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A TRIGGER CIRCUIT FOR A HOT-WIRE-ANEMOMETER AEROSOL DETECTOR

by

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DEPARTMENT OF THE ARMY
Headquarters, Edgewood Arsenal
Aberdeen Proving Ground, Maryland 21010

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This report describes a cathode-coupled multivibrator which was designed and used in conjunction with a standard constant temperature anemometer (CTA) to measure local aerosol concentrations in turbulent impaction wind-tunnel experiments. The circuit acts like an electronic switch to actuate an electronic frequency counter each time a relatively cool aerosol particle impacts on a standard heating filament of the CTA and serves to prevent erroneous multiple counts from a single droplet.

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PREFACE

The work described in this report was authorized under Task 1W762718A084-02. This work was started in January 1971 and completed in March 1971. The experimental data are recorded in notebooks 8514 and 8531.

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A TRIGGER CIRCUIT FOR A HOT-WIRE-ANEMOMETER AEROSOL DETECTOR

I. INTRODUCTION.

The turbulent impaction of liquid particles on man-sized targets is a matter of great practical importance in chemical warfare offensive and defensive operations. Although certain cases of turbulent particle deposition can be formulated and analyzed mathematically, other potentially important deposition mechanisms are not amenable to rigorous mathematical treatment. To discern the mechanisms influencing the turbulent impaction of particles in these cases, experimental studies have been designed for representative bluff bodies (cylinders and sphere). These experiments are customarily performed in a controlled turbulent flow field produced in a wind tunnel. The effects of particle size distribution can then be studied effectively and synthesized by use of a variety of monometric (single-sized) and monodispersed particles.

The collection efficiency of a cylinder of sphere is defined by the fraction of the aerosol that is deposited on the bluff body in comparison with the total aerosol challenge. The total challenge is usually obtained by sampling the aerosol cloud by the so-called "isokinetic method" or by the impaction method. In both of these methods, the analysis and calibration are based on the assumption of laminar flow. It is expected that when turbulent flows prevail, quite different results are obtained which vary with the Reynolds number, the intensity of turbulence and the scale of turbulence, making the laminar results suspect for application to the case of turbulent flows.

Experimentally, the collecting material is usually a nondegradable absorbent paper, which must be removed from the sampling device and placed in a solvent as soon as possible after sample collection without loss of sample accuracy and then transported without degradation to a chemical laboratory for analysis. Additionally, an adequate description of the airborne fraction at low concentration levels, typical of wind tunnel-type dispersers, makes it necessary to sample for prolonged times in order to meet the sensitivity requirements of the spectrophotometric or colorimetric methods used in the chemical analysis.

A new method of measuring the local aerosol concentration in both laminar and turbulent flow conditions without the need for chemical analysis, extensive sample handling and time-consuming chemical analysis is the modified hot-wire-anemometer technique proposed by Goldschmidt[1] and Goldschmidt and Householder[2]. A block diagram of a hot-filament aerosol detection technique is shown in figure 1. In this technique a standard heated sensor of a constant temperature anemometer (CTA) such as a fine tungsten wire or quartz-coated wire, is exposed to a turbulent air stream-laden with aerosol. The heated sensor undergoes temperature changes caused by the velocity fluctuations of the carrier air stream and also by losing heat to the relatively cold droplets which strike the heated filament. For the usual subsonic flows produced in a wind tunnel, most of the turbulent energy is contained in frequencies less than approximately 1 kHz, while the cooling signals resulting from the impaction of aerosol droplets on the heated

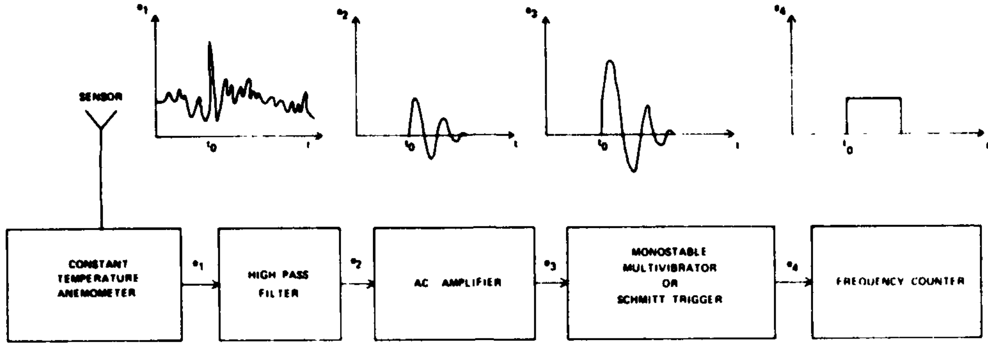

Figure 1. Configuration of Hot-Wire-Anemometer Aerosol- Detector System

filament display characteristic frequencies greater than 1 kHz. Therefore, the two effects can be discriminated by an appropriate high-pass frequency filter. Since the output of the filter is oscillatory by nature, it is necessary to eliminate these oscillations to prevent erroneous multiple counts for a single aerosol droplet impacting on the heated sensor. It is well known that a Schmitt trigger, or a one-shot multivibrator will produce pulses from some external source. If the pulse width of such a circuit is made equal to or longer than the oscillation time of the filter cooling signal, a countable pulse signal will be generated for each aerosol droplet impaction.

This report describes the design and testing of a one-shot or cathode-coupled multivibrator that will suitably perform the required waveshaping on the oscillatory cooling signal due to an aerosol droplet impaction.

II. BACKGROUND.

The basic one-shot or monostable multivibrator used to produce pulses, the duration of which is predetermined by circuit time constants, is shown in figure 2. The circuit is called a cathode-coupled monostable multivibrator since the cathodes are connected to a common cathode resistor, R_k. This circuit has the advantage that the triggering circuit is isolated from the multivibrator's output circuit by V1. The circuit has one stable and one semistable state. The bias applied by R_k is such that when there is no external trigger impulse applied to the grid of V1, it is cut off, so that the anode current of V2 will be a maximum and the output voltage a minimum (the stable, quiescent state). On the arrival of a positive triggering impulse at the grid of V1, the tube will conduct for a period, T, its anode voltage will drop, and C_1 will be charged. Thus, a voltage negatively directed will be applied to the grid of V2 which will drive V2 beyond cutoff. The output voltage will rise to a maximum for a controlled period of time; that is until C_1 has discharged through R3. After this period of time, the circuit automatically returns to the stable condition and the output voltage drops to its minimum value.

The repetition-triggering rate of the circuit, or more appropriately, the particle-counting rate, is determined by T_p, the pulse width and T_R, the recovery or reset time of the multivibrator. A second output pulse cannot be started even if an input is applied, until V1 has been restored to its nonconducting condition.

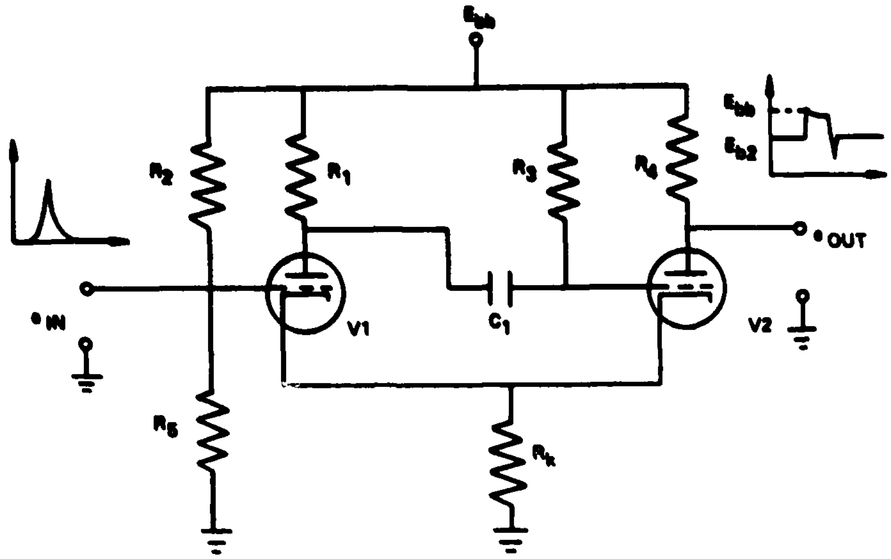

Figure 2. Diagram Of A Typical Cathode-Coupled Monostable Multivibrator

III. DESIGN

A schematic diagram of the cathode-coupled monostable multivibrator designed around a dual triode 6SN7 tube is shown in figure 3 which will be referred to throughout this section. Cirucit values were generally selected in accordance with the principles outlined in Electonic Designers' Handbook by Landee, Davis and Albrecht.[3] Sufficient stability in gate width and amplitude was obtained using standard 10-percent resistors; however, a substitution of a few different resistors for R_7, R_8 and R_9 was required to insure that V1 is cut off when V2 is conducting as discussed in the previous section.

The filtered and amplified signals of the constant temperature anemometer are connected to the grid of V1 through coupling capacitor C_4. V1 is normally cut off and V2 conducting but a positive voltage greater than approximately 8-volts peak will trip the circuit causing V1 and V2 to reverse roles for a predetermined period of time. Capacitors C_5 through C_{10} in conjunction with resistors R_{11} and R_{12} allow an adjustment of the duration of this time period from approximately 25 μs to 10 ms, as shown in figure 4. The correspondence between the RC time constant of the circuit and the pulse width is given by the regression line $T_p = 0.512\ T_{RC}^{1.05}$. The variable resistor R_{13} provides an adjustable output pulse amplitude up to 20 volts peak which is clamped near the zero volt reference level by diode D_1 and R_6. The power supply for the multivibrator circuit consists of transformer T1, full wave rectifier V3 (6X5), a RC filter network, R_1, R_2, R_3 and C_1, C_2, C_3 and two voltage regulators (VR150) V4 and V5. The ripple factor of the power supply is 0.002.

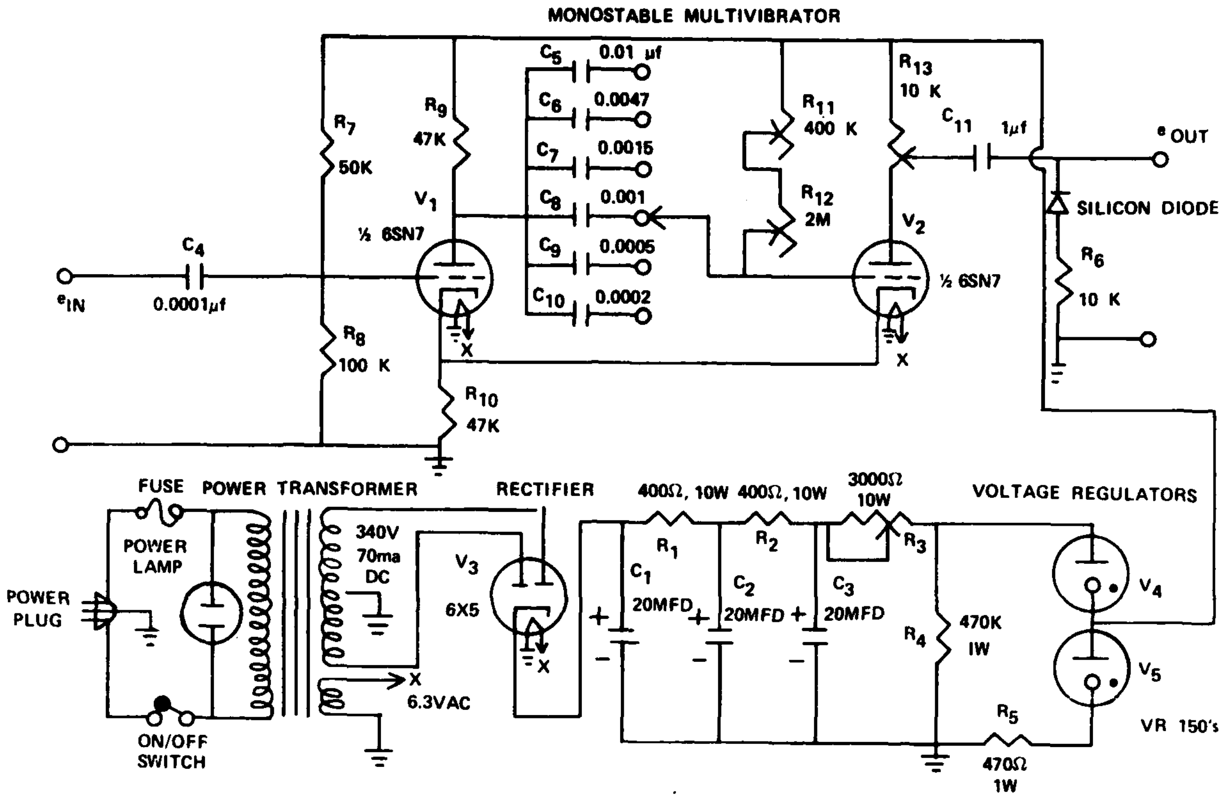

Figure 3. Schematic of the Monostable Multivibrator Pulse Shaper

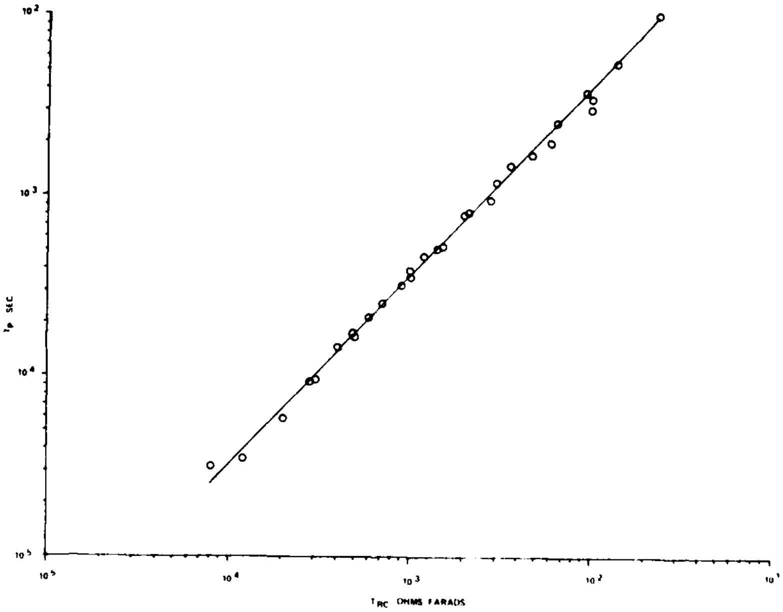

Figure 4. Output Pulse Width Versus RC Time Constant

IV. TESTING AND DISCUSSION

The maximum counting rate for the cathode-coupled multivibrator circuit for a particular RC time-constant selection was determined using the arrangement shown in figure 5. The external triggering signal was a train of short impulses obtained by differentiating a square pulse provided by an HP 3310A Function Generator. The frequency of this input signal was increased until the multivibrator failed to produce an output pulse of the same frequency and was then decreased until the one-to-one frequency correspondence was again achieved. Since some hysteresis was noticed, the "up-count" frequency was slightly larger than the "down-count" frequency. The lower value was used as an estimate of the maximum triggering rate of the circuit. The counting rate is plotted in figure 6 as a function of the output pulse width of the multivibrator. The test results indicate that, for a particular value of the timing capacitor, the frequency sensitivity of the multivibrator begins to decrease noticeably if the value of the timing resistor (R_{11}/R_{12}) is reduced below approximately 800kΩ. At this point, it is better to decrease the timing capacitor than the timing resistor. The straight line which corresponds to a duty cycle of 0.6 is, therefore, a conservative estimate of the maximum counting rate of the multivibrator when triggered by a periodic signal and, as shown, the rate can be varied from 10,000 events per second to 60 events per second for pulse widths of 60 μs and 10 ms, respectively.

In reality, the physical event of liquid particles impacting on a small heated sensor of a constant temperature anemometer will not occur with ideal electrical response as does the periodic test signal used above. The collisions of the particles on the detector element will be random in nature and thus, the possibility exists that one, two or more droplets could strike the heated sensor simultaneously, that is during the time interval $T = T_p + T_R$ where T_p is the pulse width and T_R the reset time of the multivibrator. Such coincident events are not detected by the CTA aerosol sampler and could be a major source of error for certain test conditions.

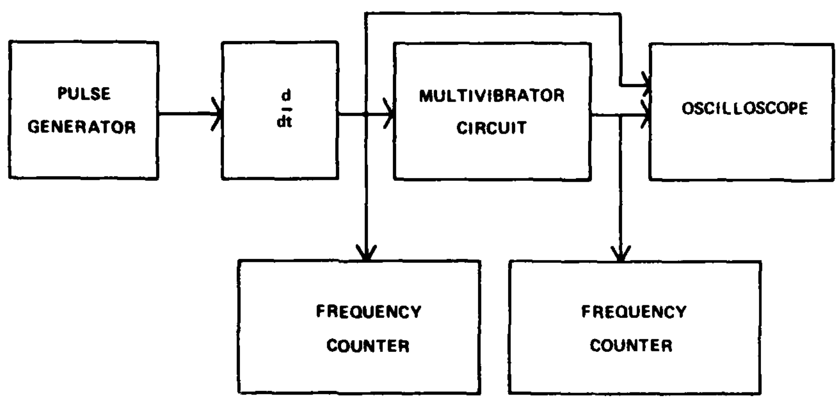

Figure 5. Configuration Of The Test Setup To Determine The Maximum Triggering Rate Of The Multivibrator

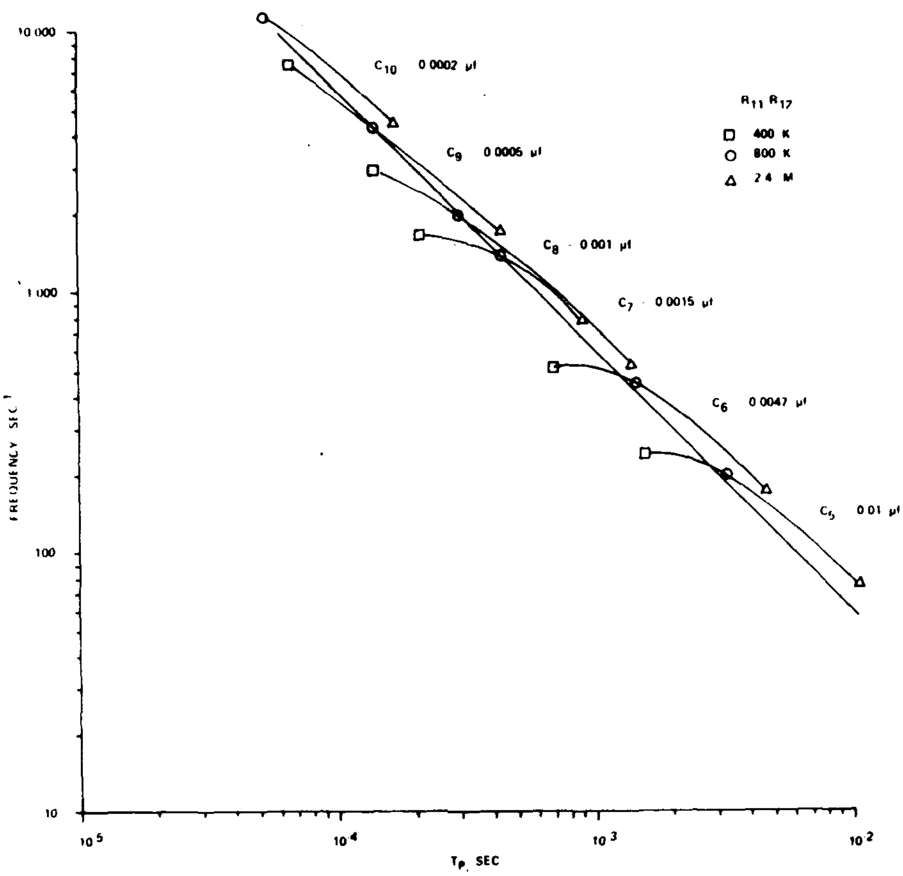

Figure 6. Estimation Of The Maximum Triggering Rate Of The Multivibrator For Selected Pulse Widths

However, it is reasonable to expect that the process satisfies the condition of a Poisson distribution, that is a collision occurs randomly on an average of λ times per second and the occurence of n events in any time interval $(t_o, t_o + \tau)$ is independent of the number of occurrences of the event before t_o and depends only upon the length of the interval τ. Hence, the collision times are Poisson distributed and thus $P_K(\tau)$, the probability of K collision in τ seconds is given by

$$P_K(\tau) = \frac{(\lambda \tau)^K e^{-\lambda\tau}}{K!}$$

The probability of two or more collisions in a time interval τ for a collision density, λ, is then

$$\text{Prob}\ (K > 1; \lambda\tau) = 1 - P_0 - P_1$$

where P_0 is the probability of no collisions and P_1 is the probability of one collision in the time interval τ. Figure 7 shows the permissible particle collision rates that were calculated using the above relationship as a function of pulse width of the multivibrator for seven selected probability levels ranging from 0.0001 to 0.10. The results indicate that the probability of simultaneous collisions for low collision rates, typical of wind tunnel test conditions[4], is very small and, therefore, the time response of the multivibrator should be more than adequate to measure accurately the aerosol droplet challenge in such wind tunnel impaction experiments.

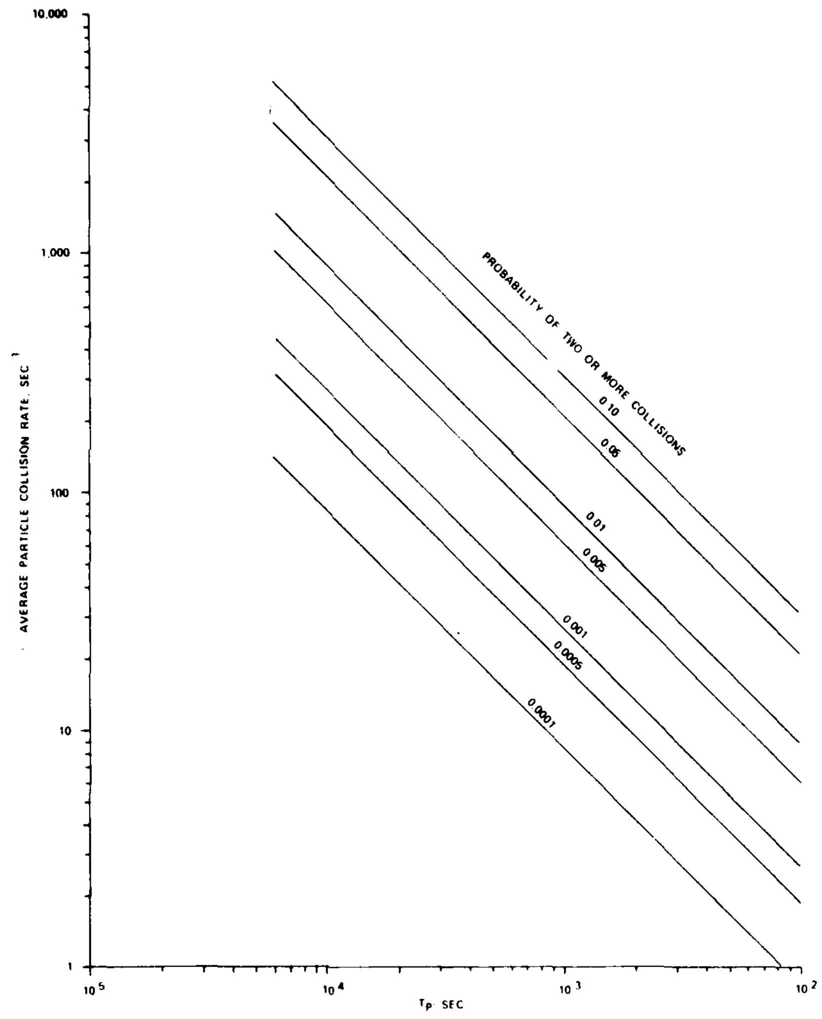

Figure 7. Estimation Of Multiple Collisions Or The Probable Error In Particle Count

V. CONCLUSIONS

A cathode-coupled multivibrator circuit was designed to produce pulses of a duration predetermined by circuit constants to facilitate counting the number of liquid particles striking a heated sensor of a constant temperature anemometer for measurement of the aerosol challenge in turbulent impaction experiments. Pulse duration of the multivibrator can be varied from 60 μs to 10 ms when triggered by an external impulse with an amplitude of 8-volts peak or greater and has a duty cycle of 0.6.

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