LIGHT ACTIVATED TACHO

This tachometer measures rotational speed without physical contact, by picking up reflected light.

THE USE OF a non-contact method of measuring RPM is not only convenient but sometimes the only method possible. Some motors used for model aircraft have a capacity of only 0.15cc yet run at speeds in the 25000 RPM region. The power required to turn a mechanical tacho would be many times the power of such a motor. Also on some machines there is no convenient place a normal tacho can be fitted.

SPECIFICATION – ETI 555

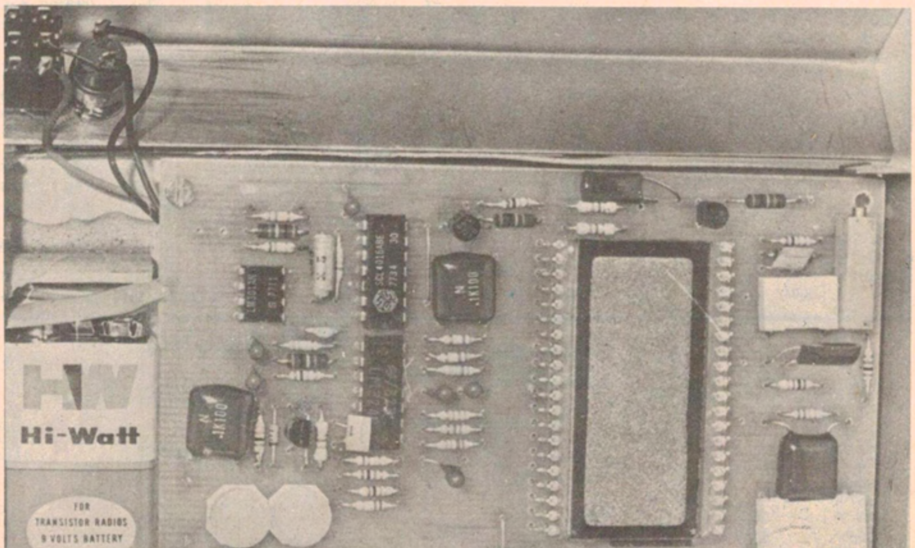
RPM range	
Low	0 – 20000
High	10000 – 30000
Resolution	10 RPM
Display	12mm LCD
Detection method	reflected light
Power	9V dc @ 4mA
Battery life (216)	about 150 hours

Design Features

As the main application for this unit was to be outdoors it was decided that an LCD display would be preferable to an LED and more easy to read than an analogue meter. Unfortunately LCDs are not yet readily available, and nor are the ICs needed to drive them.

However the Intersil Evaluation kit which we have used in the past is fairly easy to get hold of, and so we based the design around this unit. This meant converting the pulses from the sensor into a voltage. This however has another benefit in that a greater resolution can be obtained more quickly. To have a resolution of 10 RPM with a two bladed propeller a sample time of three seconds would be necessary.

The use of the BPW34 photodiode in the photovoltaic mode, ie actually generating a voltage, simplifies the biasing otherwise needed.



Construction

All the electronic components are mounted on a single pc card with the exception of the photodiode. To save on real estate the main voltmeter IC is mounted under the display.

Initially, assemble all the components apart from the ICs and the display, taking care not to bridge between the tracks with solder. Also note that some of the capacitors have to be laid on their side to give a low height.

The ICs can now be added being careful to polarize them correctly. Due to the display being mounted over the main IC it is not posible to use a socket. A socket can be used for the display if desired however it will have to be modified by cutting it into two strips.

As there are no polarity marks on the display it is necessary to hold it at the light and look for the outline of the digits. A link for the decimal point should be added as shown in the diagram.

We mounted our unit in a metal box we made with the photodiode mounted about 25mm from the end of a 75mm long tube in front of the box. This narrows the field of view of the diode as well as giving a little more clearance between high speed propellors and the fingers!

Calibration

Switch on the unit and cover the photodiode to prevent any light reaching it. Now adjust RV1 until the display reads zero.

Uncover the diode and point it at a fluorescent light. It will now give a reading and RV3 should be adjusted to indicate 3000 RPM.

Again cover the diode, then press the high range button and adjust RV2 to give a reading of −10000 RPM. Under fluorescent light it should read −7000 RPM

Operation

This unit relies on a changing light level for its operation. For use with a model aircraft, holding the unit near the propeller enables detection of the changes in the reflected light level. To measure the speed of other rotating equipment it may be necessary to paint a series of white lines to give the sensor something to 'see'.

However the unit cannot be used under fluorescent lights as it will see the 100 cycle flicker (see calibration section). In cases where this has to be done, and places where the ambient light is low, a small incandescent globe can be used to shine on the spot looked at by the sensor.

The unit, as described, is scaled to read up to 20000 RPM with a 10 RPM resolution, assuming two input pulses per revolution. If a different number of input pulses is to be used, e.g. a three or four bladed propeller, the value of R1 can be changed. (R1 $\approx$ 360k / number of pulses). The use of more than four pulses per revolution is not recommended on this range. If 2000 RPM is more than is needed for your application the value of R1 can be increased by a factor of 10, preferably with more than ten pulses per revolution.

Unlike a frequency meter, overranging this unit will cause the display to blank and greater resolution cannot be obtained simply by using a lower range. However an offset of a fixed number of RPM can be used as described in the 'How It Works' section. Using the values given, when the high range button is pressed, 10000 RPM must be added to the reading.

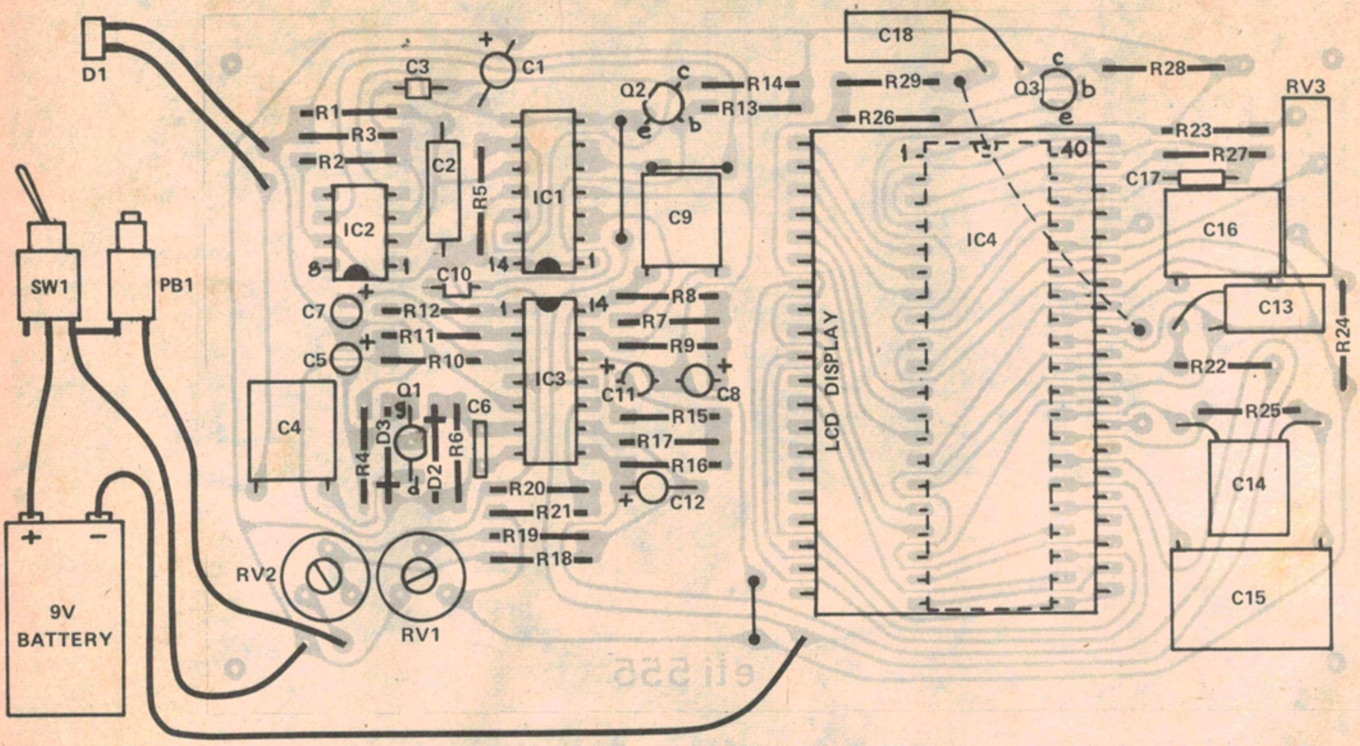
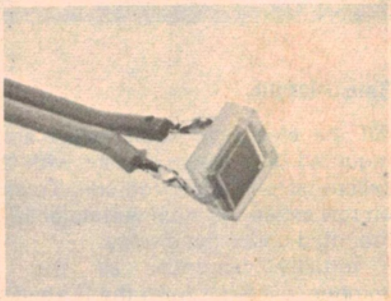


Fig. 1 The component overlay and wiring diagram of the tacho. Note that the polarity of the sensor diode, D1, is not important.



HOW IT WORKS – ETI 555

When using this unit to measure RPM, be the application a model aircraft motor or some other rotating object, the propeller or the white line (see operation section) gives rise to a changing light level. D1 which is a photo diode used in the photovoltaic mode, sees this light level and gives out a voltage proportional to the light. As this is only a small signal it has to be amplified before it can be used. This is done by IC3a. The transistor Q1 is included to provide some gain control allowing the unit to be used in differing light conditions without the need for any adjustment. The output of the amplifier is rectified by D3 to provide a negative voltage on the gate of Q1. When the output of the amplifier is small the gate to source voltage will be near zero and the FET will appear as a low value resistor giving high gain to the amplifier. If the light change is such that the output of the amplifier is large, the rectified voltage on the gate of Q1 will cause the resistance of the FET to increase decreasing the amplifier gain. In this way the output of the amplifier is held relatively constant irrespective of the light level. Diode D2 is necessary to prevent the amplifier from saturating on the positive swing.

The output is then squared up by IC3b where the positive feedback provided by R12 ensures that the output switches quickly. The output from this IC then triggers the monostable formed by Q2. What we have now is a pulse about 50 μs long every time the propeller blade passes the light sensor.

Before continuing, you may have noticed that besides the +9 V and 0 V we also have a line marked Vref. This is derived from IC4 which is a voltmeter chip and is a stable voltage of about 2.8 volts below the +9 V line.

The output of the monostable (Q2) turns on IC1a for 50 μs, discharging C2 which is then allowed to recharge to Vref. This voltage is compared (by IC2) to the voltage set by R2 and R3. The output of IC2 is a negative pulse of about 900 μs. As it is on a stable voltage supply, variations in battery voltage will have very little effect on the output pulse width. Capacitor C3 is used to force the positive input of IC2 above the negative one for the 50 μs pulse ensuring that this time is not included in the output pulse. IC1b is used to invert this pulse and its output, and the output of IC2, control IC2c/IC2d. The output of IC2c/IC2d is a positive pulse switching between Vref. and the +9 V line.

This is then filtered by two 2 pole active low pass filters, IC3c and IC3d. As these have a cutoff frequency of around 10 Hz the output for most applications will be the dc voltage component only. This is measured by IC4 which is a complete voltmeter.

As offset voltages and currents can cause the output of the filters not to be exactly zero with no input, the positive input of IC3d is biased up about 30 mV and then by injecting a current into the negative input (by R19 and RV1) correction can be made. For measuring RPMs above 20000 and below 30000 a current is injected into the negative input via R18 and this subtracts 10000 RPM from the reading.

PARTS LIST – ETI 555

Resistors all ¼W, 5%

R1 . . . . . . .180k
R2 . . . . . . .150k
R3 . . . . 100k
R4 . . . . 1M
R5 . . . . 47k
R6 . . . . 4M7
R7,8 . . . . . . 180k
R9 . . . . 12k
R10. . . . . . . 10k
R11. . . . . . . 100k
R12. . . . . . . 330k
R13. . . . . . . 100k
R14. . . . . . . 10k
R15. . . . . . . 33k
R16. . . . . . . 15k
R17. . . . . . . 4k7
R18. . . . . . . 120k
R19. . . . . . . 1M
R20. . . . . . . 150k
R21. . . . . . . 1k
*R22. . . . . . . 1M
R23. . . . . . . 10k
R24. . . . . . . 2k2
R25. . . . . . . 220k
R26. . . . . . . 4M7
*R27. . . . . . . 100k
R28. . . . . . . 100k
R29. . . . . . . 4M7

Potentiometers

RV1,2 . . . . 50k VTP trim
*RV3 . . . . . 1k, 10 turn trim

Capacitors

C1. . . . . . . 1μ 35V tantalum
C2. . . . . . . 4n7 polystyrene
C3. . . . . . . 1n5 polyester
C4. . . . . . . 100n "
C5. . . . . . . 1μ 35V tantalum
C6. . . . . . . 100p ceramic
C7,8 . . . . . 1μ 35V tantalum
C9. . . . . . . 100n polyester
C10. . . . . . 820p ceramic
C11. . . . . . 3μ3 16V tantalum
C12. . . . . . 1μ 35V tantalum
C13. . . . . . 10n polyester
C14. . . . . . 100n "
*C15. . . . . . 220n "
*C16. . . . . . 100n "
*C17. . . . . . 100p ceramic
C18. . . . . . 10n polyester

Semiconductors

IC1 . . . . . . 4016 (CMOS)
IC2 . . . . . . 301A
IC3 324
*IC4 . . . . . . ICL7106
Q1 . . . . . . 2N5485
Q2,3 . . . . . BC548
D1 . . . . . . BPW34
D2,3 . . . . . iN914

Miscellaneous

PC board ETI 555
toggle switch
pushbutton switch
*3½ digit LCD
case to suit
battery clip
9V battery

* Note; These components are supplied with the Intersil ICL7106EV evaluation kit.

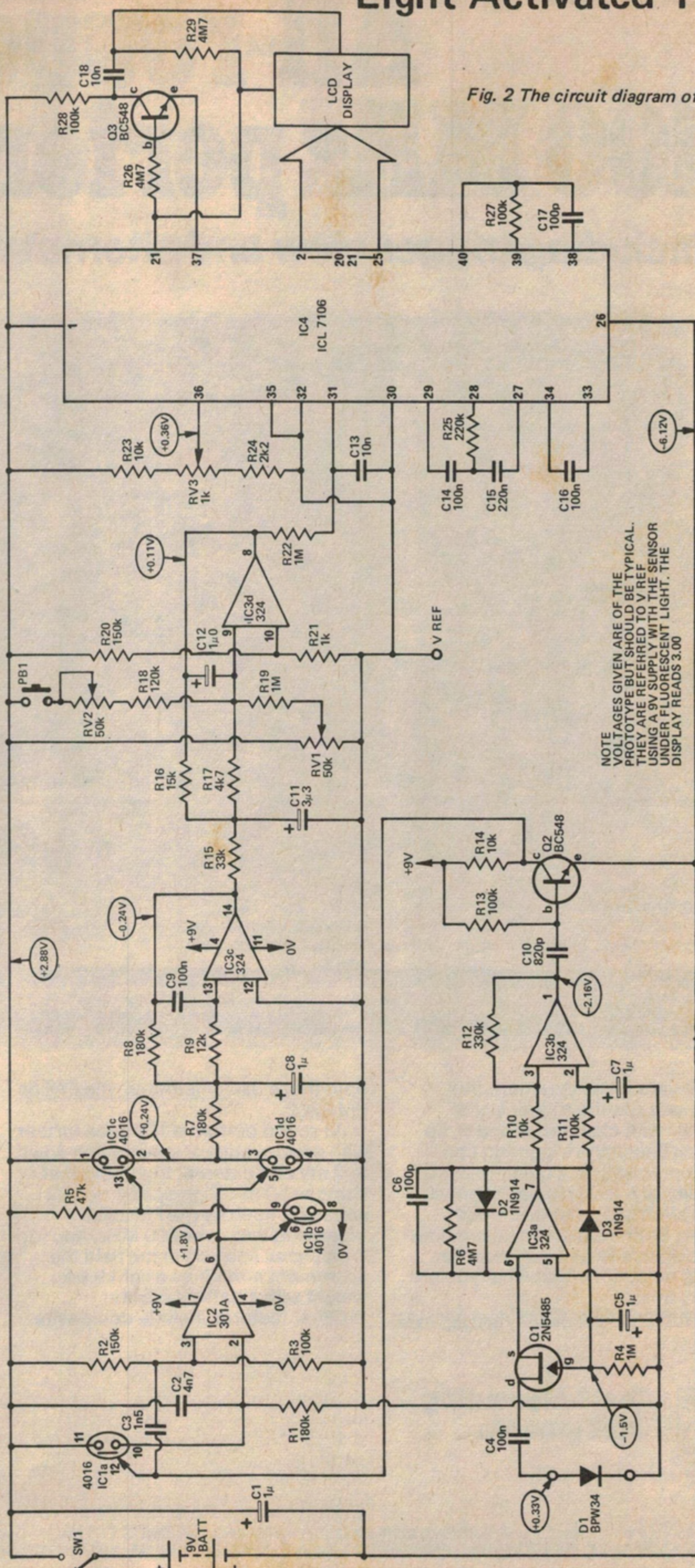


Fig. 2 The circuit diagram of the tacho.