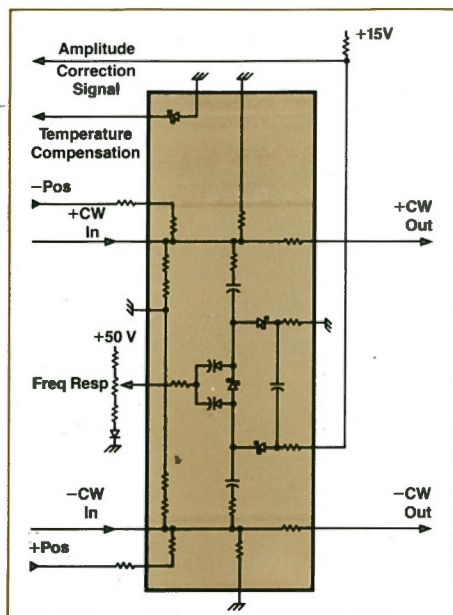


**Fig. 3.** Staircase signal displayed with the sweep free running. Both gain and linearity can be quickly checked with this display.



**Fig. 4.** Schottky-diode switch produces fast-rise output pulse (a). The L-C networks have a response that compensates for the diode capacitance (b). The resultant output pulse has a fast, clean leading edge with less than 2% aberration.





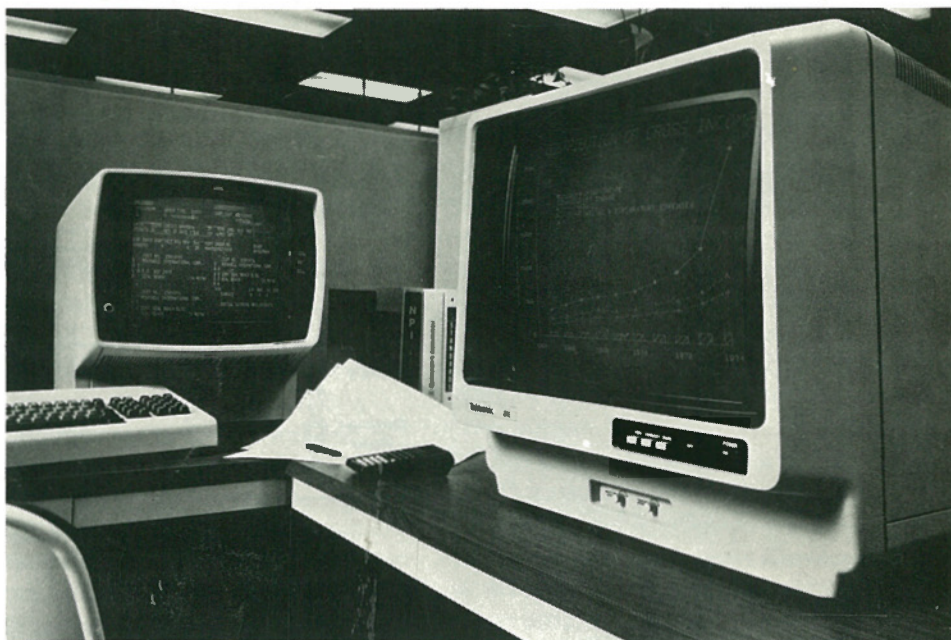
**Fig. 5.** Hybrid peak detector for the sine wave leveler is unique in that it detects from rail to rail. This gives proper leveling even with the presence of common-mode signals.

our customers in maintaining their TEKTRONIX Products.

#### Acknowledgements

I would like to express my appreciation to Ed Strande for his work on the elastomer switch, and to Jan Bowden for building the prototypes.

## New Products



### New Tektronix 618 Display Fully Compatible With IBM 3277 Graphics Attachment

The new TEKTRONIX 618 Storage Display Monitor combined with the IBM 3277 Graphics Attachment (RPQ 7H0284 from IBM) brings graphics to current IBM 3270 installations.

The 618 is fully compatible with the IBM 3277 Graphics Attachment and adds a wide range of graphics capabilities. Addition of the 618 monitor results in a dual display station with the 3277 showing alphanumeric data while the 618 displays graphic information and special symbols. The 618 with RPQ 7H0284 is fully compatible with standard IBM 3270 operating environments and does not interfere with normal operation of the 3277.

IBM software support for the Graphics Attachment includes basic

routines for drawing lines, for placing text, and for coordinate transformation. Advanced routines for geometric structures and 3-dimensional displays are also provided.

The 618 is a 19-inch diagonal monitor driven as an X-Y directed beam display using analog inputs. It offers the benefits of low-cost, high-resolution graphics found in a storage tube, with the added capability of displaying up to 1,000 vectors in Write Thru Mode.

In Write Thru Mode, refreshed data appears on the screen at the same time as stored graphics. This refresh portion of the display adds the benefits of selective erase, interactivity, and dynamic motion, without any loss of resolution.