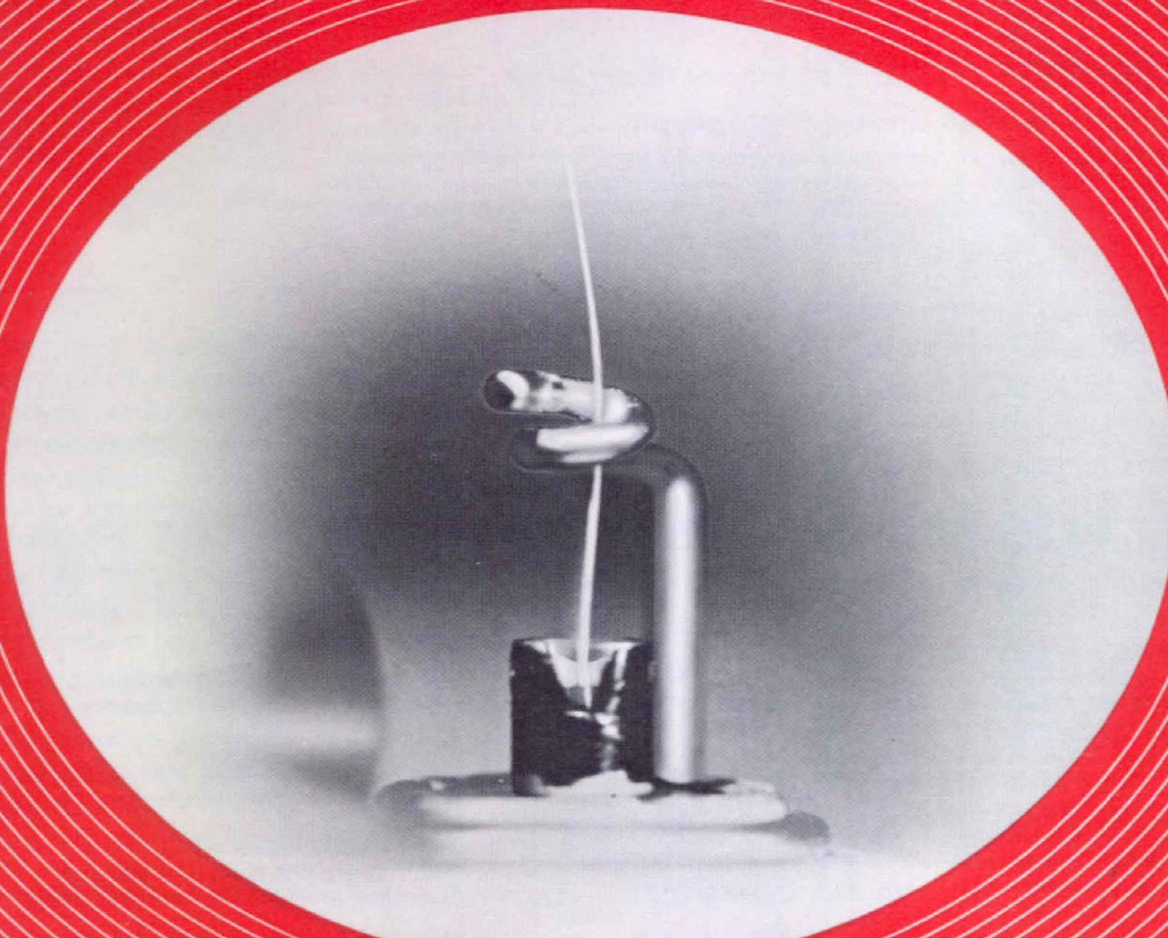
THE GENERAL RADIO

Experimenter

Photographed at 250,000 RPM



This Issue
New STROBOTAC® electronic stroboscope
Stroboslave · Photoelectric Pickoffs

VOLUME 40 · NUMBER 4 / APRIL 1966

www.americanradiohistory.com

Volume 40 • No. 4
April 1966

the GR Experimenter

© 1966 — General Radio Company, West Concord, Mass., USA

Published monthly by the General Radio Company

THIS ISSUE

GENERAL RADIO COMPANY
West Concord, Massachusetts 01781

* NEW ENGLAND
22 Baker Avenue
West Concord, Massachusetts 01781

* METROPOLITAN NEW YORK
Broad Avenue at Linden
Ridgefield, New Jersey 07657

PHILADELPHIA
Fort Washington Industrial Park
Fort Washington, Pennsylvania 19034

* WASHINGTON and BALTIMORE
11420 Rockville Pike
Rockville, Maryland 20852

ORLANDO
113 East Colonial Drive
Orlando, Florida 32801

SYRACUSE
Pickard Building, East Molloy Rd.
Syracuse, New York 13211

CLEVELAND
5579 Pearl Road
Cleveland, Ohio 44129

* CHICAGO
6605 West North Avenue
Oak Park, Illinois 60302

* DALLAS
2600 Stemmons Freeway, Suite 210
Dallas, Texas 75207

* LOS ANGELES
1000 North Seward Street
Los Angeles, California 90038

SAN FRANCISCO
626 San Antonio Road
Mountain View, California 94040

* TORONTO
99 Floral Parkway
Toronto 15, Ontario, Canada

MONTREAL
1255 Laird Boulevard
Town of Mt. Royal, Quebec, Canada

* Repair services are available at these offices

GENERAL RADIO COMPANY (OVERSEAS), 8008 Zurich, Switzerland
GENERAL RADIO COMPANY (U.K.) LIMITED, Bourne End, Buckinghamshire, England
REPRESENTATIVES IN PRINCIPAL OVERSEAS COUNTRIES

www.americanradiohistory.com

Flash!...a new STROBOTAC® electronic stroboscope

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.

> The new high-speed Strobotac® electronic stroboscope described in this issue 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.

> **Shown on our cover is a Leesona false-twist spindle, used to put stretch in textile yarn. What makes the picture cover-worthy is the fact that the spindle 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 new Type 1538-A Strobotac®, flashing 125,000 times a minute.**

www.americanradiohistory.com

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

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

	Type 1531-A	*Type 1538-A*
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 μs	0.5, 0.8, 1.2, 3 μs
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
Price	$295.00	$465.00

www.americanradiohistory.com

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.

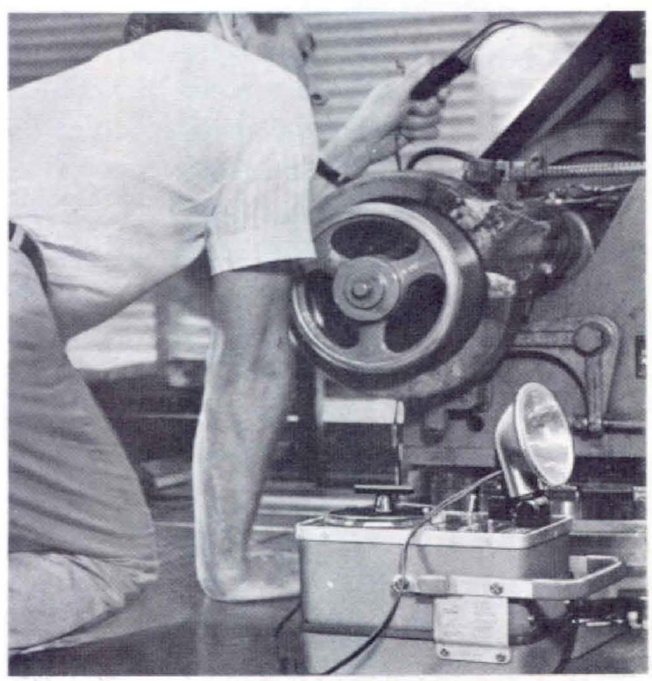
The flashing rate of the stroboscope is controlled by an electronic oscillator and is adjustable over a very wide range. If it is set to flash at, say, 1800 times a minute and if its light is used to illuminate a fan rotating at 1800 rpm, each successive flash will occur with the fan in the same position, 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.

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 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 pickoffs (see page 11), 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.

www.americanradiohistory.com

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 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.

* U. S. Patent No. 2,977,508.
** Patent applied for.

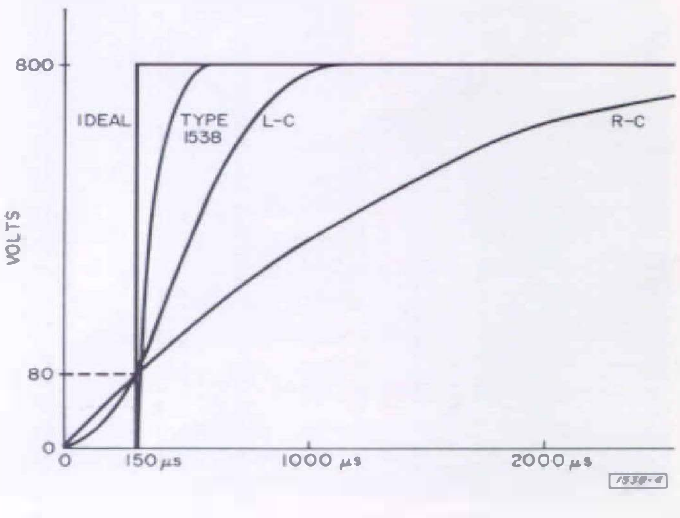


Figure 1. Voltage-vs-time characteristics of various charging circuits.

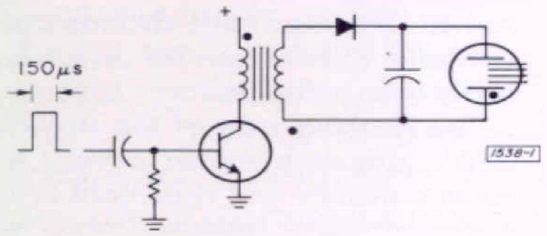


Figure 2. The charging circuit of the new Strobotac.

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 "holdover," 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 deionization time after the strobotron has flashed, the transistor, acting as a switch, is saturated and the transformer primary current increases, storing en-

www.americanradiohistory.com

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.

ergy 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 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

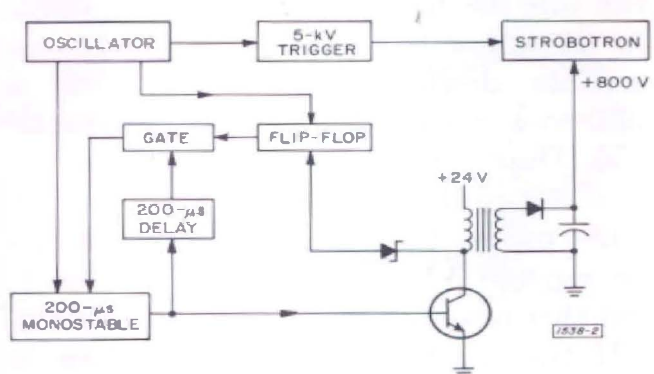


Figure 3. Block diagram of the Type 1538-A Strobotac electronic stroboscope.

www.americanradiohistory.com

M. C. Holtje received his BSEE and MSEE degrees from the Massachusetts Institute of Technology in 1950. He then joined General Radio Company as a Development Engineer and in 1960 became Leader of the Industrial Group. He is a Senior Member of the IEEE and has served on several IEEE standards committees.

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 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

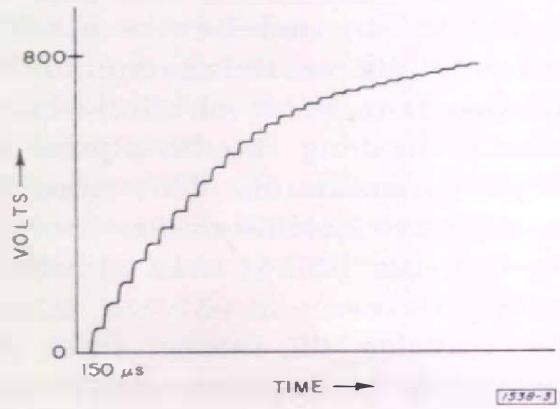


Figure 4. Curve showing step voltage buildup on charging capacitor.

www.americanradiohistory.com

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

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: ±1% of reading on all ranges after calibration against line frequency.

Flash Duration: Approximately 0.5, 0.8, 1.2, and 3 μs for high-to-low speed ranges, respectively, measured at ⅓ peak intensity; for single flashes with Type 1538-P4 High-Intensity-Flash Capacitor, 8 μs.

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 10⅝*, height 6⅝, depth 6⅛ inches (270 by 170 by 160 mm), over-all.

Net Weight: 7¼ lb (3.3 kg).

Shipping Weight: 10 lb (4.6 kg).

* Includes handle.

Catalog No.	*Description*	*Price in USA*
1538–9701	Type 1538-A Strobotac® electronic stroboscope	$465.00
1538–9601	Type 1538-P1 Replacement Strobotron Lamp	15.00
1538–9602	Type 1538-P2 Extension Lamp	55.00
1538–9603	Type 1538-P3 Battery and Charger, with case	225.00
1538–9604	Type 1538-P4 High-Intensity-Flash Capacitor	75.00

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 sim-

www.americanradiohistory.com

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.

ple 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.

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 (2½ by 5⅜ by 4⅛ 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 Contactor, or any device capable of supplying a contact closure or a positive pulse of a 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, observe 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

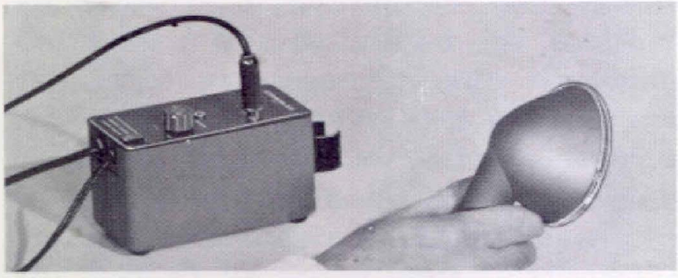
SPECIFICATIONS

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 μs, measured at ⅓ 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.



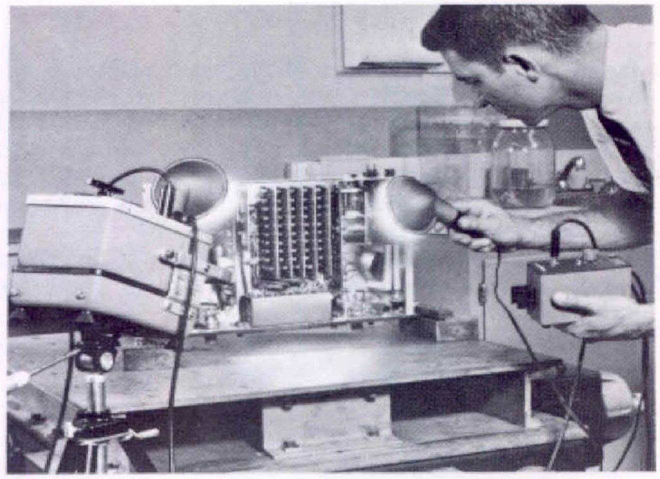
Lamp, at end of five-foot cable, can be held in hand as shown here or attached to case as shown on page 9.

www.americanradiohistory.com

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 2½, height 5⅜*, depth 4⅛ inches (64 by 215 by 105 mm), over-all.
Net Weight: 2¾ lb (1.3 kg).
Shipping Weight: 8 lb (3.7 kg).

* Without lamp attached.

Catalog Number	*Description*	*Price in USA*
1539-9701	Type 1539-A Stroboslave	$165.00
1531-9604	Type 1531-P4 Trigger Cable (for use with Type 1531-A Strobotac)	15.00



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.

PHOTOELECTRIC PICKOFFS

There are now two photoelectric pickoffs in the General Radio line: the TYPE 1536-A,[1] 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 ½ 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.

[1] "Using a Photocell Where It Counts," *General Radio Experimenter*, October, 1962.

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.

www.americanradiohistory.com

SPECIFICATIONS

Operating Rate: Greater than 2500 pulses/s.
Sensitivity: Effective irradiance must be at least 6.0 mW/cm² to switch on, less than 0.6 mW/cm² to switch off, at 1 micron wavelength.
Power Required: 3 to 25 V dc; 0 to 100 μA depending on operating rate. Power is supplied by instrument with which it is used.
Accessories Supplied: 10-ft roll of 3/8-in black tape, 10-ft roll of 3/8-in silver tape, carrying case.
Mounting: C-clamp (capacity 1 5/16 in, flat or round) or 1 1/2-in magnet, both supplied.
Dimensions: Pickoff head, 11/16-in dia, 2 in long. Linkage consists of two 5/16-in diameter stainless-steel rods, 6 and 6 1/4 in long, and adjustable connecting clamp. Cable is 8 ft long, terminated in phone plug.
Net Weight: 1 1/2 lb (0.7 kg).
Shipping Weight: 4 1/2 lb (2.1 kg).

Catalog Number	*Description*	*Price in USA*
1537-9701	Type 1537-A Photoelectric Pickoff	$65.00

SEMINAR IN HIGH-SPEED PHOTOGRAPHY

A one-week seminar on the scientific and engineering uses of high-speed photography will be held at the Stroboscopic Light Laboratory of the Massachusetts Institute of Technology, July 25 to 29. Mornings will be devoted to theory and demonstrations, afternoons to laboratory practice. Subjects to be covered include pulsed stroboscopic lighting, optical high-speed cameras, Kerr cells, Faraday shutters, image converters, etc. For more information, write to:

Office of the Summer Session
MIT, Room E19-356
Cambridge, Massachusetts 02139

DO WE HAVE YOUR CORRECT NAME AND ADDRESS — name, company or organization, department, street or P.O. box, city, state, and zip code? If not, please clip the address label on this issue and return it to us with corrections, or if you prefer, write us; a postcard will do.

PRINTED IN U.S.A.

the GR Experimenter

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS 01781

www.americanradiohistory.com