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

An Intelligent, Programmable Transient Digitizer

A New Calibration Fixture for the 7000-Series

New Products

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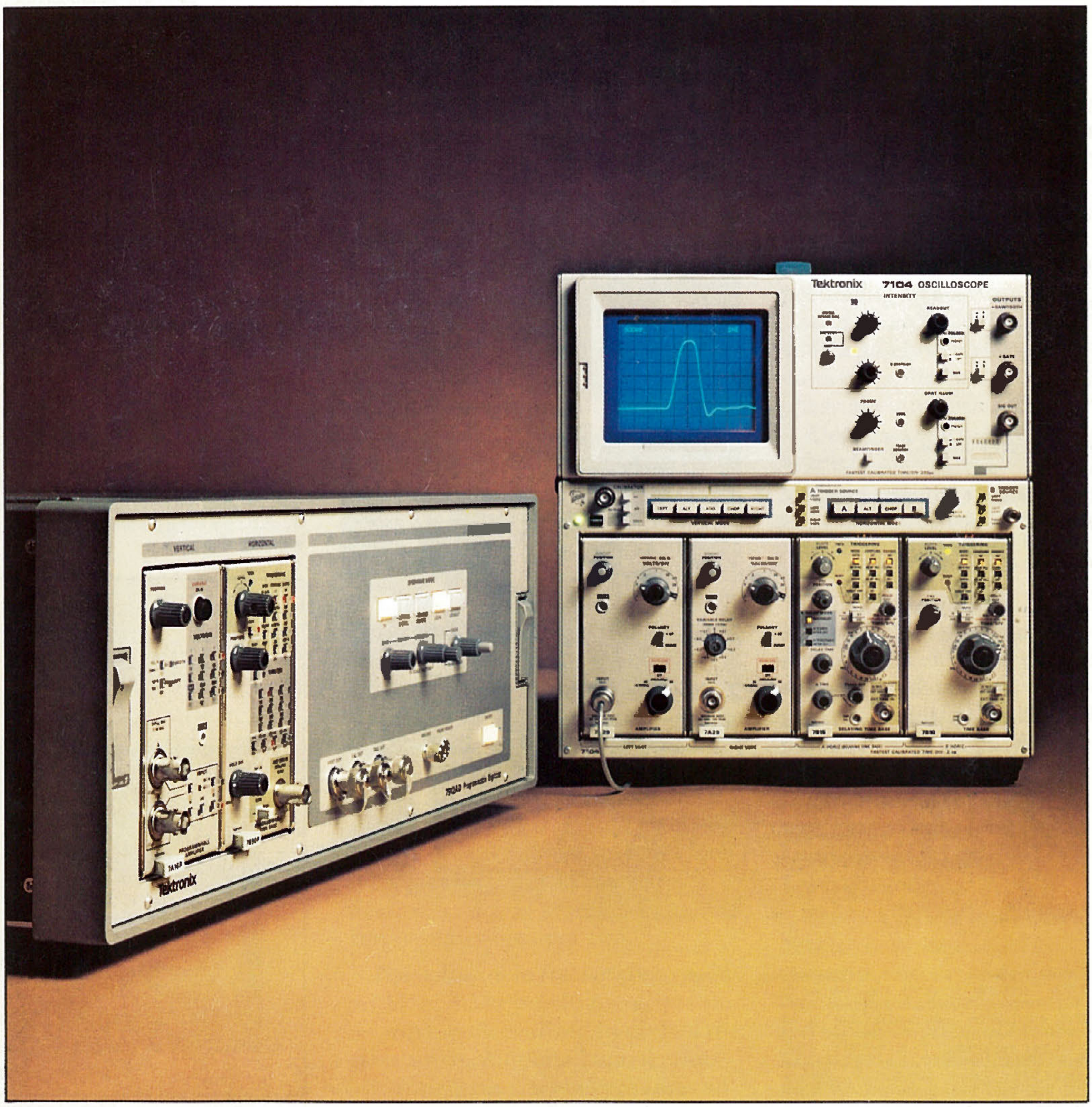

Tektronix®
COMMITTED TO EXCELLENCE

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 ultimate 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

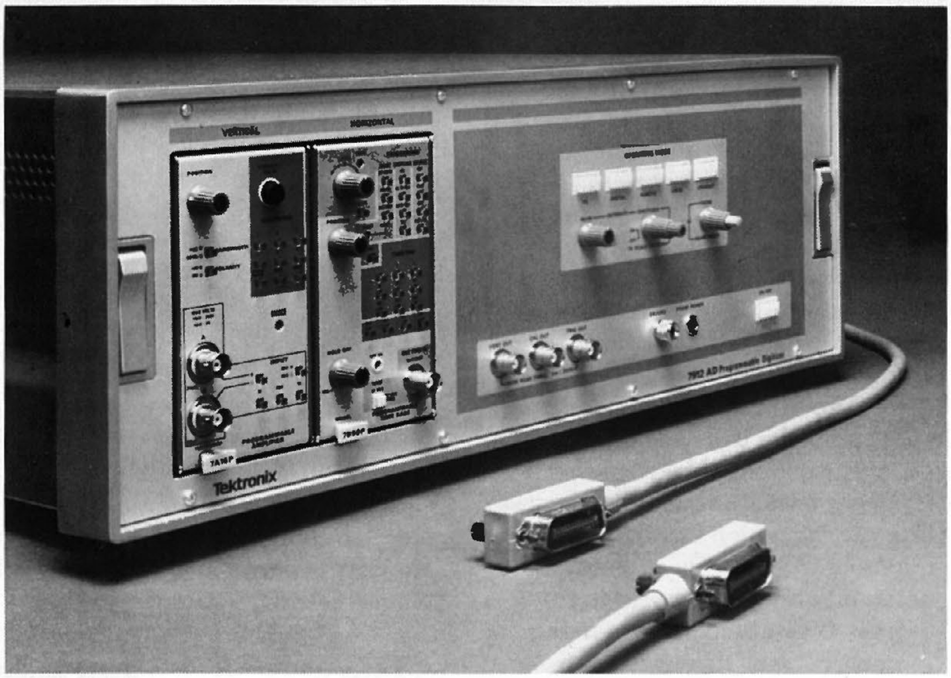

Fig. 1. The 7912AD Programmable Digitizer uses the IEEE 488 (GPIB) for control and signal interfacing with a variety of instrumentation controllers.

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 fascimile of the high-speed signal in a more usable, low-speed format.

A Microprocessor Team

The 7912AD uses two microprocessors to control the instrument, preprocess 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.

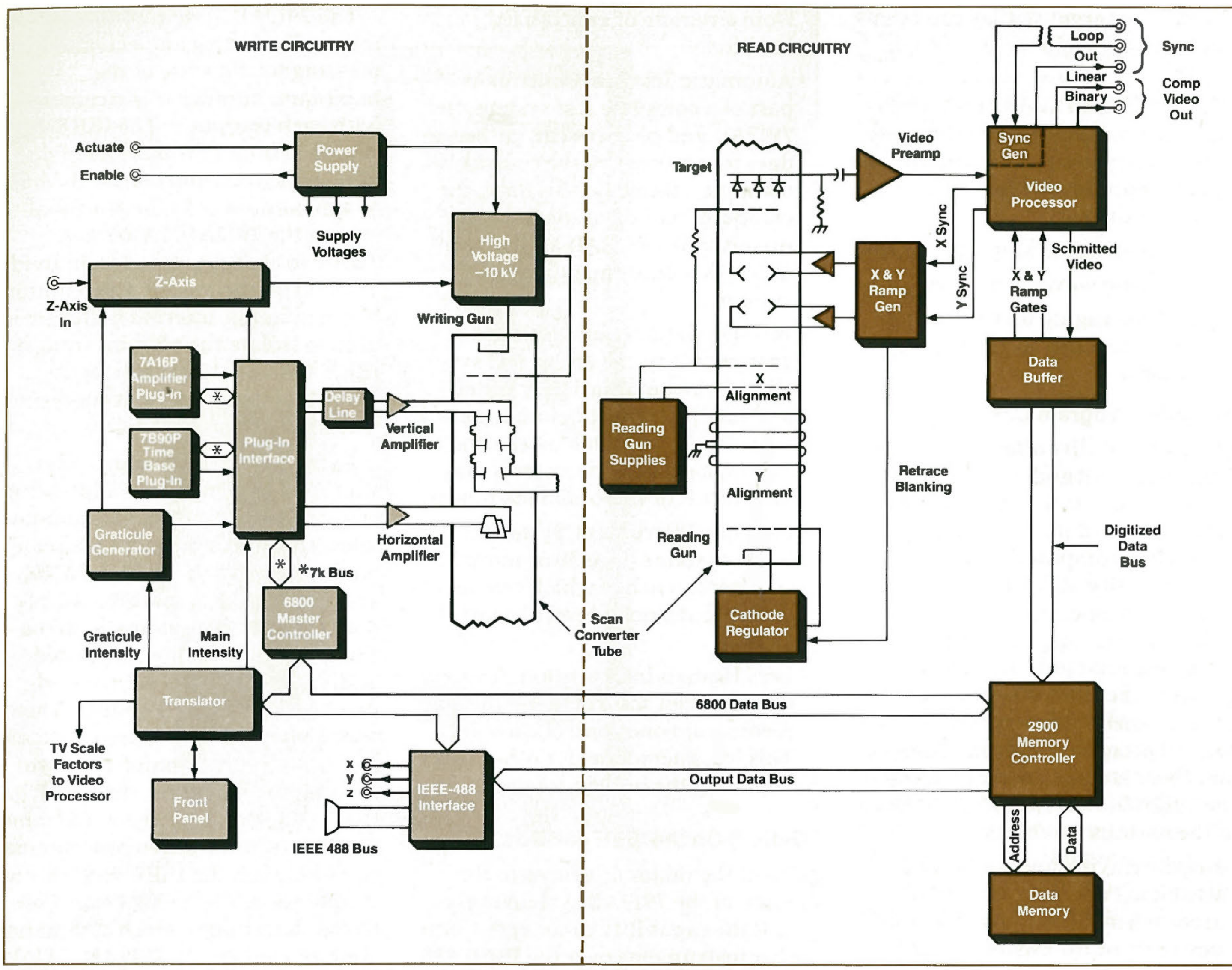

Fig. 2. Block diagram of the 7912AD showing the read and write section of the scan converter.

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

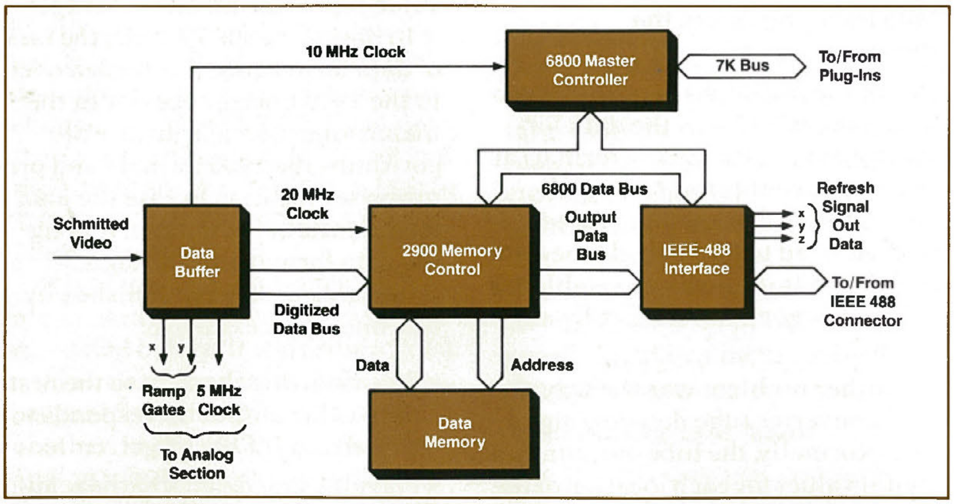

Fig. 3. A microprocessor team controls the instrument, preprocesses data, and directs storage of data in local memory.

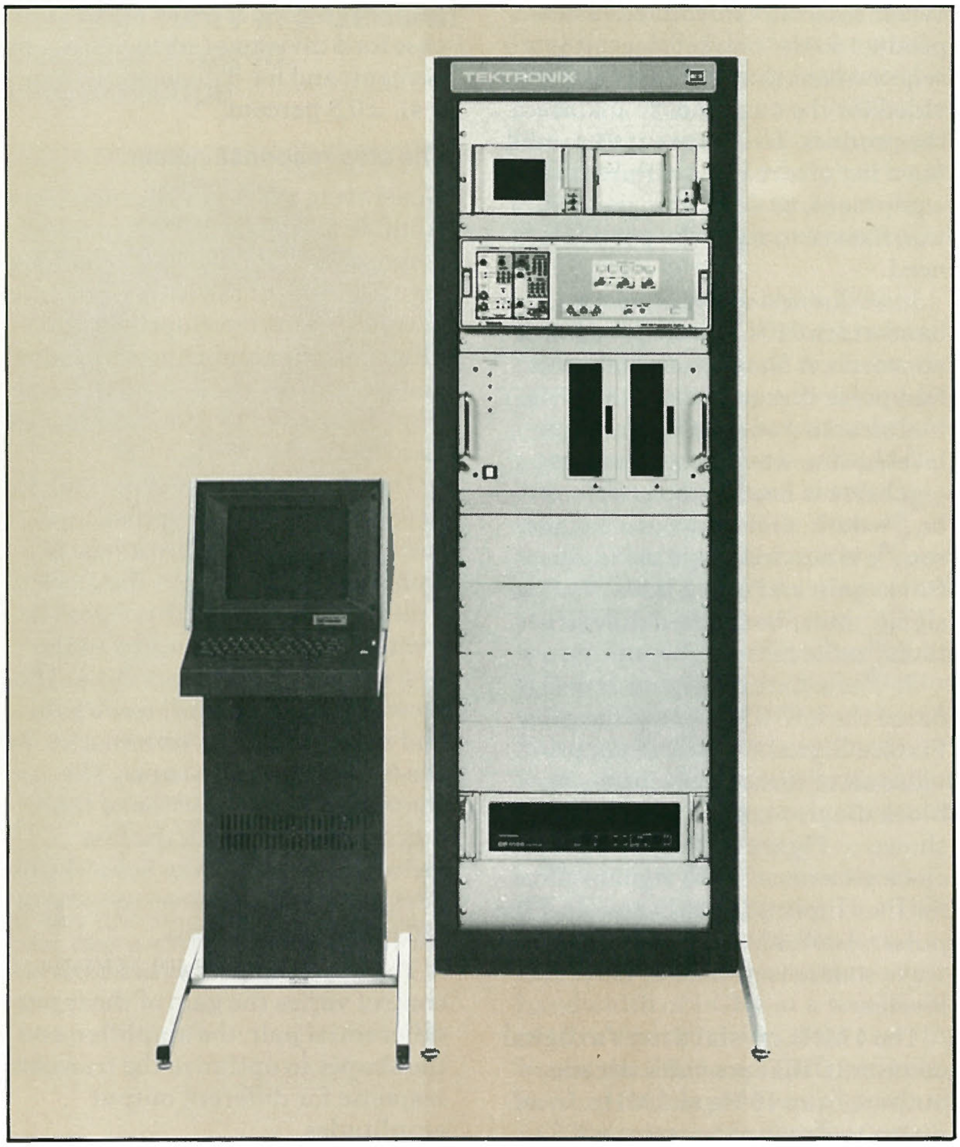

Fig. 4. The WP2250 Programmable Digitizer System is a self-contained signal acquisition and data processing system with CP4165 Instrument Controller and TEK SPS BASIC. Up to three additional 7912ADs can be added to the WP2250.

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 measurement 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 onboard 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.