THE SYNCHROGUIDE: A DESIGN HISTORY

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AMONG the many requirements of good design of television receivers is one of picture stability under various and adverse conditions of reception, including that of interference by electrical noise. The section of the receiver most vulnerable in this respect is the Line Scanning Oscillator, since its timing determines the precise positions of picture elements on the kinescope face. Adequate protection from electrical disturbances is obtained through a buffer circuit in a form of Automatic Frequency Control, and Synchroguide is the form used in the RCA receivers since 1947. While several modifications have been made since that time, the basic patterns of its operation have survived to this day essentially unchanged.

EARLIER FORMS OF AUTOMATIC FREQUENCY CONTROL

Effects of electrical noise on television reception had been studied by K. R. Wendt and Dr. G. L. Fredendall before the war, and they arrived at the conclusion that the serious aspect of this interference was not in the dots and streaks appearing in the picture, but in the contamination of the synchronizing signal which caused erratic timing of scanning oscillators, resulting in scattering and scrambling of the elements of the picture in a manner illustrated in Fig. 1.

To counteract this effect they developed an "Automatic Frequency and Phase Control of Synchronization in Television Receivers," which, by averaging the timing information in large numbers of synchronizing pulses and thus filtering out their individual disturbances, prevented the misfiring on individual scanning lines. They used a blocking oscillator followed by a saw-tooth-forming discharge tube, and a push-pull phase detector followed by a d-c amplifier whose output was fed back to the oscillator to control its frequency and phase. With a total of five tube functions, these men achieved a noise immunity vastly greater than any obtainable heretofore by conventional "triggering" means.

A later form, by A. Wright and E. L. Clark, utilized a sine wave oscillator and a reactance tube across the tank for frequency control, followed by a saw-tooth-forming discharge tube and a push-pull phase detector controlling the bias of the reactance tube—a total of five tube functions in 3½ envelopes. This circuit, called "Synchrolock" by its inventors, achieved a high noise immunity and a high degree of frequency stability at the same time. "Synchrolock" was used commercially, for example, in the RCA 630-TS series television receivers and played a tremendous role in making the post-war "Eye-Witness Television" a success.

The drawbacks of Synchrolock, however, were its high cost, high power drain, and a relatively low phase sensitivity of sync riding the smooth slopes of the sine wave, and a tendency for the picture to shift rather excessively on the kinescope face.

The form of AFC known as Synchroguide, using only two tube functions in a single envelope, was developed by the author. Because of its low cost, low power drain, and good phase sensitivity, it replaced the Synchrolock beginning with the RCA 721-TS in 1947, and has been used in all RCA receivers built to this day.

THE PRINCIPLE OF SYNCHROGUIDE

The philosophy behind the development of Synchroguide was to control the oscillator by *guiding* it into a very nearly correct frequency with the information from a slow-changing averaging device. Then, accurate *synchronizing* occurs at the ends of individual scanning lines, with synchronizing pulses of a relatively low amplitude, thus reducing the effect of noise to a very low level. The reason for the very low level is that the effect of noise on picture stability varies as the square of sync amplitude*, since a reduction of the latter means (1) a reduction of the time range of possible misfires, and therefore of the amplitude of disturbance of scanning, and (2) a reduction of number of noise pulses occurring within this reduced-time range, and therefore of the number of disturbances of scanning-per-second. Guiding of the triode oscillator into a very nearly correct frequency was to be achieved with a minimum amount of circuitry, using the second triode of a dual-triode tube as a single-ended phase detector-amplifier. The triggering, of course, required no additional tubes.

* The noise amplitude is held down to sync amplitude by the clipper action of the sync amplifier chain.

SIMEON TOURSHOU received his B.S. in E.E. from Robert College, Istanbul, Turkey, in 1928, and his M.S. in E.E. from Michigan College of Mining and Technology in 1930. His experience covers, in main, seven years with Philco and nearly seventeen with RCA. The latter includes development of the second "Personal" radio, the BP-12, development and design work on pulse altimeters and airborne radar, and on television.

In the Black and White TV Engineering, he is the Manager of Product Development group which has been responsible for a number of RCA and industry "firsts," such as the receivers with metal kinescopes, receivers with "wide angle" deflection, 21-inch receivers, receivers with 90° deflection, as well as many deluxe, top of the line models. The group spearheads the continuous search for better and cheaper circuits, techniques and products.

While the idea was being proved in, it was found that a still greater noise immunity was obtained when the sync pulses were completely eliminated from the oscillator circuit, and replaced by information from a second averaging device that was fast enough and sensitive enough to detect any tendencies of the oscillator to deviate from its proper phase. Fig. 2 shows the two averaging devices in the cathode of the control tube: the large capacitor C_1, acting as a storage tank for pulses of current produced by the sync pulses on the grid, and the small resistor R_2 shunted by a small capacitor C_2 acting as a fast and sensitive indicator of any tendencies to deviate in phase. The combined

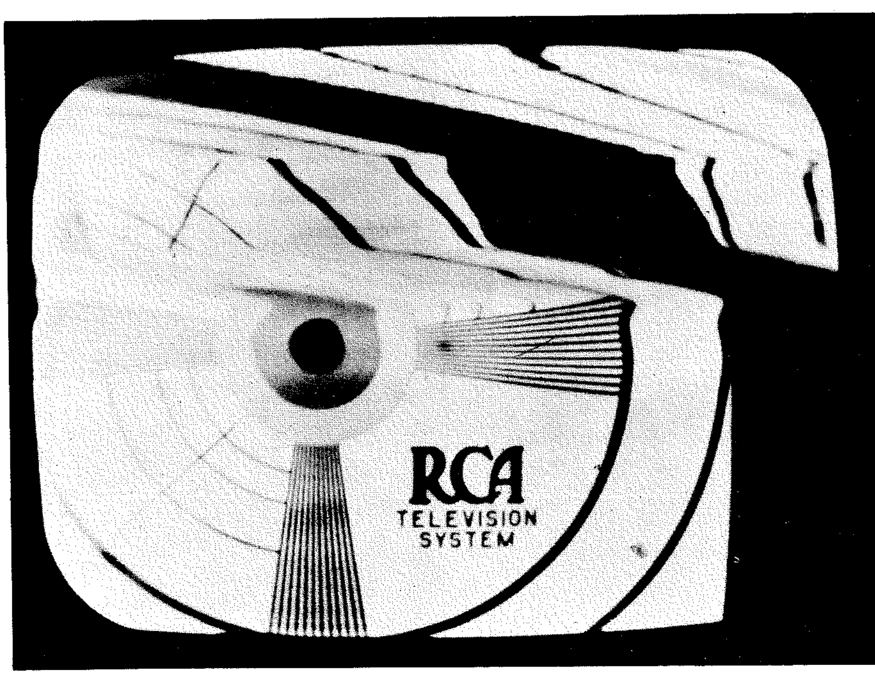


Fig. 1—The effect of electrical noise on early horizontal synchronization

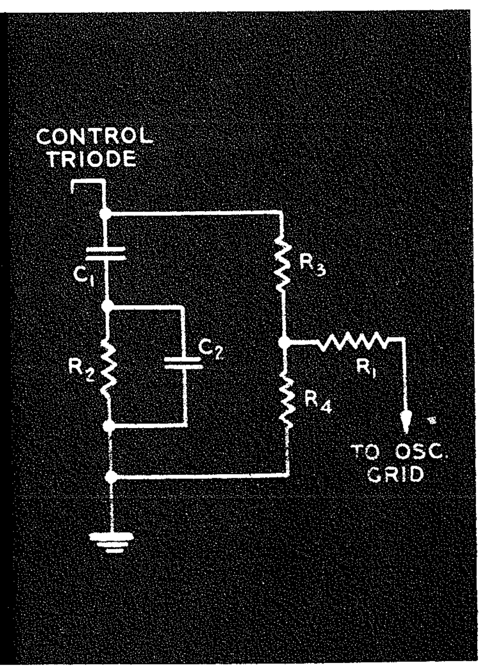


Fig. 2—Oscillator control tube averaging device

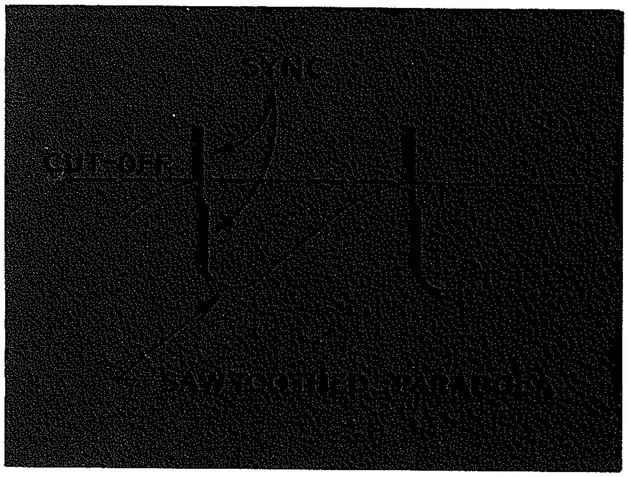


Fig. 3—Waveform at the control tube grid

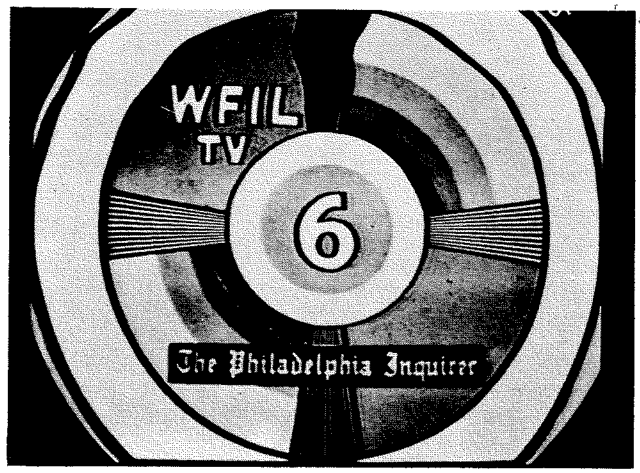


Fig. 4—"Hunting" due to improper control tube constants

voltages of C_1 and R_2C_2 are fed, through the divider R_3R_4, to the oscillator grid leak R_1 to vary its reference bias and frequency, as required.

CONTROL VOLTAGES AND THEIR SOURCE

The voltages of C_1 and R_2C_2 vary with phase between the oscillator wave (shaped into a saw-toothed parabola) and the synchronizing pulse on the grid of the control triode, as shown in Fig. 3. The synchronizing pulse rides partly atop the corner of the saw-toothed parabola derived from the oscillator and partly in the valley just beyond the corner. Since the triode is biased off except for the corner, the width of the triode current pulse is essentially the same as the portion of sync atop the corner. The wider this portion, the wider the pulse of current, and the greater the average control power delivered to the cathode circuit. Any tendency of the oscillator to slow down and fall behind in phase results in an immediate widening of the sync atop the corner and in an increase in the positive reference bias for the oscillator, which speeds it up to the correct rate. Similarly, any tendency of the oscillator to "speed up" results in a narrowing of sync atop the corner, and a decrease in the positive reference bias for the oscillator, which slows it down to maintain the precise synchronism with the transmitter*.

Since C_1 is made rather large to prevent the noise pulses from producing appreciable changes in its voltage level, its response to changes in the oscillator phase is rather slow. Were it not for the fast R_2C_2, which registers the slightest changes in phase and applies corrective voltages to the oscillator almost without delay, the latter would be swinging freely away from its correct position to one side, then to the other, in endless see-saw. See illustration (Fig. 4) where the C_1 voltage is always lagging behind, and never really able to catch up. Were R_2 made too large, the sensitivity of the oscillator to noise pulses would be high, and it would jitter almost as badly as was illustrated in Fig. 1. Thus there exists a balance between the C_1 and the R_2C_2 magnitudes, depending on the sensitivity of the control triode to changes in phase, and on the sensitivity of the oscillator to changes in control.

Such is the meaning of Synchroguide, and now a brief summary of the modifications made since its early inception.

THE FIRST PRODUCTION VERSION IN THE RCA 721-TS

The control-grid wave form of this version was a composite of a parabola derived from the saw-tooth, a

* This "width modulation" is also one of the characteristics of the Synchroguide that makes it different from other systems which depend on the amplitude modulation instead.

Fig. 5—The synchroguide in the RCA-721TS—First production in 1947

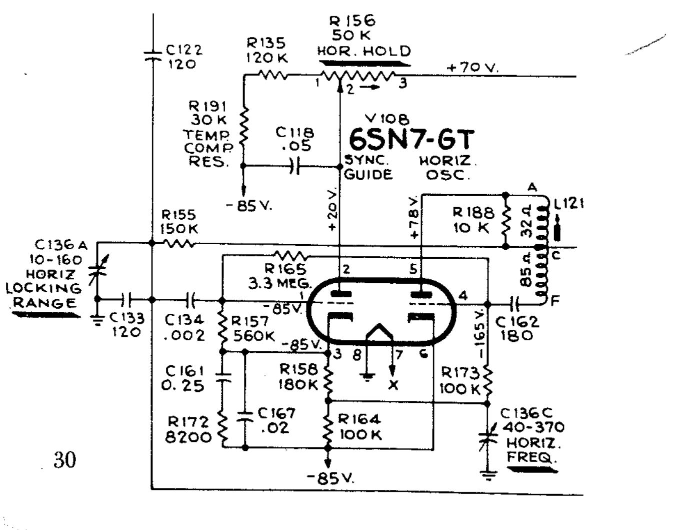
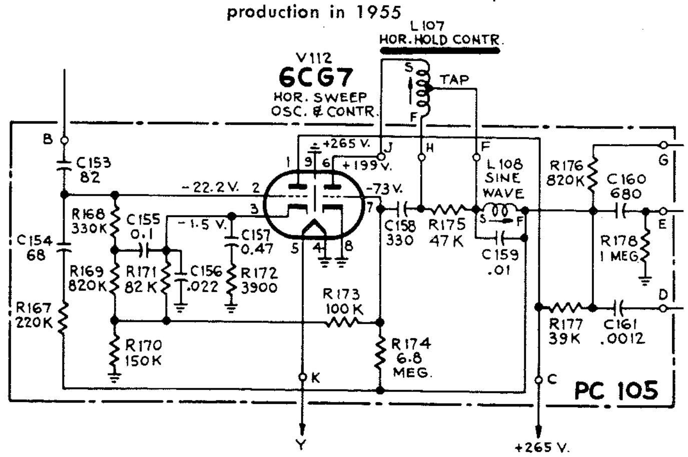


Fig. 6—The synchroguide in the RCA-21T641—First printed circuit production in 1955



negative kick-back pulse derived from the deflection yoke to produce the sharp drop in voltage following the "corner," and the synchronizing pulse. Bias for the control tube was derived from the bias developed by the oscillator. An oscillator grid leak resistor of a very stable carbo-film type was used, and except in a few cases where particles of dust had been trapped underneath the film resulting in instability and requiring replacement, it served the purpose. Microphonic instability of the blocking oscillator required rubber mounting of the socket. The Tube Division gave assistance by improving the mountings of the tube elements to make them more rigid. The hold control range had to be very considerable to accommodate the gradual shift in frequency with aging of the tube.

SECOND PRODUCTION VERSION BROUGHT OUT WITH METAL KINESCOPES IN 1949

Here a stabilizing sine wave tank was inserted in series with and just below the oscillator coil. The addition of the thus generated sine wave voltage to the exponential wave on the grid, and to the saw-tooth wave on the plate, "stiffened" the frequency characteristic by a factor of about three. It also gave some increase in noise immunity, since a basically more stable oscillator required less control. It allowed an ordinary carbon resistor to replace the carbo-film grid leak, and later to eliminate the rubber mounting of the socket.

INTRODUCED IN THE 21" SETS THE THIRD PRODUCTION VERSION

Biasing of the control stage from the oscillator bias was replaced by self-bias, which should have further reduced the effect of tube aging on frequency. The attained improvement, however, was masked by another factor, uncovered recently by RCA Laboratories and the Tube Division, namely the gradual formation within the tube of the "cathode interface resistance," which, by adding degeneration, weakened the oscillator and shortened the grid capacitor time of discharge.

THE PRESENT CIRCUIT VERSION STARTING WITH THE 1954 LINE

The advent of the controls compartment at the front of the set has made it possible for the oscillator coil to replace the potentiometer as a hold control, making a wide range of adjustment available to the user through an easy vernier action. Through the cooperation of the Tube Division and RCA Laboratories, steps were also taken to prevent the formation of the "cathode interface resistance," and it is believed that the field problems due to frequency shift are getting to be a thing of the past. This circuit version is shown in Fig. 5.

THE PRESENT PRODUCTION VERSION ON A PRINTED BOARD

Electrically this is the same as the previous version. Physically it is contained on one printed board, with the exception of the oscillator coil, which mounts at the front of the receiver to serve as a "hold control."

Although the development of the Synchroguide to its present state of refinement involved inherent frequency instability of blocking oscillators and the aging characteristics of the older type 6SN7GT tube, the high degree of the circuit phase stability afforded by Synchroguide, and its performance in the millions of sets in which it is used, have proven its value and acceptance over the years. Any further improvements in tubes toward better frequency stability will not only further minimize the long-term drift, but can also be translated into further increases in noise immunity by reduction in the amount of the needed control.

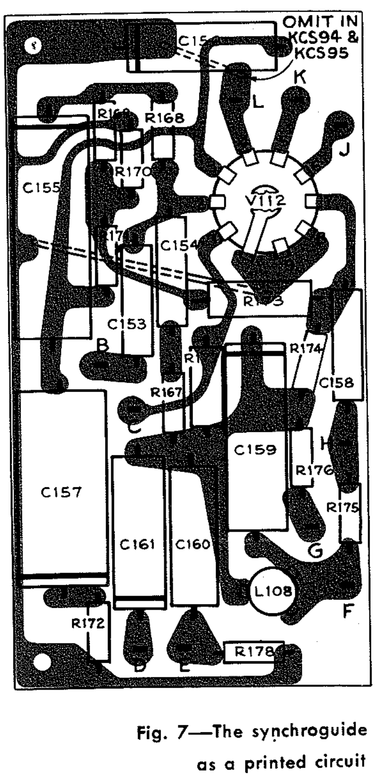


Fig. 7—The synchroguide as a printed circuit

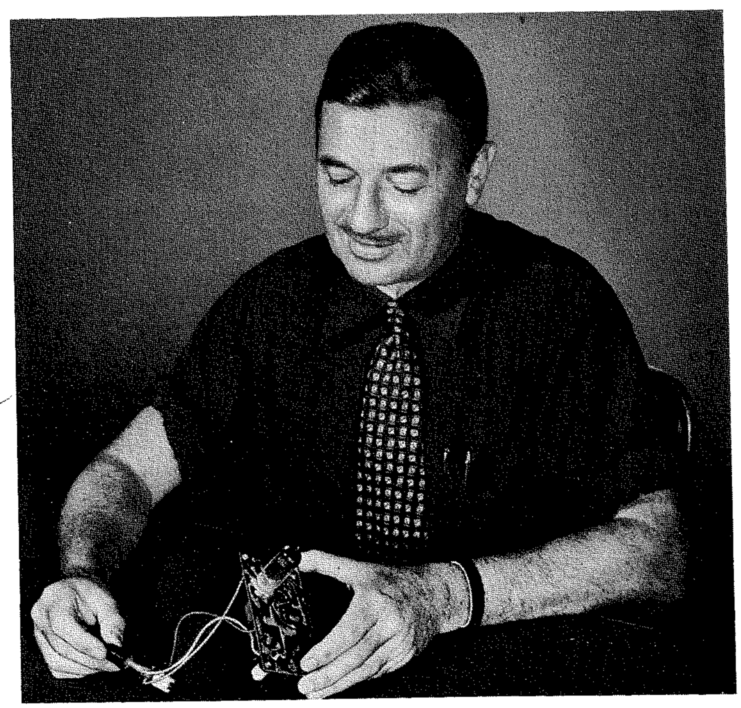


Fig. 8—The author examining a production version of the synchroguide on a printed board