A pulsed crystal oscillator range calibrator

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A PULSED CRYSTAL OSCILLATOR RANGE CALIBRATOR

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A PULSED CRYSTAL OSCILLATOR RANGE CALIBRATOR

by

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ABSTRACT

A pulsed crystal oscillator calibrator unit is described, which will accept either positive or negative synchronizing pulses and will produce a finite series of pips of either 2-km or 20-km spacing. After a desired interval, say 300 km, the crystal is stopped and the system is returned to its initial condition, and is ready to accept another trigger pulse. This unit has given satisfaction when used with spark-gap modulated pulse transmitters, the range error of the calibration pips being less than 0.1 per cent.

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I Introduction

In radar systems where the range sweep is initiated by the transmitter pulse (e.g. by a spark-gap modulator) it is necessary to trigger off the range-measuring circuits from this pulse. For accuracies of the order of one per cent, this can be conveniently done by using the usual regenerative L-C ringing circuits to produce calibration pips of the desired spacing. Precision ranging techniques customarily use a continuously-running crystal oscillator to produce the standard reference frequency, and both the transmitter and the sweep circuits are triggered from this oscillator. When a spark-gap modulator is used this method cannot be employed. This report describes a method of triggering a crystal oscillator from a synchronizing pulse so that the standard reference frequency starts in the same phase each time the transmitter fires, regardless of jitter or varying recurrence frequency. The circuits described are modifications of a circuit developed by the Radiation Laboratory, Cambridge, Mass. [1]

The pulsed crystal calibrator can either be built into the radar range-measuring system directly, or it may be built as a separate portable unit which can be used for periodic checks of L-C range-measuring circuits. This crystal calibrator has given satisfaction in the SSR system (Shooting-Star Radar) employed at the National Research Council.

II Circuit Operation

Refer to the schematic, Fig. 1, and to the waveform diagram, Fig. 2, :-

V_2 functions in a Kipp relay stage which can be triggered by a positive pulse through V_{1A}, or a negative pulse through V_{1B}. The output from the first anode is a positive square wave approximately 2,000 microseconds long (for a 300-km. sweep), determined by the time constant of R_7 and C_2. This positive square wave is applied to the grid of V_3 and cuts off the second half of this tube, producing a pulse of short duration in the secondary of the pulse transformer, T_1. This pulse shock-excites the crystal, which has a very high Q, causing it to oscillate with imperceptible damping over the desired length of time, and without the need of any regeneration. The amplitude of the oscillations is approximately 6 millivolts. These oscillations are amplified by the dual triode, V_4. The brunt of the shock excitation pulse does not get through to the grid of V_4, because it is balanced out by the bridge network formed by the centre-tapped secondary of the pulse transformer, the capacity of the crystal, and the condenser, C_7.

(1) P.F.Brown, "Pulsed Quartz Crystal Oscillator" , Radiation Laboratory Report No. 803, Cambridge, Mass., August 21, 1945.

At the end of the positive square wave on V_2, the second half of V_3 will again conduct and act as an amplifier. The amplified crystal oscillations are fed back to V_3 through C_{15}, L_1, and P_1. The second half of V_3 is turned off for the duration of the Kipp square wave so that the feed-back link is inoperative for this time. At the end of the square wave, the second half of V_3 is turned on and feed-back is applied to the crystal, 180 degrees out of phase, thus stopping its oscillations within a few cycles. If this were not done the crystal would be oscillating with practically undiminished amplitude when the next synchronizing pulse arrives, and unless the synchronizing pulse strikes at precisely the right point on the operating cycle of the crystal, the amplitude and phase of the new train of crystal oscillations would vary greatly. It is very important to stop the crystal before applying the next synchronizing pulse.

V_5 is an amplifier which obtains its screen voltage from the positive square wave developed across R_{13} in the cathode, V_3. Thus, V_5 amplifies only during the sweep time and is turned off for the remainder of the cycle, avoiding the possibility of random noise triggering off the divider tube, V_{10}, in the absence of 2-km pips. V_6 and V_7 are squaring tubes. The first half of V_8 is a cathode follower. The square waves produced in V_6 and V_7 are differentiated through C_{24} and R_{42}. The second half of V_8 is a clipper tube, biased beyond cut-off so as to allow only the positive peaks of the differentiated square waves to appear on the second plate of V_8 as negative pips.

The frequency of the crystal is 74.93 kc/s. The period of this crystal thus corresponds to a radar distance of two kilometres. Since it is desirable to have 20-kilometre markers as well, a counting-down circuit is used (V_{10}) to trigger on every tenth pip from the plate of V_8. In V_{10}, the screen is normally conducting with the plate cut off, due to the negative bias on the suppressor with respect to the cathode. The first negative pip from V_8 passes through V_{9A} to the grid of V_{10}. This allows the screen voltage to rise suddenly and the plate conducts, and in going negative drives the grid negative through C_{28}. The result is a linear, negative run-down voltage on the plate of V_{10} and a positive-going square wave on the screen of the same tube. V_{10} will not accept another negative trigger pulse until its cycle is complete and the plate again cut off. The period of the cycle is adjusted by C_{28} and R_{51} to insure that V_{10} will accept every tenth input pulse. The square wave on the screen of V_{10} is differentiated through C_{31} and R_{56} and coupled into the grid of V_{11}, which is a cathode follower and is biased to allow only the positive pips to appear on the cathode. The two-kilometre markers are coupled into the second grid of V_{11} and are mixed with the twenty-kilometre markers on the cathode. Switch, S_2, is provided to turn off the two-kilometre markers when not required.

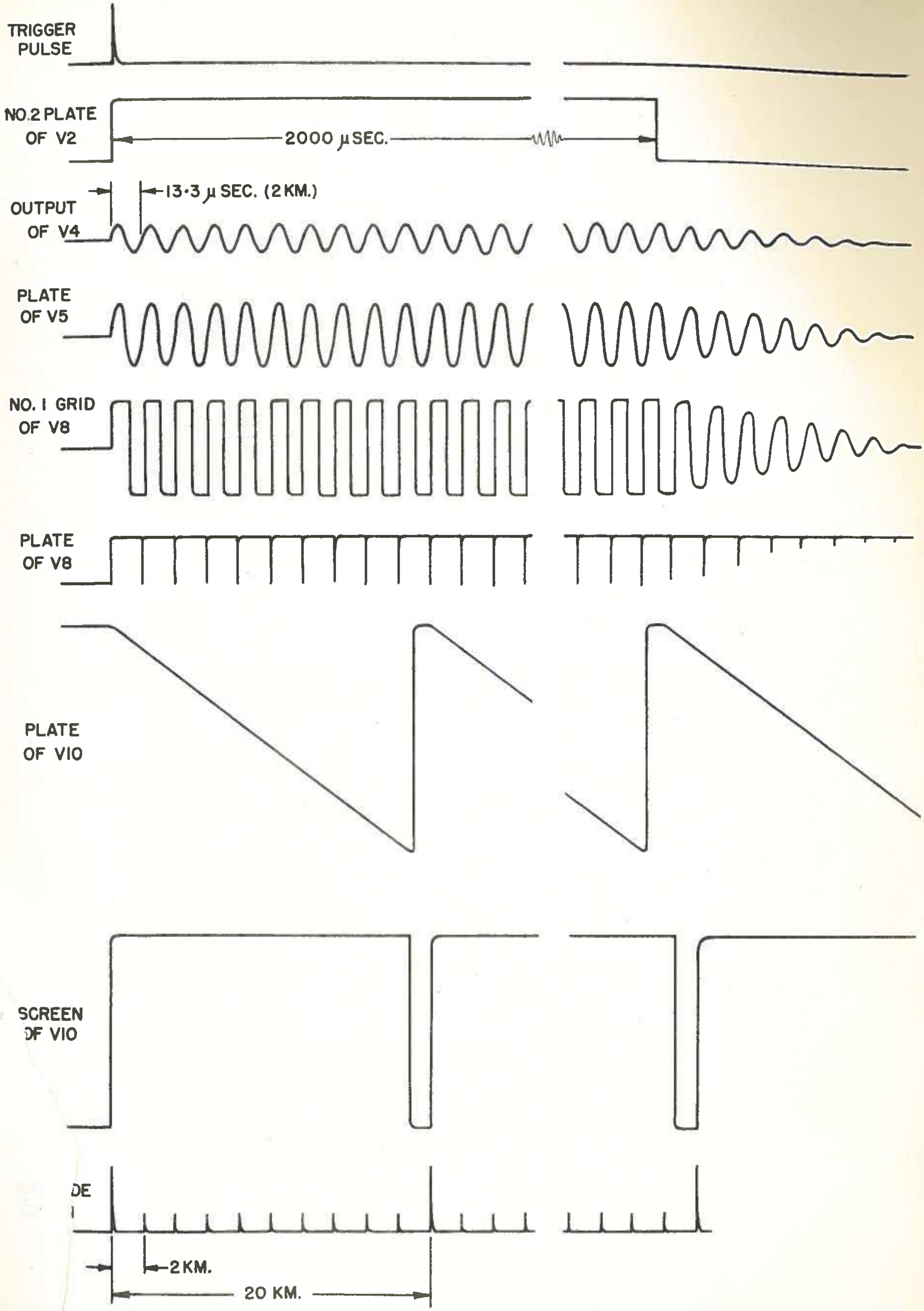
III <u>Type of Crystal</u>

The crystal used is a type FM6, frequency 74.93 kc/s, made by the Bliley Electric Co., Erie, Pa., and actually was intended for use in a continuously-running oscillator. It is perhaps fortuitous that its frequency under shock-excitation conditions differed from its continuously-running frequency in a conventional circuit by less than 30 cycles per second, or less than 0.05%. Under shock conditions, other modes might well be excited in such a crystal and care should be taken to see that these unwanted frequencies are not present. If the shock conditions are specified in ordering the crystal from the manufacturer it can be cut to ensure that no spurious responses are present.

IV Accuracy

With the exception of the first pip, all the two-kilometre pips are correctly spaced from the start of the synchronizing pulse. Close examination reveals that each of the succeeding pips may have a small and constant displacement error which does not exceed 0.05 km. This error is to be added to the proportional frequency error of the crystal itself. The overall range error thus runs from ± 0.06 km at 20 km, to ± 0.20 km at 300 km. Over the working range of the SSR system (60 to 300 km) the percentage range error does not exceed 0.1%. The first two-kilometre pip should not be used, as it is formed from the sum of the crystal oscillator voltage plus the remainder of the synchronizing pulse voltage, and can be in error, depending on the degree of balance of the bridge. A small unbalance can shift the position of this pip considerably, but does not affect the absolute positions of the rest of the pips. In the SSR application, only the 20-kilometre pips are used, of course, but the 2-kilometre pips may be injected for lining-up purposes.

If reasonable precautions are observed in shielding the bridge elements of the circuit, as indicated on the diagram, the bridge is not at all critical in adjustment. Once set up, it remains balanced during wide variations in temperature and line voltage.



WAVEFORMS

(Fig.2)

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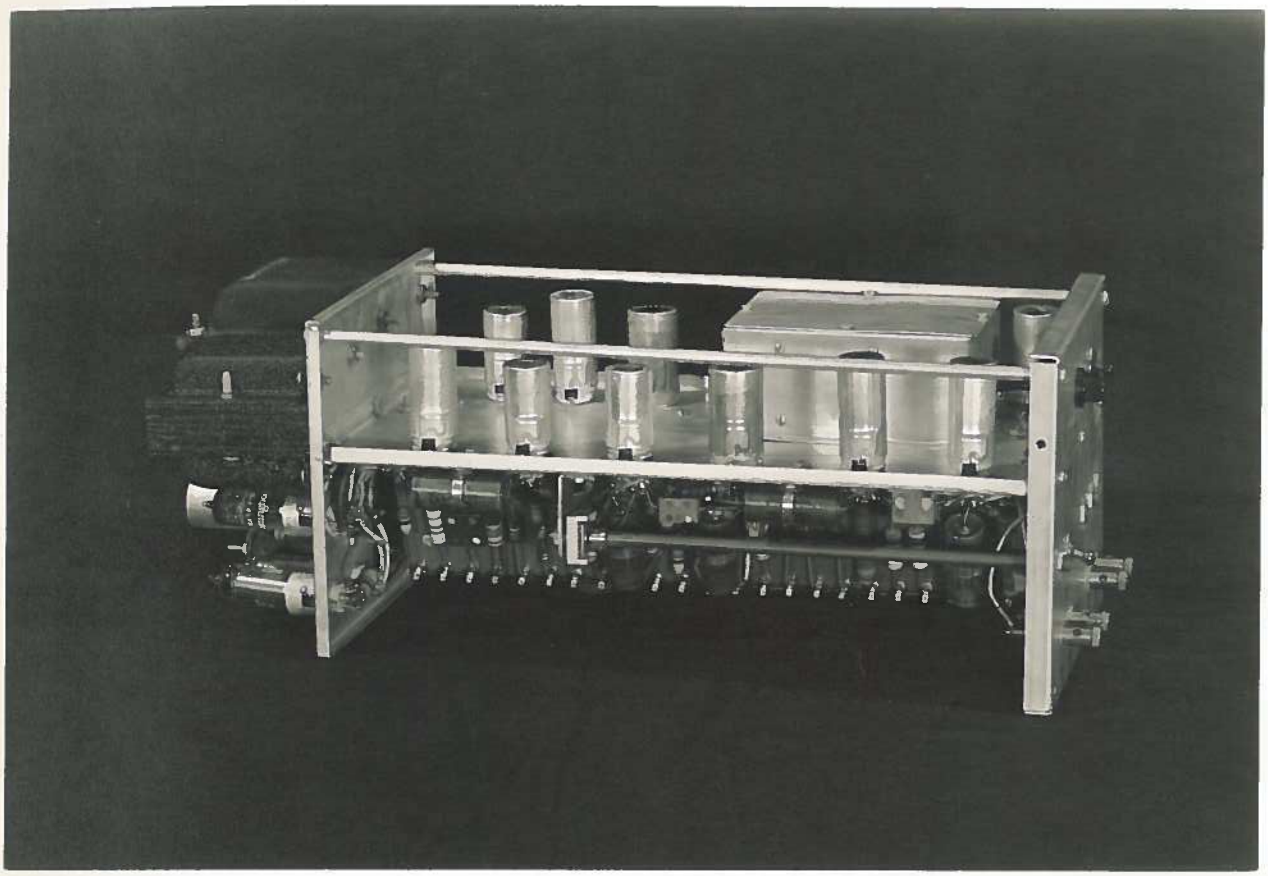

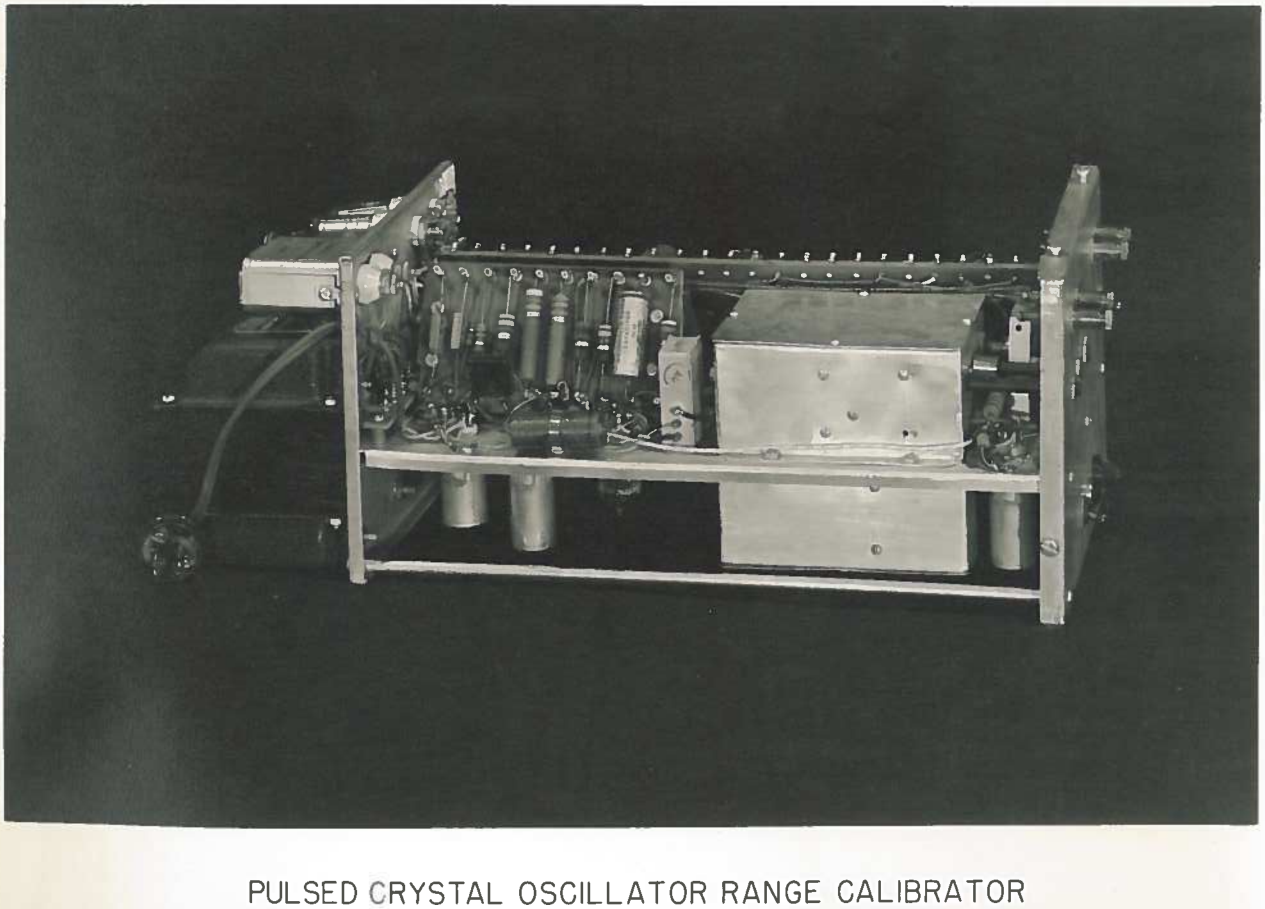

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