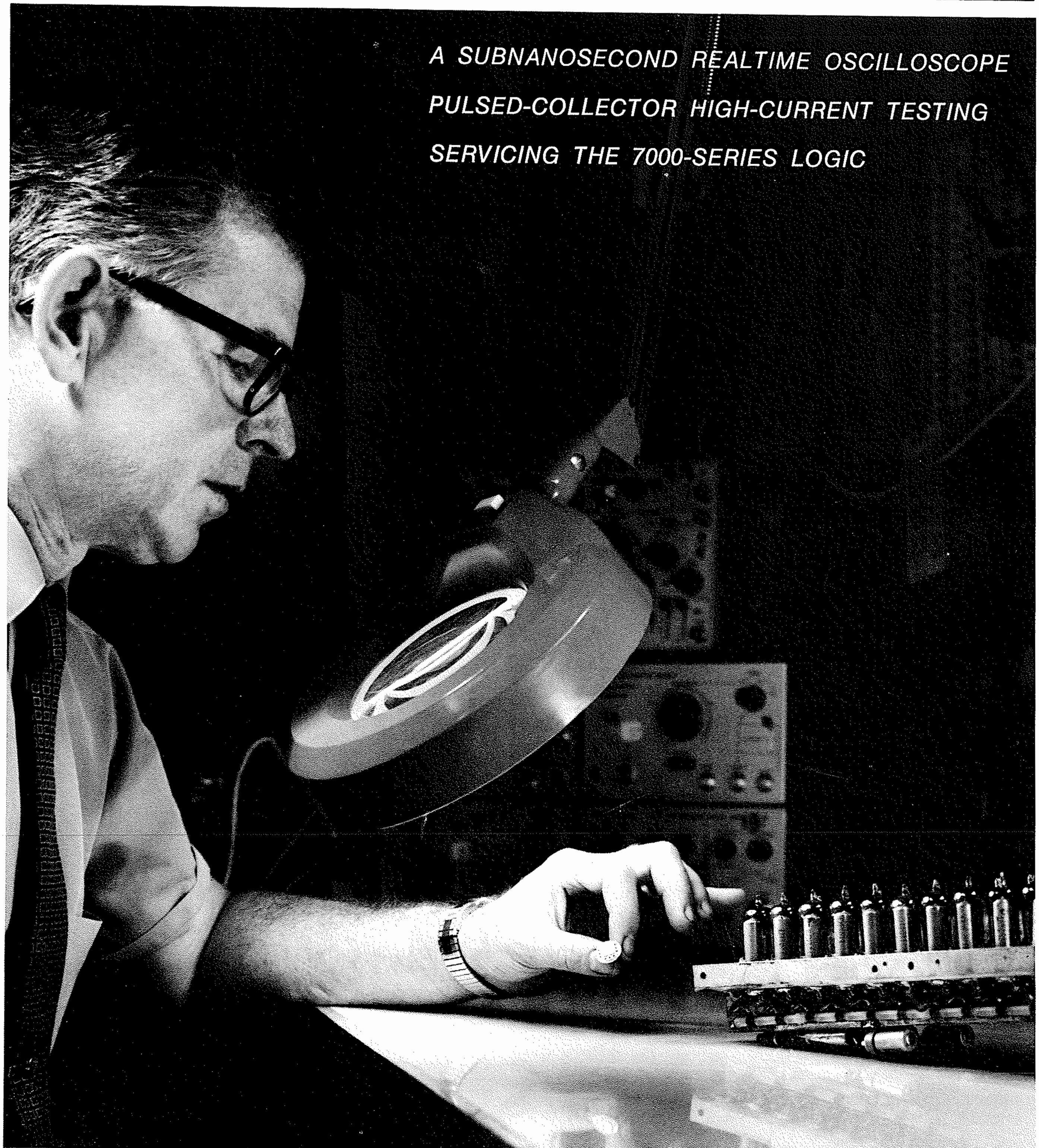
TEKSCOPE

JULY 1971



Jack Murdock

On May 16, Jack Murdock, Chairman of the Board and co-founder (with Howard Vollum) of Tektronix, Inc., suffered a seaplane mishap on the Columbia River. He has been missing since and is presumed drowned.

Many of you as Tektronix customers and friends have, through the years, expressed your appreciation for the quality of products and services provided by Tektronix. Jack was a major influence in instilling the pride of workmanship and concern for the customers' needs reflected in these products and services. That influence is best expressed in the following letter to Tektronix employees from Howard Vollum, President.

Newspaper stories since Jack Murdock's death have merely sketched, rather than elaborated on, his many achievements. This is fitting; Jack was a modest and unassuming man with no taste for the limelight.

Yet he was warm and outgoing. To many of you, as to me, he was a good friend, a person you could bring your problems to. Jack deserved his reputation as a great listener – always genuinely willing to tune into "the other guy's" point of view.

I met him in the spring of 1937. He had opened a store on 67th and Foster, after high school graduation. His father had offered to send him to college, or give him an equal amount of money to start a store. He chose the latter, and began Murdock Radio and Appliance Company.

While Jack was a very competent technician, it was more important that he spend full time managing the store. So I took on the radio service job. Jack was an excellent salesman, largely because he was such an exceptional listener. No high pressure at all, just genuineness; but many times I saw a person who had come in only to complain stay to make another purchase, once he had his troubles all talked out.

Jack was always oriented toward the customer's viewpoint, and toward the ideal of service. Both these characteristics were transmitted to Tektronix, when it was founded in 1946. He is responsible for our first-name salutations, for our disregard of status symbols and for many other ways we have come to behave toward one another, and toward our customers.

He led by setting an example. Despite his achievements, he was a humble man, without pretense. For many years our general manager, Jack was responsible for Tek's then-innovative "personnel policies" (although we didn't call them anything so formal then), most of which continue today.

But his biggest contribution was as the key Tektronix organizer. He was the person with enough business experience and contacts that the rest of us felt the thing would "go". Without his leadership, I think none of us – even though we knew by then we could build a superior product – would have felt comfortable starting such an enterprise.

Jack was deeply involved with the mental-health and human-relations aspects of industry, also with the study of semantics. He always felt that knowledge was the key to solving any problem, and that if you knew enough about it you could arrive at the appropriate solution. He played down his own academic achievements – largely because he had chosen not to go to college – but in terms of broad education, he had far more than many college graduates do.

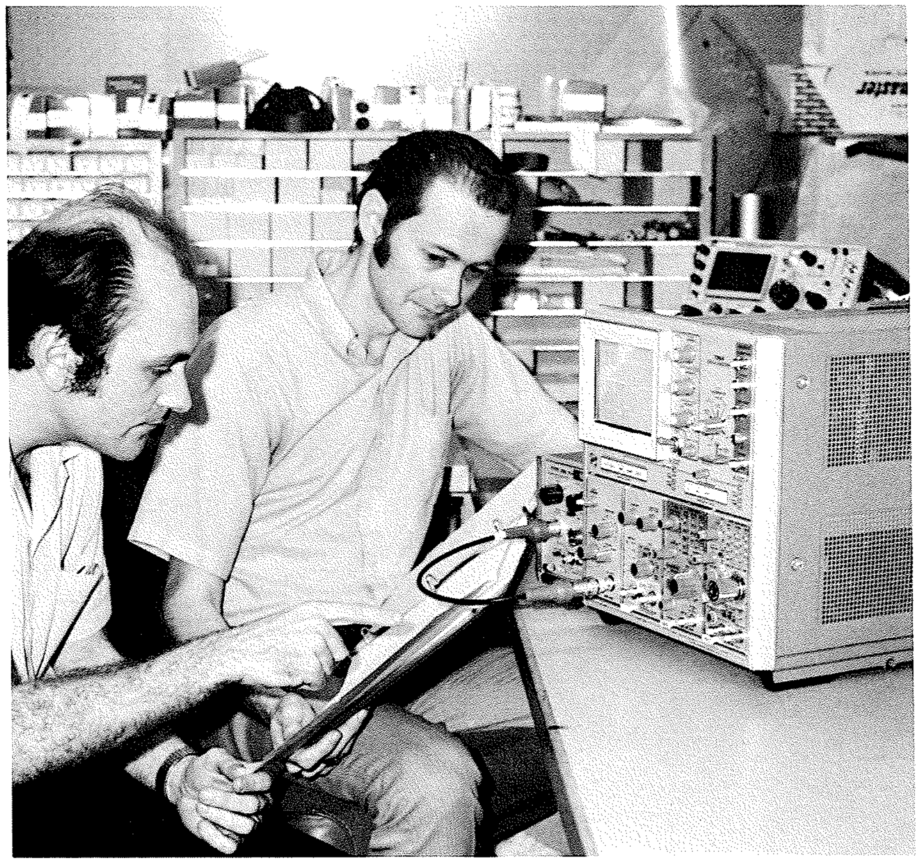
Although both eager and able to be outgoing, he intensely disliked personal publicity, particularly in the news media. (It was always my feeling, however, that he could have charmed any of the press corps off their feet.)

Many of his beliefs will live on as part of our company. But Tektronix, like the rest of the business world and the community at large, has suffered a loss now that his service to it has ended. The world is always the poorer when a positive influence is lost. So it will miss Jack Murdock, a good man and a close friend to so many of us.

Howard Vollum

COVER—Advances in state-of-the-art amplifier circuitry is dramatically illustrated in photo showing the output amplifiers for the 7904 and the 517. The 517, for many years, was the high-speed scope standard.

Val Garuts and Thor Hallen discuss operation of the 7904.



a subnanosecond realtime oscilloscope

"The window to electronics" – you have probably heard this phrase used to describe the oscilloscope. Today, we can see more through this window than ever before. The new Tektronix 7904 now expands the real-time horizon from DC to 500 MHz. We have viewed signals of this bandwidth before but with limitations. The signals needed to be several volts in amplitude to drive the CRT directly, or repetitive in nature to permit the use of sampling techniques. With the 7904, fast signals only a few millivolts in amplitude and of single occurrence can be measured.

With the introduction of the 7000-Series instruments in the fall of 1969, Tektronix brought unparalleled versatility and performance to oscilloscope users. The 7904, latest in this series, brings exciting new performance with no sacrifice in versatility. For example, any of the twenty-two 7000-Series plug-ins currently available can be used in the 7904.

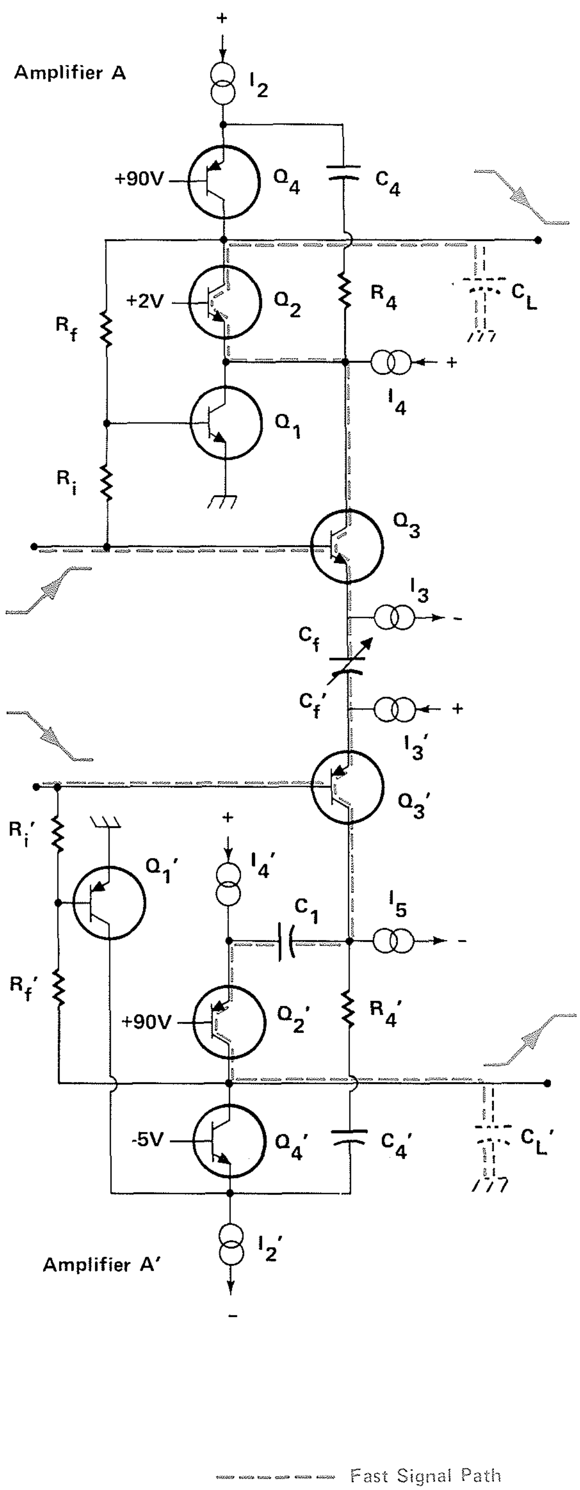
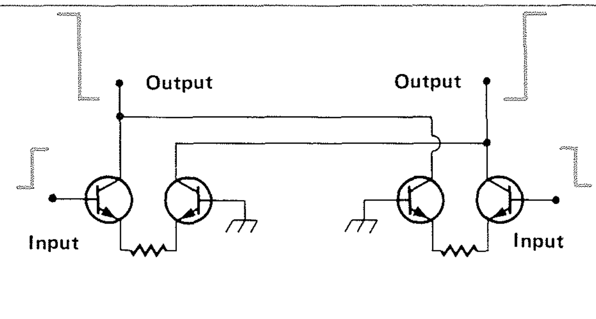


Fig. 1 Simplified schematic of the horizontal output amplifier.



The fT Doubler Circuit.

The CRT

Design work on the 7904 commenced with development of the cathode ray tube. The goal: a tube with sensitivity and spot size similar to the CRT in the 7704, but having 3 to 4 times the bandwidth and increased writing speed.

The 7704 CRT uses a segmented vertical deflection-plate structure with a top bandwidth of about 500 MHz. To achieve the additional bandwidth needed in the 7904, we selected a helical traveling-wave structure. Similar structures have been used in CRT's for high-speed scopes for several years. Their major drawbacks have been limited scan, low sensitivity, and cost.

The problems of sensitivity and limited scan are overcome by using a dome-shaped mesh electrode between the deflection-plate structure and the post-accelerator field. The mesh effectively shields the beam in the deflection area from the post-accelerator field and shapes the field to achieve a deflection magnification of 2 times in both the vertical and horizontal axis.

The optimum shape for the mesh to achieve good geometry was determined using a computer to plot the fields developed by the mesh, and the path of the electron beam through these fields. The equation producing the desired shape of mesh was then fed into a numerical control machine which made the tool for producing the mesh.

A unique method of fabricating the helical deflection structure yields a vertical scan of 8 cm and bandwidth in excess of 1 GHz. It is also relatively inexpensive to produce.

The CRT uses a ceramic funnel, now standard for most Tektronix CRT's, which permits edge lighting the internal graticule.

The 24 kV accelerating potential applied to the CRT yields excellent visual brightness and photographic writing speeds. Using a C-51-R Camera, P11 phosphor and 10,000 ASA film, the writing speed is 10 cm/ns. Fogging techniques extend this to 20 cm/ns.

THE VERTICAL SYSTEM

Coupled to the advances in CRT design is a vertical amplifier system containing many advances in state-of-the-art amplifier design.

Acquisition and processing of 500-MHz signals requires techniques considerably different from those used to handle signals in the 100-MHz region. In the early planning stages of the 7000 Series, the designers anticipated that bandwidth limits would be continually pushed upwards, and designed the interface between the mainframe and plug-ins to accommodate these greater bandwidths. The characteristic impedance at the interface is 50 ohms, an ideal environment for piping around UHF signals. In the 7904, the signal paths between circuit elements are all transmission lines terminated in their characteristic impedance. The result is a very clean transient response with aberrations typically less than 5%.

A new delay line design avoids preshoot and contributes much to the clean response. Optimized for maximum delay in a minimum volume, and short risetime, the line consists of two parallel solid conductors in a polyethylene dielectric with a foil wrap and extruded polyethylene protective jacket.

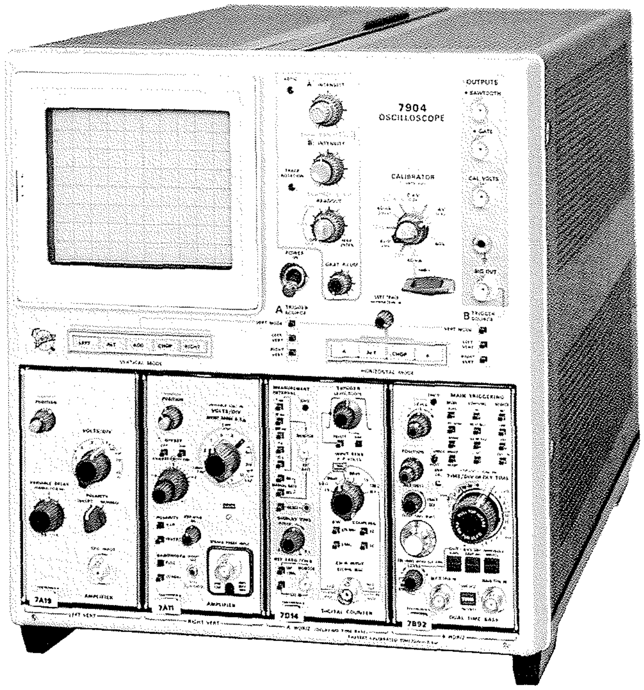
The input impedance of the 7A19 Amplifier Plug-in is 50 ohms. A Tek-made high-frequency cam switch permits input coupling of AC, DC or ground. The signal then passes through a 50-ohm turret attenuator providing deflection factors of 10 mV/div to 1 V/div. Attenuator switching is done ahead of the preamp except for the 10 mV/div position. The basic sensitivity of the plug-in amplifier is 20 mV/div. Since the 50-ohm line carrying the signal from the plug-in to the mainframe is double terminated, switching out the source termination increases the gain by a factor of 2 for a sensitivity of 10 mV/div.

An optional variable delay control permits matching the transit time of two preamps and probes to within 50 picoseconds. The delay is varied by mechanically moving a trombone section of transmission line. Range of delay is ±500 picoseconds.

From the variable delay the signal passes to the first amplifier stage. This is a unique wideband circuit which we call an f_T doubler. The simplified schematic opposite shows the basic circuit. The circuit was originally conceived several years ago by Carl Battjes. Considerable work by Thor Hallen coupled with the development of sophisticated IC fabrication techniques put the concept to practical use.

The f_T Doubler Circuit

f_T is the frequency at which the common-emitter current gain is one. If normal cascading of stages is used, no more than unity current gain can be achieved. The f_T doubler overcomes this limitation by effectively arranging for the base-emitter inputs of four transistors to be in series. The push-pull configuration allows the collectors to be effectively paralleled. At f_T the current gain of this arrangement is approximately two.



The 7904 DC to 500 MHz Oscilloscope System.

The f_T doubler can be thought of as an amplifier building block with twice the f_T of a single device. Using several of these building blocks, an amplifier with significant current gain at f_T can be built.

Once the basic design for the vertical amplifier had been chosen, the next step was to develop state-of-the-art high-frequency IC fabrication techniques to produce the transistors and couple them together. The emitter degeneration resistors were to be processed on the same chip with the transistors. This called for depositing precise amounts of nichrome on the substrate, a state-of-the-art process in itself. Since many critical processes were involved in producing a single f_T doubler stage, we decided to use a separate IC for each stage rather than integrate the entire vertical amplifier on one chip. The mainframe vertical amplifier uses three f_T doubler stages with coupling between stages via 50-ohm transmission lines.

The Output Amplifier

The output amplifier is a hybrid IC with a substrate carrier for mounting five silicon chips. Included on the IC is an f_T doubler, two small chip capacitors and two discrete output transistors.

Considerable design effort was expended in eliminating circuit elements that did not contribute to improving the signal gain. For example, there are no DC level shifting stages in the amplifier. The inductance of bond wires in the IC's, usually a problem in high-frequency design, is used as peaking inductance. There are no high-frequency adjustments in the vertical amplifier in the conventional sense. Transistor leads forming half-turn inductors are adjusted for optimum transient response.

THE TIME BASE PLUG-IN

The 7B92 Dual Time Base Plug-in used in the 7904 system features a fast 500 picosecond/cm sweep which complements the ultra-high bandwidth of the 7904 mainframe.

Delaying sweep measurements are made more convenient by a single front panel control which selects sweep rates for both normal and delayed sweeps, and selects either for display.

A new system of triggering the delayed sweep permits setting the time delay control to zero to view the triggering event on the delayed sweep.

An ALTERNATE sweep mode, available for the first time in a single plug-in, provides essentially dual beam operation for many applications.

Viewing of signals to 600 MHz and beyond is possible using the HF Sync triggering mode. When using an external trigger, either 50-ohm or 1-megohm input impedance can be selected to minimize loading of the trigger source.

THE HORIZONTAL AMPLIFIER

The top sweep rate of 500 picoseconds/cm places some pretty stringent demands on the horizontal amplifier. The CRT horizontal deflection plate sensitivity is 7 volts/cm which means the output amplifier must swing 70 volts in five nanoseconds. Fig. 1 is a simplified schematic of the circuit developed by Val Garuts to provide the fast, large-signal amplification needed in the output amplifier.

The horizontal output amplifier actually incorporates two amplifiers: A and A′. Amplifier A provides drive to the negative-going deflection plate and so is designed to have good performance in the negative direction of output. Amplifier A′ drives the positive-going deflection plate and has good performance for positive-going output signals.

Each amplifier provides two signal paths to its horizontal deflection plate, a high-frequency path using series feedback and a low-frequency path using shunt feedback. The bandwidth of the high-frequency path is 1 MHz to about 200 MHz and that of the low-frequency path is DC to about 30 MHz.

The high-frequency path for Amplifier A is through Q3 and Q2 to C_L, the load capacitance, consisting of the deflection plate, output amplifier and distributed capacitance. The gain of the fast (series-feedback) path is the ratio of the feedback capacitance to the load capacitance (C_f/C_L). C_f is made variable and set for a gain of ten for the high-frequency path.

The low-frequency path is through Q1 and Q2 to C_L. The values of the input resistance and feedback resistance are chosen to give the low-frequency amplifier a gain of ten also.

Amplifier A′ driving the positive-going deflection plate is arranged slightly differently, but the dual-path principle is maintained. The fast path is through Q3′ and Q2′ as before but a coupling capacitor C_I is inserted between them for DC blocking.

The low-frequency path is through Q1′ and Q4′ (rather than Q2′) because of the DC level at the emitter of Q2′. A gain of ten for both low- and high-frequency paths is selected as in Amplifier A.

An additional fast path is provided in each amplifier by C4, R4 and C4′, R4′ to speed up the positive transition of C_L and the negative transition of C_L'.

The Z-Axis Amplifier

The Z-axis amplifier in the 7904 uses a dual-path amplifier similar to the positive-going horizontal amplifier. The main difference is that the high-frequency path consists of PNP devices and the low-frequency path uses only NPN devices. This provides large output current for a negative-going output, and while the risetime in the negative direction is not as fast as in the positive direction, it is considerably faster than in the configuration used in the horizontal amplifier.

THE POWER SUPPLY

Both the low-voltage and high-voltage supplies in the 7904 are contained in a compact unit weighing just 7½ pounds. The high-efficiency supply provides 150 watts of regulated DC at an efficiency of about 80%.

A considerable savings in cost, weight and space is realized by winding both low-voltage and high-voltage transformers on a common core. The inverter, operating at about 23 kHz, drives both supplies.

Pre-regulation to better than 0.5% is achieved by controlling the inverter conduction time. The control circuitry is designed to switch the inverter transistors off at the zero-voltage point on the sinewave. This eliminates the large amount of EMI normally generated by high-efficiency supplies, and reduces the likelihood of damaging the inverter transistors.

Secondary regulation of the high-voltage supply is achieved using an amplifier to control only the −3 kV section of the supply.

Acknowledgments

Design of the 7904 system was a team effort. Val Garuts was project manager and developed the large signal amplifier circuit used in the horizontal and Z-axis amplifiers. Thor Hallen did the vertical amplifier and John McCormick the horizontal. The trigger and time base were done by Les Larson and Bill DeVey. Bill Peek worked on the Z-axis amplifier and auto-focus, with Hans Springer doing the mainframe interface and channel switching. Joe Burger's work on the power supply, coupled with Joel Swanno's efforts in mechanical design, reduced the weight to only 30 pounds. Ken Hawken did the fine job on the CRT. Certainly much credit is due the IC development team who built the devices that make possible the 7904's 500-MHz bandwidth.

TEKNIQUE: PULSED-COLLECTOR HIGH-CURRENT TESTING WITH THE 176

by Jim Knapton, Senior Engineer

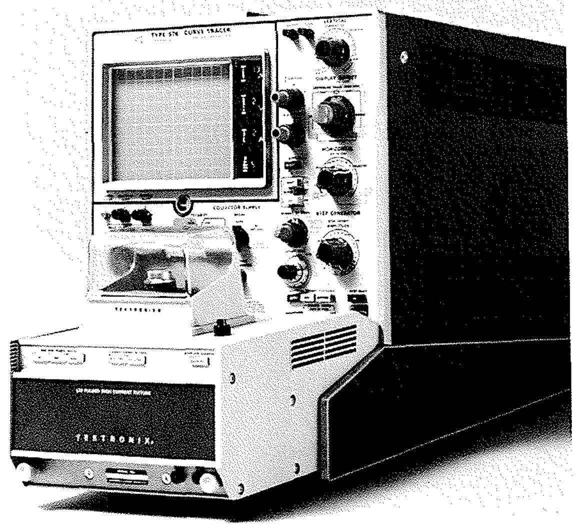
The 176 Pulsed High-Current Fixture brings a new dimension of operating convenience to semi-conductor high current and high power testing. Used with the 576 Curve Tracer, it provides currents up to 200 amps peak and power levels up to 1000 watts.

With the pulsed collector supply, new tests are possible in the area of breakdown voltage where the device normally would latch up. Other tests are possible at current levels available in the 576, but which could not be made on low power devices because of the duty cycle. Probably the two most neglected tests now made possible are rectifier forward drop at normal peak operating current, and transistor secondary breakdown.

The pulsed nature of the 176 collector output with its low (1.8%) duty cycle makes heat sinks unnecessary in most cases – even at the highest power levels. The same Kelvin contact device adapters used for low power tests may be used even at the highest current levels, and device adapters to cover the more common high power device packages are now available.

Soon to be announced is a TO-5 device adapter with Kelvin contacts. This will make possible accurate high current measurements on devices in TO-5 and other small signal packages. The internal wiring of the adapter can be readily rearranged for different lead configurations.

Now, let's look at some of the measurements that can be made with the 176.



The 176 Pulsed High-Current Fixture slides into the 576 in place of the Standard Test Fixture. It provides a pulsed collector supply of 200 amps peak and pulsed step generator output of 20 amps peak.

Power Transistor High Current Beta and Saturation Tests

The 176 may be used to perform high current beta, saturation and breakdown tests on power transistors. Saturation and beta tests may be performed at collector currents up to 200 amps and, as previously noted, usually without using heat sinks. Because of the Kelvin connection method of measurement, devices may be connected using relatively small wires without measurement error. However, the voltage drop that occurs in the collector and emitter leads will limit the peak currents obtainable. The maximum peak power watts position that should be used will depend on the device being tested. In general, the 10 and 100 positions are safe for forward biased transistor characteristics without heat sinks, if the peak collector voltage is limited to a value below device breakdown. The 1000 position should be used with some caution as average power dissipation can be about 20 watts (1.8% duty cycle).

Because Kelvin connections are not used on the *base* connection, some measurement error could be present when making $V_{BE\ (SAT)}$ measurements.

Figure 1 shows DC beta (h_{FE}) of a Westinghouse 1743-0620, TO-3 power transistor. The point of interest is a collector current of 90 amps at a collector voltage of 10 volts. This particular device required eight steps of 500 mA each to get 90 amps of collector current. Since $h_{FE} = I_C/I_B$ we have $90 \div (8 \times 0.5)$ for an hFE of 22.5. If the base steps selected do not give us a curve that crosses the desired reference point, we can use the step generator offset to achieve the desired collector current. This offset must be added to or subtracted from the base current drive when calculating beta.

Keep in mind that when the X10 step button on the 176 is illuminated, the steps and offset are both pulsed. When it is extinguished, only the steps are pulsed. A note of caution – it is possible to put excessive average power into a transistor base when making high current collector measurements using offset base drive.

Small signal beta (h_{fe}) can easily be measured by noting the distance between two characteristic curves for different base drive levels. The β per division readout does the calculating for you. All that is necessary is to multiply the vertical separation of two adjacent curves by the β per div readout. For example, the h_{fe} of this device is about 9 at 90 amps. The display offset can be used with the vertical magnifier to improve resolution for this type of measurement.

$V_{CE\ (SAT)}$ can be readily read from the same photograph. For example, $V_{CE\ (SAT)}$ at 50 amps is 3.0 volts and for 90 amps it is 6.9 volts.

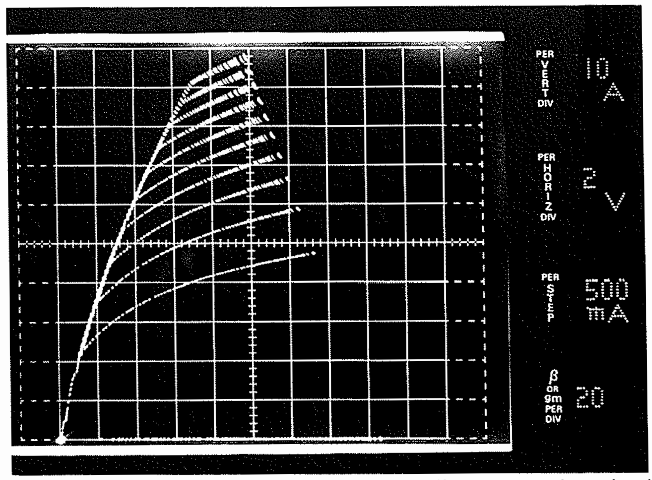


Fig. 1 Family of Ic vs Vc curves with collector supply pulsed on for 300 μs at power line frequency. Photos of waveforms are time exposures with the collector supply control manually advanced.

Transistor Breakdown Tests

The pulsed collector feature of the 176 makes it possible to make many breakdown tests that would otherwise destroy the device. This applies to secondary breakdown or any other situation where the device will "latch up" so that a pulsed base test cannot be used. For this reason, the 176, is quite useful for measuring breakdown voltages of small signal transistors as well as high power devices.

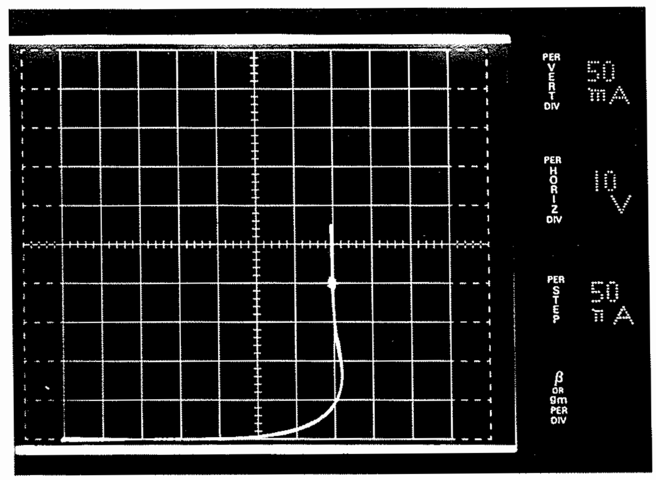


Fig. 2 Open base breakdown ($BV_{CEO(SUS)}$) of a 2N3771 measured at 200 mA. Bright spot at 200 mA is caused by momentary pause in manual advance of collector supply at point of interest.

There is a less convenient way to test BV_{CEO} where latch up may occur, using only the 576. It involves using one step of offset to saturate the transistor at all times except during the 300 or 80 microsecond base pulse interval. During this interval, the offset is canceled by a one step base pulse, effectively opening the base momentarily while the measurement is made. This method can be used only at relatively low currents.

When measuring reverse breakdown characteristics with the 176, the maximum peak power watts 10 position should usually be used. Caution must be exercised whenever looking at reverse characteristics as small amounts of power in the breakdown mode destroy some very high power devices.

There is no provision on the 176 to open the base connection. However, BV_{CEO} can be measured by setting the base step generator to a very low current position so that for all practical purposes the base can be considered as open.

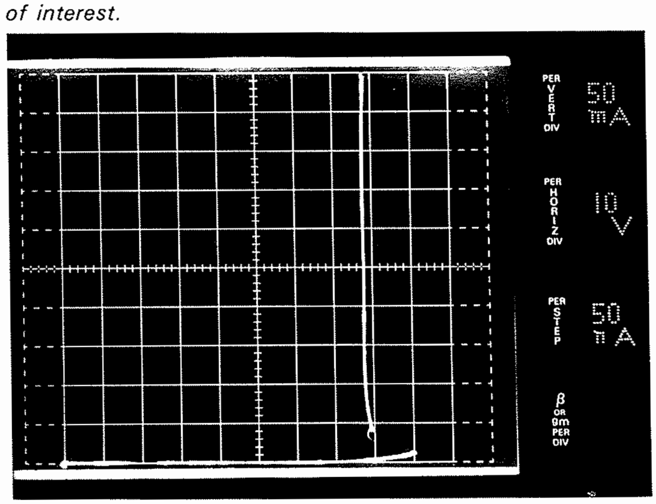


Fig. 3 Collector breakdown with the base shorted to emitter $BV_{(CES)}$ for the same 2N3771 pictured in Fig. 2.

BV_{CES} is measured by connecting a patch cord between the BASE and GND connectors on the front of the 176. Care must be taken to avoid dangerous shock when connecting the jumper if the collector supply is energized on the 75 V or 350 V range. The device under test might be shorted collector to base and open base to emitter. An insulated jumper should be used and it should be connected to GND terminal first. Quite often the breakdown characteristic will be such that oscillations will occur because of the negative resistance region of this characteristic.

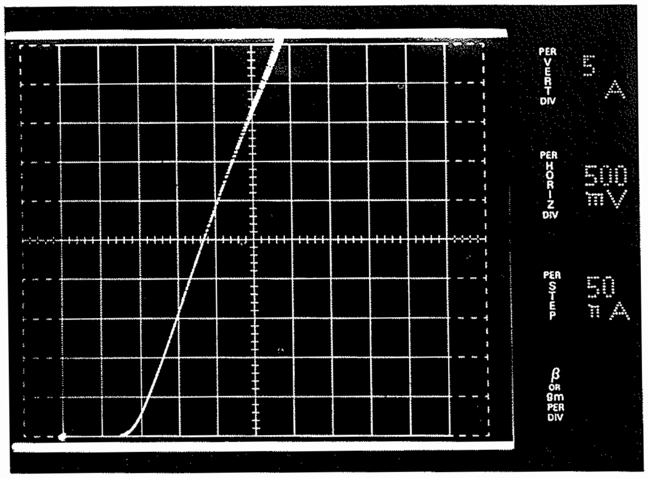


Fig. 4 Curve showing forward drop of 1N3194 rectifier. Note dot slashing above 35 amps caused by junction heating.

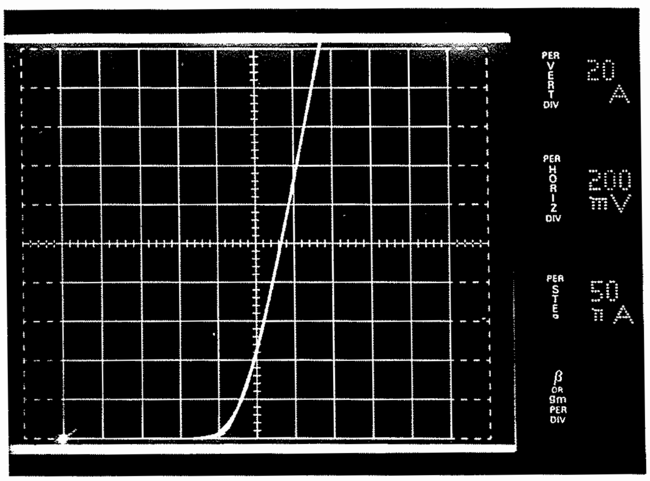


Fig. 5 Curve showing forward drop of 1N4721 3-amp rectifier at 200 amps illustrates high current capability of the 176.

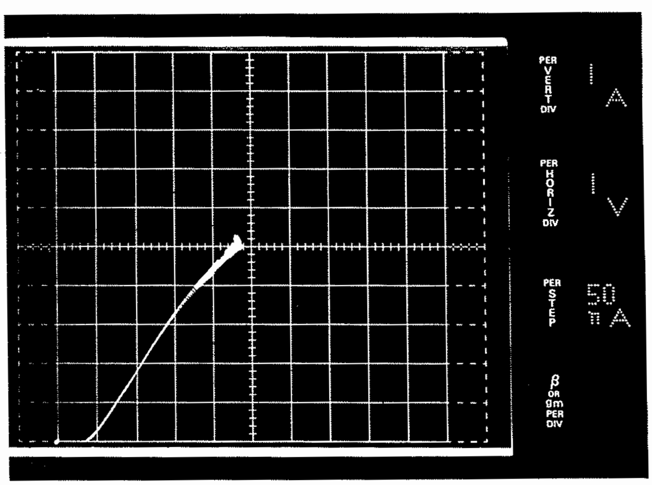


Fig. 6 Voltage vs current curve of a 1N3605 small signal diode graphically illustrates dot slashing caused by junction heating with excessive drive.

Figure 2 shows a 2N3771 silicon NPN power transistor tested for open base breakdown ($BV_{CEO(SUS)}$) at 200 mA.

The base terminal is opened by adjusting the step generator amplitude to .05 μA, as previously discussed. The variable collector supply is adjusted to obtain the desired current. Some enlarging of the spot will occur, especially before breakdown occurs. This is caused by the collector waveform turning on the base through the capacitance between collector and base. It can be ignored by measuring only the lowest current point on the enlarged waveform.

Figure 3 shows the same 2N3771 transistor as in Figure 2 tested for collector breakdown at 200 mA with the base shorted to the emitter (BV_{CES}).

To perform the test, the BASE and GND terminals at the front of the instrument are shorted with a patch cord. Then the variable collector supply is increased until the 200 mA level can be observed.

Rectifiers

With the 176 it is possible to test rectifier forward drops at currents up to 200 amps. Because the tests are done with pulses at a low duty cycle, far higher currents can be used than would otherwise be possible. For example, the Type 1N3194 rectifier is rated at 750 mA I_F average, 7.5 amps repetitive peak current and 40 amps non-recurrent peak current. Forward drop can easily be measured at 750 mA using the full wave rectified pulsating DC collector sweep of the 576. However, this does not represent actual operating conditions in a capacitor input filter. The forward drop at 7.5 amps is more meaningful as this rating allows for the actual operating current which might be encountered in a capacitor input filter. However, forward drop at this current level cannot be safely tested except at a low duty cycle such as provided by the 176.

The photo in Figure 4 shows the forward drop of a 1N3194 rectifier. The test shows the forward drops at these specified ratings to be 800 mV, 1.2 volts and 2.4 volts respectively; well within the specification. The tests at 750 mA and 7.5 amps were conducted casually with no heat sink and with plenty of time to take readings or photographs. Above the 40 amp level the device was heating rapidly but there was adequate time to take the photo without damaging the device.

Care should be taken to select the proper maximum peak power watts setting on the 176. In general, most rectifiers of the 500 mA to 1 amp variety cannot be destroyed on the 100 position if not tested for long periods of time.

Reverse breakdown of rectifiers can be investigated at higher current levels than possible before if the device has a breakdown of 350 volts or less. It is recommended that the maximum peak power watts 10 position be selected.

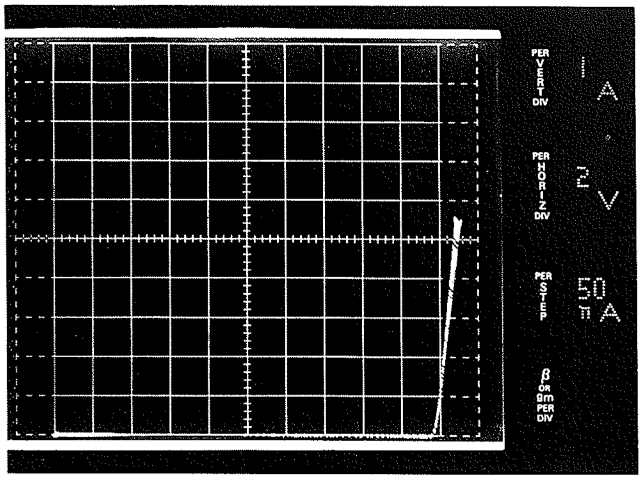


Fig. 7 Forward drop of zener diodes at high current levels can be readily checked with the 176. Curve shows characteristic of 1N3027B zener at 5 amps.

Small Signal Diodes

Just as with power rectifiers, it is possible with the 176 to test small signal diodes at high current levels not possible with the 576. However, care must be taken not to destroy the device. If the maximum peak power watts position of 10 is selected, the maximum obtainable average power will be about 200 mW in the 300 μs pulsed steps mode. The maximum peak power may be as high as 10 watts which will cause some junction heating during the pulse, depending on the thermal time constants.

When observing forward voltage current characteristics this will show up as a slash in the dot that is along the load line rather than along the characteristic curve. It increases in amplitude as the variable collector supply is advanced. When slash like this starts to occur, further advancement of the variable collector supply control may destroy the device.

Breakdown characteristics of the diode may also be displayed. However, it is very easy to destroy the unit as no warning is displayed prior to failure.

Figure 6 shows the voltage vs current characteristic of a 1N3605 small signal diode. This diode has an average current rating of 150 mA. Note the dot slashing caused by junction heating that is occurring above about 3.5 amps. The 80 μs pulse width may prove useful at these higher current levels. If some devices of a given type exhibit more change during the pulse than others, it may indicate poor die attachment.

Zener Diodes

With the 176 it is possible to measure zener breakdown voltages at high current levels. The maximum peak power watts 10 position should be used on 400 mW and lower zeners to avoid overheating. On higher power devices, the higher power levels may be used. Stud mounted devices can be tested on the 100 or 1000 positions if care is taken to avoid overheating.

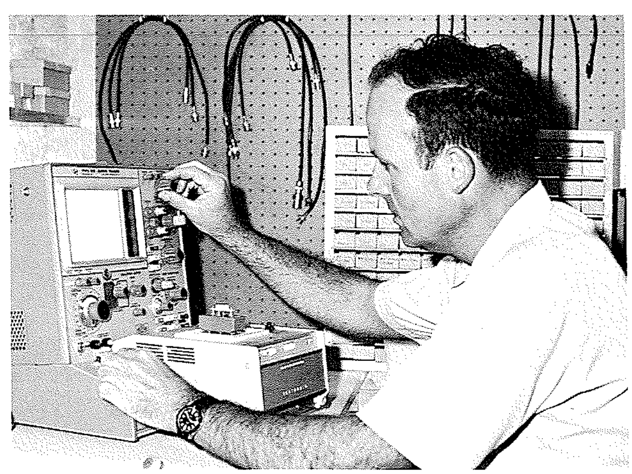
Figure 7 shows the voltage drop at 5 amps of a 1N3027B, 20 V, 4 watt zener diode. This particular device has a V_Z of 20.9 V at 5 amp. If a reading of greater accuracy is needed, first obtain the desired current without using the display offset, being careful not to over dissipate the device. Then use the display offset to magnify and reposition the display for a more accurate measurement.

Silicon Controlled Rectifiers

The 176 may be used to test the forward drop of SCR's at currents up to 200 amps. Testing methods would be the same as for ordinary power diode rectifiers except that the step generator must be used to turn the gate on. Gate firing levels may be determined readily using the offset feature of the step generator.

JAMES H. KNAPTON—Jim started his career with Tektronix in November, 1961 with design of the horizontal amplifier and calibrator in the 647, Tek's first solid state lab scope. After a period of working with pulse generators and time mark generators, he tackled the chore of developing a replacement for the 575 Curve Tracer. Jim contributed many of the fine features found in the 576, and recently added the 176 Pulsed High-Current Fixture.

Jim received his BSEE in June of '48 from the University of California at Berkeley. He spends his leisure time sailing with his wife and two children, skin diving and dabbling in photography.



SERVICE SCOPE

SERVICING THE 7000-SERIES LOGIC AND READOUT

by Charles Phillips,
Factory Service Technician

This is the concluding article on servicing the 7000-Series oscilloscopes. Other articles in this series appeared in the March and May issues of TEKSCOPE.

The one word that best describes the 7000-Series oscilloscopes is versatility. The key to this versatility is the logic circuitry which develops control signals for circuits in the plug-ins and the mainframe. The CRT readout also plays a key role in extending this versatility to encompass measurement areas formerly outside the scope domain. Digital multimeter and counter applications are now conveniently handled by Tektronix oscilloscopes using the CRT readout.

This article discusses servicing the logic and readout circuitry. Since the instrument instruction manuals include detailed operation of these circuits, we will limit this discussion to a brief summary of their operation and then discuss troubleshooting techniques and typical problems.

The Logic Circuit

The logic circuit is comprised of seven integrated circuits, seven transistors and a handful of components all located on one circuit board. The logic board is mounted on the rear of the main interface circuit board.

The basic functions of the logic circuits are to:

1. Provide command signals to the Vertical Channel Switch, Horizontal Channel Switch and Trigger Selection Circuit.
2. Provide CHOP and ALTERNATE drive signals to dual trace amplifiers.
3. Provide sweep inhibit signals for either the A or B Time-Base Plug-ins.
4. Provide logic for steering of Z-axis signals from:
   a. Time-base plug-in blanking circuits.
   b. A and B intensity controls.
   c. External Z-axis inputs.
   d. Vertical and horizontal chopped blanking circuits.
   e. Z-axis commands from the readout circuit.

All of the logic inputs and outputs are binary signals except for the Z-axis logic. The external Z-axis input, the intensity control inputs and the Z-axis logic output are analog signals. Inputs to the logic circuits come from the Vertical and Horizontal Mode Switches and the plug-in units. In addition, the Z-axis logic receives inputs from the sequencing logic in the readout, the intensity controls and the external Z-axis input.

The logic circuit outputs go to the Vertical Channel Switch, the Horizontal Channel Switch, the Trigger Selection Switch, the plug-ins and the Z-axis amplifier.

Mainframe Interface Switches

We should briefly discuss the function of the vertical, horizontal and trigger selector switches. Each is a separate etched circuit board mounted on the main interface board.

The Vertical Channel Switch determines which input signal drives the delay-line driver. The Horizontal Channel Switch determines which input signal drives the horizontal amplifier, and the Trigger Selector Switch determines which trigger signal is connected to the A and B Time-Base units. It also provides the drive signal for the Vertical Signal Amplifier whose output is the Vertical Signal Out.

A block diagram of the switches with their respective inputs and outputs is shown in Fig. 1.

Pictured on pages 13 and 14 are the switching sequences of the horizontal and vertical channels for several modes of operation.

The Vertical Mode Switch selects one of two different binary signals to be the Vertical Mode Command. In CHOP operation the Vertical Chop signal (1 MHz) is the command signal. When the Vertical Mode Switch is in ALT, the output of the Vertical Binary is the command signal. In this mode the command signal changes state at the end of each sweep (with Horizontal ALT) or at the same time the Display B Command switches (with Horizontal CHOP).

Notice that with the Vertical Mode Switch in ALT (Fig. 2 a and b) that the left vertical is slaved to B sweep and the right vertical to A sweep. This is with the time bases operated in INDEPENDENT mode. If the delayed sweep is used, the switching sequences are changed to that shown in Fig. 3 a and b.

The switching sequences for dual trace plug-in operation are shown in Fig. 4 and 5. The plug-in CHOP command (500 KHz) is always present regardless of the mainframe operating mode selected. It is directed only to the vertical plug-in compartments.

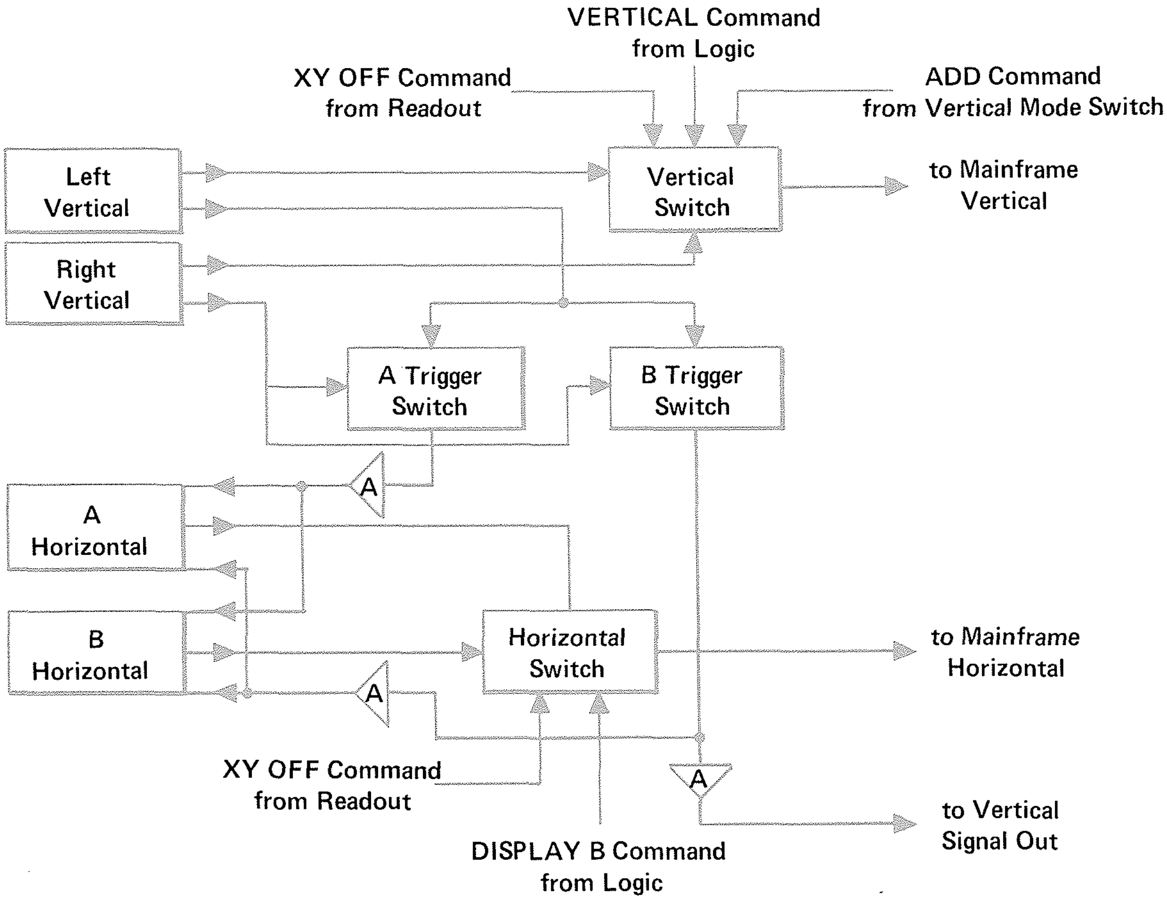


Fig. 1 Vertical, Horizontal and Trigger switching block diagram.

The plug-in ALT command is connected to all four plug-in compartments. It switches states at the end of each sweep for LEFT or RIGHT Vertical operation in the mainframe. In Vertical Mode ALT the plug-in binary counts down by 2 so that the plug-in ALT is operating at half the rate of the mainframe Vertical ALT. Notice that in Fig. 4a and Fig. 5a and b that left vertical is slaved to B sweep and right vertical to A sweep. When the Horizontal Mode is ALT or CHOP, the Vertical Mode is LEFT or RIGHT, and a dual trace plug-in is operated in ALT, Channel 1 is slaved to B sweep and Channel 2 to A sweep.

Troubleshooting the Logic Circuit

There are twenty display modes possible using the Vertical Mode and Horizontal Mode switches on the front panel. In addition, there are several other modes available using the mode switches on the vertical and horizontal plug-ins. Since it is beyond the scope of this article to present the logic signals for each of these modes, we have elected to list the logic output levels available at the test points on the logic board and describe what these levels accomplish. Also listed are the operating malfunctions that would occur should a given active component fail in the logic circuit.

Most of the problems experienced in the logic circuitry are caused by temperature-sensitive components. A can of spray coolant can be very helpful in locating this type of problem.

Following is a list of the logic outputs showing the output level and the function performed. The command signals from the logic circuit are typically small. In most cases the high level is about +1.0 volt and the low level about -0.5 volt. You will need to remove the low-voltage power supply from the scope mainframe to reach the test points on the logic board.

TP 196 Vertical Mode Command – A high level displays the right vertical channel.

TP 137 Plug-in Chop Command – A high level displays channel 2 in dual trace plug-ins.

TP 190 Plug-in Alternate Command – A high level displays channel 2 in dual trace plug-ins and is locked (slaved) to the A horizontal time base when the horizontal mode is in ALT or CHOP.

TP 164 Display B Command – A high level displays the B horizontal time base.

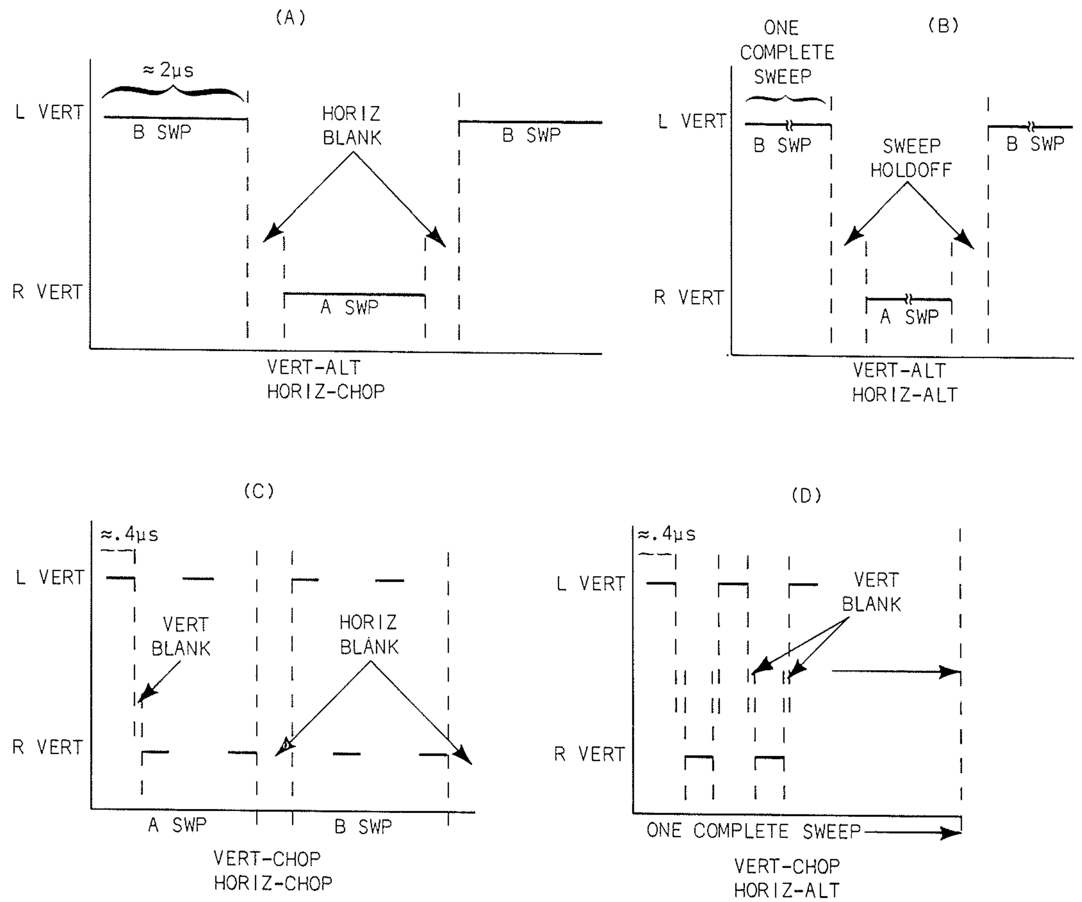


Fig. 2 Switching sequence of two single trace amplifiers with two time base units operated in the INDEPENDENT mode.

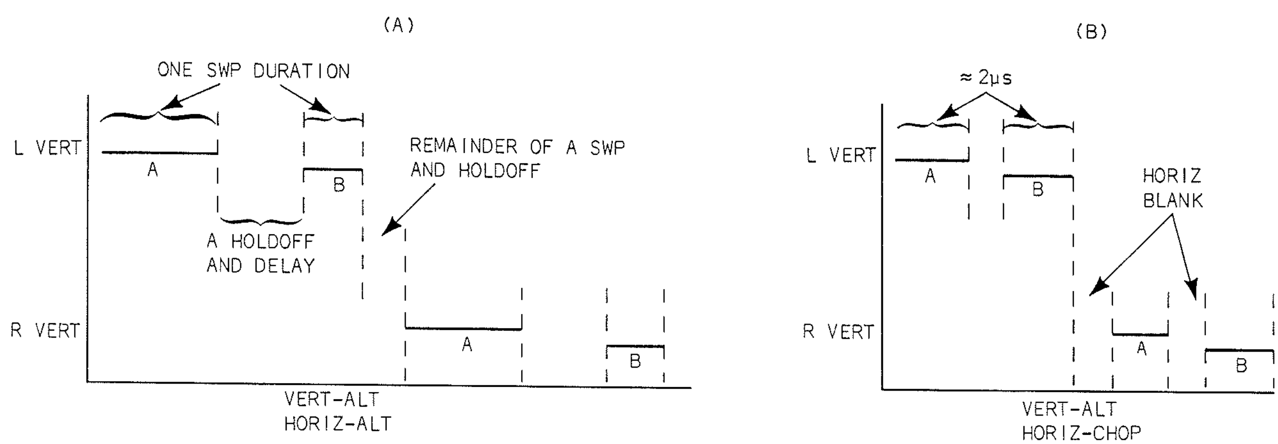


Fig. 3 Switching sequence of two single trace amplifiers with two time base units operated in the DELAYED SWEEP mode.

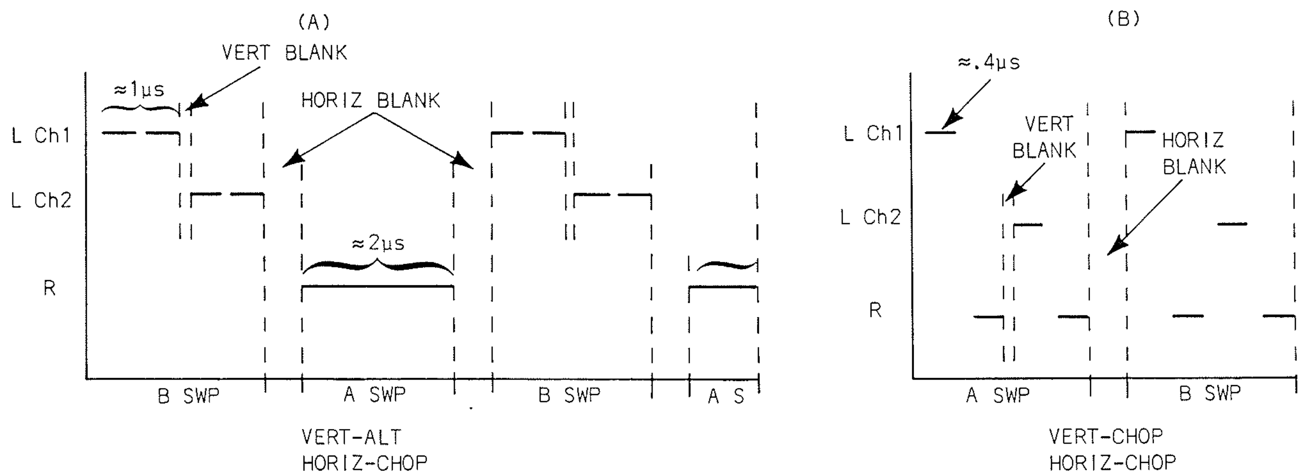


Fig. 4 Switching sequence of one dual trace amplifier operated in CHOP mode with one single trace amplifier and two time base units.

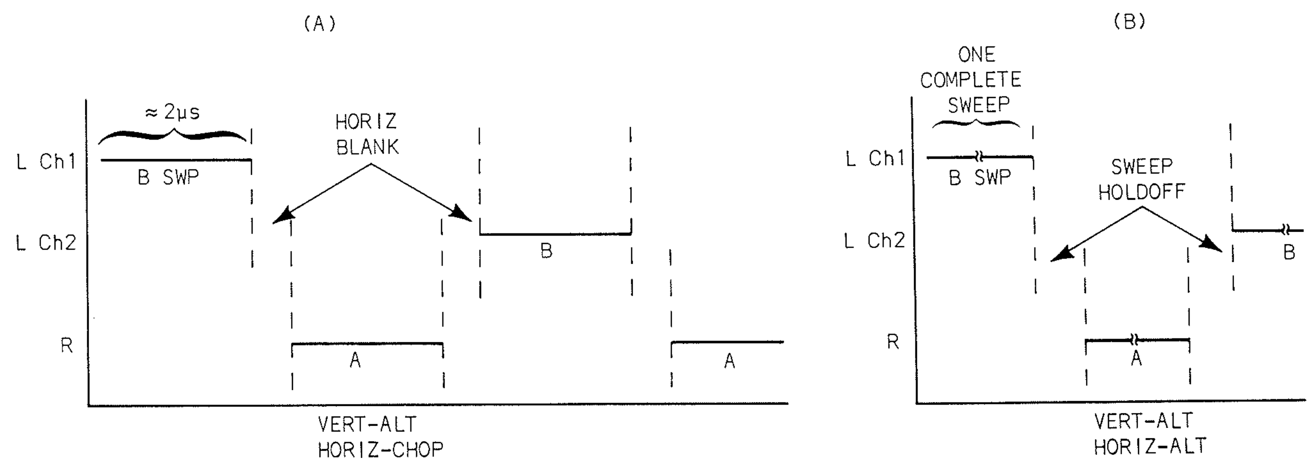


Fig. 5 Switching sequence of one dual trace amplifier operated in ALT mode with one single trace amplifier and two time base units.

TP 167 A Sweep Inhibit – A high level prevents A sweep from running during the time B sweep is displayed.

TP 168 B Sweep Inhibit – A high level prevents B sweep from running during the time A sweep is displayed.

Z Axis Signal – Provides the drive to the Z axis amplifier for the A and B intensity controls. Blanking signals for the vertical, horizontal and readout, and intensity limit control for the 6 slower sweep rates. The output will be about +6 volts with A & B intensity counter-clockwise and the readout turned off.

Following is a list of operating malfunctions and the logic component failure most likely to cause the malfunction.

1. No vertical chopped mode
   No horizontal chopped mode
   No plug-in chopped mode
   Check U120
2. No trace intensity
   Check U130, U170, Q146.
3. No vertical alternate mode
   No horizontal alternate mode
   No plug-in alternate mode
   Check U160, Q168.
4. No horizontal alternate mode
   No horizontal chopped mode
   No horizontal "B" mode
   Check U150
5. No slaving when operating vertical mode in alternate and horizontal in chopped or alternate.
   Check Q182

6. No delayed mode control when operating vertical and horizontal in alternate. The right vertical is displayed with A sweep and the left vertical with B sweep. B sweep is delayed.
   Check Q162
7. No vertical alternate mode
   No plug-in alternate mode
   Check U180
8. No plug-in alternate mode
   Check U190
9. No slaving when vertical mode is in LEFT or RIGHT and plug-in is in alternate.
   Check Q192
10. No vertical alternate, chopped or right mode.
    Check Q194
11. Right vertical mode only. Other vertical modes don't work or foul up readout display.
    Check Q196

THE READOUT SYSTEM

The readout system in the 7000 Series employs an electronic character generating circuit which time shares the CRT with the normal scope function. The characters are formed by a series of X and Y analog currents developed by character generating integrated circuits. Analog data generated in the plug-in determines which characters will be displayed. You must have a plug-in installed in the mainframe for a readout to be displayed.

The character generating circuitry is located on the readout etched circuit board mounted on the right side of the instrument. This board is easily removed and, since it is interchangeable from instrument to instrument, you can speedily confirm that the board is defective by substituting a known good one. A defective readout board can cause the normal scope functions to malfunction. This is true even though the readout is turned off by the front panel intensity control. Removing the readout board will confirm whether the problem is in the readout or elsewhere in the scope circuitry.

A defective plug-in can, in turn, cause the readout to function improperly. This can be quickly checked by substituting another plug-in. The time bases will readout properly in the vertical plug-in compartments and the amplifier plug-ins in the horizontal compartments in a properly operating instrument.

Now let's look at some typical problems that may occur in the readout circuitry. As in the logic circuit, the cause of the problem is often a temperature-sensitive device and a can of spray coolant is of help in troubleshooting.

The readout can be divided into three main sections: the sequencing logic, data collection, and the character generators and output processors. Here are the typical problems relating to these sections, and their probable causes:

The Sequencing Logic

1. No readout
2. No trace
3. No readout and the readout intensity control varies trace intensity.
   Check U1210
4. No readout, trace intensity normal
   Check U1226

NOTE: Troubles in the sequencing logic usually affect the complete display.

Data Collection

1. Mixed up information or no information on one channel of the readout display.
2. Typically the IDENTIFY function will be misspelled when displayed.
3. Interchanging the two suspected IC's will generally cause the problem to go to a different channel (usually a vertical channel).
   Check U1130 and U1170.
4. Symptoms similar to those above but there will be more missing letters or wrong spelling of words.
   Check U1166 and U1186.
5. Improper number of zeros in the displayed word. Typically there is a ten times error such as 1 ms instead of 10 ms.
   Check U1190.

Character Generators and Output

1. One or more characters missing from a word.
   Check U1251 through U1255.

NOTE: Each of five IC's makes ten different characters. If one is suspected, you can trade with another to verify the problem. However, each IC should be put back in its correct location to permit selection of the proper characters.

2. All of the characters smeared or positioned incorrectly on the CRT.
3. Trace displayed vertically or horizontally and no readout.
   Check U1270.
4. Characters overlapping or not spaced properly on the CRT.
   Check U1260.

These are the readout problems encountered most frequently by the factory service center. The instrument instruction manual contains a more detailed troubleshooting procedure should you experience problems not covered here.

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Customer Information from Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005
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INSTRUMENTS FOR SALE

526. Frank Maser, WBEN, 2077 Elmwood Ave., Buffalo, N.Y. 14207. (716) 876-0930.

585, Viewing Hood, 86, 10X Probe, Scope-Mobile Cart, Mod. 500A. All $1200. SSR Instrument Co., 1001 Colorado Ave., Santa Monica, Calif. 90404. (213) 451-8701.

511A. Best offer. Ira Goldstone, Emerson College, 148 Beacon St., Boston, Mass. 02116. (617) 262-2010, Ext. 230.

504. Bernie Cohen, P.O. Box 862, Stamford, Conn. 06904. (203) 327-6967.

647A, 10A2, 11B2, All $1500. Stevens Engineering, P.O. Box 25070, Portland, Ore. 97225. (503) 292-9201.

RM565 with two 2A63's. Total $650. Jack von der Heide, Optron Corp., 30 Hazel Terrace, Woodbridge, Conn. (203) 389-5384.

545A, 1A1, CA, 500/53A Scope-Mobile Mod 2, $1400 complete. Bob Cobler. (916) 273-0322.

519 w/misc. attenuators, 201-1 Scope-Mobile Cart. All $3500. George Sakai, P.O. Box 2999, Torrance, Calif. 90509. (213) 534-2121, Ext. 145.

162, Four 161's. Mobilscope, Inc., 17734½ Sherman Way, Reseda, Calif. 91335. (213) 342-5111.

Two 611's, Mod 162C. M. Giallango, P.O. Box 1999, Hudson, Ma. 01749. (617) 562-3424.

422, 6 mo. old, $1425. Frank Leenecht, Telemation. (714) 278-9680.

564B/3A74/3B3 complete, including Scope-Mobile Cart. Jerry Huber, Diversified Products, 7625 E. 46th Pl., Tulsa, Okla. 74145. (918) 622-5809.

561A, 3A6, 3B4. All $1100. Pierre-Yves Cathou, MIT Branch, P.O. Box 104, Cambridge, Mass. 02139. (617) 492-2526.

502A, 24 hr. use. Best offer over $900. Dr. M. Siegman, Dept. of Physiology, Jefferson Medical College, 1020 Locust St., Phila., Pa. 19107.

1A1, $520. Brian Wachner, 1600 E. 25th, Los Angeles, Calif. 90011. (213) 934-9991.

3L5. Never used. Dave Hohlfeld, Security Systems, Inc., P.O. Box 595, Siloam Springs, Arkansas 72761. (501) 524-6441.

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517A w/Cart, $250 or w/trade for 531. Mr. Sargeant, Chelmsford, Ma. (617) 256-9344.

535A, $600. 1A1, never used, $500. Q, $80. Cover & two 10X probes included w/Oscilloscope & Plug-In. Hugh Adams, 1008 Beachview Dr., Fort Walton Beach, Fla. 32548.

502, $450. 532, M, $500. Dr. Joseph Tupper, Syracuse Univ., Biology Dept., Syracuse, N.Y. 13210. (315) 476-5541, Ext. 2584.

535, 53/54C. David Singh, Nothelfer Winding Labs, 220 Ewingville Rd., Trenton, N.J. (609) 882-2500.

520A. Roger H. Baum, Bennett Respiration Products, 1639 11th St., Santa Monica, Calif. 90406. (213) 451-1671.

543B w/CA and Scope-Mobile Cart, $1620 or best offer. Robert Moss, WBNB-TV, P.O. Box 1947, St. Thomas, U.S. Virgin Islands 00820.

422 Mod 125B w/scope cart 200-2. Ken Chant, Standard Power, 1140 W. Collins Ave., Orange, Calif. 92667. (714) 633-1092.

132, 160A, 162, Plug-in TU-2. Jack Wilkinson, Ex-Cell-O Corp., 850 Ladd Rd., Walled Lake, Mi. 48088. (313) 624-4571.

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502A S/N 027572. Mr. Vavoudis, 4 Naples Ave., E. Norwalk, Conn. 06855. (203) 846-0232.

502A. Gd. Cond. Dr. W.R. Klemm, Biology Dept., Texas A&M, College Station, Texas 77843. (713) 845-6131.

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453-127C Scope, S/N 38600, P6028 BNC 1X Probe. Frederick Bock, Bock Video Systems, Inc., 11 Kercheval Ave., Grosse Pointe, Mi. 48236. (313) 886-4050.

515A, #8748. $600 or best offer. F. Robert Werner, Professional Electronics, 7054 South 2300 East, Salt Lake City, Utah. (801) 277-0200.

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547. 6 mos. old. $1600. Dick Peugeot, Ridge Instrument Co., 4176 First Ave., Tucker, Ga. 30084. (404) 939-1554.

549 Scope, 1A1 Amplifier & probes. $2700 or best offer. Mr. R. Olsen, Hospital for Sick Children, 555 University Ave., Toronto, Ont. (416) 366-7242, X1648.

581A, 82; 585A, 82, 661, 4S1, 5T1A; 531, 53/54C. All w/scope carts. Fred Besnoff, Computer Test Corp., 3 Computer Dr. Cherry Hill, N.J. 08034. (609) 424-2400.

535A, 565, 555, 551, 515A, 531A, 545A, 661, 647A, Plug-ins CA, R,S,G,H. Mr. R. Inabinette, Anaheim, Ca. (714) 956-2300.

262, S/N 299, $650; 3S76, S/N 1114, $450; 3T77, S/N 951, $450. Will trade for 2 or 3 Series Plug-ins. Mr. John Forster, MIT Branch PO, Box 48, Cambridge, Ma. 02139. (617) 864-6900.

(2) 541A, (2) CA Plug-ins, (2) 500/53A Scope-mobiles; (1) 545A, (1) CA Plug-in, (1) 500A Scopemobile. Gene Horn, Offshore Systems, Inc. (713) 464-8301, X59.

INSTRUMENTS WANTED

453, any condition. John Lum, 825 Erie St., Apt. 3, Oakland, Calif. 94610. (415) 893-7033.

576. Dick Landis, Cal State Electronics, 5222 Venice Blvd., Los Angeles, Calif. 90019.

422 or 453, Gene Bilich, 2525 S. 44th St., Milwaukee, Wi. 53218. (414) 545-0958.

453. Bernard L. Terrill, Computer Maintenance, Iowa Tech. Ottumwa, Iowa, 52501. (515) 682-8081 or (515) 684-8707.

531A w/o plug-in. D.K. Hiskey, 4662 Lakeview St., Yorba Linda, California, 92686. 528-7379.

MISSING INSTRUMENTS

453's, Ser. Nos. 44002, 45595, 45652, 45657, 45658, 45559. Contact IBM, World Trade Dist. Ctr., East Fishkill, New York.

Telequipment Scope, Ser. No. 412844, in San Francisco 4/16/71. Contact S. N. Bragg, Novar Corp., 2370 Charleston Rd., Mt. View, Calif. 94040.