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STABILIZED RELAXATION OSCILLATOR

by

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ABSTRACT

An unsynchronized thyatron relaxation oscillator circuit has been developed, whose rate is stabilized through the use of a Schmitt discriminator to determine the thyatron firing point. Drift and jitter in the period are less than 0.1% after warmup

In electronic instruments it is frequently necessary to have timing pulses occurring at accurate, stable intervals of the order of seconds, and to be able to vary these intervals conveniently. The simple, unsynchronized thyatron relaxation oscillator would seem most attractive for such an application because of its simplicity and because its period is controlled by only one RC time constant. However, the stability leaves so much to be desired that it is not so used. Hard-tube circuits, including many types of multivibrators, also have stability problems resulting from the effect of tube characteristics on the timing. Also, in most of such circuits the period is controlled by more than one time constant, making variation inconvenient. Phantastrons and other Miller-effect circuits are more stable but do not readily lend themselves to repetitive operation.

The stability problem for the simple relaxation oscillator arises because the circuit uses the thyatron beyond its capabilities. It is not only expected to discharge the timing capacitor very quickly at the end of each cycle, which it can do quite well, much better than a hard tube, but it also determines the capacitor voltage, and thus the time, at which the cycle should end. Here the thyatron does quite poorly, as the starting voltage of a gas tube is erratic and nonreproducible, resulting in an unstable period.

It would seem that the stability could be improved by using a more stable element to determine the end of the cycle, using the thyatron only to discharge the capacitor. This is done in the circuit shown in Figure 1. The 884 thyatron V1 is biased so that it will not fire by itself. The voltage on the timing capacitor C is applied to the ac-coupled Schmitt trigger circuit by means of V2, whose triggering level is set at 150 volts by R4 and R5. While C is charging, its voltage is less than 150 volts. Hence, V2a is cut off and V2b is conducting. When the voltage on C reaches the triggering point, V2a turns on and V2b cuts off. The rise in the plate voltage of V2b is coupled to the grid of V1, causing the thyatron to fire and discharge C1.

As the voltage on C1 drops, the trigger circuit returns to its previous state, and the cycle repeats.

Figure 1

Stabilized Relaxation Oscillator Circuit

Irregularities in the period could also be induced when the thyatron turns off. There would be variations in the voltage remaining on C when V1 stops conducting, which, of course, would lead to variations in the time required for C to charge up to firing voltage. This is overcome with the aid of the rf choke L1 and the silicon diode D. Besides keeping the peak V1 plate current within ratings during the discharge, L1 produces an overshoot when V1 stops conducting, which drives C and the plate of V1 below ground potential. The diode D, however, catches C at ground and thus provides a definite starting point for the next cycle.

The remaining instability in the period apparently arises from two factors. The first, variability in the thyatron de-ionization time, is minimized by the use of a triode rather than a tetrode thyatron, so that the second, fluctuations in the discriminator triggering point, seems to be the dominant factor. Provisions to minimize this include placing R4, R5, and C1 in the grid circuit of V2b to filter out any ripple remaining in the B supply, thereby preventing it from affecting the triggering point. Both R and C presumably perform the same function for the grid of V2a, at least

for slow rates. However, high-frequency hash in the B supply may reach the grid of V2b through R2 and C2. Even very small amplitudes of such hash can cause noticeable premature triggering.

Since loading the timing circuit will affect the period, the cathode follower V3 is provided to isolate the output. The sawtooth waveform is available at the cathode of V3, while C4 and R12 differentiate that waveform to produce a 150-volt negative pulse.

The stability of this circuit was tested with the aid of the delayed-sweep function of a Tektronix 545A oscilloscope. This enabled the end of the cycle to be displayed on a greatly magnified time scale. By making a long time exposure of the oscilloscope screen, the dispersion in period during this time could be photographically displayed. For values of 0.75 to 5.11 megohms for R and 0.2 to 2.0 μ f for C, corresponding to 0.1 to 6 sec per cycle, the dispersion after a few minutes of warmup was less than 0.1% for exposure times up to 24 hr. Faster rates showed somewhat greater percentage dispersions, most likely because of the increasing importance of deionization time variations.

Variations of ± 10 volts in the B+ voltage produced changes in period of about 0.03%, the period increasing with increasing voltage. Thus, the circuit is not extremely voltage-sensitive, but should not be operated from an unregulated supply. Such supplies show continual output fluctuations of fractions of a volt resulting from similar fluctuations in the line voltage. These will vary the charging voltage for C during a cycle, and thus act as an additional source of jitter. In addition, regulation is helpful in eliminating ripple. On the other hand, the negative supply serves only as bias, so regulation is of no consequence.

When the circuit is turned on, the tube heaters must be allowed to come to operating temperature before the B+ voltage is applied. If the B+ is applied too soon, C will charge up past the Schmitt triggering point before the tubes are capable of functioning. Then C would never be discharged and oscillations would not start. Failure to start can also occur if the time constant of R4, R5, and C1 is longer than that of R and C. Then the voltage on the grid of V2a would rise faster than the voltage on the grid of V2b. Thus V2a would remain turned on while C charges to B+ voltage, and no oscillations would occur. Both of these problems could be circumvented by providing means for discharging C or triggering V1 manually.

The period of oscillation T is given by the formula

$$T = RC \ln \frac{E_B}{E_B - E_T},$$

where E_B is the B+ voltage and E_T is the triggering point of the Schmitt. The stability of R and C should, of course, be commensurate with the

stability expected from the circuit. Both R4 and R5 should also be of high quality, since they largely determine E_T/E_B .

This circuit could perhaps be adapted to use with semiconductors by using silicon transistors in the Schmitt trigger and a silicon-controlled rectifier in place of the thyatron. However, the semiconductors would have to be selected for low cutoff currents, since cutoff currents not negligible with respect to the charging current of C would introduce temperature-dependent timing errors. A semiconductor circuit would be considerably more expensive than the vacuum-tube version.