American Oscilloscope Technique

With Some Remarks on Anglo-American Divergencies

By A. J. REYNOLDS*

THOSE readers who were in the radio industry in pre-war days will remember the very high regard in which instruments by such American companies as General Radio, Boonton, Ferris and Measurements Corporation were held. In the early and mid 'thirties the British Instrument as we know it today hardly existed. We had, of course, famous companies such as Cambridge, Muirhead, Sullivan and Tinsley, but they were fully occupied making what can be regarded as laboratory standards, bridges of extreme precision, potentiometers and variable air capacitors of exquisite workmanship. Little was then available, British made, for those awkward characters who required to generate few microvolts at many megacycles or who cherish a notion to measure the Q of the Litz-wound glass-former inductors in their super short-waver.

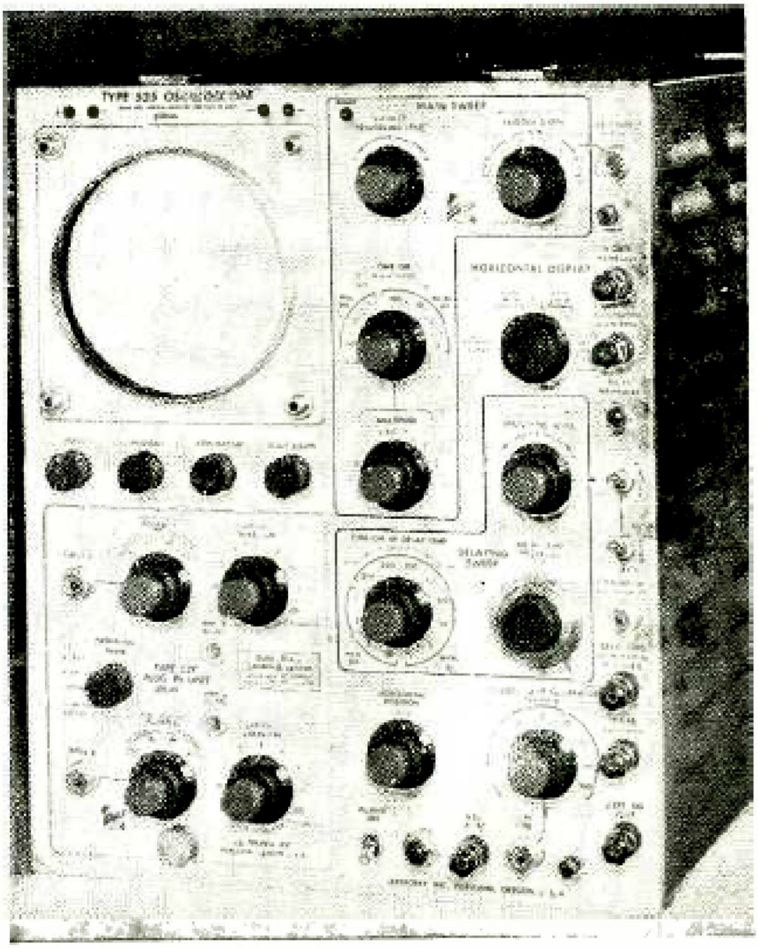
The founder member of the new brigade of instrument firms was undoubtedly Marconi-Ekco who, in the late 'thirties, began to make American-style instruments in this country. Having a relatively clear field they expanded rapidly, but when war broke out most of the serious work in British laboratories was still being done with instruments of American manufacture. During the war few American instruments found their way into the country and the small British industry expanded enormously. It had to: in pre-war days the Standard Signal Generator was an object of awe and veneration enshrined amongst the polished teak and lacquered brass binding-posts of the standards room, one per factory being about the number required. In the Services thousands were necessary, and such old favourites as the Marconi TF144 were bounced across the desert in 15-cwt trucks and dragged across the gooey mud of forward airstrips by sodden "erks."

After the war Britain found herself with a new industry—electronic instruments. New names appeared: Advance, Airmec, Cintel, Dawe, Solartron, Wayne Kerr and a whole host of others. The well-publicized dollar shortage precluded the entry of American instruments and as a result the styling, electrical and mechanical design of the products of the two countries have moved steadily apart. A somewhat similar state of affairs exists to that in the motor industries of the two countries.

Across in the States conditions were very similar to those at home. The war gave the instrument industry a tremendous fillip and while the old-established companies grew enormously, and along lines that could have been fairly easily predicted, a horde of new companies shot up overnight. (Some of them also shot down again pretty quickly.) Amongst these were two destined to become the giants of the industry. They are Hewlett-Packard, born in the garage of one Dave Packard just before the war and now the largest instrument company in the world in terms of turnover, and our heroes on this occasion Tektronix.

Company Organization

Tektronix Inc. was organized as an Oregon corporation in January, 1946, for the purpose of developing



Front panel of Tektronix oscilloscope Type 535, giving some idea of the facilities available.

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and manufacturing cathode-ray oscilloscopes. The owners all had extensive wartime electronic experience in either military or civilian capacities. The president, Howard Vollum, actually worked in this country on radar development during the war.

The company and its products form a useful guinea pig for a miniature study of current American thought in light current engineering. It is a successful company; from small beginnings as late as 1946 it now dominates the American wide-band oscilloscope market and is by far the largest producer of these instruments in the world. Before going on to the instruments let us look at a few points concerning the general organization and see how they tie up with your own conception of an American company and normal British practice.

First, the president, Howard Vollum, is a distinguished engineer, completely *au fait* with the performance of his company's oscilloscopes and the designer of some of them. This is a theme constantly reiterated in the new generation of U.S. instrument companies. Bill Hewlett and Dave Packard designed all of their company's original products. Rarely is the accountant-cum-financier type of director found over there. On enquiry you will be told " You can always take an engineer and train him as a business man, but rarely does the converse apply."

Secondly, at Tektronix they are more nearly self-sufficient than any other comparable company in the world. The only bought-out components are those such as valves and resistors. When the commercially available article is not good enough there is no hesitation in setting up a department to improve on current practice. Commercial capacitors could not be bought that were sufficiently good for use in their time bases, so they wind their own to ±0.25%. Bought-out c.r. tubes were insufficiently linear for the sort of accuracy sought—so they made their own, incidentally solving a major tube manufacturing problem in the process. The new Tektronix tube uses a helical post-deflection accelerator ring that starts at the top of the tube neck and runs helically right up the flare to the screen. This, of course, is an old idea and obviously the right way to make a p.d.a. tube, but up till now no manufacturer has succeeded in holding the resistivity of his material sufficiently constant to achieve a uniform potential gradient down the tube. Hating the conventional tag-strips and group-boards, they developed and manufacture their own ceramic group-boards that contribute greatly to the internal appearance of the instruments. This may surprise those who thought, as I tended to, that the American manufacturer produced a set of drawings that were effectively a stock list enumerating the bought-out parts that merely had to be assembled in the parent works. This philosophy, once prevalent, is now regarded with disfavour by the most progressive companies.

A third feature is the generosity of the electrical performance compared with the specification. Many experienced observers in this country have been forced to apply a "transatlantic factor" to written specifications emanating from the U.S.A. It has sometimes even appeared that in the Great Democracy the output watts were larger than ours and input watts smaller. (Something to do with the size of the U.S. gallon no doubt.) Here, however, is a conservatism of claim at least equal to the best of the British firms. On the type 535 oscilloscope, for example, the claimed Y amplifier bandwidth of 10 Mc/s measures as 3 dB down at 13.5 Mc/s.

The last point, which I am sure has a sizeable bearing on the company's success, is its method of payment. Every month 22½% of the company profit is divided amongst the employees in the ratio of their salaries and a further 7½% added to the pension fund. A simple enough payment by results system, but one which ties an individual's earnings to the performance of the company as a whole. Under this system what matters to each employee is that the customer is satisfied. Surely all men should be working to please the customer rather than to put one over on an inspector three benches away!

Two Outstanding Models

As examples of the instruments themselves we have space to deal with but two, the fabulous type 517 and the latest of the line, the type 535.

The 517 is a wide-band high-voltage oscilloscope designed primarily for the observation and photographic recording of very fast rising waveforms having a low duty cycle. The use of 24 kV accelerating potential on a metallized cathode-ray tube permits photographic recording of single sweeps at the maximum writing speed allowed by the Y amplifier and sweep circuits. Distributed-type Y amplifiers provide a rise time of 7 millimicroseconds with a maximum sensitivity of 0.1 V/cm. Both amplitude and time calibrators are provided. Sufficient time delay is incorporated in the Y amplifier to permit viewing the leading edge of the waveform which triggers the sweep.

In order to provide sufficient vertical deflection voltage with a rise time as short as 7 millimicroseconds for a cathode-ray tube using 24 kV accelerating potential, a distributed amplifier is employed. This amplifier consists of five distributed stages plus a phase inverter and trigger valve. The first two stages use six 6AK5 valves each, next a stage of seven 6CB6 valves and a phase inverter of three 6CB6s. The signal then goes to a push-pull driver stage having six 6CB6s each side and finally to the output stage with twelve 6CB6s on each side.

The performance on the X axis is just as impressive. Since many fast-rising pulses are either non-repetitive or non-uniformly spaced, it is essential to have a sweep which can be triggered by the observed pulse itself. To enable the type 517 to trigger from fast rising signals of small amplitude, a wide-band, distributed amplifier is incorporated. Signals of 0.3 V amplitude with a rise time of 1 millimicrosecond will easily trigger the sweep. When using the observed signal as a trigger, any signal giving a deflection of 2 mm is adequate.

The time base on its fastest speed runs at 10 mμ sec/cm, that is, a complete sweep of 8 cm in 80 mμ sec. Although their invariable practice, and one well suited to the method of calibration, this style of specifying time base speed strikes me as slightly ludicrous. It is rather like saying "Poor old Charlie was nicked for failing to exceed 0.033 hours per mile in a built-up area." Come to think of it, they are in effect quoting the time base slowness rather than time base speed.

That then is type 517, a slightly fabulous beast in that few of us could live up to it. Owning a 517 must be rather like owning a 4½ Ferrari or being married to Marilyn Monroe. Let us examine another model, just as outstanding in its own sphere but more applicable to everyday problems, the type 535.

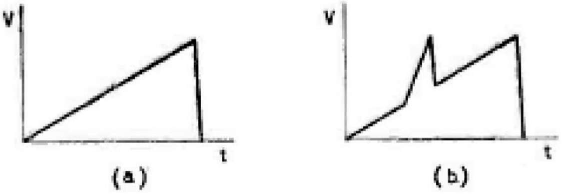

Fig. 1. Waveform of a conventional time base sweep (a) and with a second sweep superimposed on it (b).

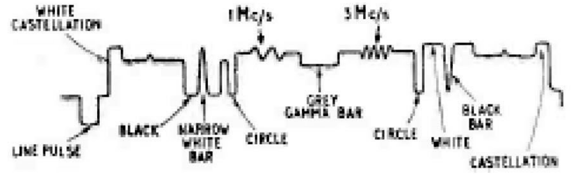

Fig. 2. Television waveform from one line of Test Card "C."

The 535 is a most unusual instrument for two reasons. First, it is the best example to date of that oft-attempted oscilloscope, the Y amplifier characteristics of which can be varied by means of a series of plug-in pre-amplifiers. The main ones of these are the 53B, with a frequency response of d.c. to 10 Mc/s and a sensitivity of 5 mV/cm, and the 53C, with a response of d.c. to 8.5 Mc/s and a sensitivity of 50 mV/cm. A double beam facility is provided by means of an electronic switching system. This beam switch can be triggered by alternate sweeps or allowed to run free at 100 kc/s. A d.c. and low frequency pre-amplifier is available, giving deflection sensitivities of 50 μV/cm. When these are allied to a time base having continuous coverage from 0.02 μsec/cm to 12 sec/cm, it will be seen that even without any other features the 535 would still be an outstanding instrument.

The second unusual facility is one that obviously springs from the firm's association with radar, as it is a well-established radar technique applied for the first time to oscilloscopes. This is the use of two time bases, one of which strobes the other. For those not familiar with this trick a word of explanation. Consider the two time bases in Fig. 1, one of which, at (a), is pictorially quite familiar. It can be so arranged that the linear rise of voltage in (a) will trigger a second time base, running much faster, at a predetermined voltage level, as shown in (b). It will be obvious that if the first sweep is triggered by a pulse, then varying the voltage at which the second sweep fires will slide this sweep up and down the slope of the first one and so provide a variable delay between the trigger pulse and the start of the second sweep. In practice no such waveform as (b) appears in the instrument, this having been simplified to establish the general principle.

Selective Observation

Let us take a practical example. We will feed into the type 535 oscilloscope a television waveform, Test Card "C" in fact, and arrange for the first sweep to be triggered by the line pulses and to have a duration of some 100 μsec. The resultant display will then consist of a jumble of all 405 lines. If, however, a rudimentary sync separator, consisting of a CR network with the correct time-constant, is included in the trigger circuit, then the time base will trigger from the frame group and permit a display on one line which looks something like Fig. 2.

Now supposing it is arranged that when the second sweep fires it applies a "bright-up" to the beam, then a portion of this display will appear brighter than the rest. The length of the bright patch can be varied by adjusting the duration of the second sweep and its position along the picture by varying the delay (point on the first sweep at which the second sweep fires). In our example we could arrange the bright portion of the trace to coincide with the 3-Mc/s bars. This done, by switching the input of the X amplifier the second sweep can be applied to the plates of the tube and a picture of the 3-Mc/s portion of one line made to occupy the whole screen, permitting detailed examination. The beauty of this system is that a complex waveform can be displayed *in toto* on the screen, a portion of it selected for detailed observation and that portion viewed on a greatly increased time scale with absolute certainty that it is the desired part of the waveform.*

This has perforce had to be a rather sketchy treatment of a complete range of instruments, but I hope it has at least shown that, during the years when American instruments have been absent from this country, oscilloscope design at any rate has been progressing along lines rather different from our own.

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Since this article was written a further development of the 535 oscilloscope has taken place, bearing the type number 545. It is based on a new cathode-ray tube developed by Tektronix which has the fantastic deflection sensitivity of 7V/cm with 10kV on the p.d.a. ring. Use of this tube gives the new oscilloscope the following Y amplifier performance: frequency response, d.c. to 30 Mc/s; rise time, 12 mμsec; sensitivity at full bandwidth, 50mV/cm. The amplifier is 6dB down at 45 Mc/s and 12dB down at 60 Mc/s.

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* Although this example deals with the use of the type 535 as a line selecting monitor, this function is performed equally well by the simpler type 524, an oscilloscope that has been a standard instrument in American television circles for over four years.