OPERATING INSTRUCTIONS

for

TYPE 631-B STROBOTAC

FORM 394-L

GENERAL RADIO COMPANY

CAMBRIDGE 39 MASSACHUSETTS

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U. S. A.

CONDENSED OPERATING INSTRUCTIONS
FOR
TYPE 631-B STROBOTAC

TO STANDARDIZE STROBOTAC.*

(1) Connect to a-c power line. Be sure voltage and frequency are correct.
(2) Set selector switch to STROBOTAC LOW.
(3) Standardize scale as follows:

(a) Press, then release, REED button at rear. This turns on the reed.
(b) Set RPM scale to 3600 rpm (top end of low scale).
(c) Adjust trimmer (3600 ADJUST) until a single stationary image of the reed is seen.
(d) Set RPM scale to 1800 rpm.
(e) Adjust second trimmer (900 ADJUST) until reed stands still.
(f) Set RPM scale to 900 rpm.
(g) Readjust trimmer (900 ADJUST) until reed stands still.
(h) Recheck at 3600 and at 900, readjusting again if necessary.
(i) Press REED button again. This turns off the reed.

* For 60-cycle model *(see also page 4)*

TO MEASURE SPEED

(1) Set selector switch at LOW or HIGH, depending on range desired. The low range is 600 to 3600 rpm; the high range is 2400 to 14,400 rpm.
(2) Direct the light from the neon lamp upon the element whose speed is to be measured.
(3) Adjust RPM scale until a stationary image of the rotating member is seen.
(4) Read speed from RPM scale. The correct value is the ***highest*** scale setting at which a single image occurs.

(see also page 5)

TO WATCH EQUIPMENT IN SLOW MOTION

Adjust flashing speed to be slightly less than that of machine to be observed.

(see also page 7)

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PATENT NOTICE

The Strobotac is manufactured under designs and patent applications of Harold E. Edgerton, Kenneth J. Germeshausen and Herbert E. Grier.

OPERATING INSTRUCTIONS
FOR
TYPE 631-B
STROBOTAC

1.0 PURPOSE

The Type 631-B Strobotac is a stroboscopic tachometer. It provides a rapid and accurate means of measuring directly speeds between 600 and 14,400 rpm and, by indirect methods, speeds up to at least 50,000 rpm. It is particularly adapted for the measurement of speed where the end of the shaft is not accessible or in cases where the power is limited. It does not require mechanical contact with the shaft and absorbs no power from the drive. The Strobotac can also be used for stroboscopic observation of moving objects.

2.0 DESCRIPTION

The Strobotac consists of a power supply, an oscillator for controlling the rate at which the lamp is flashed, and a Strobotron or flashing lamp—all assembled in a single unit. By turning an illuminated dial, the frequency of the oscillator and hence the flashing speed of the lamp can be adjusted to any value between 600 and 14,400 per minute. The scale of the dial is graduated directly in rpm. The entire assembly is housed in a metal case, is easily portable, and operates from an a-c line.

2.1 Flash Control

In addition to the self-contained oscillator, provision is made for controlling the speed of the flash by means of the a-c line frequency, or by means of an external contact or oscillator.

2.2 Calibration

Provision is made for adjusting the internal oscillator frequency in terms of the a-c line frequency in order to compensate for drifts in the calibration. For maximum accuracy, therefore, the Strobotac should be used only on frequency-controlled power lines, i.e., those on which synchronous electric clocks can be used.

2.3 Accuracy

The dial carries two scales, one covering speeds between 600 and 3600 rpm and the other speeds between 2400 and 14,400 rpm. Between 900 and 3600 on the low scale and between 3600 and 14,400 on the high scale the accuracy of the Strobotac is $\pm 1\%$, when properly standardized

in terms of a frequency controlled power line. Outside these limits the accuracy is not quite as good. It is possible, however, to standardize the scale over any small range in terms of the line frequency and to obtain accuracies considerably better than 1% (see paragraph 6.1).

2.4 Circuit

Figure 3 is a complete circuit diagram.

2.5 Vacuum Tubes

Three vacuum tubes are used, one 6X5G-type, one 6N7G-type, and one Type 631-P1 Strobotron.

2.6 Strobolux

A jack is provided so that connection can be made to the Strobolux (a self-contained lamp and power supply) which, at the lower flashing rates, gives many times the amount of light produced by the Strobotac and, in some cases, may be used as a source of illumination for taking "high-speed" photographs.

3.0 OPERATION

(Numbers in parentheses refer to Figure 1)

3.1 Installation

Connect the Strobotac to the power line by means of the cord and plug provided. Be sure the voltage and frequency of the a-c line correspond to those engraved above the plug receptacle (1). This receptacle is located in the lower right corner looking at the back of the unit.

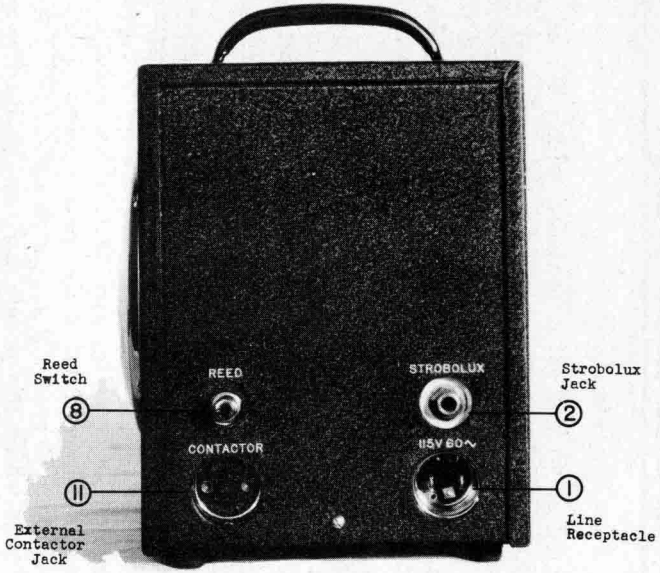
3.11 Switches

A rotary switch (4) is provided to enable the user to select easily and rapidly the desired condition of operation. The first position, OFF, with the pointer turned fully to the left, is a non-operating point, the power being turned off. The second and third (STROBOTAC) positions are for speed measurements. The low position is for speeds from 600 to 3600 rpm, and the scale marked LOW (right-hand) should be used. The third (HIGH) position is for the higher scale which is four times the low, 2400 to 14,400; the scale is marked HIGH and is the left-hand section of the dial. In the fourth or top center position (LINE), the lamp is controlled by the frequency of the power line. If operated on a 60-cycle circuit, the flashes will be 3600 per minute. The last two (CONTACTOR) positions are for contactor or external oscillator control. The LOW position is for speeds up to about 3600 rpm, while above this the HIGH position will give the best results up to the maximum for the instrument of about 15,000 rpm. The Type 549-C contactor is recommended.

3.2 Adjustment

Turn selector switch (4) to STROBOTAC LOW position. The light will flash in about 15 seconds. Usually a minute or more should be allowed for heating before expecting normal operation.

Panel View of Strobotac



Rear View of Strobotac

Figure 1.

3.22 Scale

An illuminated drum dial (5) is provided which is read through a window in the top of the instrument. The instrument may be held by the left hand, leaving the right hand free to operate the speed control knob. In the Type 631-B Strobotac the scale may be read from above without moving or setting down the instrument. The right-hand scale is for low speeds from 600 to 3600 rpm. To provide larger and more easily readable figures, the two zeros on the left have been omitted; thus, 18 should be read as 1800. The HIGH scale (left) has been planned in the same manner. The note "MULTIPLY BY 100" at the right of the window is a reminder to add the two zeros, which is simply shifting the decimal point two places to the left, a reading of 18.25 becoming 1825 rpm.

3.3 Standardization

The Strobotac is standardized in terms of the a-c line frequency by using the metal reed (10) which projects through the lamp reflector. This reed is driven from the a-c power line, and with 60-cycle supply vibrates 7200 times per minute, or twice for each cycle of line voltage. When the Strobotac flashing rate corresponds to this reed vibration rate, a multiple of it, or a submultiple, the reed will appear to stand still. The points on the Strobotac dial at which this occurs can then be used to standardize the dial calibration. The absolute accuracy of this calibration depends on the accuracy to which the line frequency is maintained at the power station; in most localities where synchronous electric clocks are used it is better than 0.1 of 1%.

3.31 Procedure for 60-Cycle Model (For other line frequencies, see 3.32, below)

Turn on reed by pushing REED button (8) at left rear of instrument. Set RPM scale to 3600 on the low scale, with the switch set at STROBOTAC LOW. Using a small screw driver, adjust trimmer (9B) marked ADJUST 3600 until reed shows no motion. Turn scale to 1800 and adjust in a similar manner trimmer (9A) marked ADJUST 900. Next, turn scale to 900 and again readjust the 900 trimmer to make the reed stand still. Recheck the setting at 3600 and again at 900. As a final check, set the dial at 1800 and at 1200. At each of these settings the reed should be stopped or show a very slow motion. Always make this check. While the ratio between LOW and HIGH scales is almost exactly 4 to 1, and both scales are accurate enough for general use when only the LOW scale has been standardized, it is suggested that for very accurate high-speed measurements the high scale be standardized, using 3600 and 14,400 and making adjustments using the 900 and 3600 trimmers, respectively. A double image will be obtained at 14,400.

3.32 Other Line Frequencies

Although the standard Strobotac will operate on any 115-volt a-c line having a frequency between 55 and 65 cycles, the points at which the scale is set for standardization will be different for each frequency. In

general, any submultiple of the line frequency expressed in cycles per *minute* can be used. The standardizing speeds should be near the ends of the scale. For 50 cycles, for instance, 750 and 3000 might be used. When the Strobotac is ordered for use on a specific frequency the calibrating speeds are engraved on the panel.

The following frequencies are ordinarily used:

Line Frequency	60	50	45	42	40	25
Reed Frequency	7,200	6,000	5,400	5,040	4,800	3,000
Set Trimmer 9B at	900	750	900	840	800	750
Set Trimmer 9A at	3,600	3,000	2,700	2,520	2,400	3,000
Final Check Speeds	1,800	1,500	1,800	1,680	1,600	1,500
	1,200	1,000	1,080	1,260	1,200	1,000
High Scale, 9B	3,600	3,000	2,700	2,520	4,800	3,000
High Scale, 9A	14,400*	12,000*	10,800*	10,080*	14,400**	12,000***

4.0 USE

4.1 Speed Measurement

In using the Strobotac to measure the speed of rotating or reciprocating mechanisms, hold the instrument so that the light from the neon lamp falls on the part to be observed and adjust the knob (6) until the moving part appears to stand still. The scale (5) gives the speed directly in rpm. In cases where no idea of the speed being measured is known, it is desirable to start at high speeds and work down. At twice the speed the pattern is doubled and the first time a true pattern is obtained (fundamental synchronism, see paragraph 4.3, below, the dial reading gives the correct speed.

4.11 Range

The lower scale covers the range between 600 and 3600 rpm; the upper, that between 2400 and 14,400 rpm. The desired scale is selected by the switch.

4.12 High Speeds

Since the life of the Strobotron tube (3) is much greater when flashed at low speeds than at high, the LOW scale should be used whenever possible. When measuring speeds of objects above 5000 rpm, the Strobotac can be adjusted at the higher speed, after which the switch is turned to LOW. The pattern seen will still be stationary because of the 4:1 relationship between HIGH and LOW scale. The accuracy of the measurement is not affected. A slight twist of the knob restores the high speed when desired.

*Double image
**Triple image
***Quadruple image

	Shaft Speed "R"	Flash Speed "F"	Appearance	Speed Equations	Remarks
a	0	0			Machine stopped Lamp off
b	1800 R.P.M.	0			Machine Running Lamp Off Spot Invisible
c	1800 R.P.M	1800 F.P.M.		$R=F$	Fundamental Synchronism
d	1800 R.P.M	900 600 1800/n } F.P.M. ("n" is integer)		$F=\frac{R}{n}$	Perfect Synchronism Less illumination on spot than "c"
e	1800 R.P.M.	3600 F.P.M.		$F=nR$ $(n=2)$	Partial Synchronism
f	1800 R.P.M.	7200 F.P.M.		$F=nR$ $(n=4)$	Partial Synchronism
g	1800 R.P.M	1799 F.P.M.		$S=R-F$ ("S" is speed of slow motion)	Slow rotation (1 R.P.M.) in same direction as true rotation.
h	1800 R.P.M.	1801 F.P.M.		$S=F-R$ ("S" is speed of slow motion)	Slow rotation (1 R.P.M.) in opposite direction to true rotation

Figure 2.

4.2 Sub-Multiples

If the lamp is flashed at a speed which is a sub-multiple (1/2, 1/3, 1/4,..$\frac{1}{n}$)of the speed of the rotating part under observation, the motion can be "stopped" in a manner identical with that at fundamental synchronism. The highest scale reading at which a single stationary image is obtained is, therefore, the correct setting.

4.3 Fundamental Synchronism

When adjusting for fundamental synchronism, a convenient and safe procedure is to start at high speeds where multiple images are obtained and reduce the flash speed until a single image occurs.

In most work the approximate speed is known and sub-multiple effects need not be considered. When using the Strobotac to view rotating objects such as the end of a shaft or a wheel with a number of identical spokes, a chalk mark or some other positive means of identification should be made on the rotating part, otherwise it is possible to obtain erroneous readings, although the subject which is being viewed may appear to be standing still. The chalk mark provides a positive means of identification since if only one mark is seen, it is certain to be either fundamental synchronism or a sub-multiple thereof.

4.4 Multiple Synchronisms

If the speed of the lamp is n times the speed of the subject, n patterns will be seen. This is covered more fully in paragraph 5.2.

4.5 Slow-Motion Studies

Stroboscopic methods of apparently slowing down high speed motion can be used only where the motion is cyclic, that is, rotating or reciprocating at approximately constant speeds. See (g) and (h), Figure 2. For best results a semi-darkened room should be used, although satisfactory work can often be done under normal factory illumination. When more light is needed than the Strobotac supplies, use the Type 648-A Strobolux.

4.6 Other Flashing Sources

4.61 Control by A-C Line

To secure flashing at the same rate as the line frequency (3600 rpm on 60-cycle circuits) which may be used to observe hunting of certain classes of electrical machinery or to measure speeds or slip of small motors, set the selector switch to the LINE position. The frequency of the oscillator is then equal to the line frequency.

4.62 Use of Contactor

A commutator or contactor such as the General Radio Type 549-C Contactor can also be used to control flash speed. Plug the contactor into the receptacle (11) at the lower left-hand corner of the rear of the instrument and turn selector switch to CONTACT position. For speeds up to 3600 rpm use contactor LOW; above this, turn switch to contactor

HIGH. Maximum illumination is obtained in the contactor LOW position.

4.63 Oscillator Control

Any audio-frequency oscillator having an output of approximately 100 volts may be used to drive the Strobotac if desired. Connections may be made through contactor jack (11). The range is usually somewhat more limited than the full scale of the Strobotac, and the accuracy is that of the oscillator. For extreme accuracy at any given frequency a tuning fork type of oscillator may be used. General Radio Type 815-A, 50-, 60-, or 100-cycle forks, may be used, which provides a flashing rate accurate to better than 0.01%. This method is often used for very accurate calibration of other equipment. An impedance-matching transformer should be used to connect fork to Strobotac.

5.0 EXTENSION OF RANGE

Multiple and sub-multiple synchronisms can be used to extend the range of the Strobotac to higher and lower speeds.

5.1 Identification of Higher Speeds

When the speed of the shaft under observation is greater than that of the flash, change the flash speed until the next point of synchronism is obtained. From the two dial readings the shaft speed can be calculated. If the two dial readings are a and b, the shaft speed is given by $\frac{ab}{a-b}$, when a is the larger of the two readings. As an example, suppose the two dial readings are 4500 and 4000. The shaft speed is then $\frac{4500 \times 4000}{4500 - 4000} =$ 36,000 rpm.

For very high speeds, the value a-b becomes progressively smaller, with a consequently larger error in the result. This can be avoided by taking a and b several patterns apart and using the expression rpm $= n \frac{ab}{a-b}$, where n is the number of patterns reached in going from a to b. As an example, consider the shaft speed measured in the preceding example. One reading is obtained at 4000, another at 7200. In going from 4000 to 7200, the number of patterns encountered is 4. Hence,

$$4 \times \frac{7200 \times 4000}{7200 - 4000} = 36{,}000 \text{ rpm.}$$

5.2 Lower Speeds

If the lamp is flashed at a rate corresponding to a multiple of the shaft speed, multiple images can be seen. For instance, a radial line on the end of the shaft will appear as several lines, spaced equally around the circumference. Twice the speed will produce two lines at 180°, three times yields three lines at 120° intervals, etc. Dividing the flash speed by the number of lines seen will then give the shaft speed. This method is

not recommended for very low speeds except when used in a darkened room, since rates below the persistence of vision (about ten flashes per second) are difficult to determine.

6.0 ADDITIONAL SUGGESTIONS

6.1 Additional Calibration Points

As the scale reading is changed slowly with the REED switch in the ON position, a number of points of synchronism will be found. Some of these produce one image, others two, three or four. Because of the difficulty of interpreting the multiple images, it is recommended that no patterns more complicated than double images be used. The frequency of the reed is 7200 vibrations per minute for 60-cycle supply. If the dial is set at any integral sub-multiple of 7200, a single image of the reed will appear to stand still. For 60-cycle supply these points will be found at the following speeds: 7200, 3600, 2400, 1800, 1440, 1200, 900, 800, 720 and 600. In addition, fractional relations producing a double image can be obtained at a number of points as, for instance, 1600 rpm, where the ratio of the flashing speed to the reed speed is $\frac{2}{9}$. For these fractional relations, the ratio of flash speed to reed speed can be reduced to lowest terms, after which the numerator of the fraction indicates the number of patterns seen. Since, however, there are so many integral sub-multiples which yield a single image, it will not usually be found necessary to use the fractional relationships.

When the flashing speed is greater than the speed of the reed, a large number of stationary patterns can be found. Most of these, however, are fractional multiples and are somewhat difficult to interpret. A double image can be found at 14,400 which is twice the speed of the reed. A triple image occurs at 10,800 corresponding to a ratio of the 3/2. It is not recommended that images with a greater number of lines be used. See Table I.

All these points are useful in calibrating the scale. The directions for calibration given in paragraph 3.31 cover the standardization of the entire scale. If, however, it is desired to measure accurately the speed of rotating machinery over a small range, or to measure deviations from a given standard speed, the scale can be adjusted by means of the trimmers (9) to be accurate, at the nearest point where a reed synchronism is obtained, or at two points at the ends of the range in which the measurements are to be made. Under these conditions, an accuracy far in excess of 1% can be obtained.

6.11

Figure 2 shows briefly the multiple and sub-multiple relationships discussed above, as well as the effect which occurs when the flash speed differs very slightly from the speed of the subject.

For obtaining patterns like those shown in the table, a small synchronous motor carrying a disc with spots, as shown, is useful. This can also be used for calibration purposes instead of the reed. Table II gives a list of speeds for images up to 5 spots, with an 1800 rpm disk, bearing one spot.

7.0 MAINTENANCE

7.1 Strobotron Life

The Strobotron tube is guaranteed for 250 hours if used at flashing speeds of less than 5000 rpm, or for 100 hours if used at higher speeds, with both of these guarantees limited to 60 days after date of shipment from our plant. Any tubes that become defective or unsatisfactory within the 60-day time limit will be replaced by the General Radio Company on a pro-rata basis, if the customer will advise us of the length of time that the tube was used and at what flashing speeds.

7.2 Effect of Flashing Speed

If the Strobotac is operated continuously at the higher speeds, the Strobotron cathode emission may eventually be reduced to the point where the tube is inoperative. When this occurs, the tube usually glows with a dull red color, but will not flash. Flickering is another symptom of this condition. Operation can often be restored by running the tube at low speeds for several hours. Eventually, however, the tube becomes completely inoperative and must be replaced.

7.3 Replacement Strobotrons

To replace Strobotron or other tubes, the entire unit may easily be withdrawn from case. Four screws hold front panel and one screw is located in the rear. Always replace rear screw as this locks the chassis in the cabinet. DO NOT REMOVE lens to replace Strobotron.

7.4 Other Tubes

Type 6X5G and 6N7G Tubes can be obtained from any radio store.

7.5 Friction Drive

This instrument is equipped with a slow-motion friction drive. Take-up adjustment can be made by removing the knob, loosening the screw in the ear of the clamp ring, and turning the brass disc slightly to the right, using the notch in the edge. Only a very slight motion is required, and adjustments need be made only after long periods of use. Be sure to tighten the clamp screw after adjusting.

TABLE I

ADDITIONAL REED CALIBRATING POINTS
LOW SCALE

Reed Speed	Dial Setting	Number of Images	Dial Speed / Reed Speed
7200*	600	1	1/12
	626.1	2	2/23
	654.5	1	1/11
	685.7	2	2/21
	720	1	1/10
	757.9	2	2/19
	800	1	1/9
	847.1	2	2/17
	900	1	1/8
	960	2	2/15
	1028.6	1	1/7
	1107.7	2	2/13
	1200	1	1/6
	1309.1	2	2/11
	1440	1	1/5
	1600	2	2/9
	1800	1	1/4
	2057.1	2	2/7
	2400	1	1/3
	2880	2	2/5
	3600	1	1/2

TABLE II

CALIBRATING POINTS USING 1800-RPM
SYNCHRONOUS MOTOR WITH ONE-SPOT DISK

POINTS BELOW 1800 RPM

Disk Speed	Dial	Spots Seen	Dial Speed / Disk Speed
1800†	1800	1	1
	1500	5	5/6
	1440	4	4/5
	1350	3	3/4
	1285.7	5	5/7
	1200	2	2/3
	1125	5	5/8
	1080	3	3/5

*For 60-cycle model. For other reed speeds (see paragraph 3.32), dial settings can be calculated using the ratios in column 4.

TABLE II—Continued

Disk Speed	Dial	Spots Seen	Dial Speed / Disk Speed
1800†	1028.6	4	4/7
	1000	5	5/9
	900	1	1/2
	818.8	5	5/11
	800	4	4/9
	771.4	3	3/7
	750	5	5/12
	720	2	2/5
	692.3	5	5/13
	675	3	3/8
	654.5	4	4/11
	642.9	5	5/14
	600	1	1/3

POINTS ABOVE 1800 RPM

Disk Speed	Dial	Spots Seen	Dial Speed / Disk Speed
1800†	1800	1	1
	2400	4	4/3
	2700	3	3/2
	3600	2	2
	4500	5	5/2
	5400	3	3
	7200	4	4
	9000	5	5
	10,800	6	6
	12,600	7	7
	14.400	8	8

† For other disk speeds, dial settings can be calculated using the ratios in column 4.

PARTS LISTS

Nominal Values Only

Resistors

R-1 = 3 $k\Omega$
R-2 = 15 $k\Omega$
R-3 = 51 $k\Omega$
R-4 = 1 $M\Omega$
R-11 = 5 $k\Omega$
R-12 = 200 $k\Omega$
R-13 = 50 $k\Omega$
R-15 = 1 $M\Omega$
R-16 = 1 $M\Omega$
R-17 = 51 $k\Omega$
R-18 = 51 $k\Omega$
R-19 = 24 $k\Omega$
R-20 = 22 $k\Omega$
R-21 = 10 $k\Omega$

Condensers

C-1 = 1 μf
C-2 = 2 μf
C-4 = 0.01538 μf
C-5 = 0.01538 μf
C-6 = 0.00516 μf
C-7 = 0.00516 μf
C-8 = 16 μf
C-9 = 8 μf
C-10 = 0.0005 μf
C-11 = 2 μf
C-12 = 0.005 μf

LAMP

P-1 = 6 volt Type 139-330

Tubes

V-1 = RCA Type 6X5G
V-2 = Sylvania Type 6N7G
V-3 = Strobotron 631-P1

Transformer

T-1 = GR 631-415 (115 v, 60 c)

FUSES

F-1 = 1 amp. Type 7AG
F-2 = 1 amp. Type 7AG

or

F-1 = 0.8 amp. Type 3AG
F-2 = 0.8 amp. Type 3AG

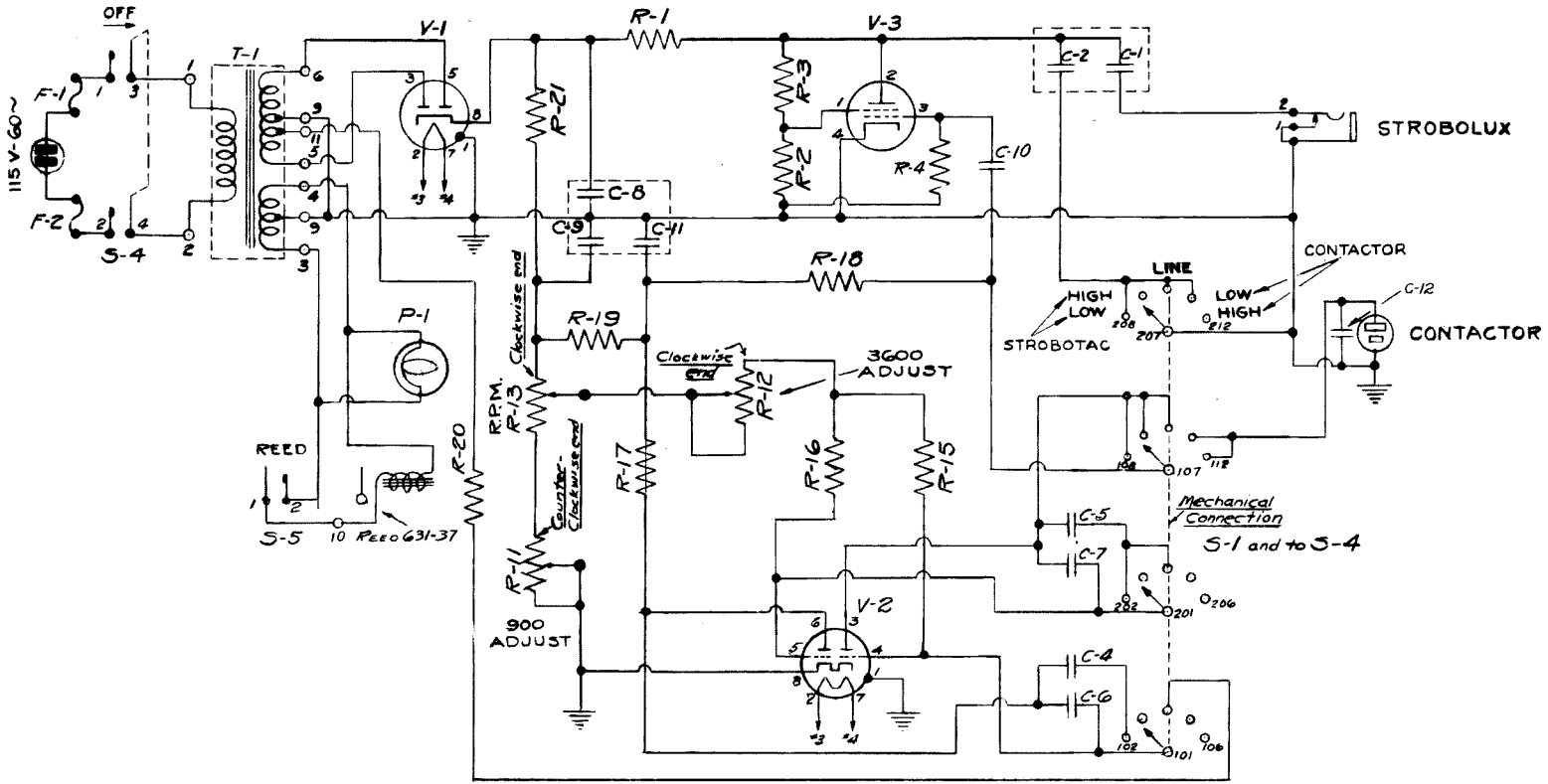


Figure 3. Wiring Diagram of Type 631-B Strobotac