

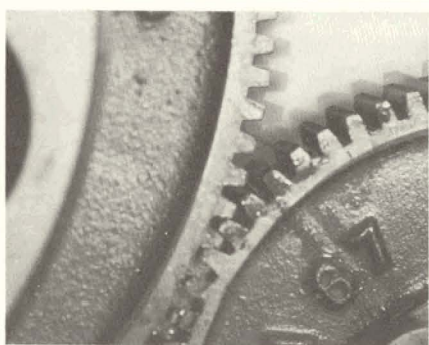
GENERAL RADIO

engineering department

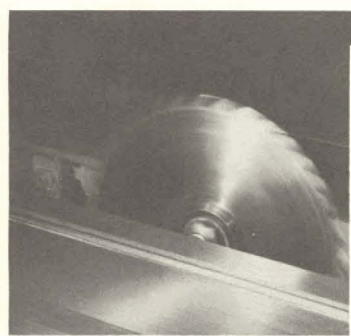


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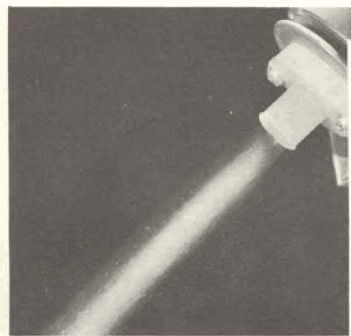
1967



FROZEN MOTION



Seeing the unseen with General Radio Strobotac® electronic stroboscopes. Here's how a pair of gears, a circular saw and a water jet appear — first to the unaided eye and next with the help of the intense, short-duration light flashes from the Strobotac.



E111

NEW EYES FOR MODERN INDUSTRY

The Type 1531-A Strobotac® electronic stroboscope

The new TYPE 1531-A Strobotac represents the most important advance in commercial stroboscope design since 1935, when General Radio first introduced the now familiar Strobotac® stroboscopic tachometer. The new instrument offers a combination of performance characteristics not hitherto available in any commercial stroboscope, and it opens up many new fields of application for stroboscopic techniques.

A radically new Strobotron lamp, developed by Edgerton, Germeshausen & Grier, Inc., in cooperation with General Radio Company, provides three very important improvements in performance characteristics:

1. A white light flash, rather than red, produces higher contrast in the viewed image and makes objects appear in their natural colors. Also, the very much higher resolving power of the human eye for white light as compared to red light permits finer detail to be seen with less strain.

2. Higher light intensity, over 70 times as bright, allows effective use under normal room-lighting conditions and also allows objects deep inside a machine to be adequately illuminated.

3. Shorter flash duration, by a factor of 10 to 20 — 0.8 μ sec at high flashing

rates — allows a corresponding increase in the upper limit of speed of the viewed object.

Supporting this improved performance are many other major improvements in electrical performance and mechanical design, which contribute greatly to the utility, adaptability, and ease of handling of the new Strobotac.

4. Higher frequency range — from 110 rpm to 25,000 rpm in three ranges — permits direct measurement of 400-cycle devices.

5. Light beam is adjustable 180 degrees vertically and 360 degrees horizontally, so that the light beam can be aimed for best illumination of the object being viewed while the panel is positioned for convenient control manipulation and anti-parallax dial readings.

6. Flip-tilt case, which provides an adjustable stand for bench use and a permanently attached cover, which totally encloses the instrument for storage or transit.

7. Simplified controls — direct-reading rpm dial requires no multiplying factors, and only the range scale in use is visible.

8. Sensitive input circuit is easily triggered by an external mechanical contact

or by electrical signals — only 6 volts, peak to peak, required.

9. Substantially smaller in size and lighter in weight, the new instrument can be held in one hand.

10. Neon calibrating lamp is located on panel, so that calibration can be easily checked at many speed settings.

New Strobotron Lamp

The new lamp produces a white light flash by an electrical discharge through xenon gas. Figure 2 shows a comparison of the light output pulses obtained from the new and old Strobotacs. Not only is the duration of the pulse much less for the new model, but the long tail characteristic of the neon Strobotron tube is not present in the new xenon tube, which results in much sharper definition of fast moving objects. Measured between the points at which the light intensity is one-third of peak light value, the light-pulse width of the TYPE 1531-A Strobotac is approximately 0.8 μ sec, 1.2 μ sec, and 3 μ sec, on the low, medium, and high intensity positions, respectively.* On the other hand, the old TYPE 631-BL Strobotac has 11- μ sec and 40- μ sec pulse widths on the low- and high-intensity

*Measured at 10 per cent of peak intensity, the durations are 1, 3, and 6 μ sec.

The Principle of the Stroboscope

A stroboscope is an instrument that permits periodic observation of a moving object in such a way as to create the optical illusion of slow or stopped motion. The electronic stroboscope is essentially a flashing light that provides periodic illumination of a cyclically moving object and thus produces the stroboscopic illusion.

The flashing rate of the stroboscope is controlled by an electronic oscillator and is adjustable over a very wide range. If it is set to flash at, say, 1800 times a minute and if its light is used to illuminate a fan rotating at 1800 rpm, each successive flash will occur with the fan in the same position, and the fan will appear motionless. If the flashing rate is offset very slightly from the fan speed, the flashes will come at successively earlier or later parts of the fan's cycle, producing a slow-motion replica of the actual high-speed motion.

The stroboscope is also widely used as a tachometer. The flashing rate is adjusted to produce the stopped-motion effect, and the speed of the device under study is read on the dial of the flashing-rate control. Especially significant is the fact that this kind of tachometry requires no physical contact with the device. In photography, the stroboscope's microsecond flash (much faster than that of conventional speed lights) "stops" almost anything, no matter how fast it moves, for the camera.



Figure 1. View of the Strobotac with case in totally open position. The convenient, large rpm dial is easily gripped by the hand for precise flash-rate setting.

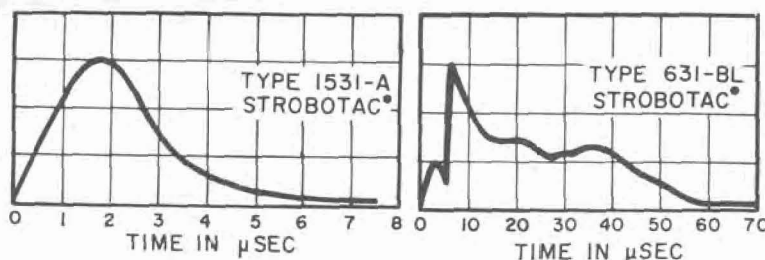


Figure 2. These plots show the marked improvement in flash duration in the new instrument. Both plots are for high-intensity, low-flash-rate conditions. Vertical scales are not comparable. Peak light intensity is about 70 times as great for the new instrument.

positions, respectively. The physical length of the arc is $\frac{3}{8}$ inch, so that a narrow beam angle, with high illumination of distant objects, can be achieved with a small diameter reflector. The life of the Strobotron is also improved, and the average user should be able to obtain between 500 and 1000 hours of operation before the lamp need be replaced.

Mechanical Features

The TYPE 1531-A Strobotac is housed in the flip-tilt case now used for many new General Radio portable instruments. The permanently attached cover of this case can be locked in either the totally closed or the totally open positions, thus providing protection in storage or transit without being in the way when the instrument is in use. The tilting feature is very convenient when the instrument is to be used on a bench top. A neck strap is provided for supporting the instrument, so that the operator's hands can be free, if desired. (See Figures 3 and 4.)

The lamp arm is hinged to provide 180 degrees of travel, and the reflector rotates 360 degrees around a second, perpendicular axis to provide free aiming of the light beam. The multiple-exposure photograph (Figure 5) shows the reflector in three positions. The reflector is securely held to the lamp arm by means

of a spring-loaded detent button, which allows the reflector to be removed easily for replacement of the Strobotron tube. A small amount of dispersion is built into the surface of the reflector, so that a nearly uniform light pattern is produced over the 10 degree width of the light beam.

All controls are located on a single panel, as shown in Figure 6. The range-selection switch and rpm control dial are concentric for ease of operation. Three rpm ranges provide flashing rates from 100 rpm to 25,000 rpm. The range in use is illuminated, while all others are covered by a mask attached to the range-selection knob to prevent confusion in reading the dial.

A power switch is provided separate from the range-selector switch, and a six-foot power cord is permanently attached to the instrument. The cord can be conveniently stored when wrapped around the reflector housing and range knob (see Figure 6).

For maintenance or servicing, the instrument can be easily removed from the case. One etched board is hinged, so that all parts are readily accessible.

Oscillator Circuit

The internal oscillator used in the new Strobotac is a free-running, amplitude-

sensitive, bistable circuit that is a modification of the familiar Schmitt circuit. The frequency at which this circuit operates is determined by a resistor-capacitor combination connected to the input and a variable dc voltage. When the dc voltage is changed, the charging rate of the capacitor and the time between output pulses change. The flashing-rate control (rpm dial) is a potentiometer, by means of which the dc voltage can be varied to produce a flashing-rate range of 6.25:1. The rpm scale is essentially linear with dial rotation. A



Figure 5. This multiple-exposure photograph illustrates the 360-degree reflector rotation. Hinged lamp assembly permits additional positioning in vertical plane.

6-to-1 change in frequency is obtained between ranges by a corresponding change in the timing capacitor. Trimming resistors, set at the factory, are used to correct for small variations in capacitor values so the three ranges track properly.

External Trigger

When the range switch is set in any of the external-input positions, the oscillator circuit is converted into a conventional amplitude-sensitive Schmitt circuit. In these positions the flashing-rate control (rpm dial) adjusts the bias on the input grid and hence the sensitivity of the circuit.

It is possible to trigger the Strobotac from electrical input signals as well as from a mechanical contactor. An input signal of at least six volts, peak to peak, is necessary. When the input electrical signal is near the minimum required amplitude, satisfactory triggering is obtained by careful adjustment of the bias

Figure 3. Two views of the new Strobotac, showing (left) flip-tilt case closed for carrying and (right) open with panel locked in tilted position for convenient use.



Figure 4. This adjustable neck strap supplied with the Strobotac frees the operator's hands for other functions.

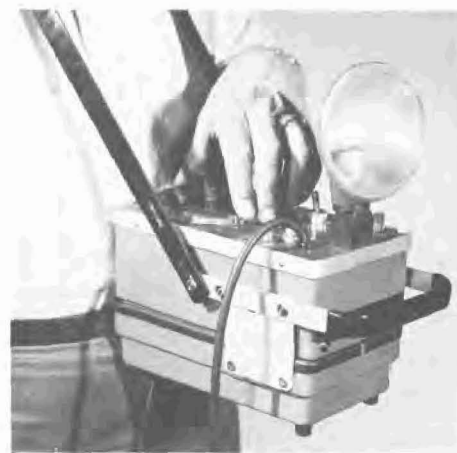
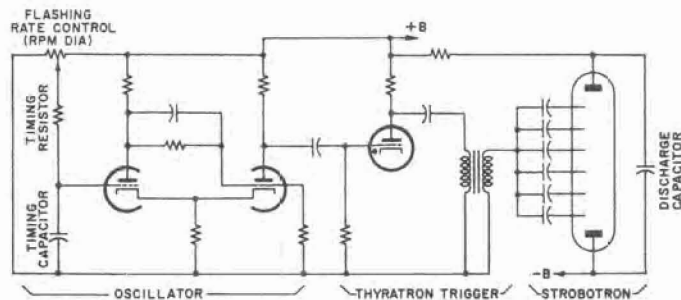




Figure 6. View of the panel, showing scale, mask, dial, and other conveniently arranged controls.

Figure 7. Elementary schematic of the circuit used in the Type 1531-A Strobolac.



SPECIFICATIONS

Flashing-Rate Range: 110 to 25,000 flashes per minute in three direct-reading ranges: 110 to 690, 670 to 4170, and 4000 to 25,000. Speeds up to 250,000 rpm can be measured.

Accuracy: $\pm 1\%$ of dial reading after calibration on middle range.

Calibration: Two panel adjustments permit calibration against power-line frequency.

Flash Duration: Approximately 0.8, 1.2, and 3 μ s for high-, medium-, and low-speed ranges, respectively, measured at $\frac{1}{3}$ peak intensity.

Peak Light Intensity: Typical on high-, medium-, and low-speed ranges, respectively, 0.6, 3.5, and 11 million beam candles (6×10^6 , 3.5×10^6 , and 11×10^6 lux at 1 meter distance at the center of the beam); for single flash, 18 million beam candles (18×10^6 lux at 1 meter distance at the center of the beam).

Reflector Beam Angle: 10° at half-intensity points.

Output Trigger: 600- to 800-V negative pulse available at panel jack.

External Triggering: The flash can be triggered by the opening of a mechanical contactor or by a 6-V, peak-to-peak, signal (2-V, rms, sine-wave signal down to 5 c/s).

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 c/s. Maximum power input is 35 W.

(rpm dial). If the input signal amplitude is large, satisfactory triggering will result over a wide range of rpm dial settings. With large-amplitude signals, a change of dial setting will vary the point on the positive-going edge of the signal that causes the Strobolac tube to fire. With a sine-wave input signal it is possible to vary the firing point over a range of approximately 120 degrees. This phase adjustment is not possible, obviously, with steep-wave-front signals.

Although the upper limit of the internal oscillator is 25,000 rpm, or approximately 420 cps, external triggering is usually possible at frequencies as high as 45,000 rpm (750 cps). The upper frequency limit depends on the characteristics of the individual Strobolac tube and will appear either as erratic operation of the tube or the formation of a low-intensity, continuous arc, called "hold-over."

For triggering by a mechanical contactor, part of a dc voltage divider is shorted by the contactor to generate the signal into the Schmitt circuit. Since a positive-going signal is necessary to produce the correct polarity trigger to op-

erate the Strobolac, the light flash occurs on the *opening* of the mechanical contact, rather than on the closing. Because the time between opening and closing of the mechanical switch is usually sufficient for the Strobolac circuit to recover, care should be taken to eliminate contact bounce, which will produce unwanted extra flashes.

Calibration

Calibration is accomplished with a neon bulb rather than the vibrating reed used in the previous model. One element of the neon bulb is excited from the power-line voltage and the other element from the voltage across the Strobolac. As the flashing rate of the Strobolac approaches either the fundamental or a harmonic of the power-line frequency, the neon light intensity will vary at a rate equal to the difference frequency. Two front-panel adjustments are available for calibrating the rpm dial at 3600 rpm and 900 rpm*. Calibrations can also be made at other dial settings, between about 600 and 7200 rpm, which are integral or fractional multiples of the power-line frequency. When the best possible accuracy of speed measurement is desired, a calibration point can often be found near the speed setting used. Calibration is made difficult below 600 rpm by flicker and above 7200 by the low amplitude of the light-intensity variation.

*3000 and 750 rpm when the power-line frequency is 50 cycles, 24,000 and 6000 rpm when it is 400 cycles.

Accessories Supplied: Adjustable neck strap, plug to fit input and output jacks, spare fuses.

Accessories Available: TYPE 1531-P2 Flash Delay and TYPE 1536-A Photoelectric Pickoff, TYPE 1539-A Stroboslave with TYPE 1531-P4 Trigger Cable, and TYPE 1532-D Strobolume with TYPE 1532-P3 Trigger Cable.

Mechanical Data: Flip-Tilt Case.

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
10 $\frac{1}{8}$ †	270	6 $\frac{1}{8}$	170	6 $\frac{1}{8}$	160	7 $\frac{1}{4}$	3.3	9	4.1

† Includes handle.

This instrument is listed by the CSA Testing Laboratories as approved.

U. S. Patent Number 2,966,257
Licensed under designs, patents, and patent applications of Edgerton, Germeshausen & Grier, Inc.

THE STROBOTAC AT WORK



Figure 8. The Strobotac produces enough light to "stop" the motion of the fan through the eight layers of glass in the door of this altitude chamber. Some reflection is produced by the glass layers, but its effect is minimized by aiming the Strobotac flash into the chamber at an angle rather than head on. The new instrument's increased speed range now makes it possible to measure directly the speeds of fans operating at 400 cycles (24,000 rpm), which are commonly used in aircraft.

The original Strobotac of 25 years ago changed the stroboscope from a laboratory toy to a reliable, inexpensive, industrial instrument, which has become an important factor in the design, operation, and maintenance of mechanical and electromechanical equipment. The new TYPE 1531-A Strobotac, with its greatly improved light intensity and flash duration of a few microseconds, provides industry with a tool of increased effectiveness for the study of not only conventional machines but also of today's high-speed and miniaturized mechanisms. Studies can be conducted now in normal room lighting, and the greatly improved clarity produced by the "sharp" flash makes possible the study of fine details that hitherto could not be seen. Where the part to be studied is inaccessible, the strong beam of Strobotac light can usually be made to reach it. This feature, coupled with the versatility provided by the pivoting lamp, permits the instrument to be located conveniently and operated by one man, while the same man observes the results without the aid of an assistant. Extensive field testing, carried out over the past year, has proved the complete acceptability of the new design and has brought to light many interesting new applications, a few of which are discussed below.

The new Strobotac operates satisfactorily from 400 cycle power lines as well as from 50-60 cycle lines, which is a great convenience in aircraft applications.

Low-Power Devices

Speeds of fractional-horsepower motors cannot be measured by ordinary tachometers, because the load of a conventional tachometer alters operating conditions. The Strobotac, because it requires no mechanical or electrical connection to the motor, is the ideal tachometer for this use. Its usable accuracy of one per cent is better than that of most ordinary tachometers.

Measurements are made to determine: normal operating speed, speed variation due to line-voltage changes, speeds at various conditions of overload and underload, torque-speed characteristics, and critical speeds at which vibration occurs. By slow-motion observations, brush action can be studied, and chattering caused by commutator eccentricity as well as vibration of frame and parts can often be detected.

Measurement of torque with the Strobotac is a widely used technique. When the motor and load shafts are connected by an elastic coupling, and the rotational motion is stopped by the stroboscope, the position of a pointer on the



Figure 9. The bright Strobotac beam penetrates both an oil bath and the tube envelope to illuminate a rotating-anode X-ray tube at Machlett Laboratories.

spring coupling will change as the driven shaft is loaded. With the addition of a calibrated scale, the system becomes a torque meter.

Air-Moving Devices

In the stroboscopic study of the operation of fans and blowers, vibration can be located, and air currents around the blades can be observed through the use of chemical "smokes" introduced into the air stream. This technique has led to a considerable improvement in fan design.

At Rotron Manufacturing Company, the Strobotac serves as the principal test instrument for speed measurements and the analysis of structural weaknesses of air-moving devices of all types. Blade resonances of developmental units are detected visually while the units are subjected to vibration on shake tables. Tests in altitude and pressure chambers are made to determine performance of fans that are to operate at high altitudes or are to push heavier-than-air gases. Other laboratory work includes dynamometer measurements and air-delivery tests in which it is important to measure speed accurately under pressure.

Electronic and Electromechanical Equipment

With the Strobotac one can study tape-recorder mechanisms, relays, servos, and transducers of all types. Speaker voice-coil clearance, spider flexing, and cone performance are all susceptible to stroboscopic observation.



At Acoustic Research, Inc., of Cambridge, Massachusetts, the Strobotac casts new light on the performance of loudspeaker radiators.

Acoustic Research, Inc., of Cambridge, Massachusetts, has used the new Strobotac to advantage in the study of a new hemispherical radiator for their AR-3 Loudspeaker System. In this technique, finely shredded rayon flock is applied on a radial line of glue along the radiator surface. The Strobotac is flashed at a rate differing slightly from an integral submultiple of the frequency of the driver, whereupon nodal points and the degree of vibration of the diaphragm can be determined by examination of the movement of the free ends of the flock under a magnifying glass (see photograph below). Radiator break-up and other irregularities are readily revealed in this manner.

With the aid of this technique, uniform dispersion and a more uniform frequency response have been achieved for a new mid-range, hemispherical radiator. Whereas direct measurements were possible at radiator excitation frequencies to 1 kc with the older Strobotac, work can now be performed to 5 kc with the new model. The flocking technique extends this to 20 kc.

An unusual application was discovered in the development of a new X-ray tube of the rotating-anode type at Machlett Laboratories. In this new tube the anode rotates at 9000-10,000 rpm, which causes the target area to change continuously. This technique permits fine focusing of the X-rays without anode burn-out from excessive emission. Where other stroboscopes either do not have a repetition range that is high enough for this work or a light flash that is bright enough to penetrate the double window in the tank, the oil bath used for cooling, and the tube envelope, the TYPE 1531-A Strobotac has been found quite suitable (see Figure 9).

Large Machines and Engines

Uses in the automotive and large-machinery industries include studies of spring surge, valve operation, determination of the effect of fly-wheel mass on speed variation, studies of piston-ring action, and vibration studies to determine where shock mounts should be applied. For the study of reciprocating parts in an internal-combustion engine, the Strobotac is usually triggered by a contactor on the crankshaft. For the study of the action of pistons and other enclosed parts, a window is often cut in the side of an experimental engine.

The development and production testing of fuel-spray nozzles for diesels is greatly facilitated by the new Strobotac. The bright, short-duration flash makes possible detailed study of the action of rapidly moving parts and the formation of fuel-injection spray patterns. The Strobotac "freezes" the motion of the high-velocity droplets in the atomized spray, permitting the study of both droplet size and range. Figure 11 shows spray patterns under study at the M.I.T. Automotive Laboratories.



Figure 10. Dr. H. E. Edgerton watches the action of valve springs in an internal-combustion engine at the M.I.T. Automotive Laboratory.



Figure 11. Watching fuel-injection sprays with the Strobotac. For a close-up of the spray, see Figure 14. The high-velocity droplets in the atomized spray can be studied in detail.



Figure 12. At General Electric's Small Aircraft Engine Department, engineers use the Strobotac to examine the vibratory modes in aircraft gas turbine blades. The short-duration white light gives excellent resolution. Mode shapes are clearly defined at various excitation frequencies produced by an electromagnetic driver.

Vibration Studies

Vibratory motion and its effects can be readily studied with the aid of the very short light pulse from the Strobotac. Displacements in vibrating parts can be measured accurately with the aid of a microscope and cross hairs. This technique has been used by automotive and aircraft-power engineers in measuring crankshaft whip, vibrations, and turbine blade displacement.

Another important use is the detection of resonances in devices subjected to the cyclic forces produced by shake tables. Relays, fans, motors, and electronic equipment and systems—large and small—are subjected to the "dithering" action of shake tables while stroboscopic light is used to detect damaging, self-created, vibratory conditions.

Printing

In the printing industry, the Strobotac can be used for all types of color registration. A manufacturer of gift-wrap paper has increased the production speed of a four-color rotogravure press to 450-500 ft./min.—twice that practical without the aid of stroboscopic light. One operator and his assistant are able to run this rotogravure press while they periodically check registration with the aid of the Strobotac. Stroboscopic observations not only show which of the four colors is off register, but also indicate the degree of correction required at the appropriate color stand. The result—more efficient utilization of production facilities.

Industrial Maintenance

In the operation of gears, cams, drills, saws, and cutting tools, the Strobotac will show misadjustments, misalignment, wear, sources of noise and vibration, etc., so that they can be corrected before failure of the machines occurs. Governor action, belt slip, lubrication, clearances, and the action of springs can be checked and measured.

Photography

It is possible to use the new Strobotac for photographing objects in motion, by either

single-flash or multiple-flash techniques*. The diesel-spray pattern of Figure 14 was photographed with the camera shutter speed set to a value equal to the period between flashes, so that only one flash occurred during the exposure time. The ability to trigger the Strobotac from an external electrical signal greatly simplifies the techniques required to synchronize the flash of the Strobotac for single-flash photography. The output of a photocell or microphone, amplified if necessary, can be used.

Medical Applications

The new Strobotac has many applications in the medical, psychological, and physiological

fields. The object of one such experiment conducted under supervision of Dr. J. Y. Lettvin of M.I.T. was to determine whether or not there was vision during eye movement. The subject's eye was connected by four circular silver electrodes to an oscilloscope, whose amplified output triggered a Strobotac each time an eye movement occurred. Thus, with the subject in a dark room, there was illumination only during periods of eye movement.

The white-light feature of the new Strobotac makes it an extremely effective aid for exploring other areas of vision such as color perception.

The instrument is also suitable for use with tachistoscopes in psychological work. In conjunction with an external gated oscillator, the Strobotac can provide bursts of light pulses up to any burst duration (even continuous), with pulse rate during the burst well above flicker-fusion frequency.

Other medical uses include photic stimulation during electroencephalographic recording of brain waves and the inducing of epileptic-like seizures.

Neurologists have used stroboscopic equipment for a number of years in the study of seizures and temporary blackouts caused by a sensitivity to rhythmically interrupted light. This same type of flicker, caused by a revolving propeller interrupting the sun's rays at a critical rate, has long been suspected as the cause of mysterious pilot blackouts.

Other Uses

Among other applications are the dynamic balancing of rotors, study of slip between friction-driven members, determination of the speed at which jaws of centrifugal clutches begin to open, the timing of moving-picture projectors, and the calibration of watt-hour meters.

A complete list of the potential uses of the new TYPE 1531-A Strobotac would take many pages. This instrument is useful wherever there are machines and moving mechanisms, and this includes just about every industrial plant.

— M. J. FITZMORRIS
C. J. LAHANAS
W. R. THURSTON

Figure 13. A model helicopter rotor in a wind tunnel is watched with the Strobotac. Blade lag and flapping are clearly observed in slow motion, just as they occur under various flight conditions. In addition to providing a good visual representation of the conditions encountered in flight, such studies serve as a visual check on vibration data provided by strain-gages mounted on the rotor head.



Figure 14. Strobotac single-flash photo of the fuel-injection spray of Figure 11. The bright, easily triggered flash makes it easy to take permanent records of observed phenomena.

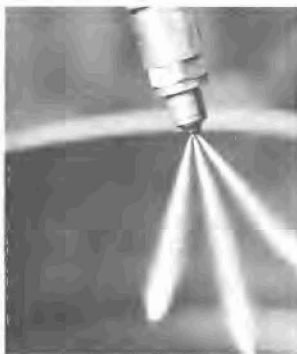
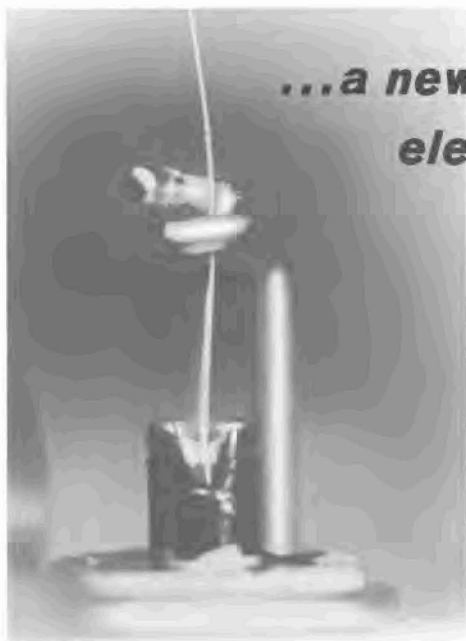


Figure 15. The Strobotac and associated equipment for eye-movement studies by Dr. J. Y. Lettvin. Note the electrodes taped to the subject's face.





...a new STROBOTAC® electronic stroboscope

A Leeson false-twist spindle, used to put stretch in textile yarn, was rotating at 250,000 rpm when it was photographed. Yet no extraordinary photographic equipment was required to make the shot; in fact, what is shown is just what an observer would have seen at the time the photo was taken. The trick, of course, is stroboscopic light, in this instance from our Type 1538-A Strobotac®, flashing 125,000 times a minute.

This Strobotac® electronic stroboscope extends the speed range for stroboscopic viewing and speed measurement to over 1,000,000 rpm. In addition, the versatility of the stroboscope is enhanced by three optional accessories: a rechargeable battery for operation independent of ac power lines, a plug-in High-Intensity-Flash Capacitor for extra-bright flashes for photographic applications, and an extension lamp for access to hard-to-reach areas.

The electronic stroboscope has always been a spectacular instrument, its optical wizardry as fascinating as it is useful. The newest member of GR's STROBOTAC® family of stroboscopes follows the tradition. Its ability to flash 150,000 times a minute means that it can be used for speed measurement and stroboscopic observation of the fastest existing motors and machines, even those in the million-rpm class. Accompanying this flashing rate are two other important features: battery as well as ac operation and an accessory plug-in High-Intensity-Flash Capacitor that boosts the light output tenfold for photographic applications. The battery-power option is sure to bring cheers from thousands of veteran strobe users whose operating radii have been the lengths of their extension cords.

The new TYPE 1538-A STROBOTAC is an addition to the line, not a replace-

ment. The popular TYPE 1531-A STROBOTAC will remain available for those who do not need the extra capabilities of the TYPE 1538-A. The table (page 8) summarizes the difference between the two models.

APPLICATIONS

The flashing-rate limit of the new STROBOTAC (150,000 fpm) by no means states the upper speed limit of the instrument's usefulness. Simple harmonic relationships extend this limit to well over a million rpm. Thus high-speed dentists' drills, textile machinery (see cover), and practically anything that moves cyclically, no matter how fast, are now subject to stroboscopic observation and measurement. It's true

that the use of harmonics can extend the effective range of the slower-speed TYPE 1531-A into the hundred-thousand-rpm area, but, as the device speed gets higher, the subharmonics come closer together on the flashing-rate dial. Then it becomes more difficult to identify them, especially if the device speed wanders. But, with the new STROBOTAC, even a million-rpm measurement presents no problem.

ACCESSORIES

The nickel-cadmium battery, with an automatic charger, is available as an optional accessory. A fully charged battery will power the STROBOTAC for about eight hours of normal operation. The battery recharges overnight from a power line. Or it can be left on charge when not used, so that it will always be ready. The STROBOTAC can be operated directly from an ac power line if it is more convenient.

Another important new accessory is the TYPE 1538-P2 Extension Lamp, a lamp-and-reflector assembly, identical to that on the STROBOTAC, with a six-foot cord and plug. The plug mates with a connector on the front panel of the STROBOTAC. Thus the lamp can be operated in spaces too small for the complete instrument or can be mounted in test chambers and controlled from a safe distance.

The light intensity of the STROBOTAC is more than adequate for many photographic applications. Still, there are times when, either because of the extremely high speed of the object



The new Strobotac and optional accessories. Next to the Strobotac, in leather case, are battery and charger. Above right are battery power cable and extension lamp. The Strobotac itself sits on the high-intensity-flash capacitor.



Goodbye, extension cords! Textile trouble-shooter carries his own power, new Type 1538-P3 Battery and Charger, in shoulder-slung leather case.

being photographed or an unavoidably high ambient light level, a brighter flash is needed. Then the photographer can connect the new Type 1538-P4 High-Intensity-Flash Capacitor to the base of the STROBOTAC. With this accessory connected, one can produce a single flash of great brilliance (44 million beam candles) and short duration (8 microseconds).

Other accessories useful with the STROBOTAC are GR's photoelectric pick-offs (see page 12), flash-delay unit, surface-speed wheel, and two stroboscopes that can be controlled by the STROBOTAC: the STROBOLUME and the STROBOSLAVE (see page 9). These instruments and accessories constitute by far the most complete line of stroboscopic equipment available anywhere.



The extension lamp solves a logistics problem. Six-foot cord attaches through connector on front panel of Strobotac.

THE CIRCUIT OF THE NEW STROBOTAC

The sixfold increase in flashing rate of the new STROBOTAC was made possible by the development of a new strobotron tube* and of new circuits** that minimize the time required between flashes for deionization and recharging. The following is a description of the STROBOTAC circuit, with emphasis on the advances of the new model.

The strobotron flash tube comprises two main electrodes, a cathode and an anode, separated by $\frac{3}{8}$ inch in an envelope filled with xenon gas at a pressure of one-half atmosphere. A specially designed capacitor acts as a low-impedance source to supply 800 to 1000 volts across these electrodes. The gas, however, remains nonconducting until

a 5000-volt pulse is applied to trigger wires between these main electrodes. This pulse ionizes the gas, causing up to 1000 amperes to flow. The peak power of almost a million watts generates an intense flash of white light of 15 million beam candles.

After the tremendous pulse of light, the tube requires about 150 microseconds to deionize. The voltage applied across the tube must remain under 80 volts during this deionization time, or continuous conduction, called "hold-over," will result. This necessary deionization period limits the maximum flashing rate of the stroboscope. Figure 1 illustrates the problem. The curves labeled *R-C* and *L-C* represent the effects of charging the capacitor through a resistor and an inductor, respectively. The slopes required to keep the voltage below the 80-volt deionization level impose delays in reaching the firing level, which in turn would restrict the maximum flashing rates to 24,000 and 54,000 flashes per minute, respectively, for the particular tube and voltages used in the TYPE 1538-A.

The answer to this problem is to hold the voltage to zero for the deionization period and then to raise it quickly to the firing level.

The new circuit shown in Figure 2 provides an almost ideal charging curve (labeled "TYPE 1538" in Figure 1). During the 150-microsecond deioniza-

tion time after the strobotron has flashed, the transistor, acting as a switch, is saturated and the transformer primary current increases, storing energy in the transformer core. The voltage induced in the secondary winding during this build-up is blocked by the diode rectifier, and no voltage appears across the capacitor and strobotron tube. At the end of this 150-microsecond interval, the transistor is switched off, and the primary current

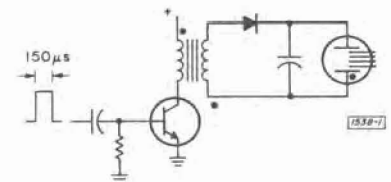


Figure 2. The charging circuit of the new Strobotac.

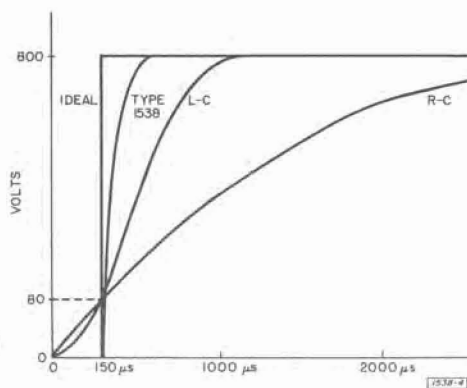


Figure 1. Voltage-vs-time characteristics of various charging circuits.

goes to zero. The collapsing magnetic field generates a reverse-polarity voltage in the secondary, causing the diode to conduct and the stored energy to be transferred to the capacitor. When the energy in the transformer is zero, the current again reverses and the diode opens, leaving all the stored energy in the capacitor. This transfer can be made as fast as one wishes, and the flashing rate can therefore be made to approach the theoretical maximum. The most important result of all this is an increase in flashing rate to almost the

theoretical maximum. This was the main objective of the circuit development, but the fallout was almost as valuable.

The transfer of energy from the power supply to the intermediate storage inductor and then resonantly to the discharge capacitor can be made with an efficiency approaching 100%. In the conventional RC charging circuit, however, one half the available energy is dissipated in the charging resistor regardless of the value of the resistor (including zero ohms). The use of inductive charging therefore saves the power ordinarily dissipated in the charging resistor and makes battery operation practical. Moreover, the use of a transformer as the inductive element permits use of a low-voltage transistor circuit to generate the high voltage required by the strobotron tube.

A block diagram of the STROBOTAC is shown in Figure 3. A transistorized RC oscillator sets the flashing rate. Once each cycle, a transistor trigger circuit

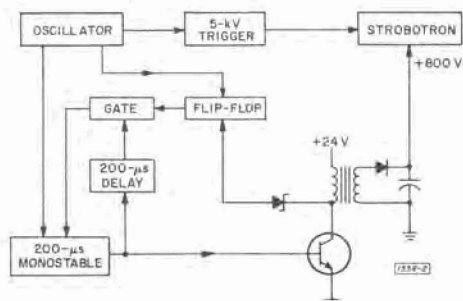


Figure 3. Block diagram of the Type 1538-A Strobotac electronic stroboscope.

generates a 5-kilovolt, 5-microsecond pulse to trigger the strobotron tube. In the time between these pulses, the main discharge capacitor must be recharged. The monostable circuit, triggered by the oscillator, generates a 200-microsecond pulse, which saturates the transistor switch, storing energy in the transformer and allowing the strobotron to deionize. At the end of the 200-microsecond pulse, enough energy has been stored to charge the capacitor resonantly to 800 volts in an additional 200 microseconds. Thus, a maximum flashing rate of 2500 per second is possible.

The average light output of a stroboscope varies directly with flashing rate and discharge capacitance. The exceptionally wide flashing-rate range of the

Harmonic techniques extend the usefulness of the Strobotac over the entire audio-frequency range. Engineer here is watching speaker motion through microscope while adjusting flash-delay unit to provide phase control.



TYPE 1538-A (1500 to 1) would mean a drastic variation in light output if only one discharge capacitor were used. On the other hand, a continuously adjustable discharge capacitor with a 1500-to-1 range is obviously impractical. The compromise solution is to switch in a different capacitor for each of the four 6:1 speed ranges. The resulting capacitance variation is 216 to 1, and this raises another design problem.

If the discharge capacitor varies in value over a 216-to-1 range, then, in the resonant charging circuit discussed earlier, either the inductance must also vary by a factor of 216 or the current must vary by a factor of $\sqrt{216}$ to supply sufficient energy per cycle. Large coils and 30-ampere currents were both unappealing, so another approach was found.

On the lower-speed ranges, where the discharge capacitance is higher, the energy stored in the transformer is insufficient to produce the 800-volt firing potential. On these ranges the 200-microsecond delay following the monostable circuit generates a trigger pulse 200 microseconds after the end of the monostable pulse to retrigger the monostable circuit. Thus, a single pulse from the oscillator starts a train of 200-microsecond pulses in the monostable circuit and its delay loop. Each of these pulses stores energy in the inductor, and this energy is repeatedly transferred

to the capacitor during the time between pulses. Each pulse raises the capacitor voltage in a small step as shown in Figure 4. This process continues until the capacitor is charged to 800 volts. At each step, a voltage pulse equal to the capacitor voltage divided by the transformer turns ratio appears across the Zener diode on the transformer primary. When the capacitor

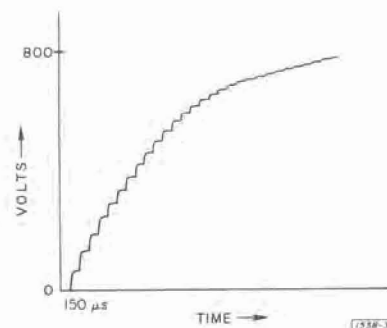


Figure 4. Curve showing step voltage buildup on charging capacitor.

reaches 800 volts, the Zener diode voltage is exceeded and the flip-flop closes the gate, breaking the feedback loop and ending the pulse train started by the oscillator. While this multiple-cycle resonant-charging technique used on the lower ranges requires more time than the single-cycle charge, a correspondingly longer time is available in which to recharge the capacitor.

— M. C. HOLTJE

	Type 1531	Type 1538
Flashing-rate range	110-25,000 fpm	110-150,000 fpm
Speed-measurement range	to 250,000 rpm	to above 1 million rpm
Flash duration (on high to low speed ranges)	0.8, 1.2, 3 μ s	0.5, 0.8, 1.2, 3 μ s
Battery-operation option	no	yes
High-Intensity-Flash Capacitor option	no	yes
Extension-lamp option	no	yes
Output trigger	600-to-800-V negative pulse	6-V positive pulse
External triggering	Contact opening, 6-V, p-to-p, signal (2-V, rms, sine wave)	Contact closure, 1-V positive pulse, 0.35-V, rms, sine wave

SPECIFICATIONS

Flashing-Rate Range: 110 to 150,000 flashes per minute in four direct-reading ranges: 110 to 690, 670 to 4170, 4000 to 25,000, and 24,000 to 150,000 rpm. Speeds to over 1 million rpm can be measured.

Accuracy: $\pm 1\%$ of reading on all ranges after calibration against line frequency.

Flash Duration: Approximately 0.5, 0.8, 1.2, and 3 μ s for high-to-low speed ranges, respectively, measured at $\frac{1}{8}$ peak intensity; for single flashes with Type 1538-P4 High-Intensity-Flash Capacitor, 8 μ s.

Peak Light Intensity: Typically 0.16, 1, 5, and 15 million beam candles (0.16, 1, 5, and 15×10^6 lux measured at 1 meter distance at the beam

center) for high-to-low speed ranges, respectively; 44 million beam candles for single flash, with Type 1538-P4 High-Intensity-Flash Capacitor.

Reflector Beam Angle: 10° at half intensity points.

Output Trigger: Greater than 6-V positive pulse behind 400 Ω .

External Triggering: Either a switch closure across the input jack terminals, a 1-V, peak, positive pulse, or a 0.35-V, rms, sine wave down to 100 Hz increasing to 3.5 V, rms, at 5 Hz.

Power Required: 100 to 125 or 195 to 250 V, 50 to 400 Hz, 15 W or 20 to 30 V dc, 12 W.

Accessories Supplied: Adjustable neck strap,

phone plug for input and output jacks, spare fuses.

Accessories Available: TYPE 1538-P2 Extension Lamp, TYPE 1538-P3 Battery and Charger, TYPE 1538-P4 High-Intensity-Flash Capacitor, TYPE 1531-P2 Flash Delay, TYPES 1536-A Photoelectric Pickoff (for use with Flash Delay), TYPE 1537-A Photoelectric Pickoff, and TYPE 1539-A Stroboslave.

Mounting: Flip-Tilt Case.

Dimensions: Width $10\frac{3}{8}$ ", height $6\frac{5}{8}$ ", depth $6\frac{1}{2}$ inches (270 by 170 by 160 mm), over-all.

Net Weight: $7\frac{1}{4}$ lb (3.3 kg).

Shipping Weight: 10 lb (4.6 kg).

* Includes handle.

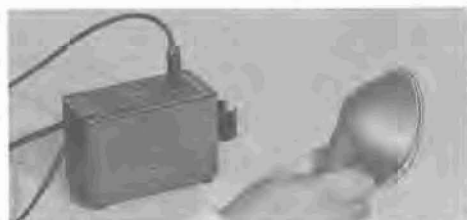
Introducing the STROBOSLAVE

Because it is widely used as a tachometer, the conventional stroboscope includes an oscillator and associated electronic circuits necessary to adjust the flashing rate over a wide range. A purchaser who wants only to make stopped-motion observations or photographs, with flashing rate under external control, thus is forced to pay for a capability that is of no use to him. Therein lies the suggestion that a simple stroboscope, designed solely for external control, is needed. Enter the STROBOSLAVE.

The TYPE 1539-A STROBOSLAVE is a small, inexpensive stroboscope, in most respects similar to the STROBOTAC. The chief difference is that the STROBOSLAVE has no internal flashing-rate control. This means that it cannot serve as a tachometer. For certain motion studies and for high-speed photography, however, the STROBOSLAVE is every bit as useful as its more sophisticated brethren.



Putting extra light on the subject. With an electronic frequency counter going through a vibration shake-table test, a Stroboslave is used to supplement the light from the Strobotac. Smaller strobe is triggered directly from output of Type 1538-A Strobotac.



Lamp, at end of five-foot cable, can be held in hand as shown here or attached to case as shown above.

It has, in fact, several advantages over the larger stroboscopes (in addition to the price differential). Its lamp, at the end of a five-foot cable, can be either attached to the case or maneuvered close to the object being observed. The case itself is small enough ($2\frac{1}{2}$ by $5\frac{3}{8}$ by $4\frac{1}{8}$ inches) to be permanently mounted on such machines as textile looms, production tools, and printing presses, where continuous stroboscopic monitoring may cut costs substantially by showing up defects in material or goods produced.

The STROBOSLAVE can be triggered by a STROBOTAC, a TYPE 1537-A Photoelectric Pickoff, a TYPE 1535-B Contact, or any device capable of supplying a contact closure or a positive pulse of at least 2 volts peak. An extremely useful combination is the STROBOSLAVE, TYPE 1531-P2 Flash Delay, and TYPE 1536-A Photoelectric Pickoff. With such a setup, one can "stop" motion, ob-

serve it throughout its cycle, and synchronize a camera shutter with the flash.

Light duration, intensity, and flashing-rate range are all the same as for the TYPE 1531-A STROBOTAC. The STROBOSLAVE operates from standard ac power lines. — M. C. HOLTJE

SPECIFICATIONS

Flashing-Rate Ranges: 0 to 700, 0 to 4200, 0 to 25,000 flashes per min on high-, medium-, and low-intensity ranges, respectively.

Flash Duration: Approx 0.8, 1.2, and 3 μ s, measured at $\frac{1}{8}$ peak intensity, for the low-, medium-, and high-intensity ranges, respectively.

Peak Light Intensity: Typically 0.6, 3.5, and 11 million beam candles (0.6, 3.5, and 11×10^6 lux measured at 1-m distance at the beam center), for low-, medium-, and high-intensity ranges, respectively. For single flash, 18 million beam candles.

Reflector Beam Angle: 10° at half-intensity points.

External Triggering: Either a switch closure across the input jack terminals or a 2-V (peak) positive pulse.

Power Required: 100 to 125 or 195 to 250 V, 50 to 400 Hz, 16 W (max) at 115 V.

Accessories Supplied: Phone plug for input, mounting bracket.

Accessories Available: TYPE 1537-A Photoelectric Pickoff, TYPE 1531-P2 Flash Delay (with a TYPE 1536-A Photoelectric Pickoff).

Dimensions: Width $2\frac{1}{2}$ ", height $5\frac{3}{8}$ ", depth $4\frac{1}{8}$ inches (64 by 215 by 105 mm), over-all.

Net Weight: $2\frac{3}{4}$ lb (1.3 kg).

Shipping Weight: 8 lb (3.7 kg).

* Without lamp attached.



Using the Stroboslave as a diagnostic tool. The reflector has been slipped off so that the strobe lamp can probe the innards of the addressing machine. A photoelectric pickoff keeps the flashes synchronized with the machine, while a flash-delay unit allows the operator to scan the motion throughout its cycle.

FLASH-DELAY UNIT SIMPLIFIES MOTION ANALYSIS IN HIGH-SPEED MACHINES

Figure 1. The Flash Delay and Photoelectric Pickoff in combination with the Strobotac® electronic stroboscope. The Flash Delay attaches conveniently to the Strobotac.



For many years the STROBOTAC® electronic stroboscope has been a valuable tool in the development and maintenance of all kinds of rotating and reciprocating equipment. Two accessories greatly expand the usefulness of this stroboscope in the study of high-speed motion, the new TYPE 1531-P2 Flash Delay and the TYPE 1536-A Photoelectric Pickoff.

The combination of pickoff and flash delay provides a convenient means of synchronizing the STROBOTAC flash to rotating equipment, even when the speed of the equipment is irregular. The flash can be delayed with respect to the pickoff signal so that the moving object can be made to appear completely stationary at any point in its rotation cycle.

When a moving object is observed under stroboscopic light with the flashing rate determined by the stroboscope's internal oscillator, slight variations in the speed of rotation will cause the moving object to appear to rotate slowly. Continual adjustment of the flashing rate is then required to obtain a stationary image at a particular point in the cycle.

If a small piece of reflective tape is placed on the rotating object, as shown in Figure 2, it is possible to obtain from the photoelectric pickoff a signal which is synchronous with the rotation, regardless of speed. By means of the flash

delay, an adjustable time delay can be introduced between the pickoff and the stroboscope, so that the stroboscope can be made to flash at any desired position of the rotating object. By continually varying the time delay, the user can observe the object at all positions during a cycle of rotation. Small speed variations will not affect the image. If the speed varies widely, the reflective tape can be placed just ahead of the desired viewing point so that only a small time delay will be required.

The photoelectric pickoff does not mechanically load the rotating equipment and can therefore be used on very-low-power devices such as relays, mechanical choppers, etc. The pickoff, with a time constant of approximately 200 μ sec, can be used with equipment rotat-

ing at speeds in the hundreds of thousands of rpm.

The TYPE 1531-P2 Flash Delay makes possible single-flash photographs of rotating equipment at any desired position in its cycle. The single flash of the STROBOTAC is synchronized both with the time the camera shutter is open and with the desired position of the rotating object.

Description

The TYPE 1531-P2 Flash Delay was designed primarily for use with the TYPE 1536-A Photoelectric Pickoff. It can be triggered, however, by any transducer that will generate a positive electrical pulse of at least 0.3 volt. The block diagram of Figure 3 shows that the flash delay consists of a preamplifier, a Schmitt-circuit pulse shaper, a time-delay generator (consisting of a flip-flop, a unijunction transistor and RC network), and an output stage. Each trigger pulse from the Schmitt circuit starts a delay cycle. When the voltage across a capacitor in the RC circuit reaches approximately 9 volts (one-half the 18-volt charging voltage), the unijunction transistor fires, discharging the capacitor, resetting the delay flip-flop, and sending a pulse to the output amplifier.

There are three delay ranges available. Range 1 allows an adjustment over 360 degrees for rotational speeds of 6000 rpm or higher; range 2 provides the

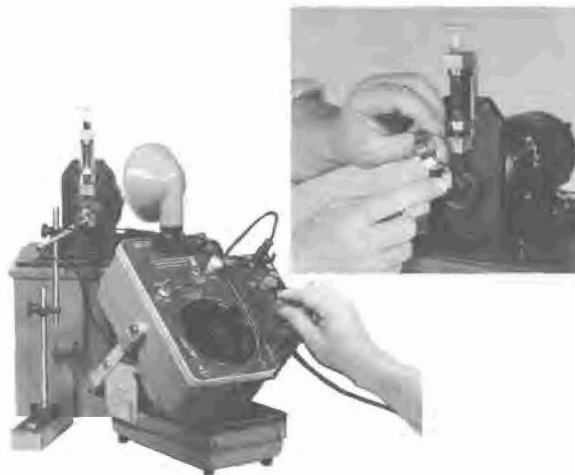


Figure 2. Photo showing the use of reflective tape to produce a pulse signal in the Photoelectric Pickoff. Pulse is then delayed by the Flash Delay to fire the Strobotac at any desired point in the rotational cycle.

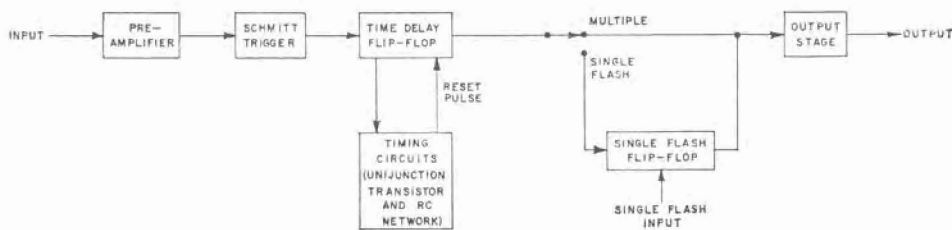


Figure 3. Functional block diagram of the Flash Delay.

360-degree adjustment for speeds between 600 rpm and 6000 rpm; range 3 is used for speeds below 600 rpm and for special applications in which a delay as long as 0.8 second is required.

For single-flash photography, the output pulse from the delay circuit goes to a flip-flop gate circuit instead of directly to the output stage. If the x contacts of a camera shutter are connected to a jack on the flash delay, their closure will make the gate circuit conduct, and the next synchronized, delayed pulse will pass to the output stage. After this one pulse passes, the flip-flop gate will reset and again become nonconducting. The flash delay, therefore, allows the first synchronized pulse occurring after the camera shutter opens (x-contact closure) to trigger the stroboscope.

Synchronism is thus obtained with both the shutter opening and the desired position of the rotating object. It is necessary to set the shutter speed so that the shutter will be open for one complete rotation cycle.

The flash delay is housed in an aluminum case with bracket which clips directly to the STROBOTAC electronic stroboscope to make a convenient, compact assembly, as shown in Figure 1.

Applications

The TYPE 1531-A STROBOTAC® electronic stroboscope with the TYPE 1531-P2 Flash Delay and the TYPE 1536-A Photoelectric Pickoff has wide applications in the development, test, and maintenance of all kinds of moving machinery. The textile, automotive, machine-

tool, and business-machine industries are only a few of the many that will find this combination an invaluable tool. The ability to obtain single-flash photographs at any desired position of a mechanism further enhances the value of these instruments. Figures 4 through 6 show a few of the applications of this versatile stroboscope assembly.

— M. J. FITZMORRIS

SPECIFICATIONS

Time-Delay Range: Approximately 100 microseconds to 0.8 second in three ranges.

Output Pulse: Better than 13 volts available for triggering the TYPE 1531-A Stroboscopes® electronic stroboscope.

Sensitivity: As little as 0.3-volt input will produce sufficient output to trigger the stroboscope.

Inputs: Phone jack for triggering; jack for camera synchronization.

Power Requirements: 105 to 125 (or 210 to 250) volts, 50 to 60 cps. 5 watts with TYPE 1536-A connected.

Accessories Supplied: Trigger cable, phone-plug adaptor, and leather carrying case.

Accessories Available: TYPE 1536-A Photoelectric Pickoff.

Mounting: Aluminum case with bracket which clips directly onto the STROBOTAC electronic stroboscope.

Dimensions: 5½ by 3½ by 3¾ inches (135 by 86 by 96 mm).

Net Weight: 2 pounds (1 kg).

Shipping Weight: 5 pounds (2.3 kg).



Figure 4. The action of cam followers can be easily examined with the Stroboscopes-Flash Delay combination. These photographs show the bounce of a cam follower at high speeds. The cam is rotating counterclockwise.

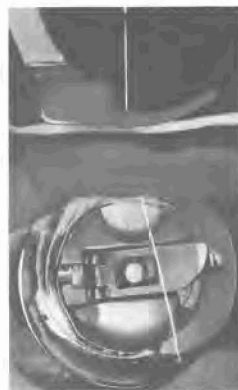
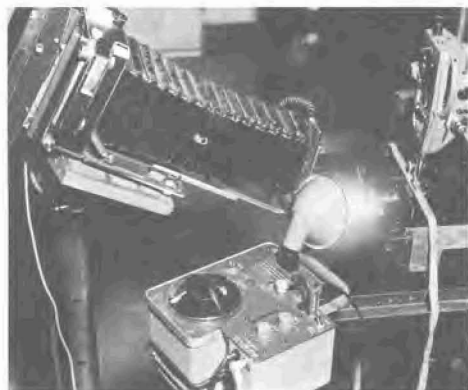


Figure 5. Study of thread behavior in high-speed sewing machine. Machine speed was 5000 stitches per minute; hook speed was 10,000 rpm. Photograph at left shows setup using Linhoff 4 x 5 with Polaroid film, Stroboscopes with attached Flash Delay, and sewing machine (the base of which is cut away to expose the parts underneath). Center and right photographs show the bobbin and hook action on thread at a specific phase selected by means of the Flash Delay. Photographs courtesy of The Singer Company.



Figure 6. A typical application in the textile field: observing tape and filling-carrier behavior of a Draper DSL shuttleless loom. Speed of the filling carrier is 274 picks per minute. The Flash Delay makes it possible to observe the filling-carrier at any particular point on its path. Synchronism with loom is accomplished with the TYPE 1536-A Photoelectric Pickoff located near a rim connected to the main power shaft and shown at the bottom of the photograph.

PHOTOELECTRIC PICKOFFS

There are now two photoelectric pickoffs in the General Radio line: the TYPE 1536-A, which includes a light source, and the new TYPE 1537-A, which does not. The latter is the less expensive and is the recommended pickoff for supplying a triggering pulse directly to a TYPE 1538-A STROBOTAC or a TYPE 1539-A STROBOSLAVE, assuming that a source of bright light is available. (A 1.1-watt No. 330 14-volt pilot lamp at $\frac{1}{2}$ inch is adequate. If the light source cannot be placed near the object, a reflector and lens can be used to focus the light.) Where no adequate light source is available, where extra sensitivity is needed, or where the TYPE 1531-P2 Flash Delay is desired for phase control, the TYPE 1536-A Pickoff is recommended. The TYPE 1536-A, with flash-delay, is the recommended pickoff for use with the TYPE 1531-A STROBOTAC.



The Type 1537-A Photoelectric Pickoff is identical in appearance with the Type 1536-A. Only difference is that the Type 1536-A contains a light source, the Type 1537-A does not.

Supplied with the TYPE 1537-A Pickoff, as with the TYPE 1536-A, are a C-clamp and a magnet, for easy mounting on a variety of surfaces, and two rolls of tape, one black and one silver. Pieces of this tape can be affixed to the edge of a shaft or wheel to produce

alternately reflective and nonreflective areas to trigger the photocell, the choice between black and silver tape depending on whether the surface is itself reflective or nonreflective.

SPECIFICATIONS

Operating Rate: Greater than 2500 pulses/s.

Sensitivity: Effective irradiance must be at least 6.0 mW/cm^2 to switch on, less than 0.6 mW/cm^2 to switch off, at 1 micron wavelength.

Power Required: 3 to 25 V dc; 0 to $100 \mu\text{A}$ depending on operating rate. Power is supplied by instrument with which it is used.

Accessories Supplied: 10-ft roll of $\frac{3}{8}$ -in black tape, 10-ft roll of $\frac{3}{8}$ -in silver tape, carrying case.

Mounting: C-clamp (capacity $1\frac{1}{16}$ in, flat or round) or $1\frac{1}{2}$ -in magnet, both supplied.

Dimensions: Pickoff head, $1\frac{1}{16}$ -in dia, 2 in long. Linkage consists of two $\frac{1}{16}$ -in diameter stainless-steel rods, 6 and $6\frac{1}{4}$ in long, and adjustable connecting clamp. Cable is 8 ft long, terminated in phone plug.

Net Weight: $1\frac{1}{2}$ lb (0.7 kg).

Shipping Weight: $4\frac{1}{2}$ lb (2.1 kg).

USING A PHOTOCELL WHERE IT COUNTS

For those wishing to measure the speed of rotating objects and to present the results as a continuous digital display, we recommend the combination of the new TYPE 1536-A Photoelectric Pickoff and the TYPE 1150-A Digital Frequency Meter.¹

The pickoff consists of a light source, an optical system, a photocell, an output cable, and a flexible linkage system. Light from the source is reflected, either by the rotating object or by reflective tape attached to it, back to the photocell, which sends electrical pulses to the frequency meter. This instrument counts the number of pulses arriving per second (or 0.1 second or 10 seconds) and displays that number on an in-line digital readout.

The cylinder containing the photocell and light source must be placed fairly close to the object being observed. The maximum distance depends on the contrast between the reflective and non-reflective parts of the rotating object. The small size of the pickoff head and the double-jointed linkage assembly, mounted on either a C-clamp or a magnet (both supplied), permit the

pickoff to be maneuvered close enough to out-of-the-way rotating parts.

With the counter set for a one-second gate (i.e., counting) period, the digital display will be in revolutions per second. For greater accuracy, the counting period can be set to 10 seconds, and the digital readout divided by 10. By obtaining more than one pulse per revolution (as, for instance, by attaching more than one reflecting strip to the rotating surface), one can increase the display possibilities: With six reflective

strips and a 10-second counting period, the counter indicates rpm. If 60 strips can be attached, one can obtain a direct rpm statement once a second. As more strips are used, the pickoff must be placed nearer to the object.

Most machine speeds are well within the range of the pickoff-counter combination. The high-frequency limit of the counter is over 13 million rpm, so there is no problem from that quarter. The limiting factor is usually the capacitance of the cable connecting the pickoff to

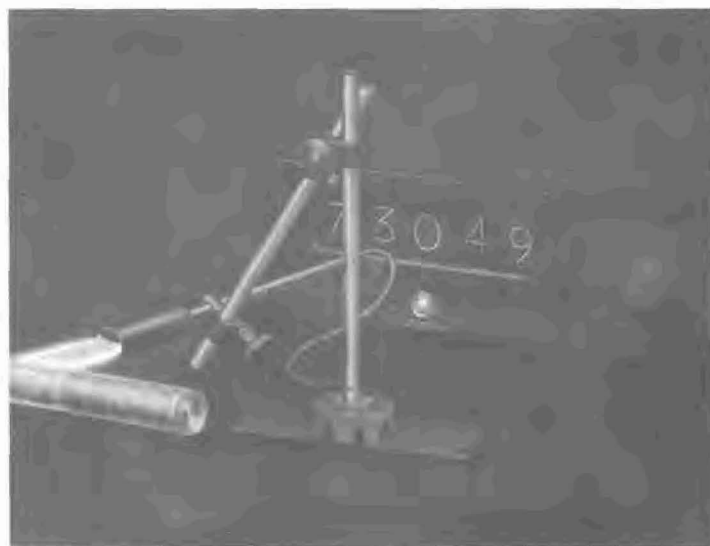


Figure 1. The Photoelectric Pickoff shown with the Type 1150-A Digital Frequency Meter (top), as arranged to measure the speed of a rotating shaft.

¹R. W. Frank, J. K. Skilling, "A Five-Digit Solid-State Counter for Frequency Measurements to 220 kc," *General Radio Experimenter*, 36, 4, April, 1962.

INDEX

<i>Description</i>	<i>Catalog Number</i>	<i>Pg No</i>
Strobotac® electronic stroboscope, Type 1531-A	1531-9430	1
Replacement Strobotron Lamp, Type 1531-P1	1531-9601	1
Strobotac® electronic stroboscope, Type 1538-A	1538-9701	6
Replacement Strobotron Lamp, Type 1538-P1	1538-9601	6
Extension Lamp, Type 1538-P2	1538-9602	6
Battery and Charger, with case, Type 1538-P3	1538-9603	6
High-Intensity-Flash Capacitor, Type 1538-P4	1538-9604	6
Stroboslave, Type 1539-A	1539-9701	9
Trigger Cable, Type 1531-P4 (for use with Type 1531-A Strobotac)	1531-9604	9
Flash Delay, Type 1531-P2	1531-9602	10
Photoelectric Pickoff, Type 1537-A	1537-9701	12
Photoelectric Pickoff, Type 1536-A	1536-9701	12
Surface-Speed Wheel, Type 1531-P3	1531-9603	13

the counter. Under favorable conditions, speeds up to 100,000 rpm can be measured.

Two rolls of pressure-sensitive tape are supplied, one reflecting and one non-reflecting. The latter can be used with objects that are themselves highly reflective.

Uses of the TYPE 1536-A Photo-electric Pickoff cover almost all rotating machinery, but it is especially desirable for low-torque devices, to which mechanical contactors cannot be attached.

SPECIFICATIONS

Maximum Pulse Rate: Approximately 2500 pulses/s as limited by the 200- μ s time constant of the photocell and cable combination.

Power Required: 20 to 28 V dc, 40 mA. Power is supplied by the TYPE 1531-P2 Flash Delay or the TYPE 1150-B (or TYPE 1151-A) Digital Frequency Meter.

Accessories Supplied: 10-ft roll of $\frac{3}{8}$ -in black tape; 10-ft roll of $\frac{3}{8}$ -in silver tape; carrying case.

Mounting: C-clamp (capacity $1\frac{1}{2}$ in, flat or round) or $1\frac{1}{2}$ -in magnet, both supplied.

Dimensions: Pickoff head, $\frac{11}{16}$ -in dia, 2 in long. Linkage consists of two $\frac{5}{16}$ -in diameter stainless-steel rods, 6 and $6\frac{1}{4}$ in long, and adjustable connecting clamp. Cable is 8 ft long, terminated in phone plug.

Net Weight: $1\frac{1}{4}$ lb (0.6 kg).

Shipping Weight: 4 lb (1.9 kg).

MEASURING SURFACE SPEEDS



Figure 1. View of the Surface-Speed Wheel, showing the two speed discs and the sectional shaft.

The STROBOTAC® electronic stroboscope, widely used for the measurement and analysis of rotary, reciprocating, and other repetitive motions, can now be used for speed measurement of straight-line motion. The new TYPE 1531-P3 Surface-Speed Wheel accessory makes the STROBOTAC dial *direct reading in feet per minute* for measurements such as the following:

Lineal speeds of metal strip, textiles, paper, wire, plastic films, conveyed material, etc.

Surface speeds of processing rolls, machine-tool cutting or grinding operations, drums, belts, webs, pulleys, etc.

Belt slippage on drums and, especially, between belts on multiple-belt pulleys to avoid unequal load distribution and excessive wear.

Description

The new accessory consists of two wheels of different sizes mounted on opposite ends of a three-section, stainless-steel rod. The smaller wheel, with a diameter of 0.764 inch, is better for slow surface speeds, while the larger wheel,

with a diameter of 1.910 inch, is best suited for higher surface speeds. However, their useful ranges have a large amount of overlap, where the choice of which one to use can be based on accessibility. The range of surface speeds with the smaller wheel is 10–2500 feet per minute, and the range of the larger wheel is 50–12,500 feet per minute.

Operation

Operation is extremely simple. One of the wheels is simply allowed to ride on the surface whose speed is to be measured, and the wheel's image is "stopped" by means of the stroboscopic light beam, after which the surface speed in feet per minute is read directly from the dial of the STROBOTAC. The fact that only the wheel has to be close to the surface whose speed is to be measured means that measurements can be made in "close quarters." The light from the STROBOTAC can penetrate well into the interior of machinery, and it is possible to build the wheel into such machinery if regular measurements must be made. For a built-in wheel, a "push-to-engage" lever is recommended in order to save wear on the wheel when a measurement is not actually being made.

The combination of the STROBOTAC electronic stroboscope with the surface-speed wheel provides an extremely sensitive indicator of small variations in

linear speed and of differences in speed between two or more surfaces having the same nominal speed. A fraction of an rpm is prominently indicated when the speed of the wheel changes.

— W. R. THURSTON

SPECIFICATIONS

Accuracy: The basic accuracy of the STROBOTAC electronic stroboscope is 1% of reading; an additional 0.5% must be added to account for errors in the diameter of the wheel, giving an over-all accuracy of measurement of 1.5% of reading for surface speed over the entire range of measurement.

Speed Range: 10 to 2500 feet per minute with small wheel and 50 to 12,500 feet per minute with large wheel.

Dimensions: Wheels are 0.764 and 1.910 inches in diameter, respectively. Shaft totals 20 inches in length.

Net Weight: 8 ounces (0.3 kg).

Shipping Weight: 2 pounds (1 kg).



Figure 2. Measuring belt speed with the Surface-Speed Wheel.