ANEMOMETER

By J.S.HAGGIS

For anyone interested in meteorology, sailing, or just wind speed, the cost of an anemometer is rather high. When the author's son became interested in meteorology, an anemometer was required, so one was constructed using readily available components.

Many commercial remote anemometers work on the a.c. generator principle, that is the faster the generator armature is rotated by the wind force on the anemometer cups, the greater the voltage produced. This has the disadvantage of not giving a linear output, with the consequent difficulty of meter scale production. It also requires about a 5 m.p.h. wind to overcome the resistance of the magnetic poles of the generator before the cups will start to rotate.

With the anemometer described, wind speeds of less than 5 m.p.h. can also be measured, and the scale is linear. The design is suitable for use on sailing yachts, and details are given on how to run the unit from the boat's power supply.

If three anemometer cups are arranged to rotate freely in the wind, and a disc with a number of holes around the periphery is fixed to a shaft being driven by the cups, the holes can be counted as they revolve with the aid of a light source and a phototransistor. This count can then be made to register on a meter.

CIRCUIT DESCRIPTION

When the holes in the rotating disc pass over the phototransistor, light is allowed to fall on the phototransistor (TR1) from the light source, producing a pulse at the collector of TR1 as indicated in Fig. 1, the circuit diagram of the anemometer. The pulse is squared off by transistors TR2 and TR3 which form a Schmitt trigger. The pulse is then differentiated by C2 and R8 to trigger transistors TR4 and TR5 which constitute a monostable. It is arranged by the selection of C2, that the monostable is in its unstable state for 3 milliseconds. This timing is such that at a wind speed of 100 m.p.h. (higher than one hopes to experience) the monostable has time to return to its stable state before the next pulse.

The time of 3 milliseconds is selected to correspond to the disc and hole size described in this article, and any increase or decrease in disc or hole size will have to be compensated for. Meter M1 integrates the 3 millisecond pulses which vary in frequency, but are all of the same duration.

At wind speeds of less than 5 m.p.h. the pulses are detectable on the meter as fluctuation of the needle. The fluctuation can be reduced by fitting a 100μF capacitor (C3) across meter M1; this does not completely eliminate the pulsing, so at very low speeds one can check that the system is not missing pulses by observing a regular flick on the meter.

CIRCUIT POWER SUPPLY

It is essential for consistent reliability to have a good stabilised power supply. The mains power supply in Fig. 2, is stabilised with the aid of the Zener diode D7. It incorporates a series resistor which provides overload protection. When the anemometer is to be used from a 12 volt or 24 volt battery the supply for lamp and circuitry can be as shown in Figs. 3 and 4; all resistors used in these two circuits are wirewound types.

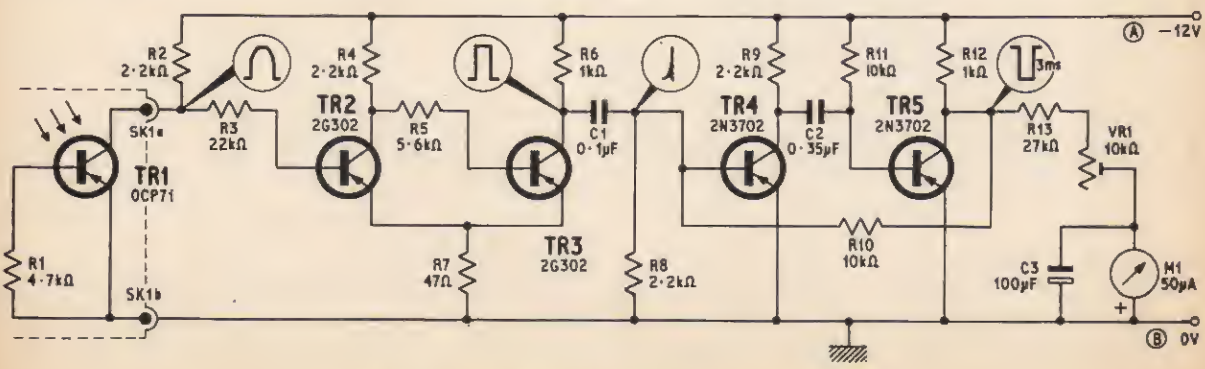


Fig. 1. Circuit diagram of the basic anemometer

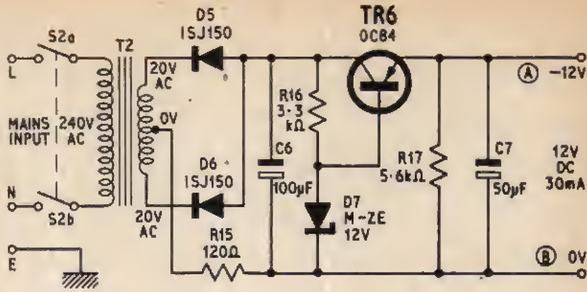


Fig. 2. Mains power supply circuit for the anemometer circuit

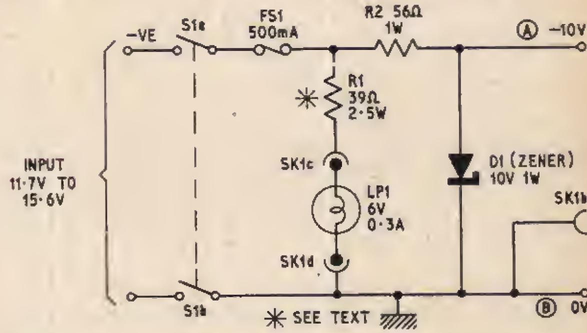


Fig. 3. Power supply to operate the anemometer circuit and lamp from a 12V battery

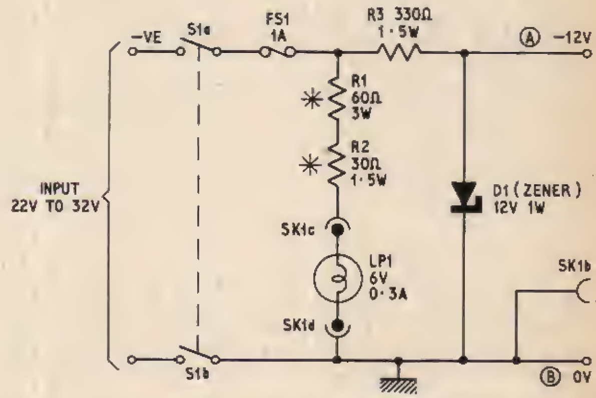


Fig. 4. Power supply to operate the anemometer circuit and lamp from a 24V battery

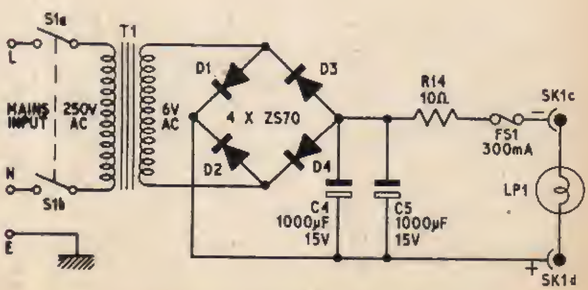


Fig. 5. Mains power supply circuit for the lamp

As can be seen from Fig. 3 the supply circuit for a 12 volt battery only provides 10 volts d.c. to the anemometer circuit. This is so that stabilisation of the 12 volt input can be effected by R2 and D1, the lower voltage will not affect circuit operation providing that the instrument is calibrated at the lower voltage, and not used at a higher voltage afterwards.

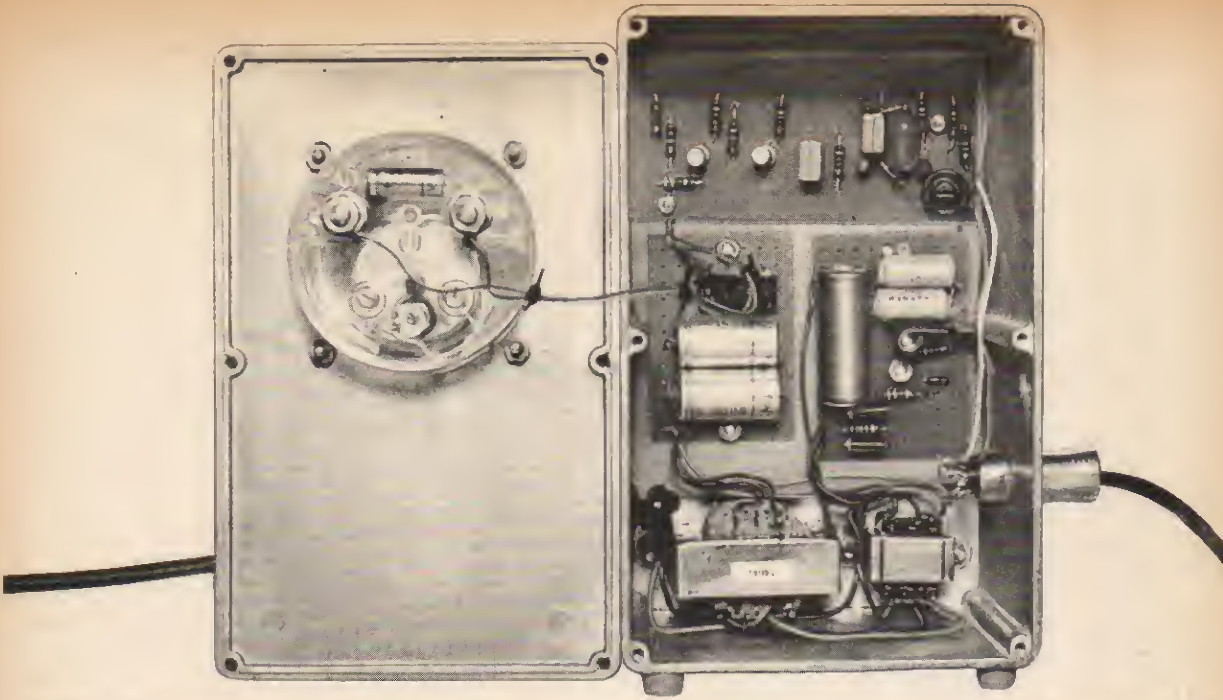
LAMP POWER SUPPLY

A 6·5 volt 0·3 amp bulb is used to illuminate TR1; the voltage on the bulb should be kept as low as possible to increase bulb life. A mains operated circuit for the bulb supply is given in Fig. 5. A good d.c. supply must be used or the anemometer will be unreliable in operation.

The value of R1 Fig. 3, or R1 and R2 Fig. 4, or R14 Fig. 5, depends on the length of wire used to carry the supply to the anemometer; in most cases this will be many yards, therefore an appreciable volt drop can be expected. Bearing in mind the need to keep the bulb voltage as low as possible, the appropriate resistor may have to be slightly adjusted in value, as explained later.

CIRCUIT CONSTRUCTION

The circuit is assembled on a printed circuit board, details of which are given in Fig. 6. Layout is not critical, but that detailed has proved successful. If the



ANEMOMETER CIRCUIT WIRING

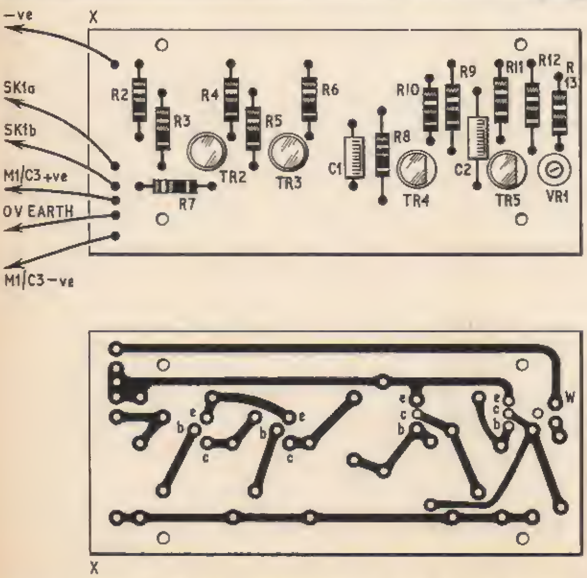


Fig. 6. Layout of the anemometer circuit on a printed circuit board

COMPONENTS . . .

Resistors

R1 4·7kΩ
R2 2·2kΩ
R3 22kΩ
R4 2·2kΩ
R5 5·6kΩ
R6 1kΩ
R7 47Ω
R8 2·2kΩ
R9 2·2kΩ
R10 10kΩ
R11 10kΩ
R12 1kΩ
R13 27kΩ
All $\frac{1}{4}$W, 10% carbon

Capacitors

C1 0·1μF polyester
C2 0·35μF polyester (0·1μF and 0·25μF in parallel)
C3 100μF elect. 12V

Transistors

TR1 OCP71 (phototransistor)
TR2 2G302
TR3 2G302
TR4 2N3702
TR5 2N3702

Miscellaneous

VR1 10kΩ skeleton preset potentiometer
M1 50μA moving coil meter
SK1 Miniature sealed four pin plug and socket
Copper clad s.r.b.p. board 4½in × 2in

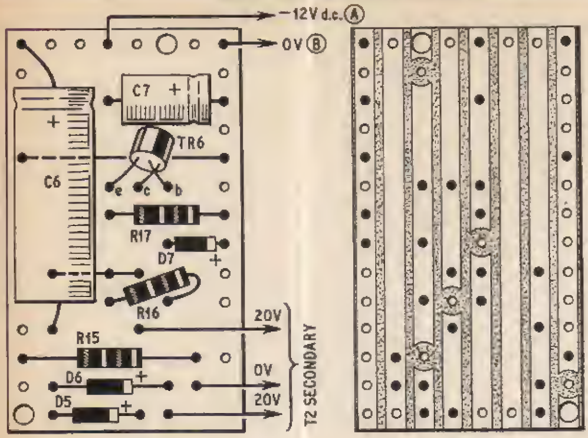


Fig. 7. Layout of the mains power supply for the anemometer circuit using Veroboard

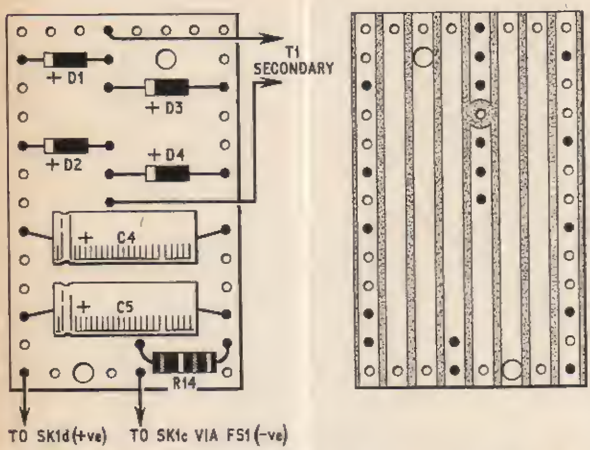


Fig. 8. Layout of the mains power supply for the lamp using Veroboard

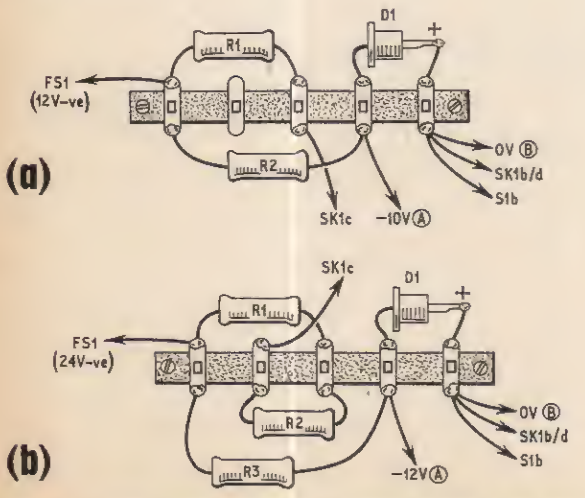


Fig. 9. Layout of the battery supplies using a five-way tagstrip (a) for a 12V battery, (b) for a 24V battery

COMPONENTS . . .

MAINS CIRCUIT SUPPLY

Resistors
R15 120Ω
R16 3·3kΩ
R17 5·6kΩ
All ¼W, 10% carbon

Capacitors
C6 100μF elect. 50V
C7 50μF elect. 25V

Semiconductors
TR6 OC84
D5, 6 ZS70 *or* SX641 *or* DD003 *or* ISJ150 (2 off)
D7 12V 250mW 5% Zener type M-ZE12 (Radiospares) or Z12

Miscellaneous
T2 Miniature mains transformer 220/240V primary 20V–0V–20V secondary (Radiospares)
S2 D.P.S.T. toggle switch
Veroboard 2in × 1¼in, 0·15in matrix

COMPONENTS . . .

MAINS LAMP SUPPLY

Resistor
R14 10Ω (see text)

Capacitors
C4 1,000μF elect. 15V
C5 1,000μF elect. 15V

Diodes
D1–4 ZS70 *or* DD003 (4 off)

Transformer
T1 Miniature mains transformer 220/240V primary 6V, 300mA secondary

Miscellaneous
FS1 300mA fuse and holder
S1 D.P.S.T. toggle switch
LP1 6·3V, 0·3A m.e.s. bulb
Clip on m.e.s. bulb holder (Radiospares)
Veroboard 2in × 1¼in, 0·15in matrix

constructor is not able to etch the component board, then Cir-kit copper strip can easily be made to follow the layout given.

Layout and wiring diagrams for the circuit and bulb supplies are given in Figs. 7, 8 and 9. The two layouts shown in Fig. 9 use tag strips because some of the components may warm up when the unit is in use. It is not normally necessary to provide a heat sink for the Zener diode as this diode will only pass current near to its maximum capability when no current is taken by the anemometer circuitry, and when battery voltage is at its highest.

The circuit boards, M1, and S1 can be mounted in a die cast box, the size of which will depend on the type of power supply used. If the unit is for use on a sailing boat, or will be out in the elements, both the inside and outside of the case should be painted; the lid, supply lead and SK1 should be sealed.

Meter M1 can be any 50μA type available with as large a scale as possible and is best mounted on a rubber

HEAD DETAILS

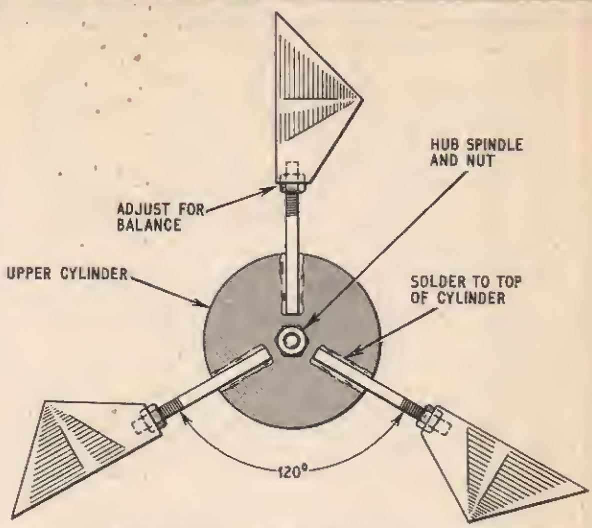


Fig. 12. Arrangement of the cups and arms on the rotating cylinder

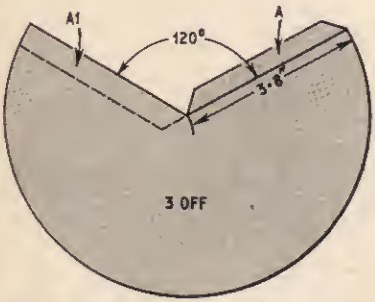


Fig. 10. Development of one cup

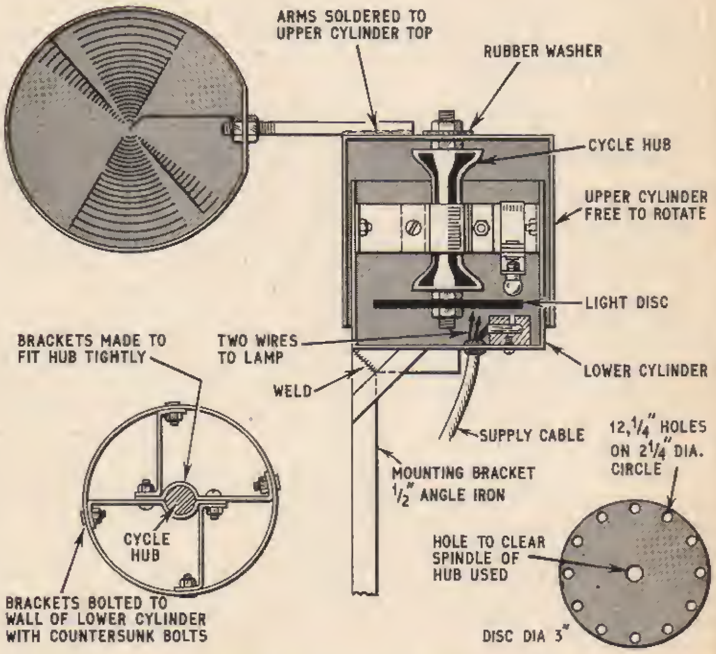


Fig. 11. Construction of the anemometer head, a four core lead out wire is needed

MATERIALS . . .

Brass plate 3½in × 3½in × 1/16in (disc)
Copper sheet 20in × 20in, 20 s.w.g. (cups, cylinders and hub brackets)
Round brass rod 12in × ¼in diameter (cup arms)
Whitworth nuts ¼in 6 off (cup fixings)
Bicycle front wheel hub complete with nuts (see text)
Nylon or rubber washer to fit hub
Countersunk bolts 4B.A., ½in, 4 off (hub bracket fixings)
Round head bolts 4B.A., ½in, 3 off (hub bracket and TR1 block fixings)
Nuts 4B.A., 6 off
Angle iron 12in × ½in × ½in (mounting bracket if required)
Tuffnol 1⅓in × ⅜in × ⅜in (TR1 and R1 mounting)
Diecast case (see text)
Veropins 3 off (TR1 and R1 mounting)

washer. The circuit boards can be mounted on foam rubber to provide shock protection where necessary.

MECHANICAL CONSIDERATIONS

With reference to the *Handbook of Meterological Instruments*, it was found that the best arrangement is an anemometer using 3 cups of 5 inches diameter, the centre of the cups rotating $6\frac{1}{2}$ inches from the axis. As will be appreciated, the aerodynamics of the cups bear some relation to the efficiency of the rotation. The cups described here are not the ultimate in design, but they can easily be constructed and are quite adequate for the job, giving reasonable accuracy to the anemometer.

Ideally, all metal work is best made from copper or brass, as there is then no trouble from corrosion, bearing in mind that the instrument will suffer the worst of the elements.

CUP CONSTRUCTION

A development of one cup is shown in Fig. 10; three of these are required to make the three cups. The copper is bent smoothly round so that tab "A" lies on "A1" where it is soldered in position.

On the edge of each cup, by the joint of tabs "A" and "A1", the shape is slightly flattened to take the arms, as shown in Fig. 11. The arms are made from $\frac{1}{4}$ inch brass rod 4 inches long, threaded at one end. The threaded end passes through a hole in the side of the cup wall near the periphery. One nut either side of the cup wall is used so that the position of the cups on the arms can be adjusted in order that the three can be balanced. It is best not to bolt the cups to the arms at this stage, but to wait until the arms have been soldered to the top of the anemometer body.

BODY CONSTRUCTION

As can be seen in Fig. 11 the body of the instrument consists of two copper cylinders, one fitting over the other. The lower cylinder is fixed, while the upper cylinder is free to be rotated by the pressure of the wind on the cups. The upper cylinder has a diameter of 4·4 inches and is 4 inches deep, while the lower cylinder has a diameter of 4 inches and is 3·6 inches deep. The construction of these two open ended cylinders is quite simple therefore no further details will be given here.

Some form of bearing is required to support the upper cylinder; the prototype unit used the hub from a bicycle front wheel. It is quite important that this hub be in good condition, for if low and reliable wind speeds are to be recorded, there must be very little mechanical friction.

The hub must be secured to the walls of the lower cylinder; this is achieved by making 4 brackets from 20 s.w.g. copper strip as illustrated in Fig. 11. The brackets must be made to fit tightly around the hub—the diameter of the clip will depend on the make of hub used. The brackets should be about 1 inch deep.

The four brackets are bolted around the centre of the hub and placed inside the lower cylinder to ensure that the hub fits precisely in the centre.

The light disc is constructed from $\frac{1}{16}$ inch brass plate as shown in Fig. 11, and is 3 inches in diameter. A hole is drilled in the centre to take the spindle of the hub. Twelve $\frac{1}{4}$ inch diameter holes are drilled around the disc, the centre of the holes being $\frac{3}{8}$ of an inch from the periphery; the holes are set 30 degrees apart. It is advisable to paint the disc with matt black paint when complete, this will stop any chance of light reflections affecting the phototransistor. The inside of both cylinders should also be painted matt black.

ASSEMBLY

The disc is bolted to one end of the hub spindle and the whole assembly, that is the hub complete with brackets and disc, is placed in the lower cylinder leaving a clearance of 0·8 inch between the disc and the bottom of the cylinder. The Tuffnol phototransistor mounting block is situated beneath the disc. No precise measurements are given for the fitting of the hub, because it depends a great deal on the type of hub used. With the hub held in the centre, and with 0·8 inch clearance between the disc and cylinder base, the 4 holes that secure the brackets to the cylinder walls can be drilled through the wall and bracket at the same time. It is necessary to countersink the cylinder holes as much as possible, this being done the brackets can be bolted to the cylinder. The heads of the countersunk bolts are then filed down to conform to the radius of the cylinder wall, to prevent them touching the inner wall of the upper cylinder. The spindle and disc should now spin freely in the lower cylinder.

The upper cylinder is completed by drilling a hole in the centre of the top to take the hub spindle. The arms are soldered in place on the top of the cylinder, they are placed at an angle of 120 degrees to each other, as shown in Fig. 12. The arms are not taken to the centre of the top, as a space is left in the centre to take the nut of the spindle.

When this has been done the cups can be fitted onto the threaded ends of the arms as shown in Figs. 11 and 12. The assembly can now be tried out in position over the lower cylinder by placing the top end of the hub spindle through the hole in the top of the upper cylinder. A nylon or rubber washer is placed over the spindle and the nut is screwed on and tightened; the nylon or rubber washer seals the spindle hole.

The upper cylinder, complete with cups, should be free to rotate over the lower cylinder without touching. Check that there is good clearance between the two all the way round and correct if necessary.

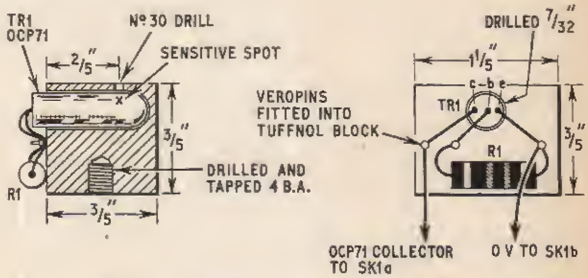


Fig. 13. Mounting block for TR1 and R1

PHOTOTRANSISTOR MOUNTING

Phototransistor TR1 is mounted on a block of Tuffnol as shown in Fig. 13. A $\frac{7}{32}$ inch hole is drilled into the side of the block, as close to the top as possible, this hole is to hold the phototransistor. A second hole is drilled at right angles to the first hole with a No. 30 drill. The two holes connect with each other as shown in Fig. 13. The second hole is to allow light from LP1 to reach the sensitive spot of phototransistor TR1.

In the block, at the rear of TR1, three small holes are drilled to take three Veropins. These pins act as connecting points for TR1 and R1. Resistor R1 is mounted close to TR1 to reduce the number of wires from the anemometer head to the remote circuitry.

A 4B.A. hole is drilled and tapped in the base of the block to secure it to the base of the lower cylinder.

Inspection of the internals of the OCP71 will reveal two junctions, one either side of a flat plate, it is the smaller of these junctions that is sensitive to light, and it is this junction that must be positioned under the small hole in the mounting block. Once TR1 is in position with the sensitive spot placed correctly, a dab of adhesive is applied to prevent the phototransistor from moving.

The bulb to supply the light is mounted in a clip on bulb holder. The clip is pushed over one of the hub brackets, as shown in Fig. 11. It should be positioned close to the disc and directly over the holes.

SETTING-UP

Before any setting up can be completed, the phototransistor block must be secured in position. To do this remove the upper cylinder from the spindle, and remove the hub and bracket from the lower cylinder. Remove the disc from the spindle, and replace the hub, less the disc, and secure. Now position the phototransistor block with its light hole immediately under the bulb and mark its position on the base of the cylinder. Remove the hub and secure the phototransistor block, complete with the phototransistor and R1, to the marked position.

The hole that secures the block to the base of the cylinder can be slightly larger than the 4B.A. bolt as this will allow the block to be finally adjusted. Now re-assemble the lower cylinder.

With the anemometer on the bench, rotate the disc until a hole is directly under the bulb so that light can fall on TR1. Connect the power supply to the anemometer circuit, ensuring the correct polarity, and connect up the bulb supply, using the same length of cable as will be required when the anemometer is installed.

Aim to apply the minimum voltage to the bulb to reliably operate the circuit. In the prototype, the component values shown in Fig. 5 were used. The circuit arrangements shown in Figs. 3, 4 and 5 apply approximately 4 volts to the bulb at the end of 40 yards of 14/0·0076 cable. The d.c. voltage supplied by the circuit of Fig. 5 has a ripple of 270 millivolts.

COLLECTOR VOLTAGE

With light falling on TR1, collector voltage must be less than minus 0·5 volts. If the collector voltage is above 0·5 volts when measured with a d.c. meter, adjust the bulb position, or the position of TR1, until the voltage is correct. In some cases it may be necessary to reposition TR1 in the mounting block. If this fails, then the bulb voltage should be increased by changing the value of R1 in Figs. 3 and 4 or R14 in Fig. 5. Once the voltage has been set rotate the disc to cut off the light, and check that the collector voltage of TR1 has increased to almost the supply voltage. When a battery supply is to be used the above procedure should be carried out at the lowest normal battery voltage.

The upper cylinder complete with cups can now be fitted and revolved. If an oscilloscope is available observe the output from TR1 collector to ensure that the circuit is not missing any pulses. If no oscilloscope is available, connect meter M1 into the circuit with C3 disconnected. Revolve the cups slowly and check that the meter registers regular pulses.

CALIBRATION

At a height of 33 feet above ground level, wind speeds will seldom exceed 70 m.p.h. in this country,

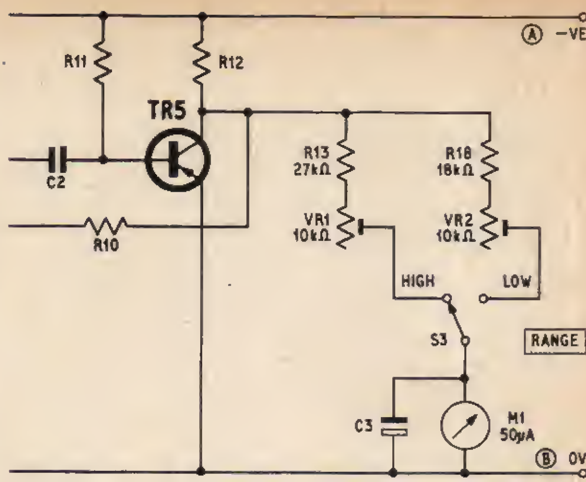


Fig. 14. Diagram of the additional range circuitry

therefore it is suggested that the maximum reading of the meter be 70 m.p.h. If it is required to operate in very exposed areas it may be necessary to have a full scale reading of 100 m.p.h., but the lower the maximum can be kept the better it will be for reading low wind speeds, unless a very large meter is used.

It is possible to add a lower scale to the anemometer by including a range switch and additional resistor and trimmer as shown in Fig. 14. If this is done both ranges will have to be calibrated as described below.

Having decided what maximum scale is required it is necessary to draw the scale on a plain meter backing card, numbering every 10 m.p.h. and marking every single m.p.h. The scale is linear.

The best way to calibrate the instrument is against the reading of an existing anemometer, but an alternative is to calibrate against a car speedometer. To do this a calm day is needed so that the only airflow is that of the cups through still air, and not against a wind adding to the required speed. Hold the anemometer as far away from the car body as possible to get away from any slipstream. With the car travelling at a steady 10 m.p.h. adjust VR1 until the meter of the anemometer reads 10 m.p.h. Then travel at greater speeds to check through the range.

POSITION OF ANEMOMETER

The wind speed near the surface of the Earth varies rapidly with height and is also greatly affected by the presence of obstacles such as trees or houses. The *Handbook of Meteorological Instruments* defines the conditions under which measurements should be made for climatological records, as over open level terrain at a height of 33 feet above ground level. "Open level terrain" is defined as an area where the distance between the anemometer and any obstruction is at least 10 times the height of the obstruction above ground level at the anemometer.

It is unlikely that all constructors will be able to fulfill these requirements, but the position should be chosen with these requirements in mind and a suitable compromise can usually be reached.

The constructor may wish to build the mechanical parts of the instrument in a different manner than that described, or with slightly different dimensions. A pair of small roller bearings can be utilised if this is found to be more convenient than the "hub" system described. ★