"OP-TACH"

WHEREVER there is a wheel spinning or a motor shaft turning, the chances are that, sooner or later, somebody is going to ask how fast it is revolving. To find out, he'll have to use a tachometer of some sort. Most commercial and industrial tachometers are designed for a specific purpose and are either permanently installed or fairly expensive, or both.

In the home workshop, the experimenter needs a low-cost, portable tachometer that can be used with any motor or engine when he is tuning up or testing. There are very few tachometers of this type.

Here's one, however, that will measure the speed of practically anything that rotates in the lab or workshop. It's called the "Op-Tach" and is battery-operated, wholly self-contained and handheld. A beam of light senses the speed of the rotating object. In many cases, using the Op-Tach is simply a matter of pointing the instrument at the rotating object and reading the speed in revolutions per minute directly from the meter.

Construction. The schematic diagram for the Op-Tach is shown in Fig. 1. As with any project using integrated circuits, you will be ahead of the game if you use a printed cuit board. You can make your own, [illegible]g Fig. 2 as a guide, or you can buy one (see Parts List of Fig. 1). In assembling components on the circuit board (Fig. 3) be sure that both the board and your soldering iron are as clean as possible and keep them that way. In inserting the integrated circuits, notice that the notches on the IC's correspond to the semicircular locating marks on the PC board. When all soldering is complete, a coat of spray acrylic or clear nail polish will keep the copper circuit from oxidizing.

To protect the photocell from high levels of ambient light and restrict its field of view, the photocell is glued to the bottom of the inside of a 5-dram pill container which has been painted flat black on the inside. A pair of holes is drilled for the photocell leads. The pill container is then mounted in an appropriate size hole in one end of the 6½" × 3¾" × 2" plastic utility box which houses the instrument. To conserve space, mount it so that approximately half of the pill bottle protrudes from the case. Save the cap from the container and use it as you would the lens cap on a camera—to prevent dust from settling on the photocell.

The two dual-battery holders are mounted on opposite sides of the case so that, when the cover is in place, the meter is between them. The PC board should be mounted with 6-32 screws and raised from the bottom of the case with short spacers. The mete[illegible] witch *S2* and controls (*R2* and *R8* [illegible]n *S1* attached) are mounted on the aluminum faceplate of the utility box as shown in Fig. 4. In the author's prototype this faceplate was covered with a mahogany-grain, contact-adhesive paper and labels were applied using dry transfers. All wires from the PC board to the controls and meter were run through a piece of large tubing, but they could be laced together in a neat bundle. Be sure to make these leads long enough to permit removal of the front cover. Notice that capacitor *C5* is mounted directly on the meter terminal lugs and not on the printed circuit board.

The suggested meter has scale markings from 0 to 500. Carefully remove the clear plastic front of the meter and use a pencil eraser to remove the "D.C. MICROAMPERES" marking. You can then use either pen and ink or dry transfers to relabel the meter "RPM × 10". If at all possible, remove the scale before doing any lettering on it and, in any case, be very careful not to bend the meter needle or damage the movement.

Calibration. The best way to calibrate the Op-Tach is by comparing it to a tachometer of known accuracy, but if such an instrument is not available, you can use one of the following methods:

Signal-Generator Method. Figure 5 shows a calibration setup using an audio signal generator. S[illegible] the generator for an output of 50 H[illegible] 1.5 volts peak-to-peak. Turn on the Op-Tach and set *R8* so that the meter reads 500 with *S2* depressed. Release *S2* and set sensitivity control *R2* at its least sensitive point (counterclo[illegible]se). You may get a reading with the [illegible]sitivity control at this position but if you don't, advance *R2* slowly until the meter shows a steady reading. Adjust the range potentiometer, *R7*, to give a reading of 3000 RPM (the equivalent of 50 Hz). While you have the equipment set up, you may want to check the tachometer at several other frequencies. Remember that indicated RPM is frequency times 60.

The electronic portion of the Op-Tach is inherently linear above about 500 RPM so any nonlinearity you may find is in the meter movement. Since most inexpensive meters have a nominal accuracy of 5%, you can expect an error of less than 250 r/min on the 5000 RPM range (usually much less).

Power-Line Method. If you don't have a signal generator, the best thing to do is to use a filament transformer and a voltage divider set up as shown in Fig.

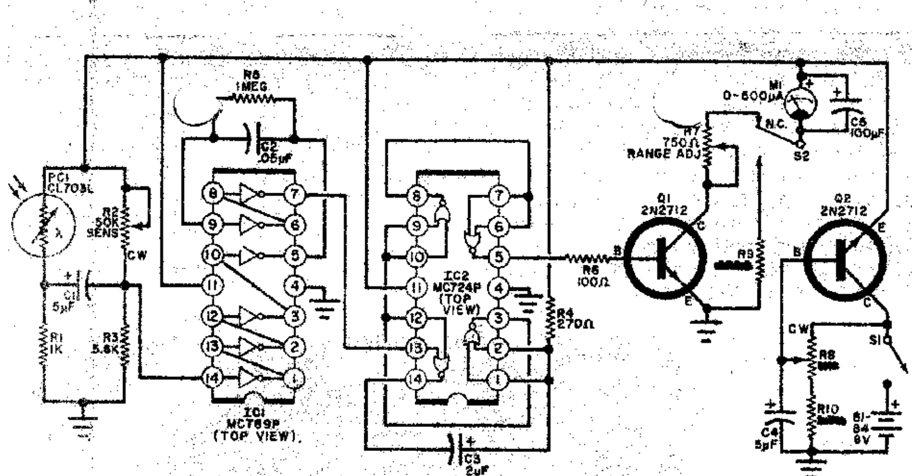
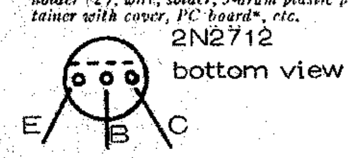


Fig. 1. The meter indicates the average current flowing through Q1 as a result of the number of light pulses striking PC1. Capacitor C5 permits the system to operate only on light pulses and not be affected by the amount of ambient light.

PARTS LIST

B1-B4—1.5-volt AA cell (penlight)
C1, C4—5-µF, 6-volt electrolytic capacitor
C2—0.05-µF, ceramic disc capacitor
C3—2-µF, 6-volt electrolytic capacitor
C5—100-µF, 6-volt electrolytic capacitor
IC1—Integrated circuit (Motorola MC789P)
IC2—Integrated circuit (Motorola MC724P)
M1—0-500-µA meter, 100-ohm internal impedance
PC1—Photocell (Clairex CL 703L or similar)
Q1, Q2—2N2712 transistor
R1—1000-ohm
R3—5600-ohm
R4—270-ohm
R5—1-megohm
R6—100-ohm
R9—[redacted]
R10—[redacted]
(All resistors ½-watt)
R2—50,000-ohm linear taper potentiometer
R7—750-ohm trimmer potentiometer
R8—[redacted]*ohm linear taper potentiometer with switch attached*
S1—S.p.s.t. switch (part of R8)
S2—S.p.d.t. pushbutton switch
Misc.—Case (6½" x 3⅝" x 2", plastic with mating aluminum cover), hardware, dual battery holder (2), wire, solder, 5-dram plastic pill container with cover, PC board, etc.*



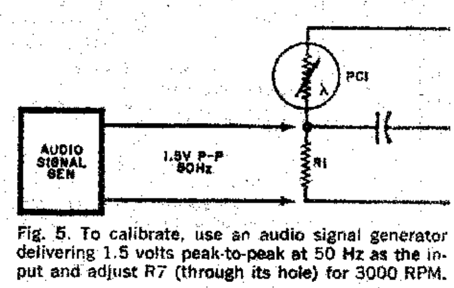


Fig. 5. To calibrate, use an audio signal generator delivering 1.5 volts peak-to-peak at 50 Hz as the input and adjust R7 (through its hole) for 3000 RPM.

. The procedure is the same as that bove except that you adjust $R7$ for a neter reading of 3600. (Unless you hapen to have a power line with a 50-Hz requency; in which case, the reading would be 3000 RPM.)

Of course the meter doesn't have to e calibrated for a full-scale reading of 000 RPM. You can set $R7$ for 10,000 or 5,000 RPM and change the meter scale narkings accordingly. However, you will ave to use an audio signal for calibraion in the higher ranges. Select a frequency near the center of the range. For instance, for a 10,000-RPM scale, se 83 Hz, which is equivalent to 4980 RPM (make the setting for 5000). Don't ry to get a full-scale range of more than 5,000 RPM or you may run into serious onlinearities.

Operation. The Op-Tach can be used in one of two ways: by reflection or by ransmission of light.

Reflective. In the first method, light is eflected from a rotating spot which is of a different reflectivity from the rest of the object. The shafts of some motors ave flats machined on them and these erve as good reflective spots. In most ases, however, the contrasting area nust be made artificially. You can use a mall piece of aluminum foil attached with clear cellophane tape or simply a piece of paper of a color which contrasts with the background. A small area paintd in contrast will also be satisfactory.

Position the Op-Tach so that light s reflected from the surface of the rotating body into the photocell. A light source is not included as part of the instrument since quite often ambient light is sufficient. If it is not, use an auxiliary light such as a flashlight or drop light.

Look at the rotating object from the direction and position in which the tachometer is located. If you can see a direct reflection from the light source, you can use the Op-Tach. If not, change the position of the light or the tachometer, or both. You can hold the Op-Tach in your hand if it is sufficiently steady to get constant readings. Otherwise, place the Op-Tach on a solid surface. For the best accuracy, always have the tachometer case in a position as close to horizontal as possible.

Turn on the Op-Tach by rotating $R8$ clockwise until $S1$ turns on. This supplies power to the meter. Depress $S2$ and continue to rotate $R8$ until you get a full-scale deflection. Then release $S2$. With the photocell pointed at the rotating body, advance the SENSITIVITY control ($R2$) until you get a steady reading. If the sensitivity is made too high, the photocell will begin to pick up minor differences in reflectivity due to surface imperfections. This results in an erratic reading on the meter, which can be cured by decreasing the sensitivity.

If the rotation being measured is below about 500 R[illegible] the meter may "dance" somewhat. This effect is not objectionable, however, until the speed is below 200 RPM. To avoid this problem, try using more than one contrasting area on the rotating object. This has the effect of multiplying the speed of the object by the number of reflecting surfaces you add, and the speed read on the meter can be converted to true speed by dividing by that number. For instance, if you have placed six contrasting strips on a rotating object and the tachometer reads 1200 RPM. Then the true speed is 1200 divided by 6 or 200 RPM.

Transmissive. The measurement method using the transmission of light through a rotating object to the Op-Tach works extremely well for slowly rotating fans. The light source is placed on one side of the fan and the Op-Tach on the other so that each blade interrupts the beam as it passes between the source and the tachometer. The instrument is turned on and the voltage is adjusted as before. Because of the extreme difference in light levels, the sensitivity adjustment may have to be increased slightly. The indicated RPM must be divided by the number of times the beam is interrupted during one revolution of the fan (number of blades). –30–

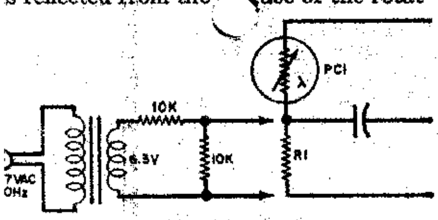


Fig. 6. You can use the commercial 60-Hz power line as a calibration source, with the divider network shown here, to calibrate the Op Tach to 3600 RPM.

HOW IT WORKS

Each time a sharp change of light hits the Op-Tach's photocell, the resistance of $PC1$ changes and a voltage pulse is created at terminal 14 of $IC1$. This pulse is amplified and shaped by the six inverters in $IC1$. SENSITIVITY control, $R2$, is used to set the amount of forward bias in the first inverter in $IC1$. Capacitor $C2$ isolates the last two inverters from any cascaded d.c. bias in the first four stages; and $R5$ prevents an excess charge from accumulating on $C2$, which would reverse bias the last two inverter stages.

The output at pin 7 of $IC1$ triggers a monostable multivibrator composed of $R4$, $C3$, and two of the four logic gates in $IC2$. Even though the reflected light detected by $PC1$ varies in duration and intensity, the output of the multivibrator is a pulse of constant height and width whose frequency is determined by the number of times that the reflected light strikes.

The pulses are squared up and buffered by the other two gates in $IC2$ and applied to the base of $Q1$. When a pulse is applied to $Q1$, it is turned on and a short pulse of current flows through meter $M1$. As the speed of the object increases, the pulses become closer together and the average value of current flowing through $M1$ increases. Capacitor $C5$ smooths the waveform and helps keep the meter needle from jiggling.

When pushbutton $S2$ is pressed, the meter is taken out of the collector circuit of $Q1$ and put in series with $R9$. The voltage across the meter is then determined by $Q2$ and can be varied by adjusting $R8$. Variations in battery output due to aging are eliminated by setting $R8$ for a current flow of 500 microamperes before each reading.

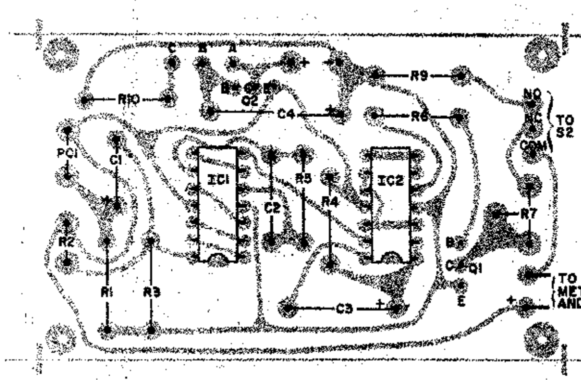
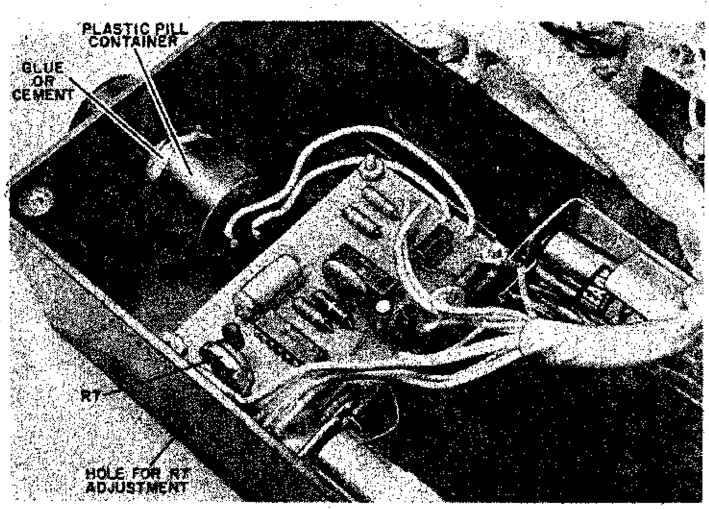
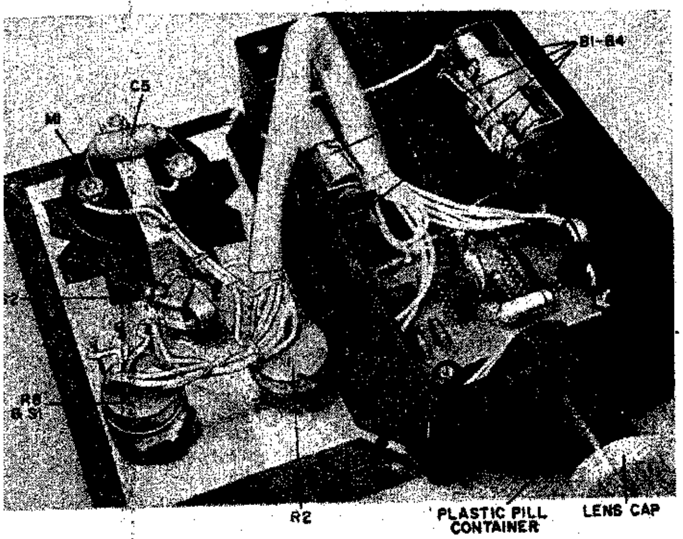


Fig. 3. Component installation. Observe correct polarity for the indicated parts.



Two holes must be drilled in the plastic case. One is for the pill container that mounts PC1, while the other is for making R7 adjustments. For maximum rigidity, mount the pill container half way in the case and use high-quality cement. Use the pill container cover as a cap when the Op-Tach is not in use. This keeps dust away from the photo cell.



The wiring between the PC board and the front panel can be made neat by passing it through a piece of plastic tubing.

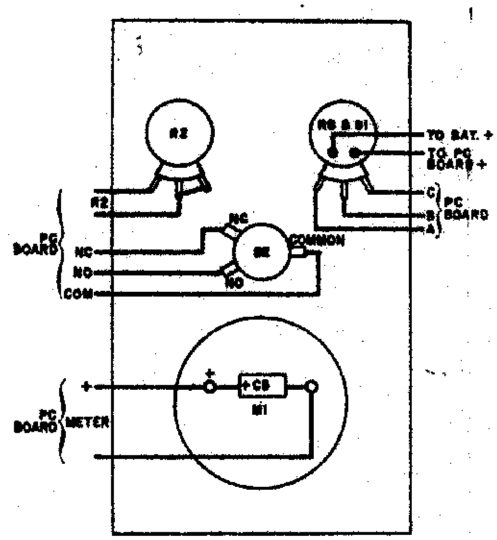
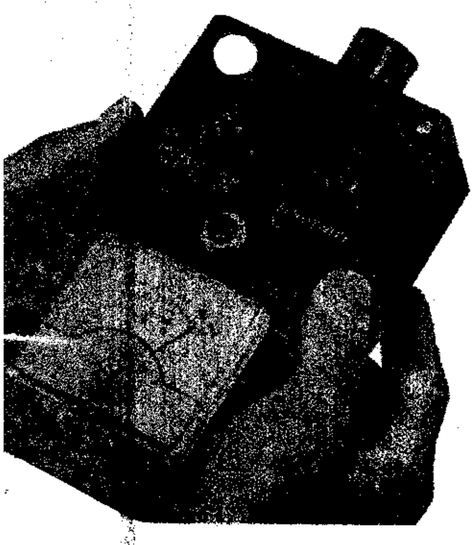


Fig. 4. Layout of rear of front panel. As circuit layout is not critical, any arrangement can be used.

OP-TACH CONSTRUCTION NOTES

An error in Popular Electronics listed R9 as being 680 ohms. This should have been 6800 ohms. This value is included in this kit.



In order to increase battery life the following parts substitutions have been made.

DESIGNATION	WAS	CHANGED TO
R8	1K pot	5K pot
R10	2.7K	10K

Resistor color coding is as follows:

R1	1K	brown-black-red
R3	5.6K	green-blue-red
R4	270 ohm	red-violet-brown
R5	1 meg	brown-black-green
R6	100 ohm	brown-black-brown
R9	6800 ohm	blue-grey-red
R10	10K	brown-black-orange

The printed circuit board is covered with a transparent film to prevent oxidation. Before soldering this film must be removed with fine steel wool.

Heat sink transistor and I.C. leads with needle nose pliers while soldering. DO NOT USE A SOLDERING IRON RATED AT MORE THAN 35 WATTS.