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THE APPLICATION OF TRANSISTORS
TO AN INDUSTRIAL TELEVISION
SYNCHRONIZING GENERATOR

RADIO CORPORATION OF AMERICA
RCA LABORATORIES DIVISION
INDUSTRY SERVICE LABORATORY

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Approved

Stuart W. Seeley

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Introduction

Point-contact transistors, such as the RCA TA-165, are suitable for many types of pulse generating and pulse shaping circuits. Consequently, a program was started to apply transistors to the simple form of synchronizing generator employed in the RCA Industrial Television equipment. Substantial savings in weight and power were made.

The resulting experimental unit is but a fraction of the size of the previously-used vacuum-tube synchronizing generator and uses only one-fifth the B power. Its performance is good with respect to B voltage changes, the count being maintained from 22½ to 45 volts. However, the counters are relatively sensitive to temperature variations, the count changing for temperature fluctuations of the order of 10 degrees C.

General Discussion

The synchronizing generator in the industrial television equipment produces the necessary 15,750 cycles/sec and 60-cycle/sec pulses needed to generate a standard 525-line interlaced picture. In this equipment, equalizing pulses and a serrated vertical pulse are not required and need not therefore be generated. Fig. 1 shows in block form the manner in which the required pulses are generated.

A master oscillator operating at twice horizontal frequency (31.5 kc/s) drives two independent frequency divider chains. The master oscillator frequency will henceforth be referred to as the 2H frequency. One divider chain comprising the first through fourth dividers divides the 2H signal by an odd number, 525, to produce the vertical scanning frequency of 60 cycles/sec. The other divider chain

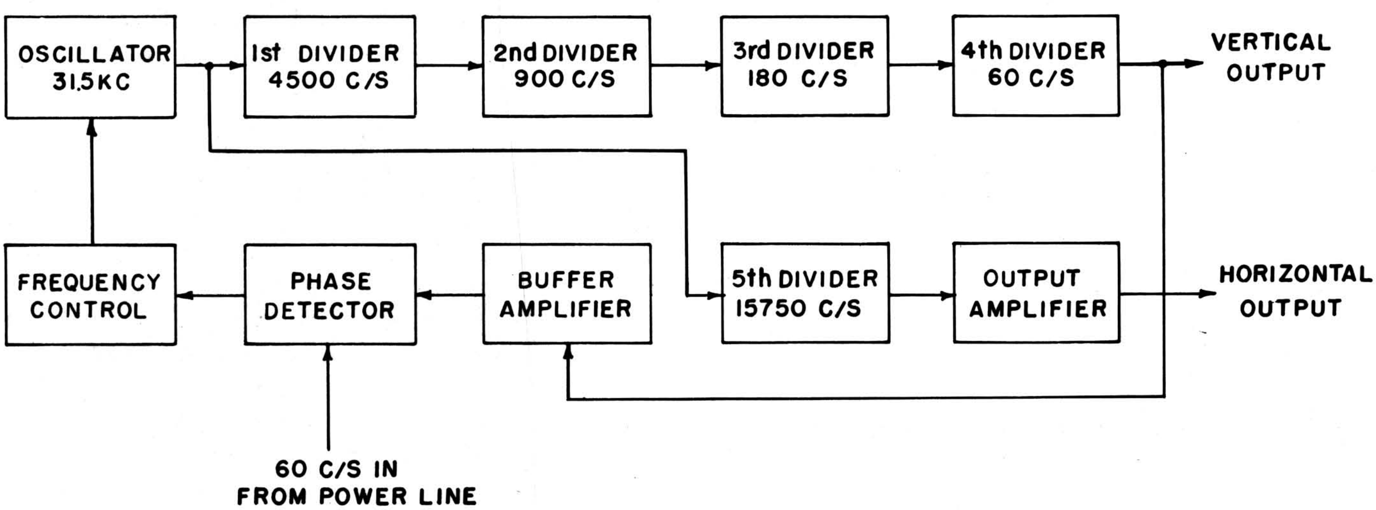


Fig. 1 - Block diagram of sync generator.

comprising the fifth divider divides the 2H signal by an even number, 2, to produce the horizontal scanning frequency of 15,750 cycles/sec. By this means the two scanning frequencies are locked together in the correct relation for interlace.

There are two common methods of insuring the frequency stability of the master 2H oscillator. One method is simply to make it a crystal oscillator. The other, as shown in Fig. 1, is to compare the counted-down output of the oscillator to some external standard, usually the local power line, in a phase detector, and control the oscillator frequency by means of a reactance tube to keep its frequency an exact multiple of the power-line frequency. The first method has the virtues of simplicity and stability, but any hum present in the television system will cause annoying moving bars in the picture. The second method avoids this, at the expense of some added circuit complications, although if the equipment is to be operated from a power supply of unstable frequency--such as a portable gasoline driven supply--it is often necessary to disable the frequency control circuit.

The frequency dividers are preferably of the pulse type and must be free from jitter if good interlace is to be maintained. The leading edge of the vertical pulse should bear a fixed and invariable relation to every 525th 2H pulse and is preferably aligned with its leading edge. Similar conditions apply in the horizontal divider chain but because of the low divisor they are usually more easily satisfied. Another important consideration is to avoid interaction of either divider chain with the other. Because of the odd-even relation between the counts, interaction will result in poor interlace or such phenomena as slight displacement of every *n*th horizontal line in the raster where *n* is usually the divisor of the highest divider in the vertical count-down chain. Practically, this means that reaction from either divider chain back into the 2H oscillator--which is common to both chains--must be avoided.

Application of Transistors to Dividers

Frequency dividers of the synchronized relaxation type are satisfactory. Such a divider has been developed using a single TA-165 point-contact transistor. The circuit is shown in Fig. 2 and its operation is as follows. Neglecting the current-limiting resistor, R_2, when voltage is applied, the base of the transistor becomes negative because of leakage in the collector rectifying contact. The potential of the base, V_b, becomes:

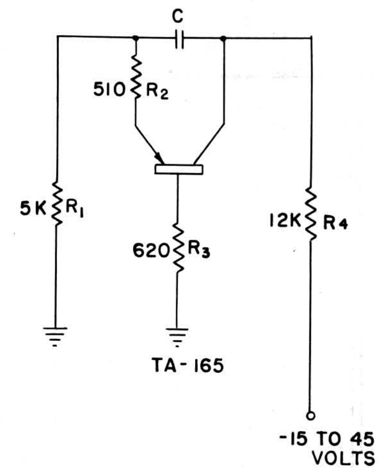


Fig. 2 - Circuit of typical divider.

$$V_b = -I_{co}R_3 \qquad (1)$$

where I_{co} is the leakage current.

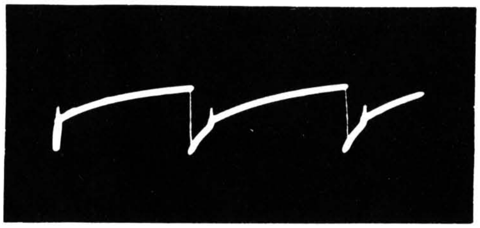
The transistor emitter also becomes negative because current flows through R_1 and R_4 to charge capacity, C. The emitter voltage is given by:

$$V_e = -\frac{VR_2}{R_1+R_2} e^{\frac{-t}{(R_1+R_2)C}} \qquad (2)$$

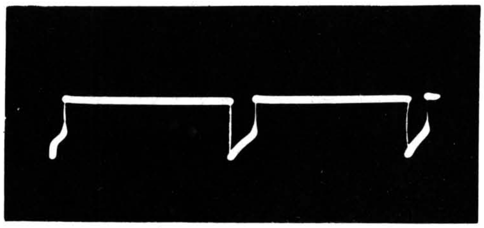
where V_e is the emitter voltage and V the collector supply voltage.

From the above it can be seen that the capacitor charges exponentially, the collector becoming more and more negative. As long as the emitter is more negative than the base, conduction through the emitter-collector path is negligible but as the charging process continues, the leakage current increases while the charging current falls off exponentially. This eventually results in the emitter becoming positive with respect to the base.

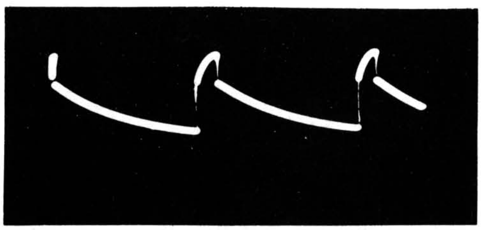
When this occurs the capacitor begins to discharge through the emitter-collector path and, since in a point-contact transistor the



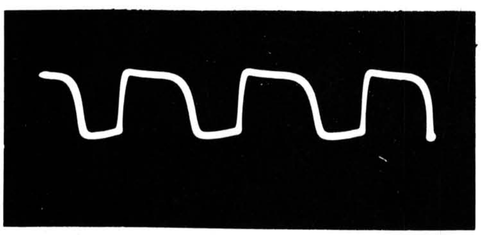
EMITTER WAVEFORM
(a)



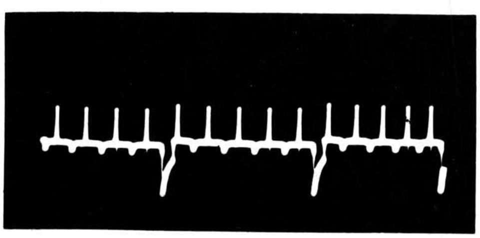
BASE WAVEFORM
(b)



COLLECTOR WAVEFORM
(c)



Z_H OSCILLATOR COLLECTOR
(d)



BASE WAVEFORM T_3
(e)

Fig. 3 – Waveforms.

current gain is greater than unity, the base current increases more rapidly than the emitter current and the action rapidly becomes self-sustaining. This continues until the capacitor is discharged and the circuit then recycles. R_2 limits the capacitor discharge current to a value below that which would damage the transistor. Photographs of waveforms at the various electrodes of the transistor are shown in Fig. 3a, b and c. Note especially the base waveform, a sharp negative pulse. This characteristic is particularly useful, as will become apparent in the following discussion.

This relaxation oscillator may be used as a frequency divider by synchronizing it from an external source. Negative synchronizing pulses may be most conveniently applied through a small capacitor to the base. The natural period of the oscillator is then adjusted in the usual manner to be slightly longer than *n* times the period between synchronizing pulses where *n* is the desired divisor. Coarse adjustment is conveniently made by adjusting C, and fine adjustment by making all or a portion of R_1 a variable resistor. Reliable division of ten is possible.

A desirable and economical feature is the ease with which one such divider may trigger a succeeding divider, by connecting their bases together through a small capacitor. There is little reaction from the lower divider back into the higher one with such a connection, and buffer stages are not required.

Transistor Synchronizing Generator

The complete circuit of a transistor synchronizing generator suitable for use in the RCA Industrial Television equipment is shown in Fig. 4. T_1 is a transistor oscillator operating at 31.5 kc which is similar to a conventional vacuum-tube Hartley oscillator. The operating conditions of the oscillator are such that the collector waveform is clipped and non-sinusoidal as shown in Fig. 3d. Capacitor C_6 and resistor R_{13} differentiate this waveform. The negative pips so produced are applied to the base of transistor T_2, the first divider, to synchronize it with the oscillator. T_2 divides by seven. Succeeding stages, T_3, T_4 and

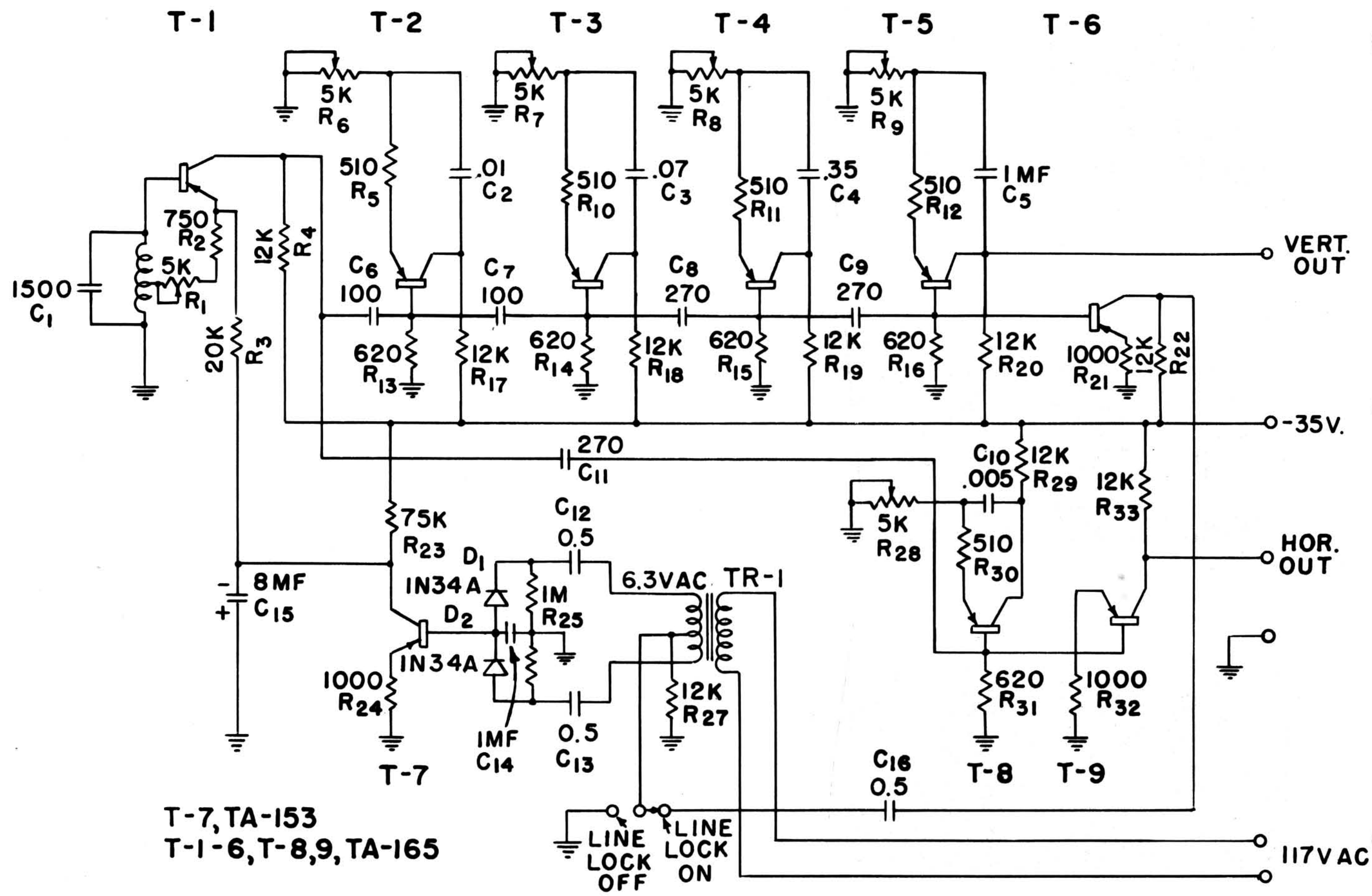


Fig. 4 - Circuit of industrial television generator.

and T_5 divide by five, five and three respectively to make the required total of 525 thus resulting in the necessary 60-cycle/sec output frequency required for television vertical synchronization. The base waveform of T_3, the first divide-by-five stage, is shown in Fig. 3e, in which the sync pulses and the somewhat larger negative pulses which occur when T_3 conducts are clearly visible. The collector waveform of T_5 has been found suitable for use in the associated equipment without further shaping.

T_8 and T_9 comprise the horizontal frequency divider and an output amplifier. The divider, T_8, is of the same type as the other dividers, its time constant being adjusted to give division by a factor of 2. The output amplifier, T_9, is directly connected to the associated divider, T_8, and with the connection shown inverts the negative pulses present at the base of T_8, to produce positive output pulses. R_{32} adjusts the bias on T_9 to the proper operating point.

The 2H oscillator is stabilized at an exact multiple of the local power line frequency by the circuits associated with T_6, T_7 and the phase detector diodes D_1 and D_2. T_6 is an amplifier similar to T_9 which amplifies the 60-cycle pulses produced at the base of T_5, the 60-cycle/sec divider. These pulses are applied to the phase detector comprising diodes D_1 and D_2 and their associated resistors and capacitors. Transformer, TR-1, applies 6.3 volts a.c. from the power line to the phase detector.

The d-c output of the phase detector i applied to the base of a TA-153 junction transistor, T_7, which by loading the tuned circuit of the 2H oscillator controls its frequency to lock the entire unit to the power line. The single-pole double-throw switch shown provides a means for disabling the frequency-contr

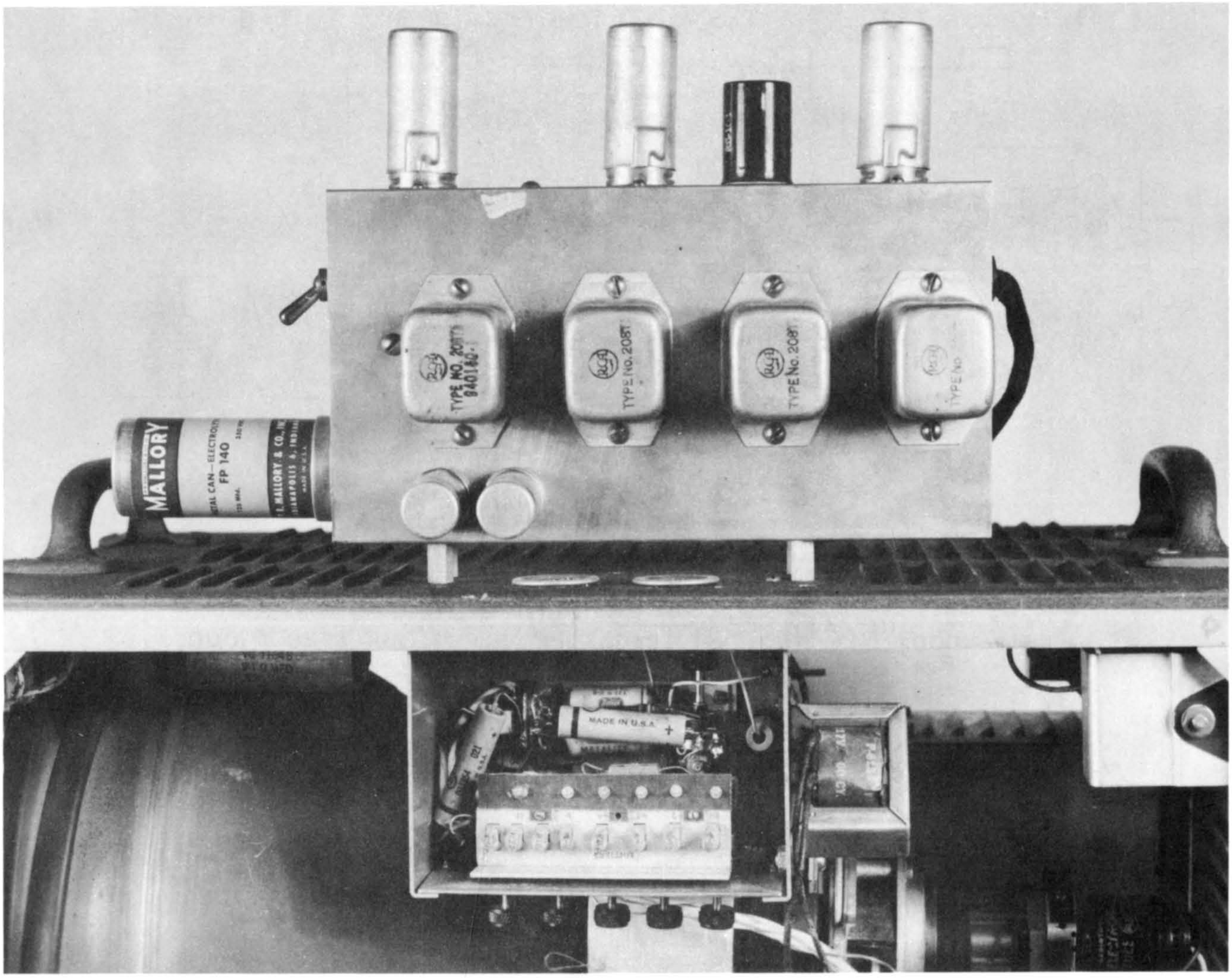


Fig. 5 - Photo of sync generator, vacuum-tube unit above.

circuit in applications where it is not required or where the local power supply is not sufficiently stable.

Fig. 5 shows the transistor synchronizing generator installed in a standard Industrial Television set. For comparison the older vacuum-tube sync generator may be seen above the transistor unit. The unit has been operated for about 200 hours. Its stability with respect to changes of collector supply voltage is quite good; the seven-time divider, for example, will count correctly over a range of collector supply potential from 22½ to 45 volts. The stability of the other dividers is comparable or better. The stability of the unit to changes in ambient temperature is such that fluctuation of 10 degrees C from room temperature may be sufficient to cause miscounting.

As shown in Fig. 5, the transistor unit is considerably smaller than its vacuum-tube counterpart which uses blocking oscillator dividers. Since the transistor unit contains no blocking oscillator transformers it is also considerably lighter. The vacuum-tube unit used about 10 ma at 150 volts for its plate supply. The transistor unit uses about the same current at one-fifth of the voltage, thus representing a considerable saving of B power.

Winthrop S. Pike