A NEW ANGLE on Phase Measurements

by G. E. Bauder

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A new approach to the problem of making phase angle measurements has been made possible with the development by Tektronix, Inc., of the Type 535 oscilloscope and the Type 53C dual-trace plug-in preamplifier. The dual-trace unit consists of two identical inputs coupled by an electronic switch to the vertical amplifier of the 535 oscilloscope. The section of the amplifier ahead of the switch consists of only two tubes and has no frequency compensation other than that required by the input attenuators. This results in two input channels whose phase-shift characteristics are identical throughout their passbands of 8.5 mc. Any phase shift occurring in the amplifier section beyond the switch is of no concern in that both signals are treated alike, both being applied to the vertical axis of the cathode-ray tube alternately through the same vertical amplifier. A pickoff circuit is available in the Type 535 oscilloscope, which, with the aid of its helipot dial, will provide accurate increments of time measurement over 10 cm of sweep.

Phase measurements can be made as follows: The reference signal is connected to the "A" input of the Type 53C dual-trace unit and also connected to the external trigger input on the main sweep of the 535 oscilloscope. This will cause all sweeps to be triggered at the same time. The signal whose phase relationship is to be determined, is connected to the "B" input of the dual trace unit. With the horizontal-display switch in the main-sweep-normal position, the input attenuators and positioning controls are adjusted until both signals appear on the screen at equal amplitude, and symmetrical in relation to the center graticule line. Sweep-time, trigger-level, and horizontal-position controls are then adjusted until one cycle of the reference signal covers exactly 10 cm across the screen. Initial setup of the above can be most easily accomplished by setting the operating-mode switch first to "A only" and setting up the one cycle of reference signal as in photo No. 1, and second, to alternate presentation, and adjust amplitude and vertical-positioning controls of the "B" channel until both traces have exactly the same amplitude and vertical position. They will then appear as in photo No. 2. Note that the two signals are now displayed on the screen in their true time relationship, and phase angle can be determined by measuring the time difference in parts per 360.

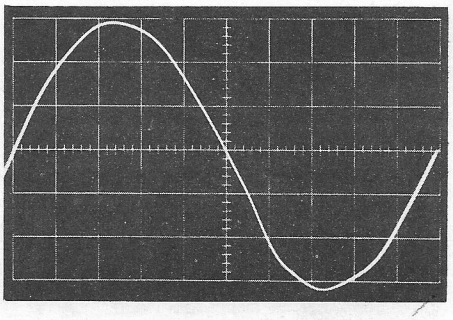

Photo No. 1

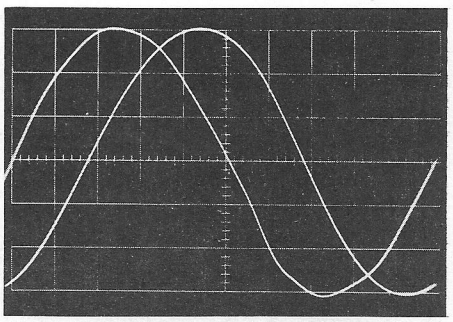

Photo No. 2

When the horizontal-display switch is in the main-sweep-normal position, the pickoff circuit is connected to the sawtooth of the main sweep. The delayed trigger provides a pulse whose position on the sawtooth is determined by the setting of the helipot dial. This is calibrated in a thousand parts per 10 cm of sweep. Connecting the delayed trigger to the CRT cathode post at the rear of the scope, and decreasing the beam intensity, will provide a blanked portion of the trace, whose start is coincidental with the pickoff point on the sawtooth.

Phase shift can then be measured in degrees as follows: Set the helipot dial so that the start of the blanked portion of the trace coincides with the zero voltage point at the end of the first half cycle of the reference signal, as in photo No. 3; note the reading

on the dial. In the example in the photographs the dial reading was 504. Next turn the dial to obtain a similar reading on the other trace as in photo No. 4. This reading was 674. The numerical difference between these two readings is the number of parts per thousand that one signal is shifted in time with relation to the other. One thousand parts equals one cycle, or 360 degrees; therefore multiply the numerical difference (170) by .36 and find the phase angle to be 68.2 degrees. The frequency used in the example was 750 kc.

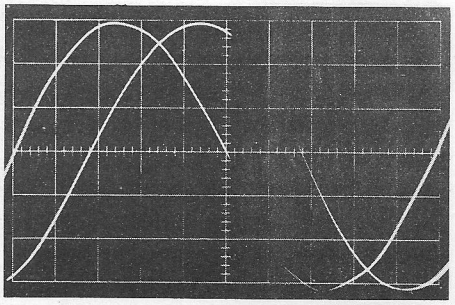

Photo No. 3

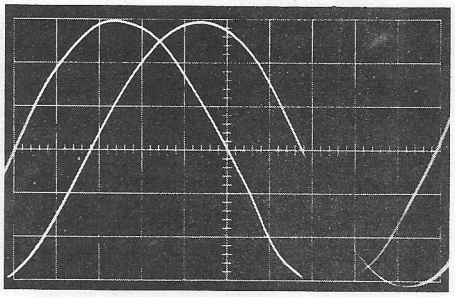

Photo No. 4

At frequencies below about 10 kc, the blanked portion of the trace becomes too narrow to be observed. This limitation can be overcome by using the + gate of the delaying sweep to drive the CRT cathode. Connect the delayed trigger to the trigger input of the delaying sweep and connect the + gate to the CRT cathode. The gate can then be made as wide as necessary by changing the delaying-sweep time. Satisfactory results will be obtained by setting the delaying sweep to run about ten times faster than the main sweep; this will provide a blanked portion of the trace which is one tenth of the visible portion.

A high degree of accuracy can be expected from the pickoff circuit; consequently the accuracy of the system will depend upon the ability of the operator to select identical points on the two traces from which to take his readings. It is helpful to have full-scale vertical deflection on the screen, and it is imperative that the two traces be of equal amplitude and that their zero voltage points are on the center graticule line.

Linearity of the pickoff circuit can be checked by connecting the delayed trigger to the vertical input. With the main sweep free running, check the helipot readings at each cm across the screen, using the horizontal positioning control to make them coincide at the start. Adjustments will be found on the right side of the scope that allow the operator to set the start and stop position of the pickoff so that it will coincide with the 0 and 10-cm points on the graticule. It will be noted that at the fastest sweep speed (0.1μsec/CM) the time required for the pickoff circuit to get under way will be appreciable, and that the delayed-trigger pulse will first appear near the center of the screen even though the helipot dial may be set near 100. This will not affect the accuracy of readings, however, as the pickoff will be linear over the last 5 cm of the screen, and readings can be taken as before, except that the lower end of the dial will be used.

Standard Tektronix Type P510A, 10-to-1 probes can be used on the inputs to the dual-trace unit, providing they are properly compensated. This can be done by connecting both probes to the calibration-output connector and, with the dual-trace switch in alternate position, adjust both probes until the tops of the square waves appear flat. If the adjustments have been made correctly, the two traces can then be superimposed, one on the other, and will appear coincident. This will assure that their phase characteristics are equal.

Measurements can be made from a few cycles per second to 1 mc. Above that, it is no longer possible to display only one cycle on the screen without using the 5-times magnifier. With the magnifier turned on, the pickoff circuit is also magnified by a factor of 5, and only 200 units on the helipot dial cover the 10cm of screen instead of 1000, so the resolution of the system will be down by a factor of 5.

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