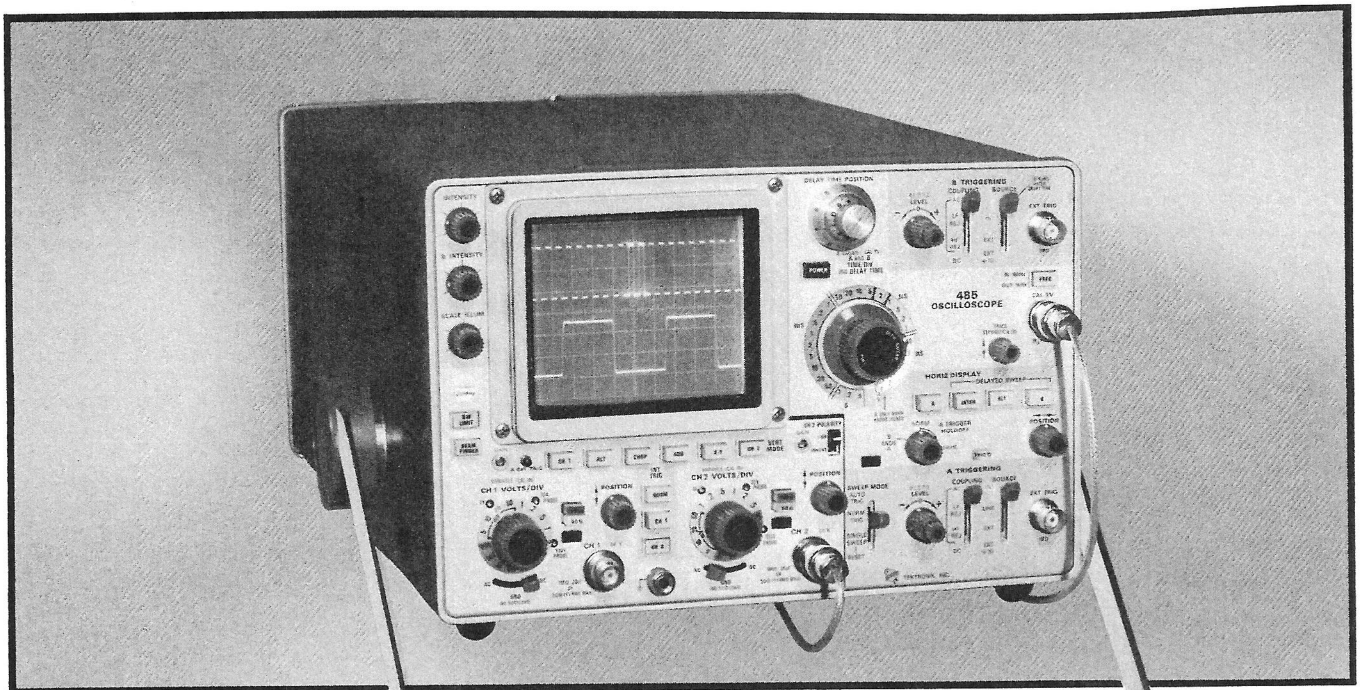


A Nanosecond Portable Oscilloscope

By Gene Andrews,
Engineering Project Manager

Nanosecond signals, limited to the laboratory environment yesterday, are appearing with increasing frequency in equipment delivered to customers today. The need to view and measure these signals in a "field" environment is upon us.

Responding to this need, the 485 offers greater bandwidth/sensitivity than any other real time oscilloscope available today, and in a portable package.

Weighing only 20½ pounds the 485 boasts 350-MHz bandwidth at 5 mV/div with a 50-ohm input impedance. Selectable input impedance permits you to easily switch to the traditional 1-megohm input for measuring power supplies and other high level signals. Bandwidth in the 1-megohm position is 250 MHz.

The wide bandwidth is complemented by a top sweep rate of 1 nanosecond/div with stable triggering to full bandwidth. A variable holdoff control permits viewing of complex waveforms such as digital words without multiple triggering.

Smaller and lighter than the world's most widely travelled oscilloscopes, the TEKTRONIX 453A and 454A, the 485 possesses all of the capability you have come to expect in portables, plus several new features. Dependability, dual trace, delaying sweep, automatic triggering, bright trace, X-Y . . . they're all there. In addition, you have an alternate sweep presentation that lets you view repetitive signals on both delaying and delayed sweeps at the same time. Automatic focusing keeps both traces sharp even though the individual intensity settings differ widely. Because of the infrequent need for adjustment, the focus and astigmatism controls have been relegated to the rear panel.

COVER—The new 485 Portable Oscilloscope makes the going easier whether the problem is a steep flight of stairs or a difficult measurement.

Much has been done to reduce operator error and speed measurement time. For example, light emitting diodes indicate the vertical deflection factor at the probe tip, automatically switching to accommodate X1, X10 or X100 probes. Push-away variable controls prevent measurement error caused by inadvertently leaving the control in an uncalibrated position.

Operation is simplified by single-function pushbuttons; just pressing one pushbutton switches you from Y-T operation to X-Y operation. And there is no need to reach frantically for the Intensity control. CRT beam current is automatically limited to prevent damage to the screen in every display mode.

A unique feature on the 485 is the ability to view the signal applied to the external trigger input, by means of a front panel pushbutton. This is a real time-saver when the external trigger signal is frequently used as a timing reference.

State-of-the-art performance at the front panel can only be achieved by state-of-the-art components and circuit design, coupled with the latest in manufacturing techniques. Let's look at each of these areas.

The CRT Circuit

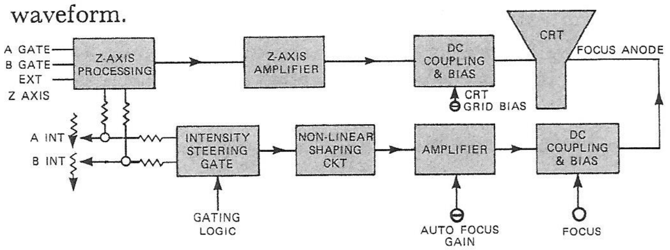
The CRT circuit produces the high voltage potentials and provides the control circuits necessary for the operation of the cathode ray tube. This section contains several innovations in circuitry that enhance the operation of the scope. Two examples are auto-focusing and beam current limiting.

Auto-Focus

Auto-focus is especially useful when viewing the delaying and delayed sweeps in the alternate mode. The focus voltage required is a function of the CRT control grid voltage or intensity setting. Since the two sweeps are normally set to different sweep rates, their respective intensity controls are set to different levels. The objective is to keep both traces in focus despite the difference in intensity settings.

In single-shot photography it is often necessary to take several trial shots to obtain the correct intensity for a good picture. With auto-focus the job is made easier because it is unnecessary to change the focus with each intensity setting.

A block diagram of the auto-focus circuit is shown below. The DC levels from both the main and B intensity controls are fed into a steering gate. Also fed into the steering gate is a gating waveform from the horizontal logic. During the blanking interval, when sweep switching takes place, the intensity levels are switched by the gating waveform.



Block diagram of the 485 auto-focus circuit.

From the steering gate the selected intensity level passes through a nonlinear shaping circuit. This circuit converts the linear intensity (CRT grid) voltage function to the nonlinear focus voltage required by the CRT. From the shaper it passes through an amplifier where the amplitude is set to match the focus function to the particular CRT. The final block before reaching the focus anode is the DC restorer circuit containing the FOCUS control located on the rear panel.

It is well to keep in mind that the purpose of the auto-focus circuit is to automatically change the focus voltage as the intensity level changes. It does not correct for defocusing caused by the geometry of the CRT and the deflection plates.[1]

CRT Beam Current Limiter

Most scope users have, at one time or another, unwittingly switched to an operating mode in which the beam was either stationary or moving slowly, with the intensity setting very high. The result was often a spot or line burned in the phosphor screen, accompanied by a sick feeling in the pit of the stomach.

Now we have a circuit in the 485 to prevent this happening. The CRT beam current is sensed at the low-potential end of the high-voltage multiplier. When the average beam current exceeds the level set by the maximum intensity adjustment (about 20 μA), a signal is fed to the Z-axis processing IC which limits the maximum Z-axis drive signal. For sweeps of 50 ms/div and slower and in the X-Y mode, average beam current is limited to 5 μA. Normal CRT operation includes instantaneous beam currents as high as 150 μA but a continuous value of 20 μA is adequate for applications such as a full-screen bright raster.

In the event there is a failure in the Z-axis system that causes the average beam current to exceed 30 μA, a back-up system automatically shuts down the power supply. After 100 to 300 ms the supply attempts to restart. If the overload is still present, the supply will cycle off and on until the trouble is cleared or the scope is turned off.

The CRT

The 485 CRT was developed concurrently with the 500-MHz 7904 CRT and uses a similar gun structure. The 8 x 10 division scan (0.8 cm/div) is accomplished by the unique construction of the vertical deflection plate structure. Each plate is a photo-etched box-like structure about 2.5 inches long. The design permits bending the structure to gradually increase the spacing between plates at the screen end. The structure is tuned by means of adjustable compensator plates to maintain a Z_O of 364 Ω within 1%. A dome-shaped mesh shields the deflection plate area from the high accelerating-anode potential and contributes a two-times deflection magnification.

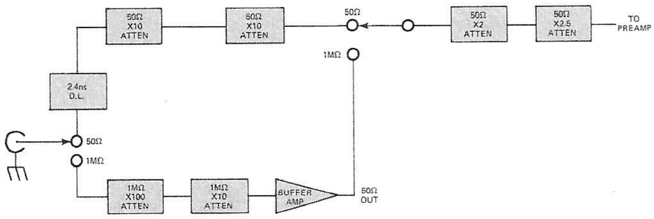
The 21 kV accelerating potential yields a writing speed in excess of 6 div/ns using a P11 phosphor and C-31 Camera with 10,000 speed film.

THE VERTICAL AMPLIFIER

Access to the vertical amplifier is through a single front panel BNC connector. Separate 50-ohm and 1-megohm signal paths are selected by a front panel push-button.

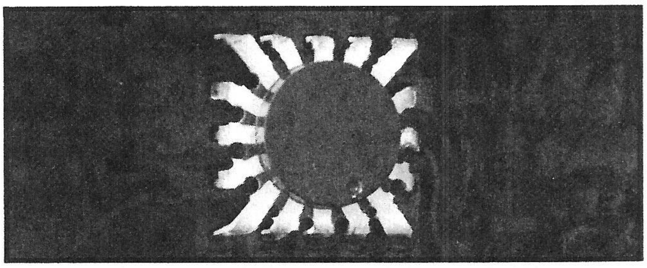
Note 1 Reference TEKTRONIX Circuit Concepts Book entitled "Cathode Ray Tubes".

The input switching relay also provides protection for the 50-ohm input by automatically disconnecting the input whenever a continuous signal exceeds 5 V RMS, or a pulse above 5 V exceeds 0.1 watt-second. A RESET light indicates overload has occurred. The input is easily reset by pressing the 50 Ω/1 MΩ input selector push-button.



Separate input paths for the 50 Ω and 1 MΩ inputs yield a low 1:1.2 VSWR.

The vertical amplifier uses nine IC's, all of the same type with the exception of the output stage. Both types are Tek-designed and manufactured. Innovation in packaging as well as circuit design contributes to the outstanding performance of these devices. The square lead arrangement of the M84AC package minimizes bondwire lengths and provides the optimum configuration for interfacing with the printed circuit board.



The M84AC is a multifunction device. It serves as an amplifier, polarity inversion switch and variable gain control. Basically it is a cascode amplifier. Connection to the base of the input amplifier is through a "T" coil arrangement partially formed by the bondwires of the device. This technique results in the input appearing as a 50-ohm load at all frequencies and a considerable increase in the bandwidth of the device is effected.

Two pairs of transistors form the output portion of the cascode amplifier. The DC voltage on the bases determines which pair conducts and, hence, the polarity of the output signal relative to the input. Variable gain control is achieved by allowing both pairs to conduct by a selected amount.

Bandwidth limiting in the stage driving the output amplifier is achieved using a similar technique. With the BW LIMIT switch in the FULL bandwidth position, one pair of output transistors passes the signal through a 50-ohm environment to the output stage. In the 20-MHz position, the signal is routed through the other pair of output transistors into a 2-pole, 12 dB/octave filter for signals above 20 MHz.

The output stage is a hybrid IC consisting of an "f_T doubler"[2] stage driving discrete transistors mounted on separate silicon chips. The output stage is housed in a TO-8 stud-mounted package with the integrated circuit chip mounted right on the stud for maximum heat transfer.

THE HORIZONTAL SYSTEM

Flexibility is the word best describing the horizontal system in the 485. Some of the features we've already mentioned briefly, such as stable triggering to full bandwidth and viewing of both delaying and delayed sweeps in an alternate sweep presentation. A single pushbutton puts the 485 in a calibrated X-Y mode with less than 3° phase shift to 5 MHz.

The top sweep rate of 1 ns/div is achieved without the use of the usual 10X magnifier. This results in improved linearity and timing accuracy for the fastest sweeps since the horizontal amplifier operates over a relatively small dynamic range. The amplifier circuitry is greatly simplified as the limiters and circuitry normally associated with the use of a magnifier are not needed.

Further simplification of the horizontal circuitry is effected through a unique scheme that uses a single time base generator to generate the 1, 2, 5 ns/div sweeps for both the main and delayed sweep functions.

Usually the main (delaying) sweep operates over the broadest range of sweep rates since this is the sweep used in the majority of applications. The delayed sweep normally does not include the slower sweep rates; however, the faster sweeps are needed for many applications. This means the horizontal system usually contains two time base generators capable of generating these fast sweeps.

In the 485 only the delayed sweep generator is used for the 1, 2 and 5 ns/div sweep rates. When operating in the Main Sweep Mode at these sweep rates, both Time/Div controls are locked together. The delayed sweep generator is automatically placed in a "zero delay" condition and starts immediately upon receiving a gate from the Main Trigger logic. In essence, it is being triggered by the Main Trigger and it is not apparent to the user that the displayed sweep is actually being generated by the delayed sweep generator.

Requiring only one time base to generate the fast sweeps results in an appreciable reduction in instrument cost. Maintenance expense is also reduced accordingly.

Another important feature of the horizontal system is the capability of operating at up to 2-MHz rep rates on

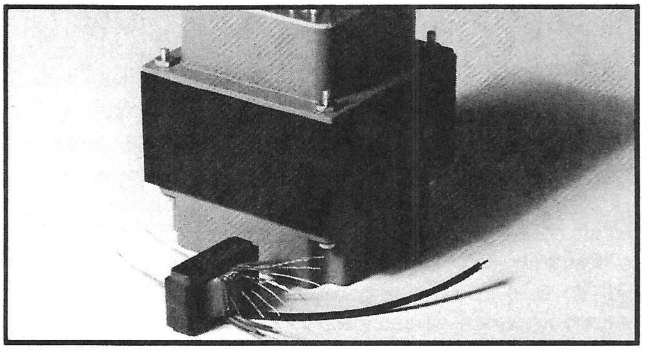
Note 2 See July TEKSCOPE "A Subnanosecond Realtime Oscilloscope".

the faster sweeps. This provides minimal loss of signal information and maximum display brightness.

THE POWER SUPPLY

The 485 uses a high-efficiency power supply; the type first used in the 7704 Oscilloscope[3]. Great strides have been made in reducing the complexity and physical size of such supplies. In the 485, total weight of the unit supplying both low and high voltages is only 2.8 pounds. Overall efficiency from line to regulated DC is 80%.

A single transformer weighing only 4 ounces and dissipating less than 2 watts powers the unit. The photo below shows its size in comparison to the power transformer used in the TEKTRONIX 547 Oscilloscope.



MECHANICAL CONSIDERATIONS

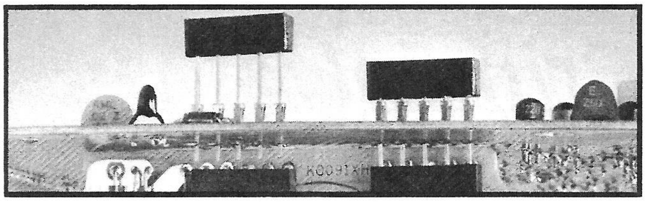
Mechanical design goals for the 485 were to produce a smaller, lighter package than the 453/454, with improved operating ease and serviceability. Close cooperation between the electrical and mechanical design groups resulted in significant achievement in each of these areas.

Some of the improvements in operating ease have already been noted, such as function changing by means of a single pushbutton, elimination of front panel controls through automatic focusing, and front panel indication of the deflection factor at the probe tip. Tektronix-developed cam switches provide smooth, easy operation for changing of sweep rates and vertical deflection factors.

Note 3 See March, 1971 TEKSCOPE.

The low 20½ pound weight is achieved by unitized construction which takes maximum structural advantage of all components. Overall dimensions of 20-5/8 x 12 x 6-9/16 inches make the 485 both narrower and shorter than other portables. It requires less bench space and is easier to carry.

Serviceability is a prime feature of the 485 design. A minimum number of printed circuit boards are used and a unique circuit board interconnection system practically eliminates cabling between boards.

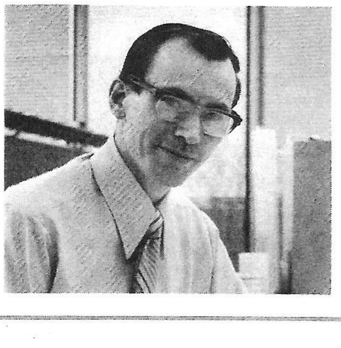


Since the 485 is expected to operate in widely differing environments, the cooling system employs a temperature sensing circuit which varies the air flow according to the ambient temperature. This insures minimum drift and maximum reliability.

Designed to meet the need for nanosecond measurements in a field environment, the truly remarkable capabilities of the 485 will undoubtedly find many applications in the laboratory and production areas as well.

ACKNOWLEDGEMENTS

A project of the magnitude of the 485 naturally involves many people. Here are some of the members of the talented team responsible for the 485. John Addis was project leader for the vertical section, assisted by Winthrop Gross. Glenn Bateman, Ron Peltola and Bob Firth designed the low and high impedance attenuators. Murlan Kaufman was project leader for the horizontal and logic systems and designed the trigger generator. Bob White designed the trigger amplifier and external trigger view circuits. Keith Taylor did the work on the fast sweeps, the horizontal and the Z-axis amplifiers. The excellent mechanical design was done by Tom Baker, Mark Anderson and Dave Curtis under the direction of Dick Duggan. Dick Troberg designed the high efficiency power supply system, contributing much to the low power and weight of the instrument. Vaughn Weidel, project coordinator, provided much valuable assistance including the unique board-interconnect design. Conrad Odenthal designed the high-performance 485 CRT. A great many other groups also made valuable contributions to the 485 project.



Gene Andrews—During his ten years at Tek, Gene has made many fine contributions to the product line. He began by working on the 10A2 amplifier, and was then responsible for the vertical amplifier design of the 453 Portable. He later was project engineer on the 647A/10A2A to bring this up to a 100-MHz instrument. When the 7000-Series was conceived he worked out the horizontal amplifier for the 7704 and designed the high-efficiency power supply for the unit; the first used in a TEKTRONIX laboratory oscilloscope.

Gene received his BSEE from Oregon State in 1954 and completed his M.S. at Stanford in 1956. For recreation he enjoys hiking with his wife and two teenagers in this great Northwest country.