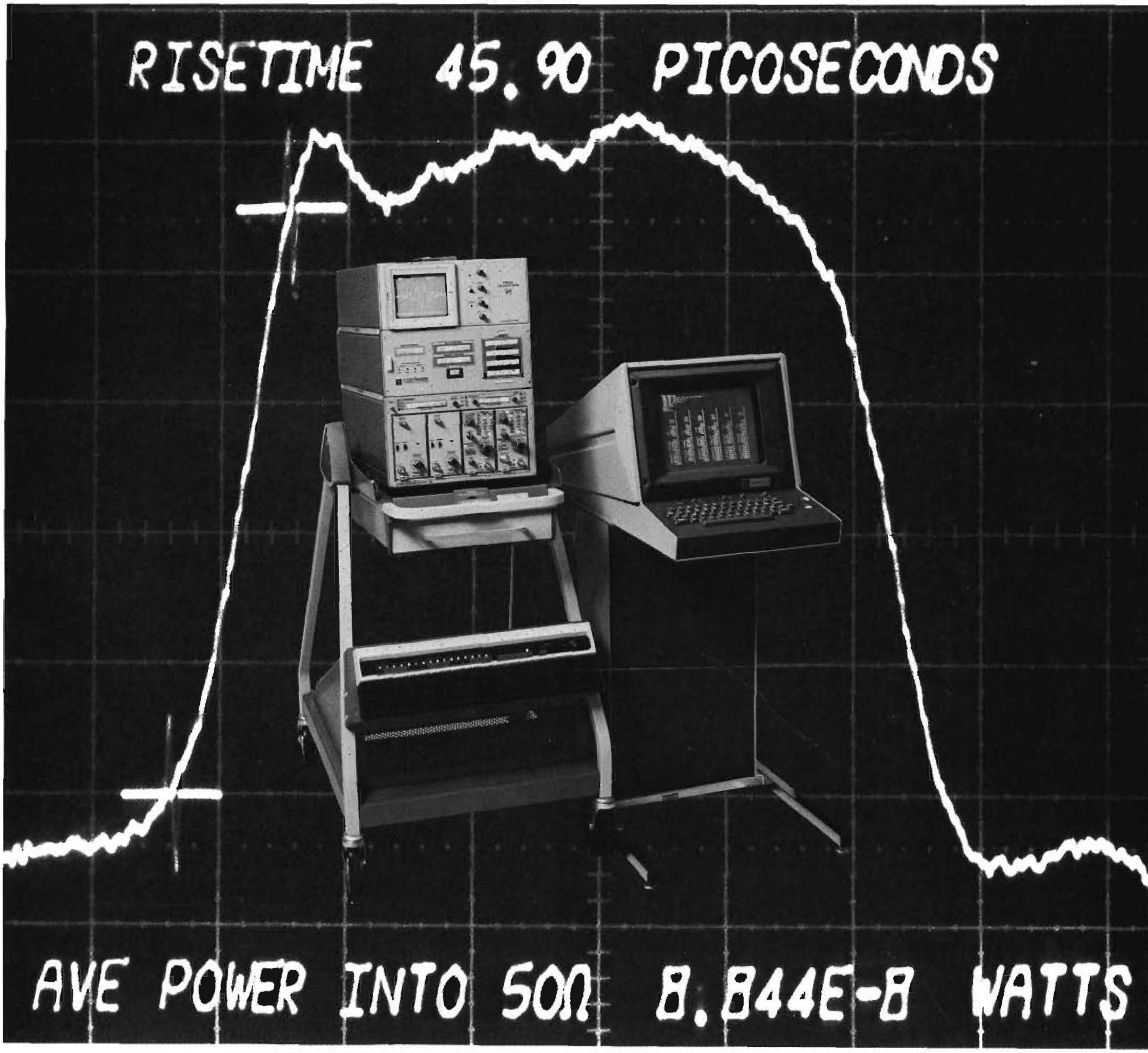
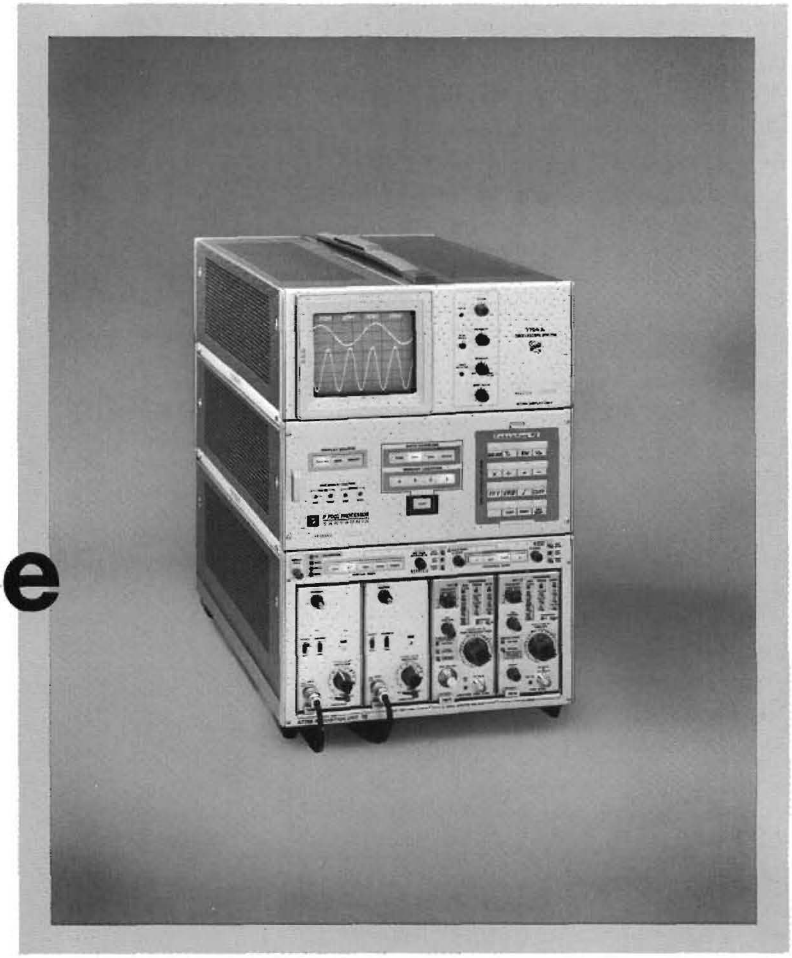
TEK SCOPE

MARCH/APRIL 1973



- THE OSCILLOSCOPE WITH COMPUTING POWER
- PORTABLE POWER
- PRESERVING SCOPE BANDWIDTH AND SENSITIVITY
- SERVICING THE 7T11 TRIGGER CIRCUIT

The Oscilloscope with Computing Power



by *Hiro Moriyasu, Luis Navarro, Jack Gilmore* and *Bruce Hamilton*

The miracles of electronics—from computers and moon walks, to color television and 6-minute baked potatoes—have one thing in common. They are possible because of the oscilloscope. This instrument, more than any other, has opened the door for scientific advancement. And now it seems destined to open that door still wider.

For the first time, the oscilloscope has acquired the calculating power of the computer. Not as an "add-on" capability but as an integral part of the measuring function.

The groundwork for this propitious marriage of the oscilloscope and the computer was laid over two years ago when design work started on the 7704A Oscilloscope. With over thirty plug-ins available for signal acquisition and display, the 7704A would be an ideal candidate for such a marriage. Accordingly, the 7704A was designed for modular construction. The top module, or display unit, contains the CRT, high voltage power supply and output amplifiers. The lower module, or acquisition unit, contains the CRT Readout circuitry, the low voltage power supplies, and houses the plug-in units.

Between these two units we have inserted a third module which we call the P7001 Processor. This unit digitizes the acquired signal and provides storage and interface to a powerful minicomputer.

These three modules—acquisition, processor and display, combine to form what we call the Digital Processing Oscilloscope; the most powerful general-purpose measuring tool available to scientists and engineers today.

Since the Processor is the key unit in the new Digital Processing Oscilloscope we will want to discuss it in detail. But before we do, let's consider some of the things this new tool can do.

***Cover:** The measurements indicated by the CRT READOUT were made by computer. The signal was acquired and displayed by the new Tektronix Digital Processing Oscilloscope pictured in the center.*

- The full versatility of the 7704A as a conventional oscilloscope is retained and enhanced.
- Signal Averaging may be performed to extract signals from noise.
- Small aberrations caused by signal acquisition may be removed by the process of deconvolution using the Fast Fourier Transform algorithm in the Processor.
- Fast Fourier Transforms and Inverse Fast Fourier Transforms can be performed and the signals displayed simultaneously in *both* the time and frequency domains.
- A signal may be viewed after passing through an arbitrarily constructed digital filter that may not even be realizable in conventional circuitry.
- Processed waveforms may be operated upon, automatically scaled and assigned with nonelectrical units to present data in its most convenient form.
- Results of CAD (Computer Aided Design) analysis can be presented on-screen simultaneously with the actual waveforms produced by a real circuit, for a one-to-one comparison.

To get a clearer picture of what adding a computer to the oscilloscope can do for us let's take a closer look at one of these applications—that of performing signal averaging to extract signals from noise. Suppose the task is to measure the risetime of, and power contained in, the noisy signal pictured in Fig. 1. Using a conventional oscilloscope, it would be a difficult and time-consuming task with little confidence in the accuracy of the results. Now take a look at Fig. 2. This is the same signal as in Fig. 1 after being digitized by the Processor, routed to the computer for averaging of 1000 sweeps and then returned to the scope for display on the CRT. Note that the vertical deflection factor has been automatically scaled to fill the screen for optimum display resolution. Now, by pressing a single button on the P7001 Processor we can direct the computer to calculate the risetime and display it using the CRT READOUT. Markers are inserted on the waveform to indicate the 10 and 90% points selected by the program. Pressing another button directs the computer to calculate the average power the signal will deliver to a 50 Ω load. This is displayed at the bottom of the screen by CRT READOUT (Fig. 3). Both risetime and power are accurately measured in a matter of seconds. How long would it have taken you using conventional means?

Let's consider another example from the field of electronics. Suppose a circuit design engineer needs to determine the power generated within a transistor at each instant during some event. He can readily measure the collector current, I_c, and the collector-emitter voltage, V_{CE}. At any one instant the power is simply the product of these two variables; but if for his purposes the event consists of 500 instants—you see the problem. The arithmetic will take awhile. TEKTRONIX' new Digital Processing Oscilloscope will multiply these two waveforms and display the product, as another waveform, without delaying the engineer, (Fig. 4).

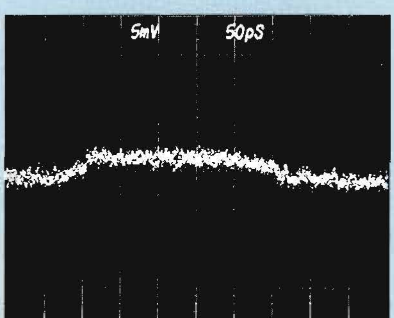


Fig. 1. *A noisy signal as acquired by the 7704A.*

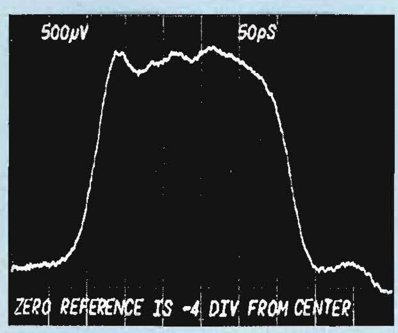


Fig. 2. *The same signal in Fig. 1 averaged 1000 times by the computer.*

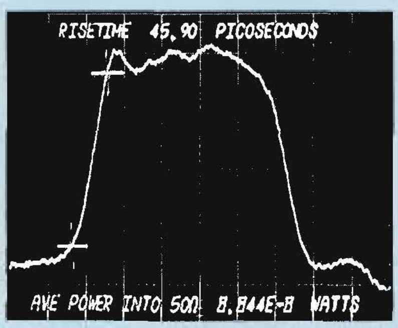


Fig. 3. *The computer calculates risetime and average power and displays it using CRT READOUT.*

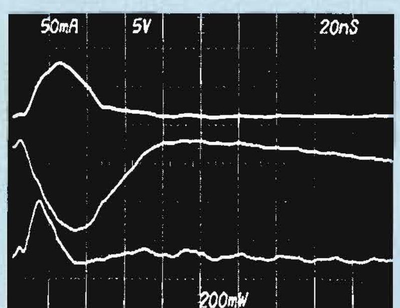


Fig. 4. *Voltage and current waveforms are multiplied by computer. Lower trace is resultant power waveform.*

Now let's take a look at the unit that makes these new measurements possible—the P7001 Processor.

Processor Architecture

The P7001 Processor is designed to provide maximum flexibility as a computer interface unit without degrading the performance of the basic 7704A Oscilloscope. The block diagram (Fig. 5) shows the architecture used to achieve this objective.

Basically, the Processor consists of two major parts: a Signal Interface and an Asynchronous Bus. The Signal Interface which controls the Display Unit receives its data from the Acquisition Unit and a variety of functional devices, 4½" x 11" EC Boards, which are plugged into the Asynchronous Bus.

The Asynchronous Bus allows the devices that are plugged into it to work independently from each other. Thus, the devices may be added or removed, as required, in order to achieve the configuration best suited to the problem at hand.

The configuration shown in Fig. 5 shows a typical mix of devices. The six devices shown use a total of eight of the eleven device positions available in the bus. Each device position consists of a single 72-pin edge connector which provides parallel access to power supplies, address, data and control lines.

A serially connected line, or daisy chain, in the bus establishes device priority. Connections are available at each device location for input and output of signals. Signals requiring wide bandwidth and/or low noise paths are routed directly from device to device via coaxial cables.

SAMPLE and HOLD and A/D CONVERTER

The heart of the Processor is a three-axis pseudo-random sampler and an A to D converter allowing simultaneous storage of up to four different waveforms, each in allocated and predesignated memory locations (A, B, C, D).

On an acquired signal the vertical axis is sampled every 6.5 microseconds and the two other major axes, horizontal and blanking, are sampled 95 nanoseconds later. This effectively displaces the vertical sample, in time, to the right of the original. A delay line in the display unit displaces the real time vertical by the same amount and thus coincidence of real time and stored signals is maintained when they are simultaneously displayed. Sampling clock noise (FM) is sufficient to eliminate nulls in the system response that would otherwise appear at harmonics of the Nyquist frequency.

The vertical sample of the acquired waveform is converted by a 10-bit successive approximation A to D converter to one of 1024 possible levels which correspond to ten CRT divisions, eight of which are displayed.

The A to D converter then converts the horizontal sample to one of 512 horizontal memory positions which correspond to the ten horizontal divisions on the CRT faceplate. However, if the blanking sample indicates that the CRT was blanked (retrace, channel switching, etc.) when the vertical or horizontal sample was taken, the converted data is discarded. Conversely, if the CRT was unblanked, a memory address is generated by adding the horizontal binary address to the location code (of A, B, C, or D) and the vertical binary word is stored at that address in the Processor memory.

The location code used to generate the memory address is derived from one of two sources, depending on whether or not multiple waveforms are being stored. If a single waveform is specified, a single memory location is used. If multiple waveforms are specified, the source codes are compared with the specified locations, and, if a match is found, the source codes are used as the location codes. If no match is found, the data is discarded. An additional data acquisition mode is available. The computer may, at any time, obtain directly from the A to D converter the value of the last vertical sample. This allows inputs of unchanging data in a single operation or construction of arrays consisting of more than 512 elements of slowly varying data.

PROCESSOR MEMORY

A 4K x 10 bit non-volatile core memory in the Processor serves to store data and act as a buffer for computer I/O. The memory stores acquired waveforms and scale factors for display and computer input, and stores computer

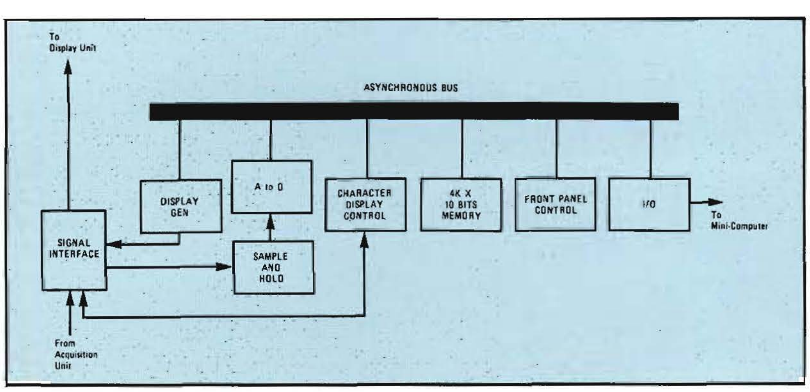


Fig. 5. Block diagram of the P7001 Processor.

output for display on the CRT. Data acquisition independent of I/O speed, and flicker-free displays are a result of this local memory.

I/O DEVICE

The I/O device provides a bilateral Processor-Computer link. The computer has full access to the Processor through the I/O device and the Processor, in turn, may interrupt the computer at any time.

DISPLAY GENERATOR

The Display Generator device is used to generate a CRT display of real-time computer output or data stored in the Processor memory. Any combination of four stored waveforms and four possible acquired waveforms may be displayed simultaneously. Also, since the display generator operates independent of other devices, changing data may be viewed during a store operation.

Two display modes are available: Y versus time (Y-T) and X versus Y (X-Y). In the (Y-T) mode, all specified memory locations (A,B,C,D) are examined sequentially by address (0-511) and all non-zero points in the array are plotted. In the (X-Y) mode, each point is plotted when directed by the computer, thus enabling the computer to generate a refreshed display of multi-valued functions (spirals, for instance).

Normally, a linear interpolation is made between the plotted coordinates, enhancing the intelligibility of rapidly varying plots or plots containing a few data points. If a point plot is desired, a strap option is easily installed on the display generator board at pins provided for this purpose.

When a STORE operation is initiated, all contents of the specified memory location (A,B,C, or D) are set to zero. Since the display generator will display only nonzero points, useful plots of single events may be generated even if the sweep speed is such that only a few points are acquired.

CHARACTER DISPLAY CONTROL

The character display control device allows use of the full character set of the 7704A for both computer input and display on the CRT. In the STORE mode, the Acquisition readout information is converted to ASCII and stored in the Processor memory, providing a permanent record of waveform scale factors. Thus, whenever a stored waveform is displayed, so are its scale factors.

Sixteen 80-character messages may be stored in the Processor memory locations. Four locations, A, B, C and D, are addressable from the front panel and normally contain only scale factors. The remaining twelve locations may contain messages from the computer to the operator and these messages, once stored, may be displayed with a single computer command.

FRONT PANEL CONTROL

Now let's take a look at the controls on the front panel of the Processor (Fig. 6). Pushbuttons on the front panel access logic circuits in the Processor, which in turn provide for simple control of the oscilloscope and its computer interface. Each time a new mode is selected such as STORE, START, etc., the Processor generates a computer interrupt which allows interaction between the operator-processor and the computer. The computer is in constant awareness of Processor status and, through the lighted pushbuttons, the operator is constantly informed. The pushbuttons are also controlled by the I/O to inform the operator of computer-initiated operations.

Ten of the twenty-eight front panel pushbuttons directly control the Processor. Two buttons set the status to STORE or HOLD, four buttons are used to designate the affected waveform memory location, A, B, C, or D, and three buttons set the CRT display source to PLUG-INS, BOTH, or MEMORY.

The START button is used to initiate any Processor or computer mode which will destroy previously stored waveform data in A, B, C or D and thereby reduces the possibility of inadvertent destruction of stored data.

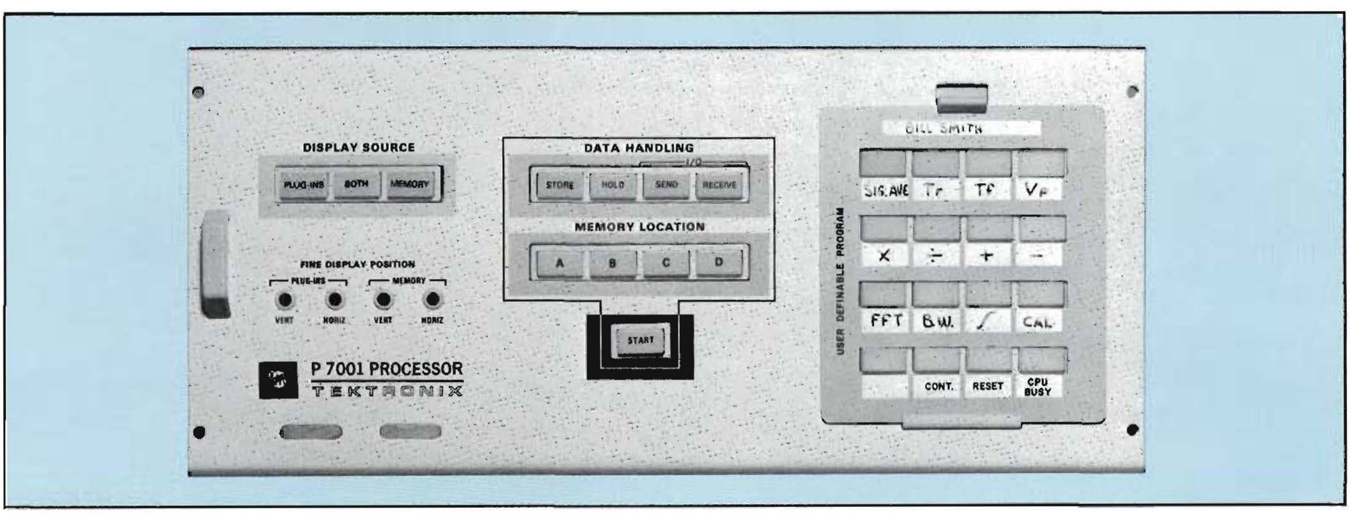


Fig. 6. *Control panel of the P7001. A user-definable program overlay permits tailoring the program call buttons at right to your specific program.*

The remaining eighteen pushbuttons are used to request computer action. The SEND and RECEIVE buttons direct the computer to input from the P7001 or output desired waveforms. Each time SEND or RECEIVE is used, the Processor is set into a HOLD mode, the acquired data is retained, and with a START command an interrupt is sent to the I/O unit. The 16 PROGRAM CALL buttons are used to direct the computer to execute user-definable programs and do not directly affect the Processor.

The computer, through I/O control, can access any individual device in the Processor and change any of its modes. This allows, under program control, operations such as simultaneous storage in, and display from, different memory locations. In addition, single sweep reset and end of sweep interrupt are available to the computer allowing further programming flexibility.

SOFTWARE

The software provided with the Digital Processing Oscilloscope plays an important role in the usability of the system. The language BASIC was chosen as a starting point for the software because it is a simple, interactive language that is easy to use. You can write a program, run it, modify the program, and run it again without reentering or recompiling the program. Some of the features of BASIC were expanded to adapt the language to the needs of the Digital Processing Oscilloscope. New statements were added to improve waveform processing, and special features were added to support the hardware. Wherever possible, the software was designed to minimize waveform storage requirements and speed up waveform processing. The software is called APD BASIC and is written for the Digital Equipment Corp. PDP-11 series minicomputers.

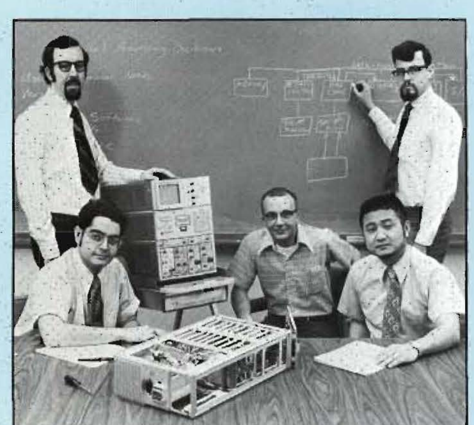
Summary

The Digital Processing Oscilloscope is a new concept in measurement capability. The calculating power of the modern computer is married to the waveform measuring power of the modern laboratory oscilloscope, creating a powerful new measuring tool. Signals that previously were difficult or impossible to measure are now displayed and measured with ease. Two or more signals can be combined to yield results that formerly required hours of computation. Signals displayed in the time domain can be quickly transformed to the frequency domain for further analysis. These, and many other measurement capabilities, are yours at the push of a button, with the new TEKTRONIX Digital Processing Oscilloscope.

ACKNOWLEDGEMENTS

As you might expect, many talented people were involved in the P7001 project. Inputs from Bill Walker, Wim Velsink, Bob LeBrun and others gave valuable direction in the planning stages. Early mechanical design was handled by Marlow Butler and Carl Dalby, with Colin Doward doing much of the later work under Bob Shand, Mechanical Project Leader. In the electronic portion, Jack Robinson and Bill Lucas designed the Sample and Hold circuitry; Jack Grimes, Dennis Keldsen and Mohamed Saba the A/D; Dick Beatty the Memory; Wayne Eshelman the Vector Generator; George Rhine the Interface I/O; and Bill Markwart the Readout Interface Circuitry. Gale Byers, with manufacturing responsibility for the P7001, gave valuable inputs on making the instrument buildable. Our thanks to others too numerous to mention, for their valuable contributions to the project.

Meet Our Authors



Bruce Hamilton—standing at left, was Software Project Leader. He obtained his BSEE from Oregon State Univ. in 1966 and his MSEE in '68 from Ohio State.

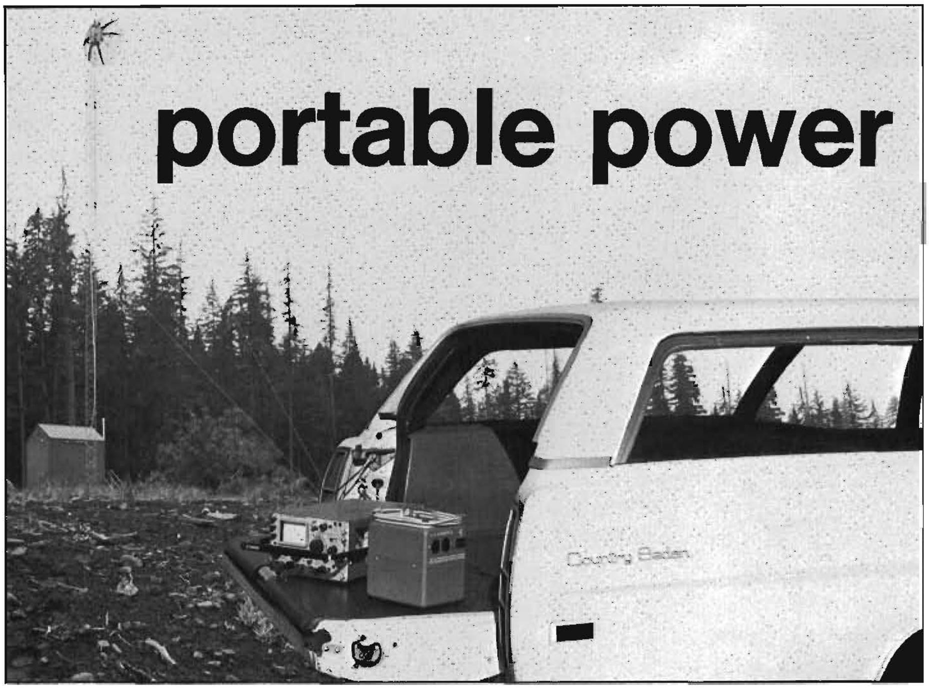
Luis Navarro—seated at left, was Hardware and Analog Circuits Project Leader. He obtained his BSEE in 1965 and MSEE in 1966 from the University of Nebraska.

Jack Gilmore—standing at right, was Logic Design Project Leader and also received his BSEE and MSEE from the University of Nebraska, though just a bit later in '66 and '68.

Hiro Moriyasu—seated at right, is Program Manager of the Computer Aided Measurements Group. He obtained his BSEE in 1959 and MSEE in 1969 from Oregon State University.

Bob Shand—the fellow seated in the middle, while not contributing words to this article did make a substantial contribution to the project as Mechanical Project Leader.

portable power



by

R. Michael Johnson,

Randy Eichman,

and

Al Schamel

How many times have you wanted to make a measurement and found no AC power available? Have noise transients on the AC line ever made your critical measurements practically useless? If you've had these or other problems with power sources, there are two new instruments from Tektronix, Inc. that will be of interest to you. First, there's the new TEKTRONIX 1105, a self-contained power source for operating your oscilloscope or other instrumentation away from the AC power line. The second unit is the 1106 which attaches to a 465 Option 7 or 475 Option 7 to make it a completely self-contained oscilloscope system.

Battery Power—Its Many Uses

Let's consider some of the applications for battery operation. The major reason for a battery-operated supply is instrument operation remote from any AC power source. However, there are many uses for battery operation when AC power is readily available. The battery-operated supply can serve as an extra wall socket when all of the AC sockets are in use. When used on a SCOPE-MOBILE® Cart or test cart, battery operation provides a completely mobile system with no power cords to get in the way.

Often the power line is carrying noise transients that might affect a critical measurement; the battery-operated supply disconnects the measuring instrument from the influence of this noise. Some measurements require a floating ground system. Battery operation allows this to be easily accomplished, but it must be kept in mind that the chassis and cabinet of instruments which are isolated from ground may become elevated to dangerous potentials.

The battery-operated supply can be used as a power converter since the battery supplies can usually be charged over a wider range of line voltages than many instruments will operate on. In this application, you can charge the batteries at the higher- or lower-than normal voltage, and later operate the instrument from the batteries. This can also be used to solve the problem of low-line voltage during hours of peak-power demand or fluctuations in the line voltage caused by heavy industrial equipment operating in the vicinity of your measurement.

Why A Separate Power Unit?

Now that we've seen some of the uses for battery-operated instruments you may be thinking that the answer is to design all instruments with battery operation built in. This would be ideal. However, even with the best circuit designs, compromises must be made to build in battery operation. Many of these compromises result in lesser performance for the battery-powered instruments, particularly at the upper limits of performance such as at maximum bandwidth, visual writing rate, etc. The concept of a separate power unit such as the 1105, or a separable battery unit such as the 1106, allows the basic instrument to be designed for best overall performance and minimal cost. If battery operation is needed at a later date, you can choose the battery-operated supply best-suited for the application.

There are other advantages to each of the new battery-operated supplies from Tektronix. Let's look at these in more detail.

The 1105—A Portable Wall Socket

Think of the 1105 as a portable wall socket that allows you to carry power to your measurement location. Now, any oscilloscope that draws less than 120 watts can become a portable. This includes the TEKTRONIX 453A and 454A. But don't limit its use to powering oscilloscopes. It can be used to power any instrument or combination of instruments that draws less than 120 watts and will operate on 60-Hertz squarewave voltages. The major items that cannot be operated from the 1105 are induction motors such as electric drills, which induce distortions back into the output of the 1105 power unit. This prevents it from operating correctly, or in extreme cases, damages the 1105. There are also some electronic instruments which cannot operate correctly on the squarewave output of the 1105. Among these are instruments which need a very accurate line frequency or waveshape for correct operation.

The 1105 offers an economy in battery operation if you have a variety of instruments which only occasionally need to be operated from batteries. Many laboratory instruments never intended for use away from the AC power line become "portable" when used with the free-standing 1105.

Since the 1105 is intended for remote applications, it is built rugged to withstand the use and abuse associated with portability. It has two built-in power sockets to power any two instruments whose total power consumption does not exceed 120 watts. These sockets match the sockets commonly in use; N.E.C. (duplex) sockets for U.S. models and I.E.C. sockets for European models.

The 1106—Take It, Or Leave It

While the 1106 provides portable power in much the same way as the 1105, it is designed in quite a different configuration. This power system is made specifically for the TEKTRONIX 465 and 475 Oscilloscopes. The 465 or 475 must be equipped with Option 7, which adds a DC-to-AC inverter board inside the instrument. With this option installed, the 465 or 475 can operate from external DC sources (11.5 to 14 volts and 22 to 28 volts) as well as from the AC line.

With the addition of the 1106 battery supply, completely self-contained operation is achieved. The 1106 contains the rechargeable batteries and the battery charger circuit. It attaches to the bottom of the 465 or 475 cabinet and supplies power to the instrument through a plug-in power cord.

Designing the 1106 as a unit separate from the oscilloscope provides several advantages. Most important, you need to carry the battery pack only when AC power will not be available—it can be added or removed in a matter of seconds. This quick removal is also an advantage if you must carry the oscilloscope/battery pack system for any distance. The 1106 has its own handle so you can remove it and carry a unit in each hand for a well-balanced load (see Fig. 1).

Fig. 1. *The 1106 can be separated from the oscilloscope for an easy-to-carry load.*

For continuous operation from batteries, two 1106 battery units can be easily interchanged. Since the battery charger is contained in the 1106 itself, the batteries can be recharged in one unit while the instrument is operated from the second unit. Interchangeability also allows you to use one battery pack to operate any of several 465s or 475s, as long as each instrument has Option 7 installed.

Another advantage already discussed is that the original design of the 465 and 475 was not compromised to build in battery operation. As a result, these instruments offer the best of two worlds—maximum instrument performance at a low price and fully portable battery operation.

A Look Beneath The Surface

While the 1105 and 1106 have quite a different outward appearance, they share many common features inside the cabinets. Both are powered by 20 type "F" nickel-cadmium cells. The battery circuits include a calibrated meter which indicates the amount of charge left.

Another feature of both instruments is a deep-discharge protection circuit (Fig 2) which shuts off the instrument when the batteries drop to a level where damage could occur by further discharge. This circuit senses the input voltage (battery level) and if it falls below about 22 volts, Schmitt trigger Q1-Q2 changes state so that Q2 is conducting. This turns on Q3 to forward bias diodes D1 and D2, by-passing the primary winding of the feedback transformer. This prevents feedback to inverter transistors Q4-Q5, shutting them down. They remain off, producing no output drive for this supply until the input voltage level rises above the turn-off level (i.e., batteries recharged).

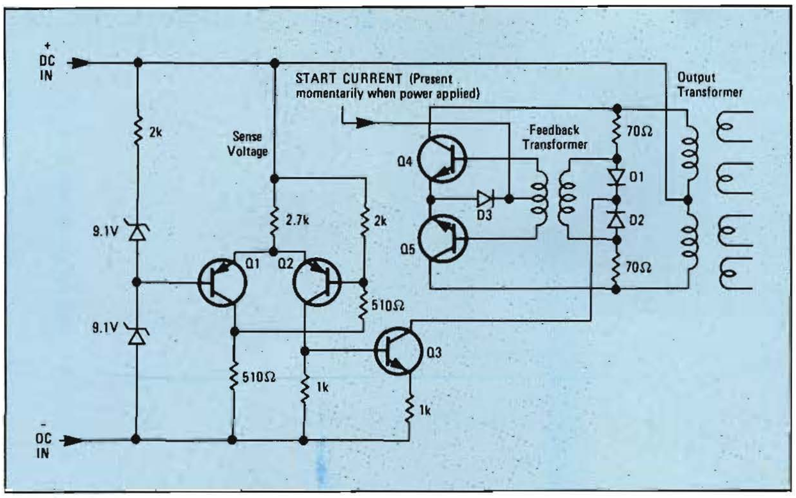


Fig. 2. Simplified schematic of the deep-discharge protection circuit. Circuitry shown is part of Option 7 for the 465/475. The 1105 protection circuit is similar.

The two instruments use different schemes for charging the batteries. The 1105 uses a single transformer which serves the dual-function of a step-down transformer when charging the batteries and a step-up transformer for power output. As a result, the batteries cannot be charged simultaneously with power output. The 1105 also incorporates a thermal-cutout charge rate selector. A characteristic of nickel-cadmium batteries is that they convert the charging current to heat as they reach full charge. The thermal-cutout charge selector senses the rapid increase in battery temperature as the batteries reach full charge and automatically switches the unit to trickle charge.

The batteries in the 1106 can be charged at the same time that the instrument is being operated from the AC line. Charge rate is determined by an external switch. Two rates are available—FULL, to charge the batteries, and TRICKLE, to maintain a full charge on the batteries once they've reached that level.

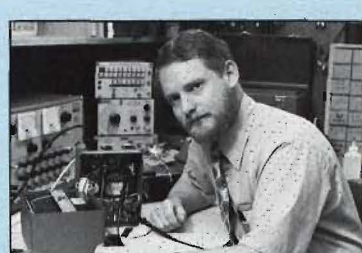
Summary

The 1105 and 1106 offer new freedom for your AC-powered instruments. No longer are your measurements limited by the length of the power cord. Instead, battery operation offers you portable power to make measurements at their source—anywhere.

ACKNOWLEDGEMENTS

The design effort on the 1105/1106/Option 7 was coordinated by R. Michael Johnson. George Ermini provided evaluation support for these projects and the preliminary electrical design for the 1105. Randy Eichman completed the electrical design. Others involved in the 1105 were: Bill Cottingham, mechanical design and Sandra Lowe, prototype support. Electrical design of the 1106 and Option 7 for the 465/475 was by Al Schamel. Bob Twigg provided the mechanical design for the 1106 and Len McCracken filled a similar job for Option 7. Iona MacKay provided prototype support for the 1106 and Pat Simonson for Option 7.

ABOUT OUR AUTHORS



R. Michael Johnson

Bob joined TEK in 1960, shortly after earning his BSEE degree at Oregon State University. He received his MSEE in '68, also from O.S.U. Bob has been involved in the design of most of TEK's portables and also helped develop the TEKTRONIX 7000-Series instruments. His most recent involvement was as Project Leader on the new 465 which was presented in the September 1972 issue of TEKSCOPE. This project led to his present work on the 1105/1106/Option 7 units. Bob likes to relax while camping, fishing, or working with his coin collection.

Randy Eichman

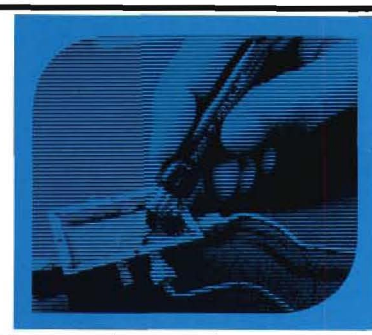
Randy is an old-timer at TEK, having started here in June of 1957. He received his early training in electronics while in the U.S. Army and has added to this by on-the-job training and specialized classes to keep abreast of recent advancements. Among the areas that Randy has worked in at TEK are the production test department, engineering evaluation, and custom product design. Randy enjoys ham radio and coin collecting in his spare time.

Al Schamel

Al attended Portland Community College to further the electronics training begun while in the U.S. Air Force. In 1965, he joined TEK in the production test department and now works as an Engineering Aide in the Portable Instrument Design group. In this position, he has assisted in the development of the 432, 434, and the 465 as well as the 1105/1106/Option 7. Leisure time pursuits for Al include working on his 1957 Thunderbird and growing roses.

TEKNIQUE

by Ron Peltola Accessories Design



Preserving Scope Bandwidth and Sensitivity

When is a 500-megahertz scope not a 500-megahertz scope? At first glance, this may seem like a facetious question, but the answer may come as somewhat of a shock. Anytime you connect a signal to the input of a high-frequency scope, you can lose a large percentage of the high-frequency information unless the signal source is carefully matched to the oscilloscope input. Since you probably bought your high-frequency scope because you need its extra display capabilities, you'll want to get all of the high-frequency performance designed into it. Here's some information to help in your high-frequency measurements.

Check the Specifications

The bandwidth and risetime of most oscilloscopes are given at a specific source impedance. Usually, this is stated similar to the following: ". . . driven from a 50-ohm terminated source" or, in other words, a 50-ohm source paralleled by a 50-ohm termination, which is equivalent to a 25-ohm source impedance. Bandwidth and risetime are seldom stated at some higher source impedance. As a result, you're left on your own to find out what the outcome might be.

Faced with this situation, you might speculate as to what source impedance will appreciably change the bandwidth of your measurement system. A one-kilohm source probably sounds high enough to affect the bandwidth, but 250 ohms doesn't sound very large, right? Well, let's take a look and see. Fig. 1 lists some of the high-frequency oscilloscope systems offered by Tektronix, Inc. and the approximate bandwidth when driven from both a 25-ohm and a 250-ohm source with various combinations of input connection methods. Particularly notice what happens when a X10 passive probe is used. In the worst case, bandwidth has degraded to about 20% of the original bandwidth.

What Causes This Loss?

This loss in bandwidth is caused by the interaction of the source resistance and the capacitance at the probe tip. Fig. 2 illustrates the equivalent circuit of the measuring system.

Is There A Solution?

There are several solutions to this measurement problem. One solution that may prove impractical in many cases is to only obtain the signal from a low-impedance source. There are two ways this can be done: obtain the signal from a 50-ohm source using a coax cable terminated in 50 ohms, or design probe jacks into the circuit at 25-ohm source impedance points. However, when troubleshooting in high-frequency systems, you often need to examine the signal at higher impedance points. A variety of passive probes are available which allow you to make these measurements with a minimum of capacitive loading. There are two problems with using passive probes: none of the passive probes can make high-frequency measurements over a wide range of input impedance, and all of the passive probes include signal attenuation. This prevents many of the critical measurements which must be made at maximum sensitivity.

An Active Solution

Active voltage probes use an active device such as a field-effect transistor (FET) to provide a high-input impedance. At the same time, the input circuitry of the probe can be designed to provide very low input capacitance. Most active probes include a wide-bandwidth amplifier to minimize probe attenuation. Fig. 3 lists the active probes presently available from Tektronix, Inc. along with their major characteristics.

SCOPE SYSTEM / PROBE	MAXIMUM SENSITIVITY	APPROX BANDWIDTH FROM 25-OHM SOURCE	APPROX BANDWIDTH FROM 250-OHM SOURCE
Type 475			
Without Probe	2 mV/DIV	≥200 MHz	....
P6075A (X10)	20 mV/DIV	≥200 MHz	50 MHz
P6201 (X1)	2 mV/DIV	≥195 MHz	145 MHz
P6201 (X10)	20 mV/DIV	≥195 MHz	182 MHz
Type 485			
Without Probe	5 mV/DIV	350 MHz (50Ω input) 250 MHz (1MΩ input)	....
P6053A (X10)	50 mV/DIV	250 MHz	50 MHz
P6201 (X1)	5 mV/DIV	325 MHz	185 MHz
P6201 (X10)	50 mV/DIV	325 MHz	273 MHz
7704A/7A18A (Opt 9)			
Without Probe	5 mV/DIV	170 MHz	....
P6053A (X10)	50 mV/DIV	161 MHz	48.5 MHz
P6201 (X1)	5 mV/DIV	167 MHz	133 MHz
P6201 (X10)	50 mV/DIV	167 MHz	158 MHz
7904/7A16A			
Without Probe	5 mV/DIV	225 MHz	....
P6053A (X10)	50 mV/DIV	200 MHz	49.5 MHz
P6201 (X1)	5 mV/DIV	218 MHz	155 MHz
P6201 (X10)	50 mV/DIV	218 MHz	200 MHz
7904/7A19			
Without Probe	10 mV/DIV	500 MHz (50 Ω input)	....
P6201 (X1)	10 mV/DIV	430 MHz	195 MHz
P6201 (X10)	100 mV/DIV	430 MHz	324 MHz

Fig. 1. *Effect of source resistance and probe input impedance on scope system bandwidth.*

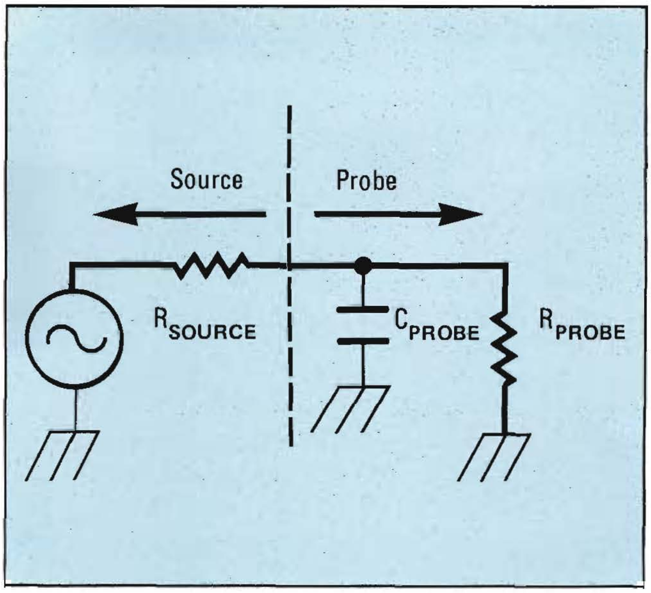


Fig. 2. *Equivalent circuit of probe and signal source.*

TYPE	ATTENUATION	LOADING		RISETIME IN ns
P6045 FET	1X	10 M	5.5 pF	1.5
	10X		2.5	
	100X		1.8	
P6046 DIFF/AMP	1X	1 M	10 pF	3.5
	10X	10 M	3	
P6051 FET	5X	1 M	2.8 pF	0.35
	20X		3.3	
	100X		2.0	
	200X		1.8	
P6201 FET	1X	100 K	3.0 pF	0.4
	10X	1 M	1.5	
	100X	1 M	1.5	

Fig. 3. *Active probes available from Tektronix, Inc.*

A Recent Addition.

The latest addition to the TEKTRONIX active probe family is the P6201 FET Probe. This probe features high input impedance at low capacitance, unity gain (i.e., 1X attenuation), and compatibility with either 50-ohm or one-megohm oscilloscope inputs. The probe is especially attractive for providing a high-impedance input for the 500-megahertz TEKTRONIX 7900/7A19 Oscilloscope or similar 50-ohm systems. When used with the 7900/7A19, the P6201 maintains sensitivity of 10 millivolts per centimeter at an overall bandwidth of at least 430 megahertz when driven from a 25-ohm source. Fig. 1 shows the resultant bandwidth when the P6201 is used with other high-frequency oscilloscope systems.

Many TEKTRONIX Oscilloscopes provide readout of the vertical deflection factor. Two methods are used to provide readout: either by lights located behind the skirt of the deflection factor knob, or with the exclusive CRT READOUT system which indicates the deflection factor on the CRT along with the waveform. The P6201 has resistively-coded attenuators which provide the correct readout of the deflection factor at the probe tip when used with these oscilloscopes. This greatly reduces the possibility of measurement errors caused by failing to take the probe attenuation into account.

Other Features of the P6201

A switch-selectable AC-DC coupling feature allows the DC component of a waveform to be removed without changing the probe's effective input capacitance. This is accomplished by use of a DC-reinsertion amplifier. The signal from the probe tip is connected to the oscilloscope through two parallel paths (see Fig. 4). The AC components of this signal are connected through the Probe Body AC Amplifier which has capacitive coupling at both the input and output. At the same time, the signal is direct coupled to the DC and LF Amplifier through the isolation resistor and the INPUT COUPLING switch. The isolation resistor allows AC coupling to be selected without affecting the input capacitance.

A broad-range DC-offset capability permits viewing of small signals riding on DC levels up to 200 volts (depending upon attenuator tip used) while maintaining DC coupled response. DC offset control is provided by the DC and LF Amplifier circuit. Fig. 5 shows the dynamic range and offset limitations of the P6201 and its attenuators. DC offset is most useful for observing low-frequency signals such as pulse trains, without the averaging or time-constant effects produced if AC coupling were used.

An internal 50-ohm termination can be selected when the P6201 is used on one-megohm vertical inputs.

Mechanical Considerations

Ever lose the use of a probe for days or even weeks because the nose pin on the probe tip broke? The probe body and each of the attenuators of the P6201 have screw-in nose pins for easy replacement of this vulnerable, but essential, part of the system.

The P6201 can be quickly attached to the vertical input connector. A special locking-type BNC connector allows quick connection. Power is supplied to the probe from probe power connectors on TEKTRONIX 7700 and 7900-Series mainframes, 475 and 485 Oscilloscopes, or by the 1101 Accessory Power Supply.

Summary

An essential part of high-frequency signal measurement is getting the signal to the input of the oscilloscope. When the source impedance is 50-ohms, most probes or cables provide satisfactory results. However, as the source impedance increases, the input characteristics of the probe determine the overall response of the measurement system. Passive probes can make some of the measurements at higher source impedances while active probes, with high input impedance and low capacitance, allow high-frequency measurements over a wide range of signal source impedances.

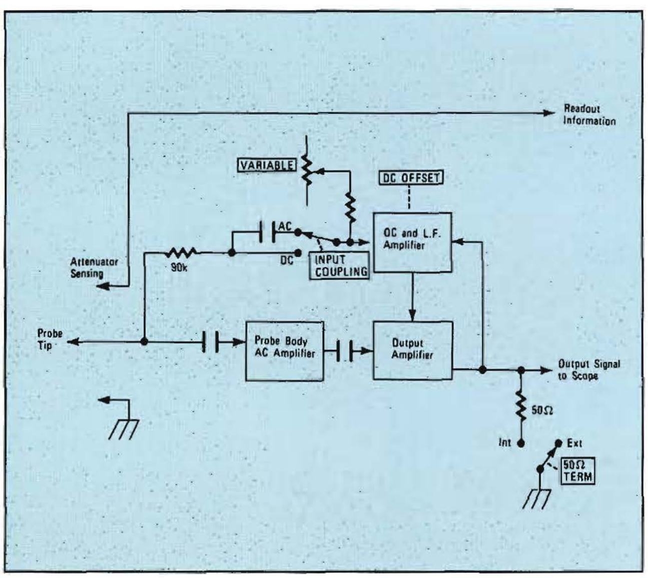


Fig. 4. *Block diagram of P6201.*

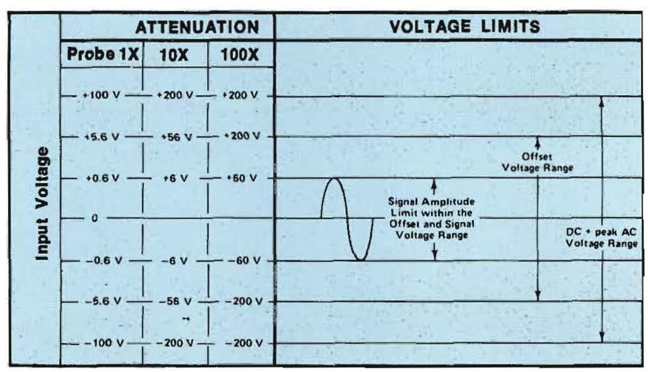


Fig. 5. *Dynamic and offset limitations of P6201 Probe and attenuators.*

References:

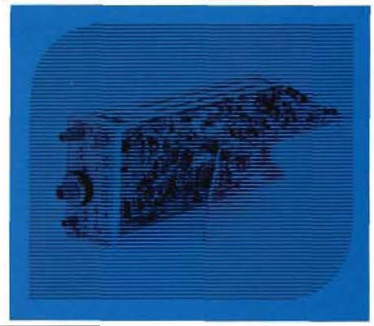
1. *"Probe Measurements", Tektronix Measurement Concepts Series, P/N 062-1120-00.*
2. *"Oscilloscope Probe Circuits", Tektronix Circuit Concepts Series, P/N 062-1146-00.*

MEET THE AUTHOR

Ron Peltola — Ron came to Tektronix in 1961 from Eugene Technical Vocational School in Eugene, Oregon. He has worked as an electronic technician in the Manufacturing Test Department and as an engineering assistant prior to his present job as a design engineer for the Accessories Design Group. Ron is coholder of Patent #3,710,270 with two other patents applied for. One of these is the Peltola coaxial connector described in the May 1972 issue of TEKSCOPE (see "The 7704A—Extended Performance Plus Modularity").

Ron is a native Oregonian. Besides family outings with his wife and three active boys, Ron enjoys metal and clay sculpture, chess, golf, and volleyball.

SERVICE SCOPE



by Ken Lindsay Sampling Staff Engineer

Servicing the Trigger Circuit in the 7T11 Sampling Sweep Unit

A finely-tuned racing car requires more frequent adjustment to keep it at its peak performance than the family car. Sampling instruments traditionally display a similar characteristic, and for much the same reason—they deal with high-speed phenomena. This article presents a simplified, yet complete, method for adjusting and troubleshooting the 7T11 Trigger Circuit.

It's frustrating to get three-fourths of the way through a calibration procedure and find a bad component that forces you to start all over again after replacement. To prevent this, it's a good idea to determine if any part of the circuit needs repair before starting to calibrate the unit. The following procedure will help you know how, and where, to look for trouble in the trigger circuit, as well as how to make the adjustments.

Initial Set-Up

1. Remove the side covers from the 7T11 and 7S11. Make sure the right side cover of the 7T11 is marked so it is not reinstalled on the 7S11. This cover should have "7T11" printed on it at the factory. Don't use any other in its place because part of the underside has a strip of insulating material applied to prevent accidental grounding of close components.
2. Since the 7T11 will be operated outside of the plug-in compartment, you will need to couple strobe pulses from the 7T11 to the 7S11. To do this, unplug the coaxial cable having a red tracer, visible through a slot in the top of the 7T11, from jack J344. Apply a piece of insulating tape to this connector to prevent it from accidentally short-circuiting anything inside the 7T11. Plug one end of the special coaxial cable (TEKTRONIX Part No. 012-0203-00) onto J344. Plug the other end of this cable into jack J430 near the rear of the left side of the 7S11 where a cable having a red tracer is normally installed. Route the cable through the 7S11 underneath the sampling head compartment. Tape the loose end of the connector that was unplugged from the 7S11.
3. If the 7T11 is calibrated in a 4-compartment 7000-Series mainframe, a separate test scope is not needed. Install a vertical plug-in such as the 7A13 or 7A12 in the left vertical compartment and a time-base plug-in such as a 7B70 in the right horizontal compartment. Then install the 7S11 containing an S-1 or S-2 Sampling Head into the right vertical compartment of the mainframe. In the adjacent horizontal compartment, install a rigid plug-in extender (067-0589-00) or flexible plug-in extender (067-0616-00). Install the 7T11 on the extender. (NOTE: The inside edge of the lower left hand plastic guide on the rigid extender may need to be beveled with a file or knife so the 7T11 fits easily and securely.) Turn on the scope power.
4. Select the RIGHT Vertical compartment and the "A" Horizontal compartment of the 7000-Series Oscilloscope for display. Set the 7S11 for 200 mV/DIV, the Dot Response pushbutton to NORMAL, and the DOT RESPONSE control with the white dot straight up. Set the 7T11 TIME POS RNG to 50 μs and TIME/DIV to 5 μs. Press the REP scan and SEQUENTIAL buttons.

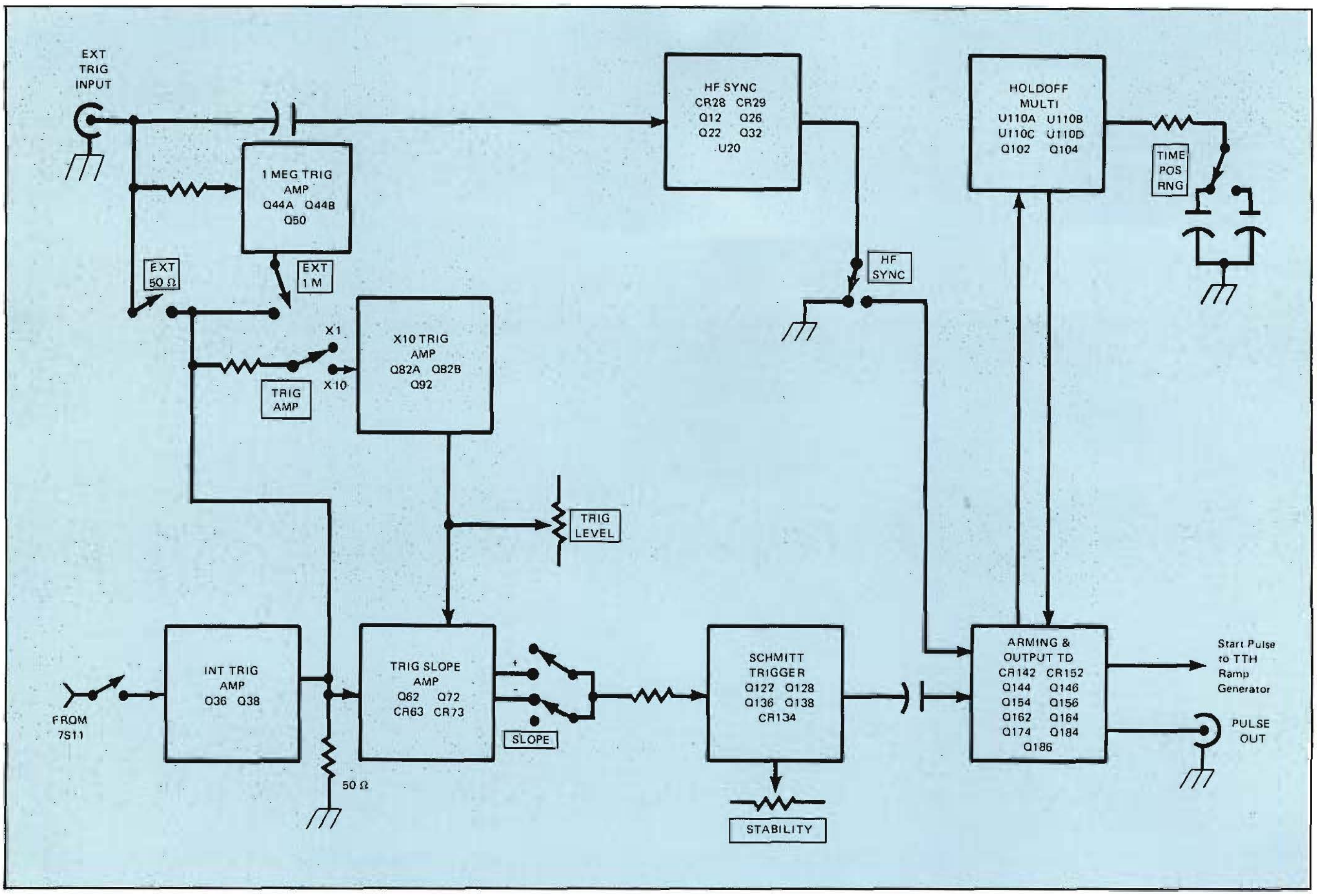


***Fig. 1.** Block diagram of the 7T11 Trigger Circuit.*

The instruments are now set up to check the trigger circuits for proper operation. This setup also prepares the 7T11 for the adjustment procedure.

Trigger Checkout

In any mode of triggering except HF SYNC, it should be possible to control whether the sweep runs or not with the front panel STABILITY and TRIG LEVEL controls. In the HF SYNC mode, the sweep should run with any setting of these controls. Push the 50Ω EXT button and set the STABILITY fully clockwise. Set the TRIG LEVEL to approximately midrange and check for a free-running sweep. You should be able to start and stop the sweep by changing the setting of the TRIG LEVEL control. If a free-running sweep cannot be obtained, check for a pulse approximately 10 volts in amplitude at the 7T11 PULSE OUT jack using a test scope and 10X probe. If the pulse is present, it means that the triggers are functioning and there is a problem in some other section of the instrument. If no pulse is present, press the HF SYNC button and recheck the PULSE OUT. This bypasses much of the trigger input circuitry and Schmitt Trig Regenerator (see Fig. 1).

If a pulse is not present even with the HF SYNC button pressed, the trouble may be in the HF SYNC block, HOLD-OFF MULTI, or the output TD's. If there is a pulse present in the HF SYNC mode but not in EXT 50Ω mode, the Schmitt Trigger circuit is not functioning properly. Before troubleshooting the Schmitt, it's a good idea to push both + and – SLOPE buttons and X10 TRIG AMP button and recheck operation. A problem in either the Trig Slope Amp or X10 Trig Amp can hold the Schmitt in one state which will produce no output. Output from the Schmitt is dependent upon the switching action, not whether it's in its high or low state.

The Schmitt Trigger is a regenerative type of circuit. An output is delivered from the Schmitt when tunnel diode CR134 changes to its high-voltage state. The amount of current needed at the Schmitt input to cause CR134 to fire is determined by the front-panel STABILITY control and Stability Zero adjust R135. Input current is delivered to the emitter of Q122 from the Trig Slope Amp.

Trig Level Zero adjust R120 balances the Slope Amp so that the same current will be delivered when either

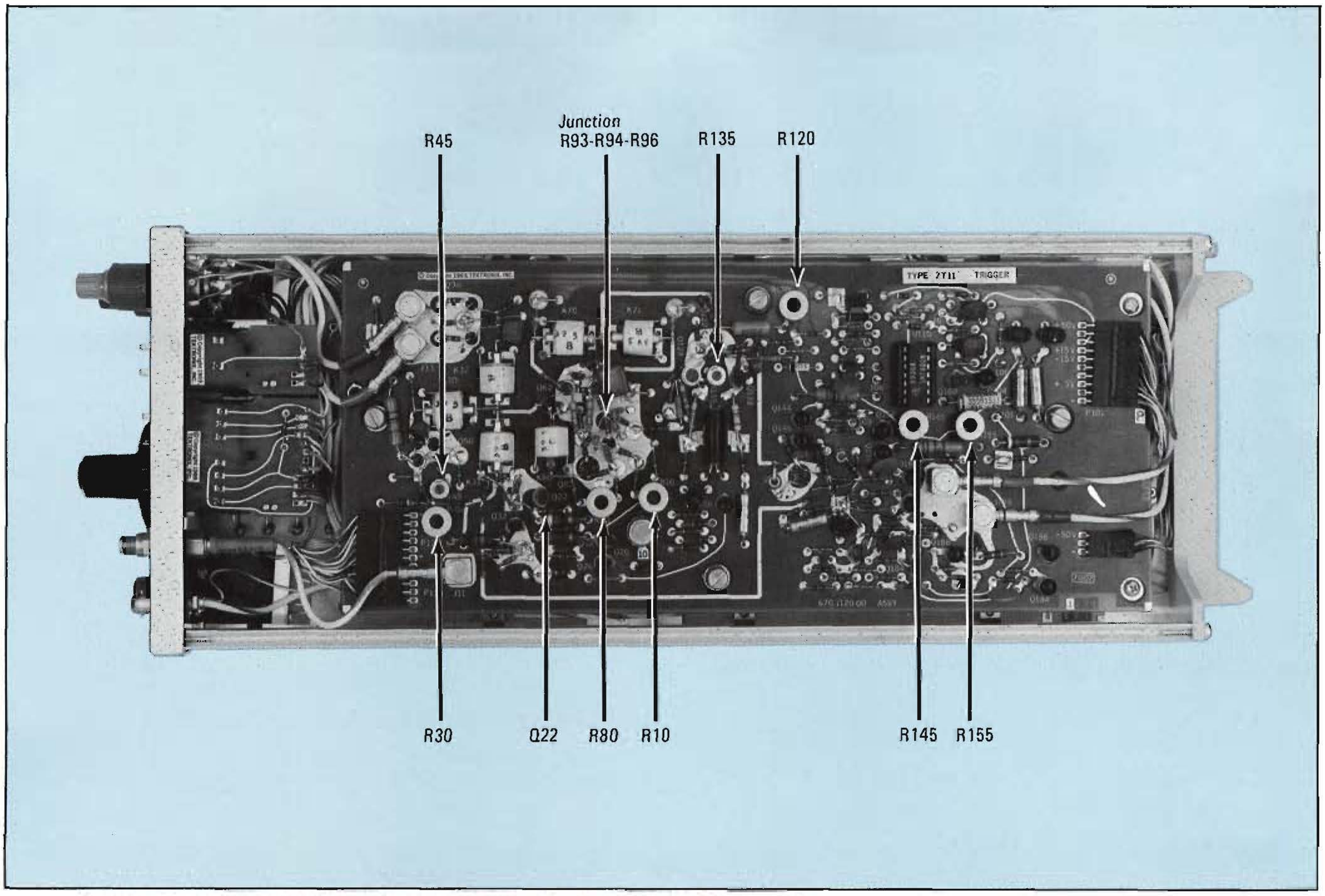


Fig. 2. Location of Trigger test points and adjustments (right side of instrument).

+ or − SLOPE is selected. The most common failure in the Schmitt circuit is tunnel diode CR134, or lamp DS136 in the optical isolator.

The output TD's, CR134 and CR152, can be checked with a DC-coupled test scope and 10X probe connected to the anode of each diode. Use an overall sensitivity of 5 volts/div since the 600 mV TD signal is riding on a −15 volt DC level. If a differential comparator plug-in is available, such as a 7A13 or W, use this at 200 mV/div (overall sensitivity) with −15 volts of offset voltage. This will make it easier to see when the TD switches.

Now, by adjusting R145 (for CR142 bias) and R155 (for CR152 Bias) throughout their entire range, you can see if the TD's turn off and on. If either of the TD's will not change state, it is either defective or there may be a problem in the Hold-Off Multi which is holding them in one state.

If trouble is encountered in the HF SYNC circuit and tunnel diode CR28 has to be changed, try to install the new one with a loop in the lead similar to the one being replaced. This loop is actually an inductor, and its distance from the board will effect the frequency of the sync oscillator. If trouble is encountered when adjusting R10 for the HF SYNC frequency range, moving the lead either closer to, or away from, the board may be all that is necessary.

The rest of the trigger circuitry, input, etc., can be checked quite easily by applying either an INT or EXT trigger signal and following it through the circuit with a test scope.

Trigger Adjustments

This procedure provides a quick method for the experienced technician to adjust the 7T11 Trigger Circuit. For a detailed calibration procedure including description of the equipment used and typical waveforms, refer to the 7T11 Instruction Manual.

Fig. 2 shows the location of the trigger adjustments and test points referred to in this procedure.

1. Push the REP button, SEQUENTIAL button, INT button, X1 TRIG AMP button, and the + SLOPE button. Set the TIME POS RNG to .5 μs and the TIME/DIV to 50 ns. Set the SCAN control to mid-range and the STABILITY and TRIG LEVEL controls fully counterclockwise (ccw). Preset R155 and R145 fully clockwise (cw). There should be a free-running trace.

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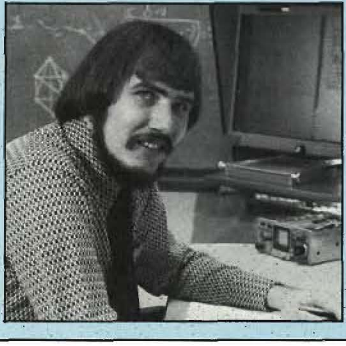
Editor: Gordon Allison, Ass't Editor: Dale Aufrecht, Graphic Designer: Tom Jones, Assistant: Diane Dillon.

2. Back off R155 (ccw) until the trace stops, then cw until sweep runs. Back off R145 (ccw) until sweep stops, then go about 10° more. If sweep will not stop, it may be necessary to back off R135 slightly. Set STABILITY cw and TRIG LEVEL for a free-running sweep.
3. Slowly turn the STABILITY ccw as far as possible while maintaining a free-running trace with the TRIG LEVEL. Note position of TRIG LEVEL. Press the −SLOPE button and adjust TRIG LEVEL for a free-running display. Note position of TRIG LEVEL. Center TRIG LEVEL between the two positions noted above and adjust R120 so sweep will free run while switching between + and − SLOPE buttons. (NOTE: It may be necessary to advance the STABILITY slightly while making this adjustment.)
4. Being careful not to move the setting of the STABILITY or TRIG LEVEL controls, press the 1 MΩ EXT trigger input button and adjust R45 for a free-running display.
5. Push the X10 TRIG AMP button and 50Ω EXT trigger input button. Monitor the DC voltage at the junction of R93, R94, and R96 (see Fig. 2) with a test scope and a 1X probe set at 50 mV/DIV. Adjust R80 for close to zero volts. Remove scope probe and press X1 TRIG AMP button.
6. Press the 7S11 NORMAL button and apply a 5 MHz to 50 MHz sinewave or squarewave to the S1 or S2 Sampling Head and the EXT TRIG INPUT connector with a "tee" connector. Trigger the display and adjust the signal source for 20 mV display amplitude. Set the STABILITY ccw and adjust R135 so that a stable, triggered display can be obtained with the TRIG LEVEL control while the STABILITY remains ccw. Remove the trigger signal and make sure the sweep will not free run at any setting of the TRIG LEVEL with the STABILITY ccw. If the sweep does free run, adjust R135 ccw slightly and recheck.
7. Connect the Pulse Output of the Type 284 Pulse Generator (or fast pulse from a similar generator such as the S-52) to the S1 or S2 Sampling Head and the Pre-Trig Out from the generator to the 7T11 EXT TRIG INPUT. Set the 7T11 TIME POS RNG to 50 ns and TIME/DIV to 1 ns. Set the Lead Time switch on the 284 to 75 ns or 150 ns. Set the 7T11 STABILITY control fully ccw and adjust the TRIG LEVEL for a stable display. Center the display with the TIME POSITION controls. Adjust R155 cw until the display jumps to the right approximately 3 ns, then ccw until it jumps back; then go ccw about 20° more. Next, adjust R145 cw until the display jumps a little to the right or breaks up; then adjust ccw for a stable display plus about 20° more rotation.
8. Disconnect all signals and set the STABILITY cw and TRIG LEVEL for a free-running display. Connect a coax cable between the EXT TRIG INPUT of the 7T11 and the vertical input to the 7S11; push the HF SYNC button. (NOTE: this will feed a synchronous trigger-kickout signal to the vertical.) Temporarily remove transistor Q22 (see Fig. 2) and set the TIME/DIV to 1 ns to display the kickout signal. Preset R30 about midrange and adjust R10 so the interval between waveforms may be varied between ≤3 ns and ≥4 ns using the front-panel STABILITY control.
9. Adjust R30 for the least display jitter as the STABILITY control is moved throughout its range. Reinstall Q22. Turn off the power and remove the 7T11 from the plug-in extender. Replace the original coax leads at J344 in the 7T11 and J430 in the 7S11. Replace the side panels.

This completes the trigger adjustments and triggering should now perform according to specifications. In a later Service Scope, we will look at troubleshooting and adjusting the timing section of the 7T11.



About Our Author

Ken Lindsay—In his four years at TEK, Ken has worked with sampling instruments in the Manufacturing Test Department, Factory Service Center, and now as a Marketing Staff Engineer. His present duties involve him in the introduction of new instruments as well as application and maintenance of older sampling instruments. Ken attended Idaho State University and Ricks College in his native state of Idaho before joining TEK.

For extra-curricular activities, Ken likes experimenting with electronics and has designed and built most of his own stereo system. He also enjoys working with sports cars and is the proud owner of a Triumph TR-6.

Ken and his wife Peggy are also enjoying getting settled in a new home they recently built.