PROJECT

Weather Station Part 1

Adding some high-tech to your weather forecasting.

Mike Feather

From the outset, it was decided that the following quantities should be measured: wind speed, direction, temperature, humidity, rainfall, and sunlight. An obvious omission from this list is atmospheric pressure. This can be measured relatively easily using one of the various forms of pressure transducer currently available.

The remaining quantities have been investigated and operational systems for the measurement of the first four are outlined below, with a full description of the construction of the weather station forming the remainder of this article. Systems for measuring the remaining quantities will be described in a future article.

Wind Speed

The Wind Speed or Electronic Anemometer uses a conventional three cup rotating arm arrangement. Speed sensing of the rotating shaft can be achieved by a variety of techniques, but for economy and simplicity of construction, it was decided to employ a disc with peripheral holes rotating in the gap of a slotted opto switch. An outline block diagram for the Electronic Anemometer is shown in Fig. 1.

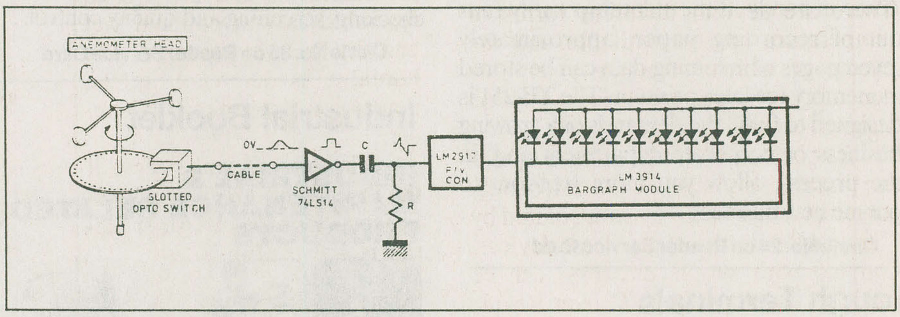


Fig. 1. Block diagram for the Electronic Anemometer (wind speed).

Wind Direction

As with a conventional wind vane, this sensor uses a lightweight pointer that is free to rotate and line up with the wind direction. In this case, the electronic sensing has to detect not the speed, but the angular position of the shaft and vane.

Once again, opto electronic sensing is employed, but this time a coded disc is used which, together with four opto sensors, develops an excess 3-bit Gray code representing the vane position. An explanation of this code and the reason for its use is given in the detailed description of the wind vane section of the weather station. An outline block diagram of the Wind Direction Indicator is shown in Fig.2.

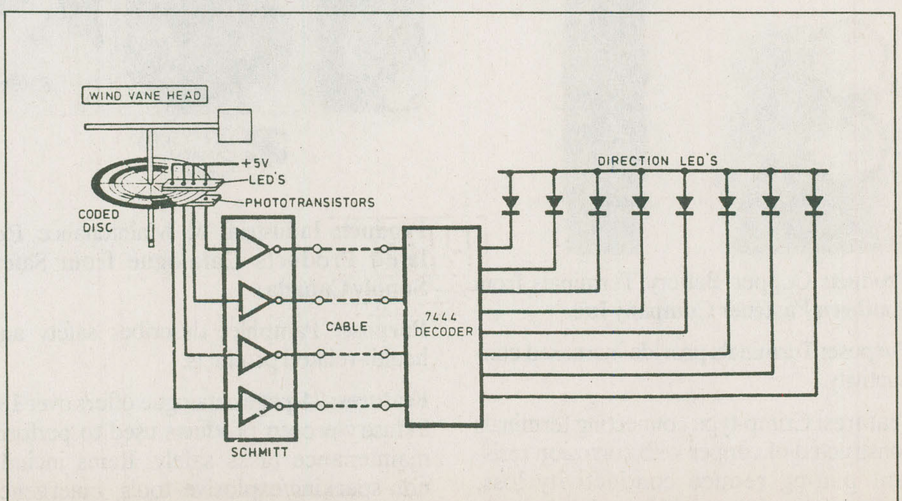


Fig. 2. Block diagram for the Window Direction unit using a coded disc.

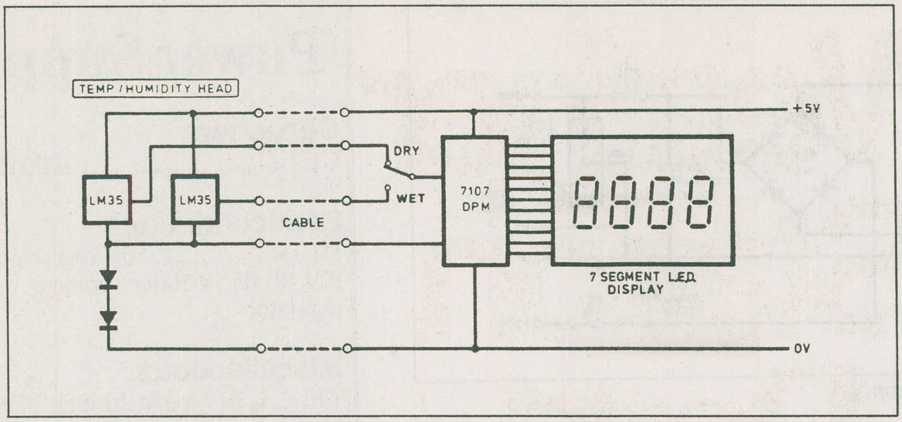


Fig. 3. Block diagram for the Temperature/Humidity unit.

In both the wind speed and direction sensors, the freedom of movement of the shaft is important and a simple low friction bearing system is described in the detailed construction notes.

Temperature/Humidity

There are several different forms of temperature sensor available and the choice of which technique to employ depends upon cost, accuracy, resolution and ease of use.

The best compromise seemed to be to use the relatively new LM35 semiconductor temperature sensors manufactured by National Semiconductors. These devices, coupled with simple circuitry, can be made to develop 10mV/°C over a wide range of temperatures and an important advantage (compared with earlier semiconductor sensors) is the fact that at 0°C, the sensor output is zero — thus obviating the need for providing a large voltage to offset the usual 273mV at 0°C.

A second temperature sensor is employed for humidity measurements and the system resembles a conventional wet and dry bulb hygrometer. The humidity is derived from the depression of the "wet bulb" sensor.

The general arrangement of the Temperature/Humidity sensing sections of the Weather Station is shown in Fig. 3.

Station Displays

The Weather Station Display unit provides instantaneous readout of all the various parameters just outlined and it includes displays, power supplies and any necessary signal conditioning circuitry. A block diagram of the internal circuitry used is shown in Fig. 4 while a possible panel layout is given in Fig. 5.

Power Supply

The system power supply circuit diagram for the Weather Station is shown in Fig. 6. This is a conventional bridge rectifier circuit and provides an unregulated dual rail supply at approximately +/- 20V.

The +5V output is obtained from the voltage regulator IC1. Some smoothing of the two 20V supplies is accomplished by electrolytic capacitors C1 and C2.

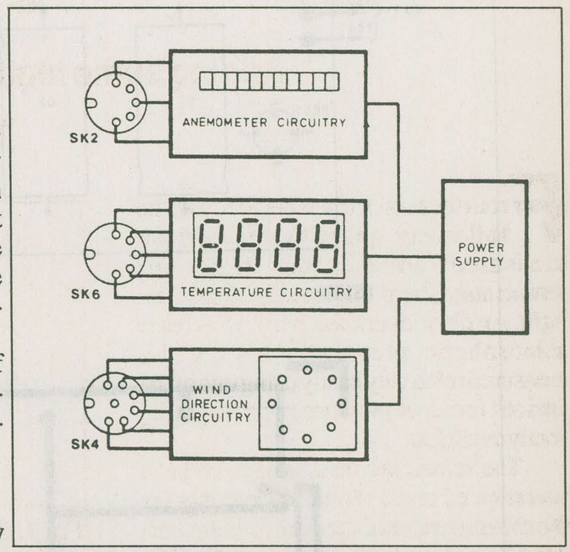
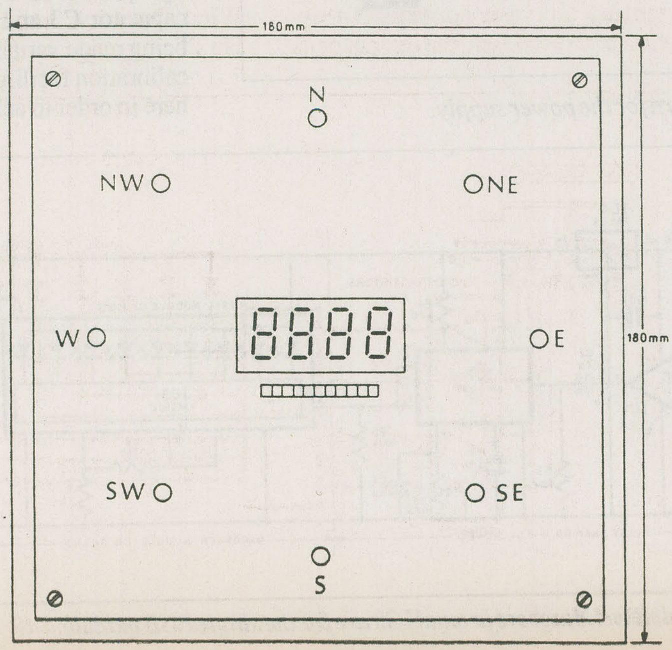


Fig. 4. Overall block diagram for the displays.

Fig. 5. Suggested weather station front panel display layout.



The printed circuit board component layout and full size copper foil master pattern for the Power Supply is shown in Fig. 7. The only points to watch out for are that the two capacitors and the voltage regulator IC1 are inserted on the board correctly.

Anemometer

The full circuit diagram for the Anemometer section is shown in Fig. 8. The circuit is divided into three sections and consists of the remote head or sensor, pulse shaping and frequency to voltage converter, and bargraph display.

The phototransistor of the slotted opto-switch X1 develops crude pulses, the frequency of which is proportional to the shaft speed (see Fig. 1) and hence the "wind speed". The pulses are transferred, via SK1/PL1/— PL2/SK2 and cable, to the display unit where they are applied to the input of one section of a 74LS14 HEX Schmitt inverter, IC1. This produces

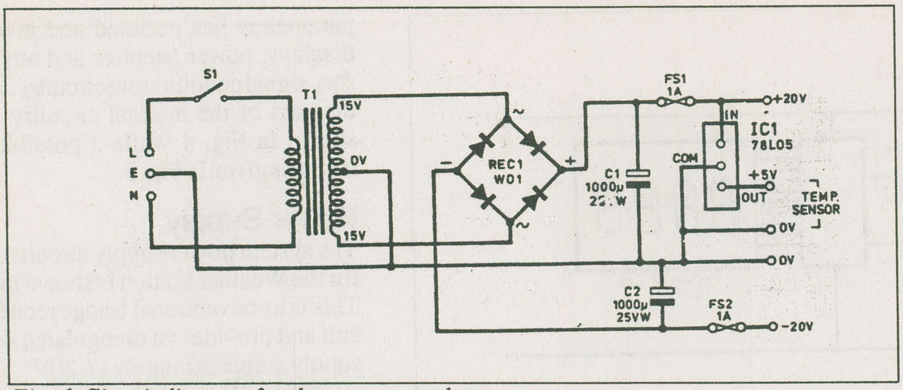


Fig. 6. Circuit diagram for the power supply.

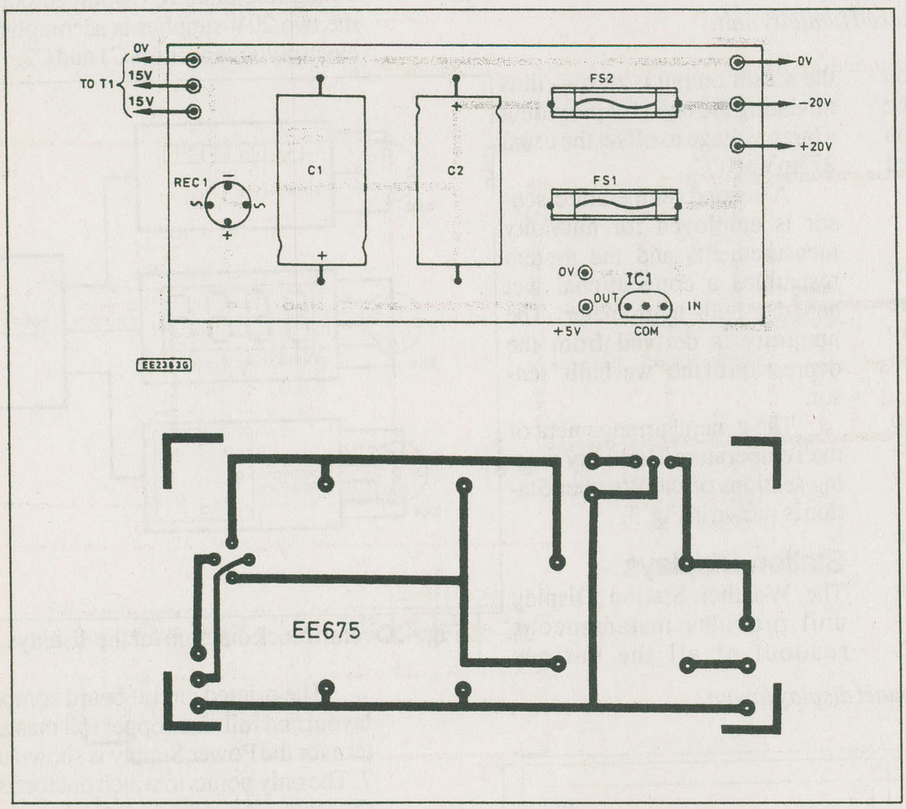


Fig. 7. Printed circuit board layout and pattern for the power supply.

Power Supply

Capacitors

C1,2 .... 1000u25V

Semiconductors

D1-D4 .... 50V 1A bridge rec
IC1 78L05 5V 100mA voltage regulator

Miscellaneous

T1.......... 20VA transformer, 30 VCT

Printed circuit board; FS1,2 1A fast blow fuse; PCB mounting fuse holders; connecting wire; solder, etc.

"clean" rectangular TTL level pulses at its output which is passed to the frequency to voltage converter IC2. A 78L05 voltage regulator IC4 provides the +5V supply to the slotted opto-switch and IC1.

The LM2917 frequency to voltage converter IC2 provides an output voltage which is proportional to the frequency of the input pulses and hence to the speed of the Anemometer head. The input to IC2 must swing above and below 0V in order that the converter can function correctly. This is achieved by the resistor capacitor network C2/R3 which produces an output consisting of positive and negative going spikes of a frequency equal to that of the input pulses.

The relationship between the input frequency and the size of the output voltage produced by IC2 depends upon capacitor C3 and preset VR1, the latter being made variable in order to provide a calibration facility. A 100k preset is used here in order to achieve an output voltage

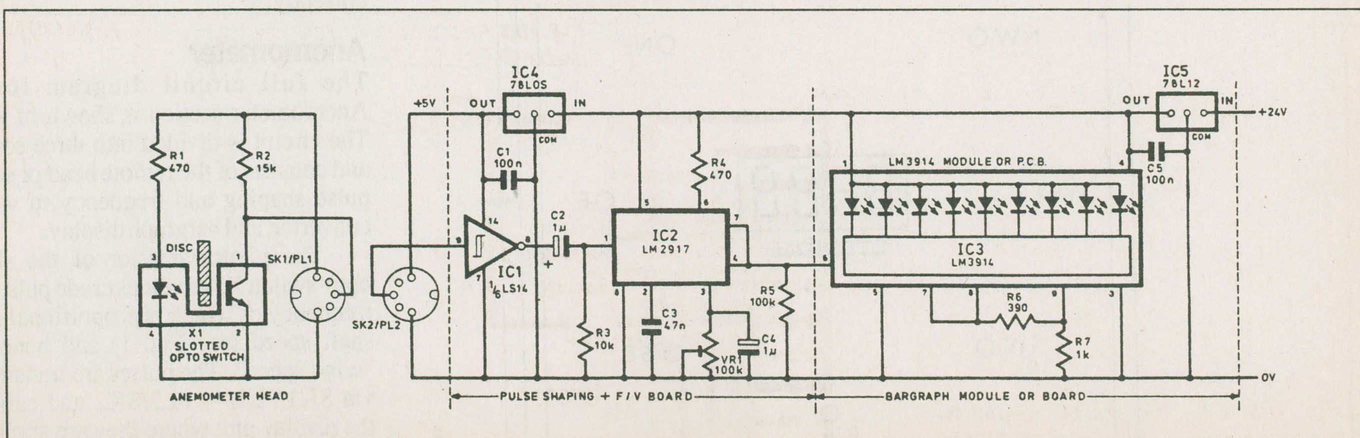


Fig. 8. Complete circuit diagram for the anemometer. Numbers around IC3 are for the single PCB module.

Anemometer (Wind Speed)

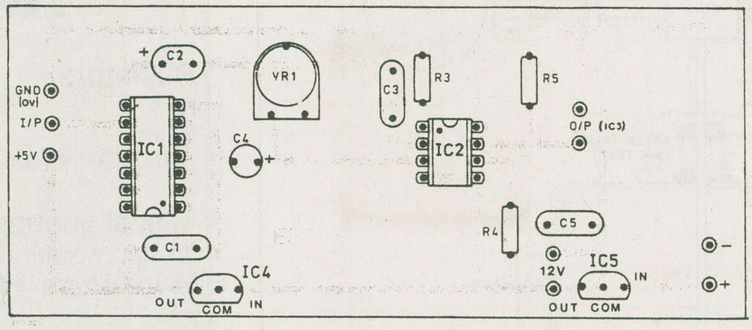
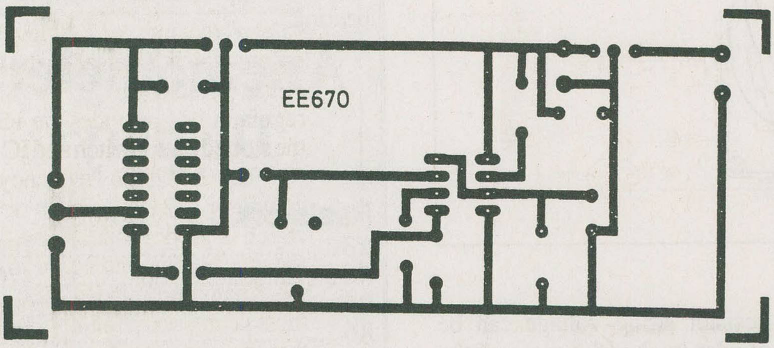
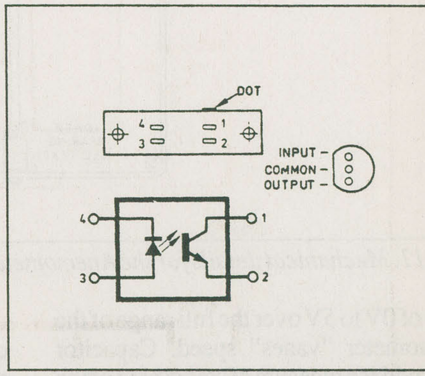
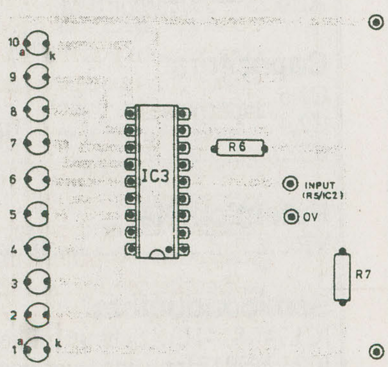


Fig. 9. PCB layout and pattern (below). Connections for the optoswitch X1 are shown below right.







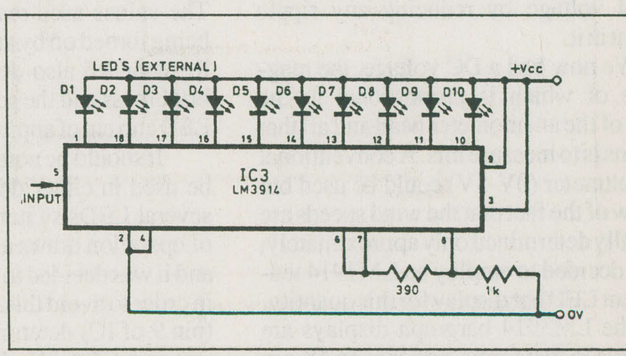


Fig. 10a. Anemometer circuit diagram using the LM3914 IC and individual LEDs.

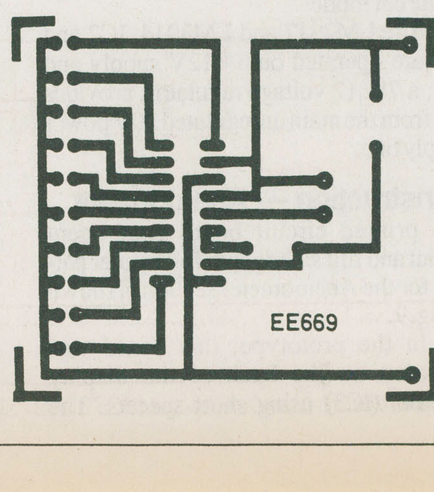


Fig. 10b. PCB component layout for bargraph display using the LM3914 IC and not the module.

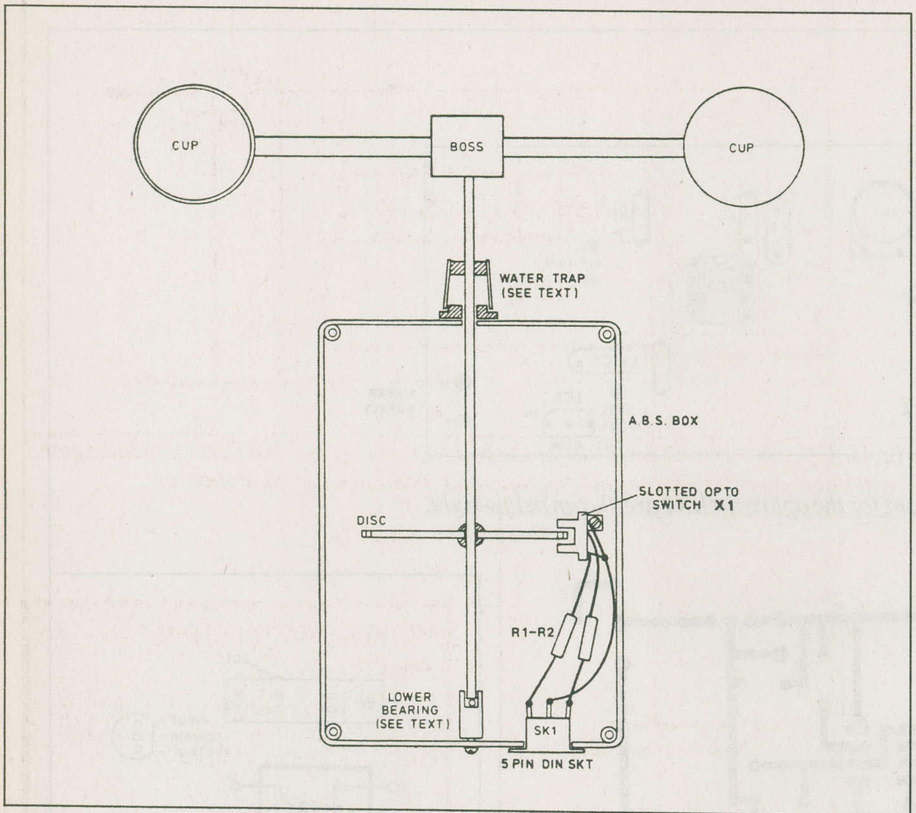


Fig. 11. Mechanical details for the Anemometer head.

range of 0V to 5V over the full range of the Anemometer "vanes" speed. Capacitor C4 provides a measure of smoothing of the output voltage by reducing any ripple present in it.

We now had a DC voltage, the magnitude of which is proportional to the speed of the anemometer head and all that remains is to measure this. A conventional DC voltmeter (0V-5V) could be used but in view of the fact that the wind speeds are normally determined only approximately, it was decided to employ an LM3914 ten-segment LED bar display for this quantity.

The LM3914 bargraph displays are available in two forms, either as an 18-pin DIP chip requiring separate LEDs or as a complete module including both the driver IC and the display LEDs. The prototype employs the latter (IC3), although there is no reason at all why the separate chip and LED alternative should not be used. A suitable printed circuit board design for this arrangement is given in Fig. 10.

The LM3914 IC and module contain a resistor divider network consisting of two precision resistors. A 1.25V reference voltage (developed internally) can be connected across the string and, in this case, each 125mV increase in the input voltage will switch on another of the LEDs.

The resistor string voltage can be changed in oder to alter the range of the device and resistors R6, R7 achieve this. The values used result in the tenth LED being turned on by an input voltage of 5V. Resistor R6 also determines the display brightness and the selected value gives an LED current of approximately 20mA.

It should be noted that the display can be used in either dot or bar mode. With several LEDs switched on, the bar mode of operation draws a considerable current and it was decided to employ the dot mode in order to avoid this. Pin 10 of the module (pin 9 of IC) determines the mode selection and it should be left unconnected for a dot display; connecting it to +V will turn on the bar mode.

The LM2917 and LM3914, IC2 and IC3 are operated on a +12V supply and IC5, a 78L12 voltage regulator, provides this from the main unregulated 20V power supply line.

Construction — Anemometer

The printed circuit board component layout and full size copper foil master pattern for the Anemometer section is shown in Fig. 9.

In the prototype, this board was mounted on the back of the display module, (IC3) using short spacers. The

Anemometer Head

Resistors

R1 470
R2 15k
All 0.25W 5% carbon film.

Miscellaneous

X1 Slotted opto switch
SK1/PL1 5-pin 180° DIN socket and plug
Fibreglass "interrupt" disc see text; push-on control knob for water trap; case; materials for bearing, shaft, arms and wind cups — see text; 4mm ball bearing.

Anemometer Display

Resistors

R3	10k
R4	470
R5	100k
R6	390
R7	1k

All 0.25W 5% carbon film.

Capacitors

C1,5	100n
C2,4	1u 16V
C3	47n

Potentiometer

VR1	100k trim

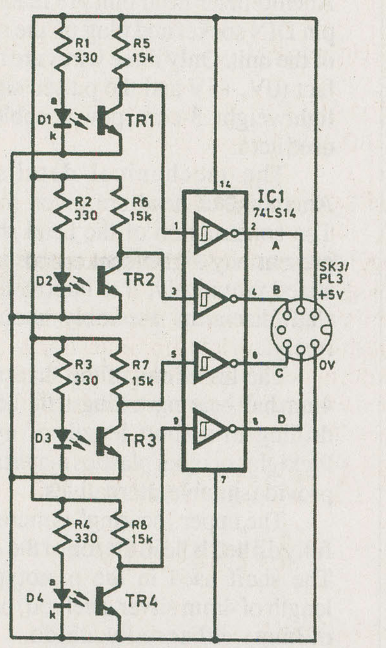
Semiconductors

IC1 74LS14 HEX Schmitt trigger
IC2 LM2917 frequency to voltage converter
*IC3 LM3914 IC or module (see text)
IC4 78L05 5V 100mA voltage regulator
IC5 78L12 12V 100mA regulator
*Ten 5mm LEDs required if IC used.

Miscellaneous

SK2/PL2 5-pin 180° DIN socket and plug

Printed circuit board; 8-pin DIP socket; 14-pin DIP socket; 18-pin DIP socket; connecting wire; solder, etc.



D1-4 OP160, TR1-4 OP500.

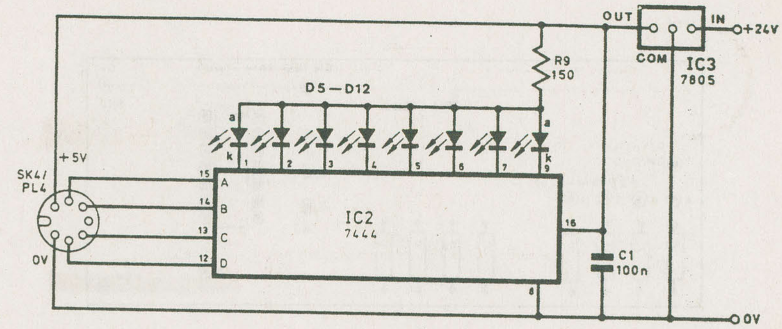
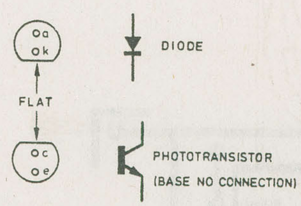
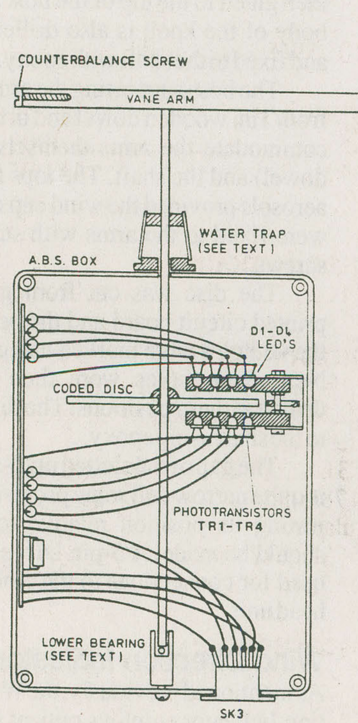


Fig. 12. Complete circuit diagram for the two sections of the Wind Direction Indicator. The connection details for the diodes and phototransistors are shown below.





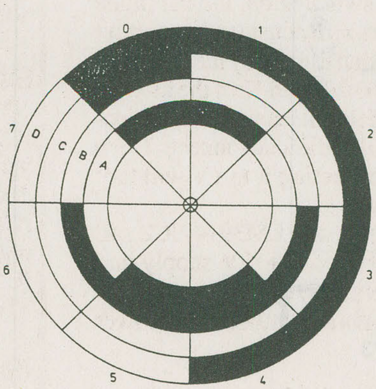


Fig. 16. Full size coded disc.

Fig. 15. Mechanical details for the Wind Direction Vane Head. The sensor bracket holding D1-4 and TR1-4 should be adjustable for aligning with the coded disc.

Wind Direction Vane

Resistors

R1-4 330
R5-8 ....15k
All 0.25W 5% carbon film.

Semiconductors

D1-D4 OP160 .... 3mm infra red LED
TR1-4 ....OP500 phototransistor
IC1 .....74LS14 HEX Schmitt trigger

Miscellaneous

SK3/PL3 7-pin 270° DIN socket and plug
Printed circuit board; case for vane head; 14-pin DIP socket; strips 5mm Plexiglas (see text); coded disc (see text); mounting bracket for sensor strips.

Wind Direction Display

Resistors

R9 150
0.25W 5% carbon film.

Capacitors

C1 ....100n

Semiconductors

IC2 7444 Excess 3-bit Gray decoder
IC3 7805 5V 100mA voltage regulator
D5-D12 5mm red LEDs

Miscellaneous

SK4/PL4 7-pin 270° DIN socket and plug
Printed circuit board; 16-pin DIP socket; LED clips.

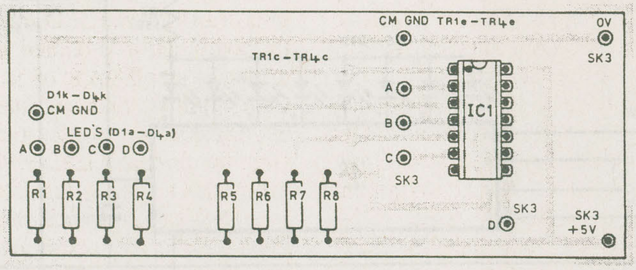


Fig. 13. PCB layout and pattern for the wind vane head.

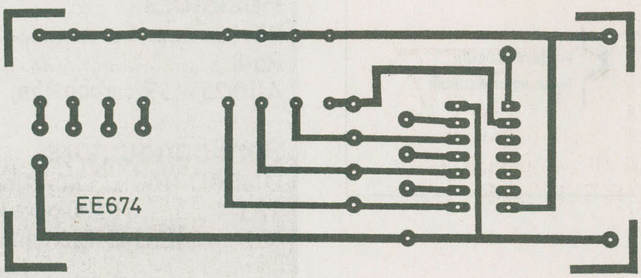
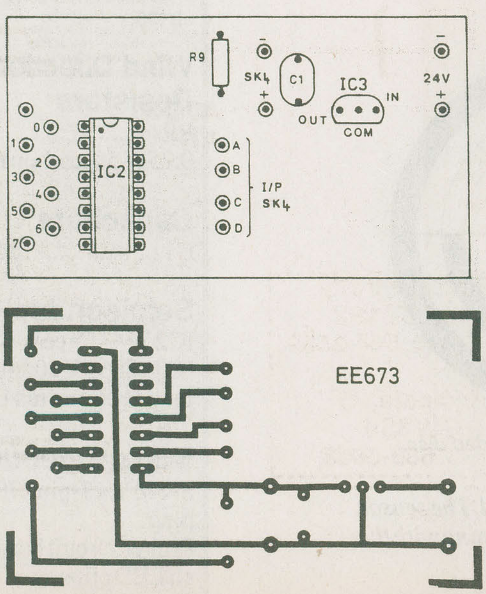


Fig. 14. Component layout and pattern for the wind direction display.



whole assembly was then mounted on the front panel of the Weather Station display with the row of LEDs positioned in a rectangular cutout; see Fig. 5.

Connections to the remote Anemometer head unit are made via a 5-pin DIN socket and plug on the rear panel of the unit. Only three wires are needed in fact (0V, +5V and the pulsed signal) and lightweight 3-core power cable can be used here.

The mechanical details of the Anemometer head are given in Fig. 11. The construction of the head should not present any significant problems, but as stated previously, it is important that the shaft/disc/arms assembly should rotate freely.

The lower end of the shaft rests on a 4mm ball bearing resting at the bottom of a drilling in a short length of nylon rod. Plexiglas or other plastics materials would provide suitable alternatives.

The upper "bearing" is merely a carefully drilled hole in the top of the ABS box. The shaft used in the prototype was a length of 4mm silver steel rod, but a piece of 3mm welding rod would do.

The water trap was fabricated from a cheap plastic push-on knob. The cap is drilled large enough to clear the shaft and then glued to the top of the box. While the body of the knob is also drilled through and fixed to the shaft with epoxy.

The boss supporting the arms was cut from 1in. wooden dowel and drilled to accommodate the arms themselves (3/8in dowel) and the shaft. The tops from used aerosols provided the wind cups and these were fixed to the arms with small wood screws.

The disc was cut from glass fibre printed circuit board and the positions of the 48 holes were marked using dividers. Next 2mm holes were then carefully drilled at these positions. The disc is fixed to the shaft using epoxy.

The gap of the slotted opto-switch X1 is quite narrow and some provision for adjusting its position relative to the disc should be made. A 5-pin DIN socket was used for connections to the Anemometer head unit.

Wind Direction Indicator

As mentioned previously, the Wind Direction Indicator employs optical sensing of the wind vane position. The shaft of the vane carries a four band coded disc which rotates between four corresponding opto-sensors.

An excess 3-bit Gray code rather than

the natural binary code is used. In this, only one digit at a time changes as the disc rotates from one position to the next and such an arrangement is less likely to introduce errors than the binary code, in which two or more digits can change simultaneously. The system used provides an indication of wind direction to within a 45° arc.

The full circuit diagram for the Wind Direction Indicator section of the Weather Station is shown in Fig. 12. The circuit is split into two stages; wind vane head and direction "compass" or display.

Taking the Vane Head first, diodes D1 to D4 are the infra red LEDs, which are sited one side of the code disc, while TR1 to TR4 are the associated phototransistors sited the other side of the disc. The opto-switching outputs from the transistors are fed to four sections of IC1, a 74LS14 HEX Schmitt inverter. The inverters are used to develop the required TTL level outputs for transferring to the display decoder IC2. The signals are transferred via 7-pin DIN sockets and plugs (SK3/PL3- PL4/SK4) and a six-core cable, which also carries the 5V DC supply, to the vane head.

In the display unit, IC2 is responsible for decoding the Gray code into one of the eight possible directions. The 7444 Gray to decimal decoder IC2 is used to turn on the appropriate "direction" LED (D5-D12) according to input code. A 7805 voltage regulator IC3 provides the +5V supply for both the display and head units.

Construction — Wind Direction Indicator

The printed circuit board component layouts and full size copper foil master patterns for the Wind Direction Indicator section are shown in Fig. 13 and Fig. 14.

The mechanical arrangement of the disc and opto-sensors is shown in Fig. 15 while a full size diagram of the disc and its code is given in Fig. 16. Each sensor consists of an infra red LED and phototransistor combination mounted in 3mm holes drilled in small strips of 5mm Plexiglas. Care should be taken with the construction of this assembly in order to ensure correct alignment of each LED with code bands and associated phototransistor.

The disc itself is cut from 3mm *clear* Plexiglas and the sectors are then marked out using dividers. The appropriate sectors are then blacked out using good quality black paint.

The construction of the remainder of the wind vane head is similar to that of the Anemometer and Fig. 15 should be consulted. once again, some provision should be made for adjusting the position of the sensor array relative to the disc.