Digital Anemometer

Impress your neighbours with the very latest in CB antennae.

Contributed by L. H. Mc Cracken

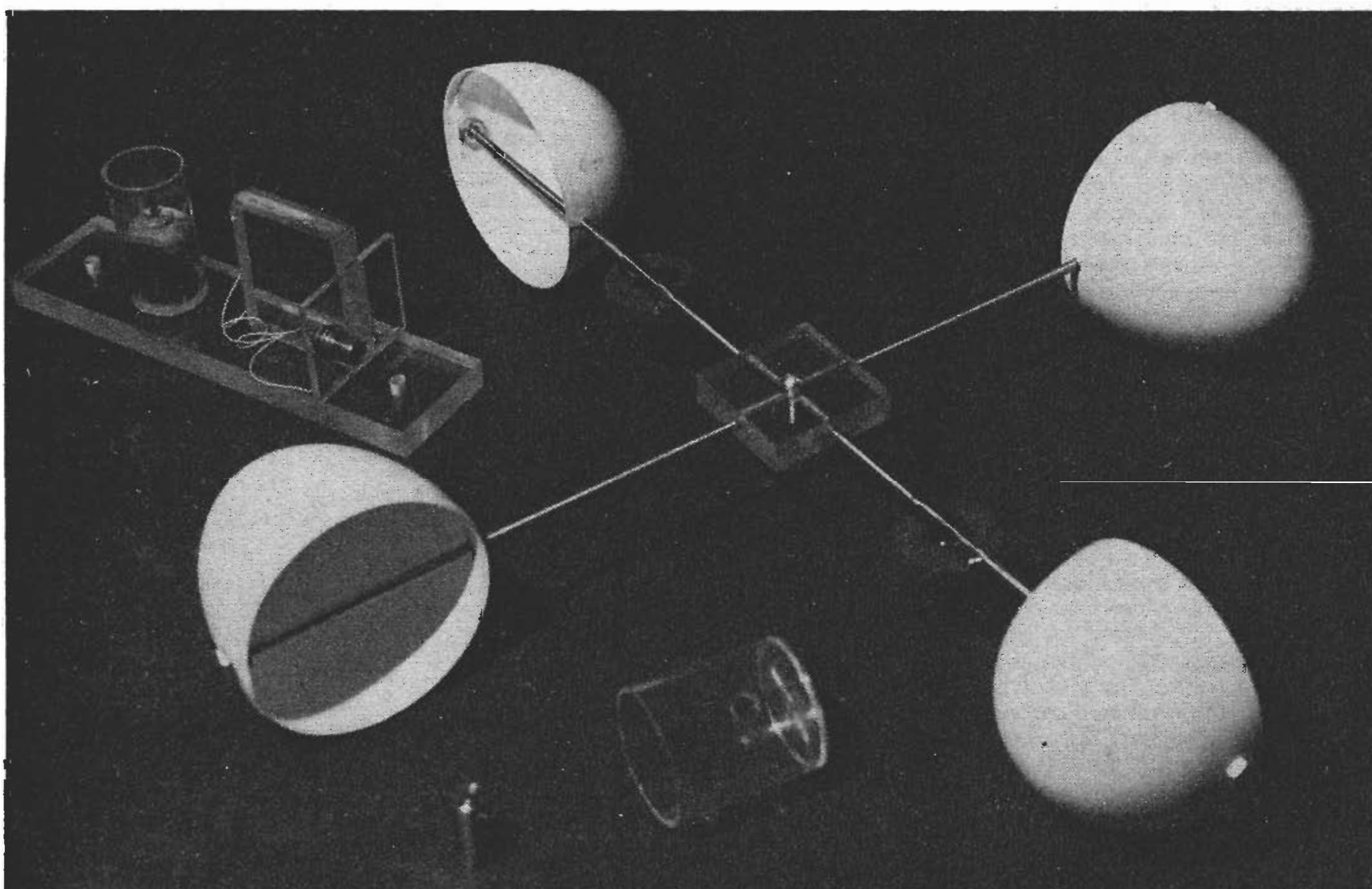
THE OCEANS AND SEAS make up about 75 to 80% of the earth's surface. Yet, there is another ocean that completely evelopes the planet. This is our atmosphere, and like the seas, it is seldom at rest. When certain physical conditions occur, it can be just as destructive as a violent ocean. Of course, this phenomenon is called wind. When both elements are in a highly agitated state, the results can be disastrous to those who dwell on land near the coast, fly in the air, or sail the seas.

Just as hydrographic and/or oceanographic agencies have sophisticated instruments to record and measure the diurnal vagaries of tides and currents, meteorological people have devices to observe properties peculiar to our atmosphere. One of these instruments is the anemometer, a device to measure wind velocities.

WIND SPEED

If you have never seen an anemometer, a visit to your local airport will satisfy your curiosity, look for a device with four cups turning in the breeze. You'll find them on the roof of the meteorological building or nearby. The control tower will certainly have one or two, while others will be strategically located near the ends of the runways, and may or may not have a vane as part of its mechanism to indicate wind direction. Weather ships, and other marine craft have them mounted on the bridge or mast. Depending where in the world you live, the wind speed is reported in knots, or in miles, or kilometers per hour.

Wind velocities are of paramount importance to aircraft pilots during landing and taking off. This is particularly so if the plane is small and a heavy cross-wind is present. Those who sail the wide open seas also have a



keen interest, as well as those who live in areas peculiarly prone to hurricanes and tornadoes. Other interested people, are the fast growing clan of amateur weather observers and kite flying buffs. Hang glider enthusiasts, just before stepping off a sheer mountain cliff, might find a final glance at a portable anemometer most reassuring to life and limb.

TWO TYPES

In general, 2 types of anemometers are commonly available, and although both use wind cups, their circuitry is quite different. The simplest of these, use a tiny D.C. generator whose voltage output is calibrated in terms of wind speed. A more sophisticated device, generates pulses and these are integrated by a capacitor and associated circuitry to produce a voltage proportional to the force of the wind. Both use a meter to indicate wind speeds. While an anemometer can be expensive, and one digital kit on the market can cost an arm and a leg, the project described here can be just as accurate, and with shrewd shopping, can be assembled under $50.00. The device generates pulses, but unlike the sophisticated manufactured type, instead of integrating them with complicated circuitry, it displays them digitally on an easy to read display board.

ABOUT THE PROJECT

The circuit is a simple 2 digit frequency counter. The display board contains all the logic to count from 0 to 99, recycle, and start over again. The larger board contains circuitry to condition the input, generate other logic, and a variable time base. The project can be applied to other counting requirements, see end of text for other suggested applications.

CONSTRUCTION

The wind sensor can be fabricated from a host of materials either found in the average household, or cheaply purchased. The 3/8 inch thick plexiglass used in this project amounted to fifty-cents, including cutting to size, plus 2 plastic vials from a local plastics outlet. The streamlined cups can be small plastic funnels (seal the small open end) or from certain round top spray cans ('Ban'). The prototype, used 'Leggs', the egg shaped containers in which ladies' hosiery is packaged. The rods that support the cups were fabricated from brass welding rod having a diameter of slightly less than 1/8 inch. The rotating shaft and bearing utilized Radio Shack's hobby motor with wiring and brushes removed.

With these ideas in mind, we are sure that constructors will have no difficulty using their ingenuity and materials at hand to make up an appropriate rotor. It should also be noted that a closest distance of 1/8 inch between magnet and reed switch appeared to be very effective.

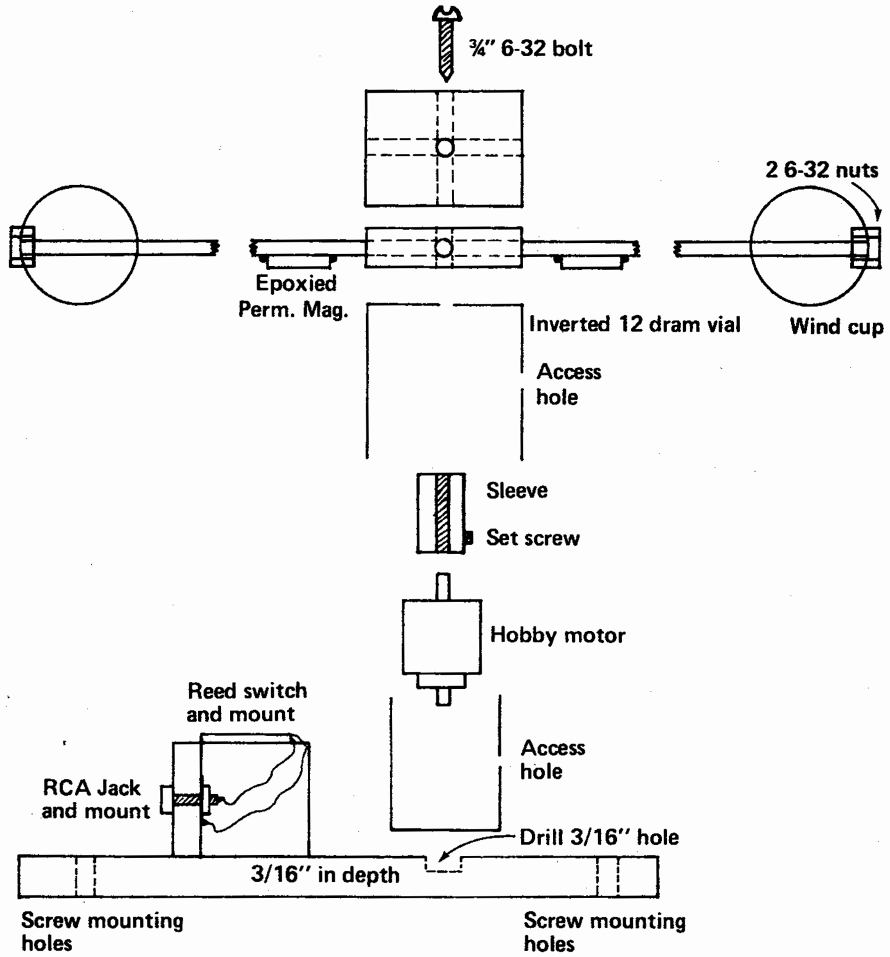
CIRCUIT ASSEMBLY

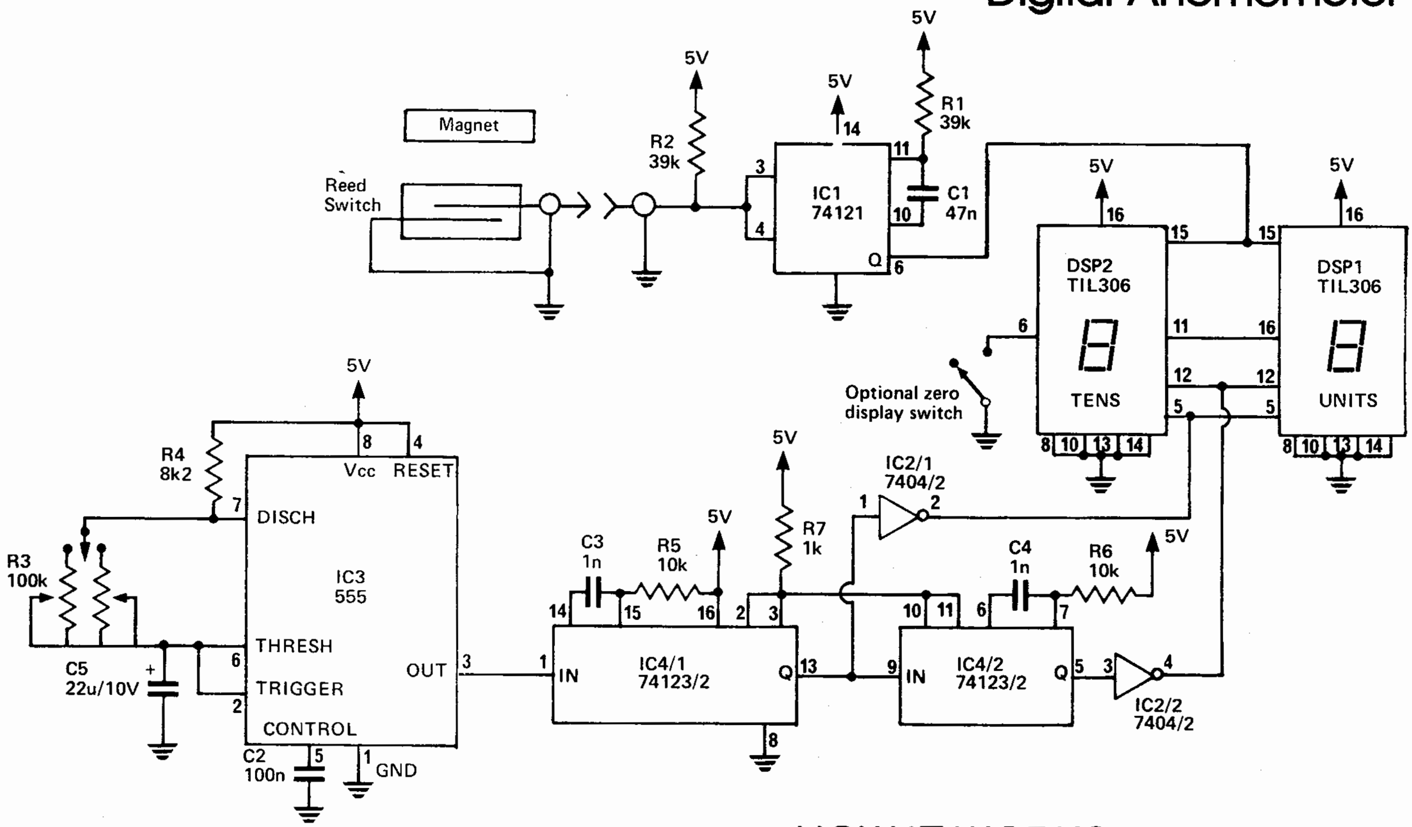
The circuit can be mounted on perf board using point to point wire wrapping techniques. The position of the components is not critical, and most any convenient layout will do. A good ground return is a consideration to be taken into account. All grounded components should be independantly wired to a central point. A narrow strip of copper can be used as a ground return bus, or a piece of heavy copper wire.

The use of the given printed circuit and drilling guides will make assembly an easy and straight forward one, and if you are careful, the project will get up and go the first time power is applied. Placement of parts have been etched on the foil sides of all boards. All resistors and electrolytic capacitors are end mounted, and be sure to correctly orientate all polarized components. Squeeze-throughs (traces between IC pads) have been used extensively, particularly on the display board. The use of a fine tipped low wattage soldering iron should be used to avoid solder bridges in these areas. IC sockets are recommended.

Calibration potentiometer R3 is mounted off board, the rear of the cabinet enclosure is a good place for it. Here, you can elaborate on the circuit. As discussed earlier, this pot is used to calibrate the device in terms of whatever wind speed units please you. By incorporating 2 or more R3s, and suitable switching, you can at will, switch between any of the commonly used methods of reporting wind speeds. The circuit diagram shows 2 calibration R3s with switching. The choice is yours.

Another option is the suppression or display of leading zeros. No connection to the BL pad on the display board results in leading zeros being displayed, and on a calm day, the display indicates 00. With a jumper to ground, leading zeros will be suppressed. Inserting a SPST switch





between the BL pad and ground, the display or suppression of leading zeros can be controlled at will. Again the choice is yours.

A regulated 5 volt supply is required. Two printed circuits are given, one for the house supply, and the other driven by a 7 to 24 volt D.C. source should you decide to have the benefit of an anemometer on board your marine vessel, or require a portable anemometer powered by batteries. The prototype has its sensor on the roof, and power is supplied by a wall type plug in transformer with a D.C. output of 9 volts at 600 milliamps. Using the D.C. driven regulated supply, the entire project was housed in a very small enclosure. In this case, Radio Shack's 270-260.

After installation of the components and you have carefully scanned all solder joints, interconnect both boards matching up the numerals 1,2, and 3 along with ground and 5V supplies. A short piece of 5 conductor ribbon wire makes a neat connection. Mount them in a housing of your choice along with whatever power supply you are using. An off-on switch and an in line fuse should be incorporated.

For an initial test, power up the unit. Temporary jumper the sensor to P1 and ground, and give the cups a spin with your hand. The display should now read out some count,

HOW IT WORKS

The wind force turns a shaft having streamlined cups fastened on four arms. Two diametrically opposed members have permanent magnets securely attached. A small reed switch mounted on a stationary base positioned so that the magnets pass over in close proximity. One complete revolution closes the reed switch twice. The pulses generated by the reed, trigger IC1, a 74121 monostable one shot. IC'1s output, free of contact bounce and other spurious pulses, is connected to the clock inputs of both TIL306 displays.

A variable time base is generated by IC3, a 555 timer connected in the astable mode. The associated circuitry and potentiometer R3 control the frequency output, and are used to calibrate the device against any convenient numerical standard. The time base triggers the first of 2 cascaded one-shots of IC4, a dual 74123 one-shot, generating a latch strobe or update pulse. To accommodate the logic of the TIL306(s), the pulse is inverted by 1/6 of IC2, a 7404 hex-inverter, and applied to the TIL306 latch inputs. Any counts stored in the latches are displayed by the read-outs.

Just after this sequence, the second half of IC4 is triggered, again, after being inverted by another 1/6th of IC2, resets or clears the TIL306 counters to 00, releasing the counter to gather new data (pulses). The net result is a steady flickerless display. Note, 00 is never displayed unless it is a calm day. The strobe and reset sequence takes only a few millionths of a second, hence the interval between the time base pulse, is spent counting the reed switch closures.

The displays may be Texas Instruments TIL306's or TIL307's, the only difference being a left or right hand decimal, and these are not used in this project. If left unconnected (high) the decimal is displayed, if grounded (low), they are blanked. Each TIL306 or 307 contains the four units necessary to display a counter frequency, that is, a BCD counter, a four bit latch, and decoder LED driver all contained in a 16 pin dip package.

Each display contains a feature called ripple blanking. If the number zero is detected in the latches, and the ripple blanking has been enabled (low) the display will be blanked. This function was incorporated to give leading zero suppresion in the counter. Starting from left to right (MSD to LSD), if zero is detected, that display will be blanked and the blanked data will be passed on to the right. Hence, a count of 5 will be displayed as 5, and not 05. The printed circuit board for the displays incorporates this feature and can be controlled at will. See text under options. The utilization of these TIL chips eliminates separate counters, latches, decoder/drivers, 2 LED displays, and 14 resistors, plus a maze of wiring or complicated printed circuit boards.

The use of a hand held calculator will be an aid in converting to other units of measurement. You may find it convenient to make up a table of M.P.H. versus knots or kilometers per hour, or any other combination beforehand.

MPH X 0.8684 = Knots
MPH X 1.6093 = km/h
km/h X 0.6214 = MPH
km/h X 0.5396 = Knots
Knots X 1.1516 = MPH
Knots X 1.8553 = km/h

gradually diminishing as the cups slow down. The rate of numerical change (up-date) will be a function of the setting of the R3 pot (s).

CALIBRATIONS

Securely mount the sensor on the roof of your car, and using temporary jumpers that are long enough to reach inside the car, connect to P1 and ground. If your unit is using the D.C. driven regulated supply, connect to a 12 volt lantern battery. Observe proper polarities. If you are using the house powered regulated supply, connect the positive side of the 12 volt lantern battery to pin 1 of the LM309K, and any convenient ground.

Have a friendly neighbor drive your car on a quiet street at a steady even rate when there is little or no wind. Adjust R3 until the display agrees with the speedometer, or if you are calibrating in knots or kilometers per hour, the readouts display the speedometer reading times the appropriate conversion factor. If more than one R3 pot has been incorporated into the circuit, switch it in, and carry on with your calibrations. When you are finished, apply a drop of epoxy to the rotor (s).

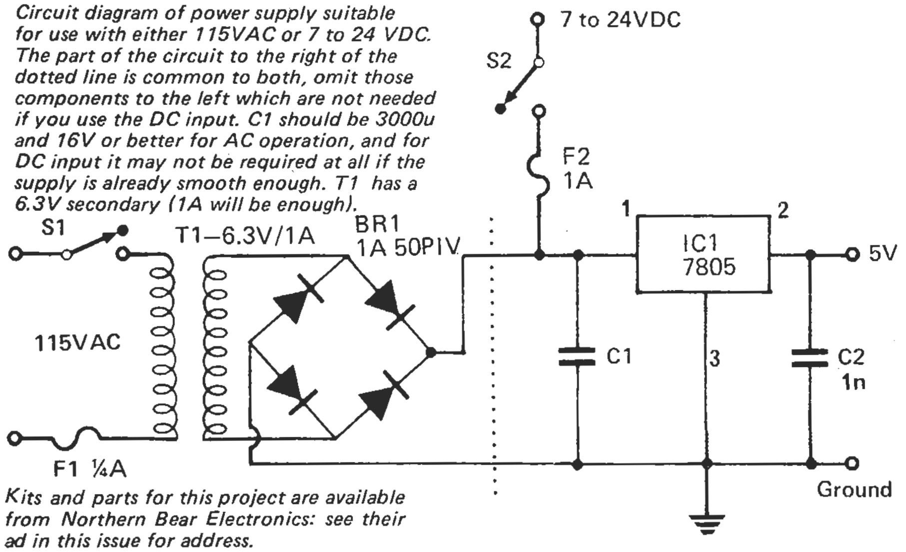
INSTALLATION

If you plan to use the device in your home, mount the sensor on the roof or in any other convenient location that will be free of obstructions. For marine use, mount the sensor on the bridge or mast. Terminate both ends of a suitable length of shielded audio cable with phono plugs and connect between the sensor and the enclosure. Be sure to weather-proof the plug and jack that is exposed to the elements.

OTHER USES

The circuit can be used in a great many other counting applications. If a digital anemometer is not for you, perhaps a digital speedometer for your car, motor bike, or that new ten speed bicycle might be of interest. No circuit changes are required, simply mount the perm mags on the rim of the wheel, and position the reed switch nearby. If the rim is ferrous, it will distort the magnetic field, hence an insulating block of wood or plastic should be inserted between the magnet and tire rim. Use a good strong adhesive. Calibrations are the same as previously outlined, only this time, wind is not a factor. You might find it convenient to calibrate in terms of kilometers per hour, since all speed limits will ultimately be posted using this portion of the metric system. Fifty miles per hour for all intents and purposes is equivalent to 80 kilometers per hour. When your bicycle reaches 100km/h., about 62.2 mph, the display will either blank or read 00, depending on the leading zero option. Simply add 100 to any reading thereafter.

Circuit diagram of power supply suitable for use with either 115VAC or 7 to 24 VDC. The part of the circuit to the right of the dotted line is common to both, omit those components to the left which are not needed if you use the DC input. C1 should be 3000u and 16V or better for AC operation, and for DC input it may not be required at all if the supply is already smooth enough. T1 has a 6.3V secondary (1A will be enough).



Kits and parts for this project are available from Northern Bear Electronics: see their ad in this issue for address.

PARTS LIST

PARTS LIST FOR ANEMOMETER

CAPACITORS

C1	47n
C2	100n
C3,4	1n
C5	22u/10V

SEMICONDUCTORS

DSP1,2	TIL306 Texas Instruments
IC1	74121
IC2	7404
IC3	555
IC4	74123

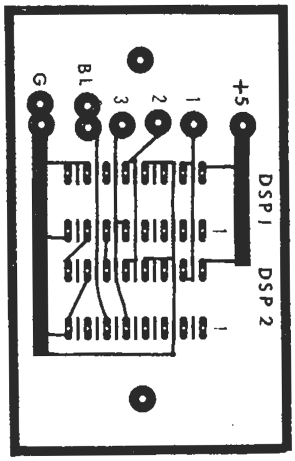
RESISTORS

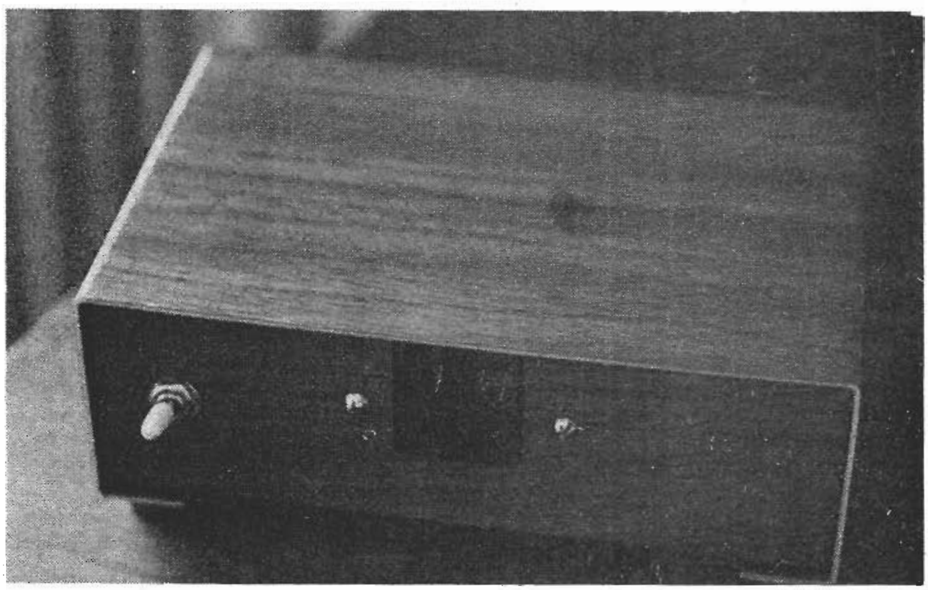
R1,2	39k
R3	100k pot or fixed resistor of your choice
R4	8k2
R5,6	10k
R7	1k

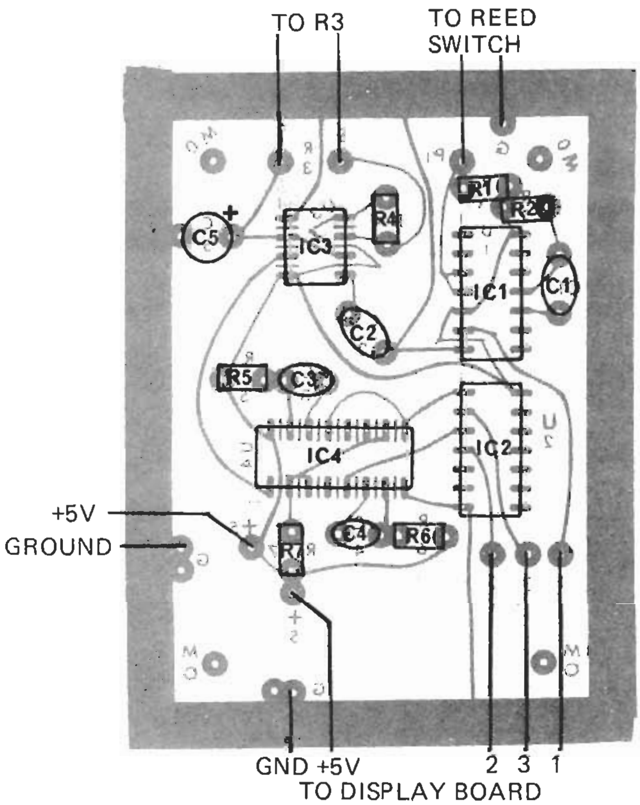
SWITCHES as required
MISCELLANEOUS hardware

Electrical Components of Anemometer Wind Rotor

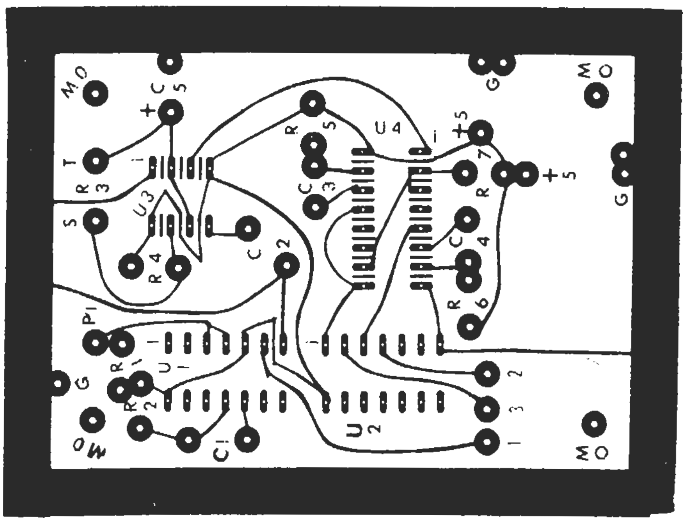
1	Reed Switch (Radio Shack 275-035)
1	'Hobby Motor' (Radio Shack 273-217
2	Magnets (Radio Shack 64-1885, or use those out of motor)

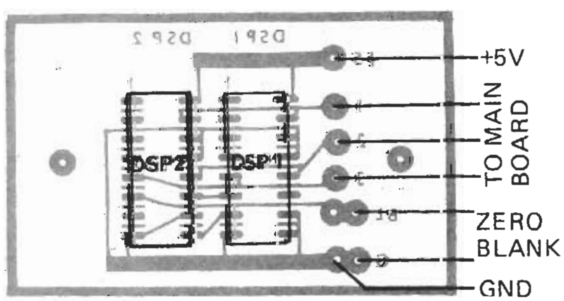






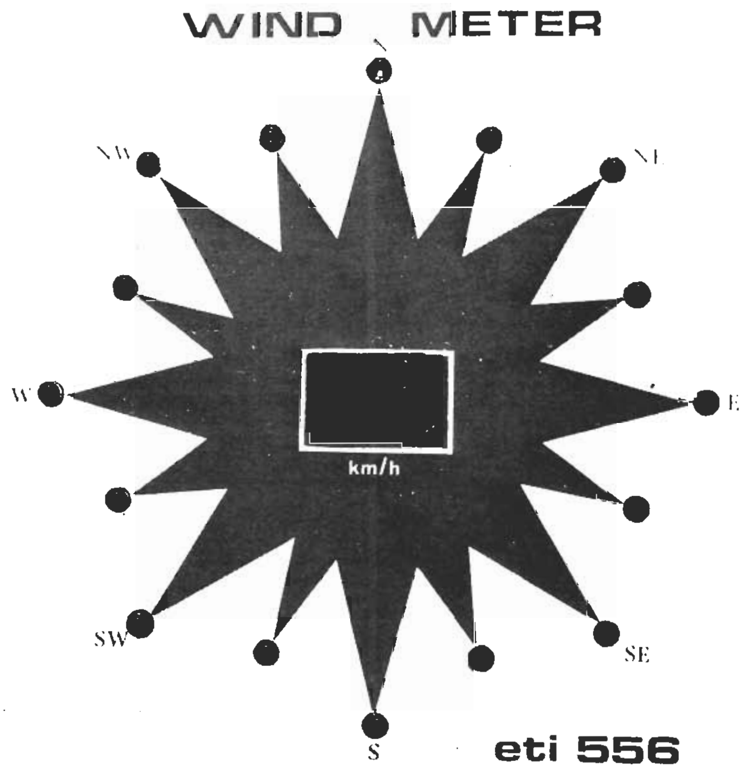
Component placement diagram for main and display boards.





WIND METER

Here is the project all you amateur meteorologists have been waiting for. When this meter gets the wind up you'll know how fast and where it's coming from.



TRADITIONALLY, THE FOUR primary elements are fire, earth, water and air. At ETI, we've designed projects concerned with the first three (temperature meters, soil moisture indicators, rain alarms), but not much for the last. The major property of the air, apart from the fact that it is necessary to support life, is the movement of the air — wind. Light winds generally aren't of terribly much significance except to meteorologists, but stronger winds can be useful as a source of power; for traditional milling, for electricity generation or as a means of propulsion for sailing yachts. Stronger winds such as hurricanes, can be destructive, causing damage to life or property.

So for all the private pilots, yachtsmen, amateur meteorologists and general weather watchers who read ETI, here is a device which will tell you the wind's speed and direction, with a remote indication of both quantities. Our design is, we'd like to think, both stylish and unusual, but there are simpler methods of mechanical construction which you can follow if you wish.

The Head

The drawings along with the photos will give the general design that we used. The actual dimensions have to be left to the individual constructor as components such as the ball races and light bulbs may vary in size.

While we used a single head for both speed and direction, it may be simpler to use separate heads.

The discs we used were 1.5mm thick clear plastic with a piece of photographic film glued onto it. It may be easier to make it out of thin aluminium and cut out the slots. For the speed disc simply drilling holes will suffice.

The most important part of the design, apart from ensuring that the discs rotate with a minimum of friction, is the shielding of the light and preventing light scatter striking a transistor which should be dark. As can be seen from the photos and diagram the bulbs and transistors are embedded in aluminium blocks with small holes providing a passage for the light beam.

The wiring of the head is shown in fig. 3. Note that the base lead is not used and can be cut off close to the body. Insulate the joints onto the transistors to ensure that they do not short on the aluminium blocks. The bulbs may touch the block with their outer connection but this is the 0 volt line and does no harm. In fact it provides some electrical shielding for the leads. The bulbs we used were 12V but they were bright enough on 6V giving a much longer life.

Design Features

When we started design on this project it was to have a digital readout of wind direction with a resolution of either one or two degrees. This would also make it useful in a sailing boat to tell the wind direction relative to the heading.

Difficulties however soon became apparent. The first of these was the sensor head. The only accurate method is a digital head, probably optical. Two methods could have been used, one using a disc with a single optical track of 360 slots and an updown counter and the second using eight or nine tracks in a grey code. The first is simpler in head design but the second is less prone to error. The problem, and the reason for rejecting both, is that with such resolution, the reading would move around so much when the wind is gusty to be unreadable. What is needed is an averaging circuit which unfortunately becomes ▶

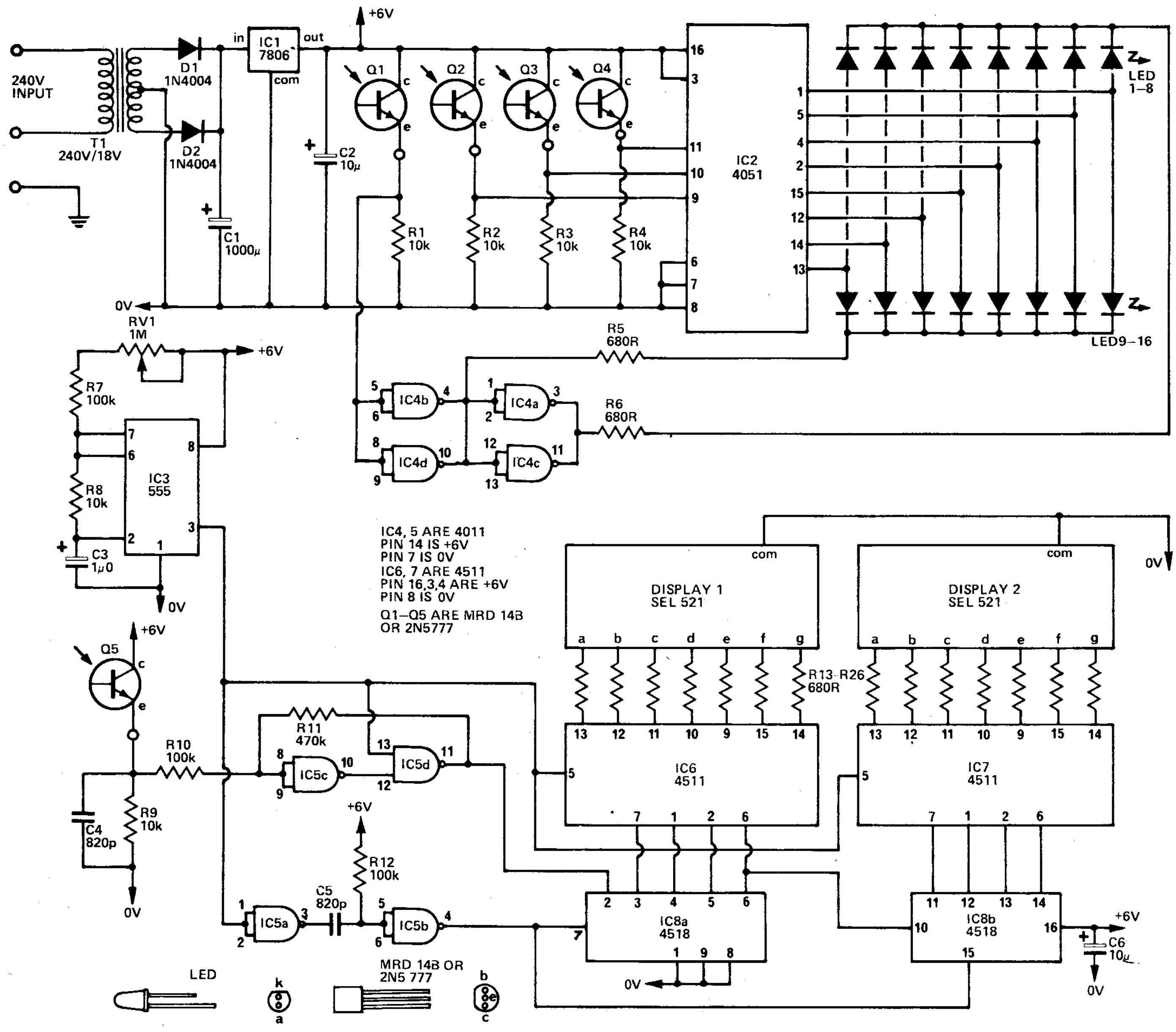


Fig. 1. Complete circuit diagram of the ETI Wind Meter

difficult when the wind is changing from just west of north to just east of north. i.e. 355 to 005. How do you average these (use a microprocessor?).

As this was intended to be a simple project we relaxed our original speification, deleting the use in a boat (we may get back to this. problem. A four track 'Grey' scale allows the wind to be given to within 11° of its true heading, without the complexity of a nine track one, and the use of LEDs to give direction solves the problem of averaging as the variations can be seen and averaged by the brain.

Construction

The electronics is relatively simple provided the PCB described is used. Due to a height limitation C1 should be mounted on the rear of the board. The LEDs should be mounted about 7mm from the board with care being taken not to damage them as the leads have to be bent out slightly. The regulator also has to lie down to give clearance.

We mounted the unit behind an aluminium front panel with the LEDs protruding through holes. If this is to be done it is preferable not to solder the LEDs until after alignment with the front panel.

The head is more difficult as some mechanical ability is necessary to ensure good results. The requirements are basically simple. A disc is to be allowed to rotate, either continuously with the wind or aligning it to the wind, with a bulb on one side and phototransistors on the other.

The method used by us is shown in fig 4 with the aluminium blocks providing the shielding necessary to give accurate results. As the unit will be exposed to the weather it must be made waterproof otherwise the ball races will corrode. The races used ▶

HOW IT WORKS

Wind Direction

Wind direction is indicated by a series of 16 equally spaced LEDs around a circle. These represent the main points on the compass. These are controlled by IC2 and IC4 which are in turn controlled by the direction sensor head.

The sensor head, which is described in fig. 3, consists of a disc which has four optical tracks and four bulbs and phototransistors. The phototransistors sense either a clear disc (logical "1") or a black disc (logical "0") and thus control IC2 and IC4. The code used is special in that only one bit is changed at each location eliminating gross errors which occur with the binary code if the heads are not perfectly aligned. An example of this is going from location 7 (0111) to location 8 (1000). If this is not done simultaneously almost any location can be specified. With the grey code the same change is from 0100 to 1100. Here there can be no ambiguity as only one bit is changed. Remember these bits are *not* weighted similarly to binary and a lookup table must be used to decide what number (decimal) a particular code is.

The decoder, IC2, is an eight output analogue demultiplexer with the common line joined to the +5V line. When a particular 3 bit code is presented to its control inputs one of the eight outputs will be joined to the +6V line. The fourth output from the sensor head controls IC4 which gives two, inverted, outputs to drive either bank of LEDs. The complete four bit code therefore specifies a particular LED to be lit. By placing the LEDs correctly around the circle the grey code is decoded.

Wind Speed

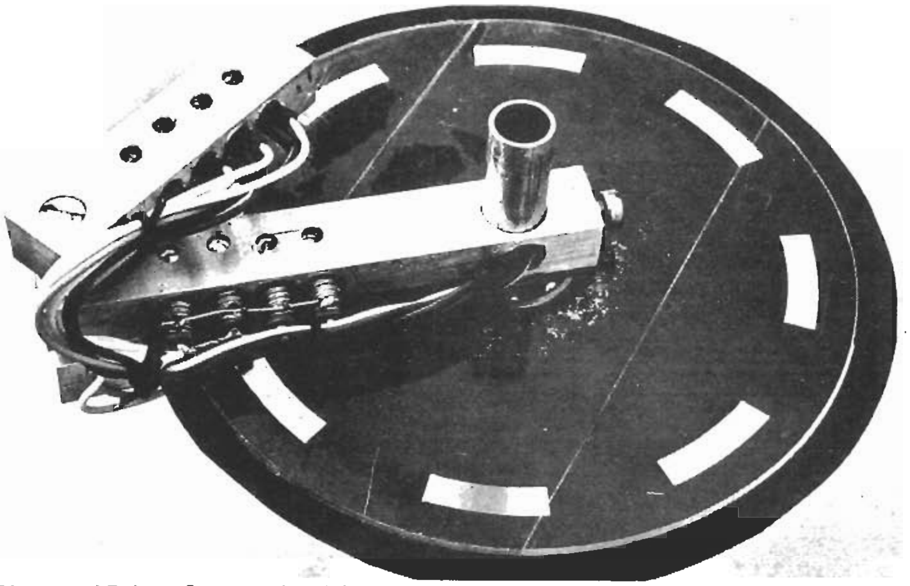
This is a simple frequency counter measuring pulses from the sensor head. The head consists of a disc with eight holes whichbreaksa light beam to its associated phototransistor. The output of this phototransistor is squared up by a schmitt trigger formed by IC5c, and IC5d.

The counting is done by IC8a and IC8b (a dual decade counter) with IC6 and IC7 providing the store and LED drivers necessary to drive the seven segment display. Time base is provided by IC3 which gives a 7 mS wide negative pulse about every one second. We say about as it is adjustable by RV1 as individual heads will have different responses and calibration will be necessary.

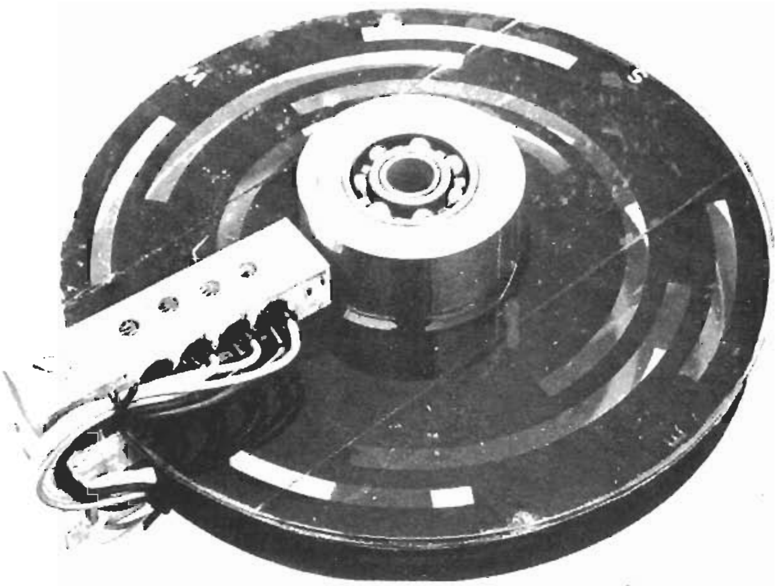
This negative pulse opens the store to allow the number reached by the counters to be displayed while simultaneously stopping any further counting by disabling the schmitt trigger. On the completion of the 7mS pulse IC5a, and IC5b generate a 50uS wide pulse which resets the counter ICs to recommence the sequence.

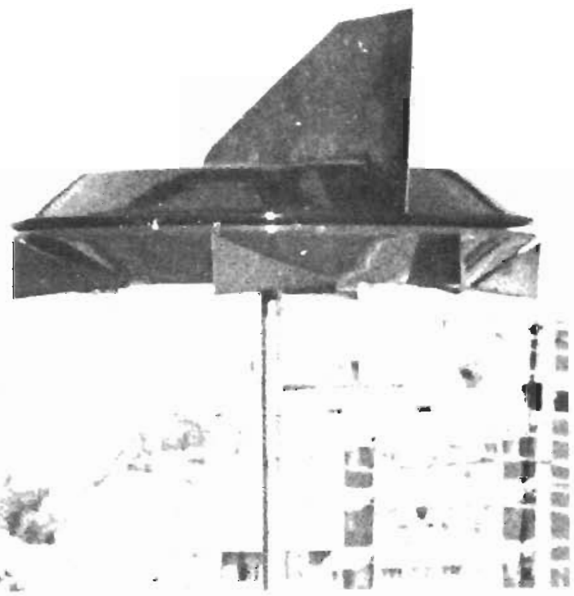
Power Supply

This is simply a full wave rectified supply with IC1 giving a regulated +6V output. This regulation is needed to ensure that the time base (IC3) remains accurate.

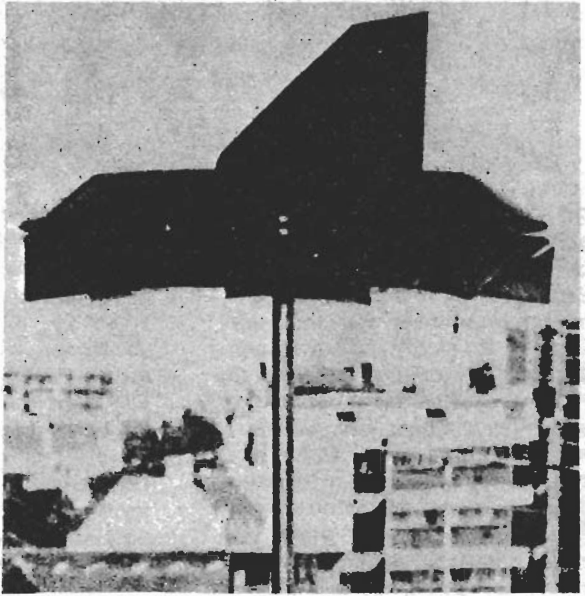


Above and Below: Constructional details of the sensor head





The finished unit in use



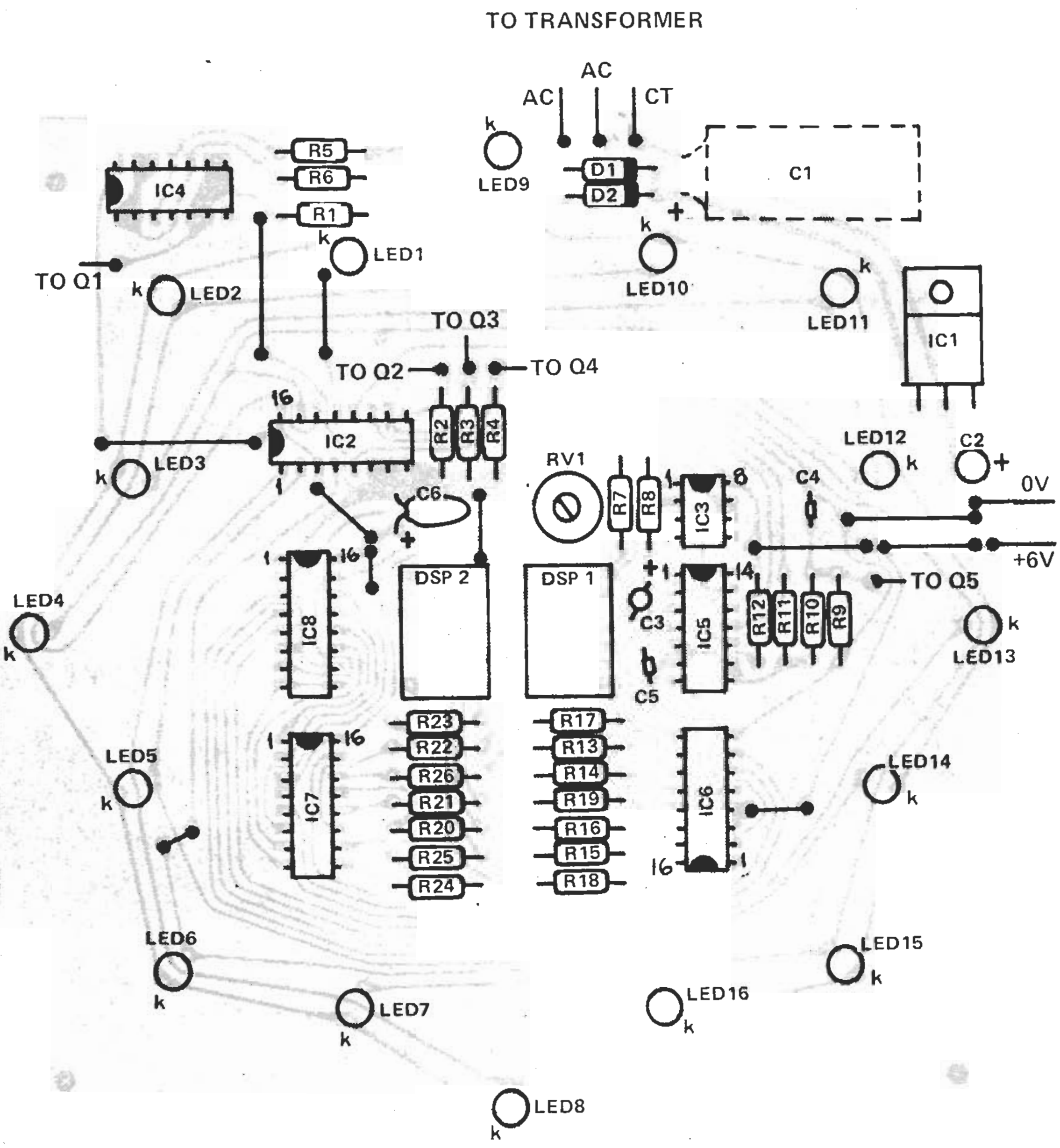


Fig. 2. Component overlay for the Wind Meter

PARTS LIST

RESISTORS all ½W 5%

R1-4,8,9	10k
R5,6,13-26	680R
R7,10,12	100k
R11	470k

POTENTIOMETER

RV1	1M trimmer

CAPACITORS

C1	1000u 16V
C2,6	10u 25V
C3	1u 25V
C4,5	820p ceramic

SEMICONDUCTORS

IC1	7806
IC2	4051
IC3	555
IC4,5	4011
IC6,7	4511
IC8	4518
Q1-Q5	2N5777
D1,2	1N4004
LED 1-16	TIL 209 or similar
DISP1,2	Common cathode seven segment (high brightness)

MISCELLANEOUS

Four miniature 12V bulbs, PCB, 240V/18V transformer box, head assembly

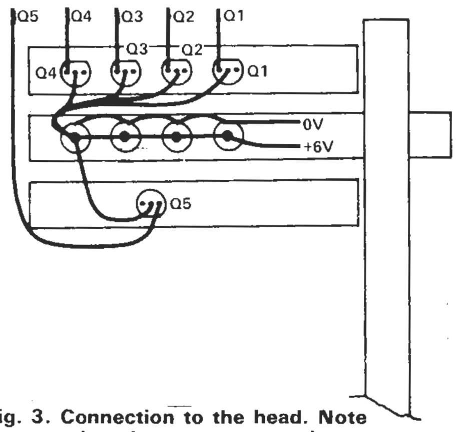
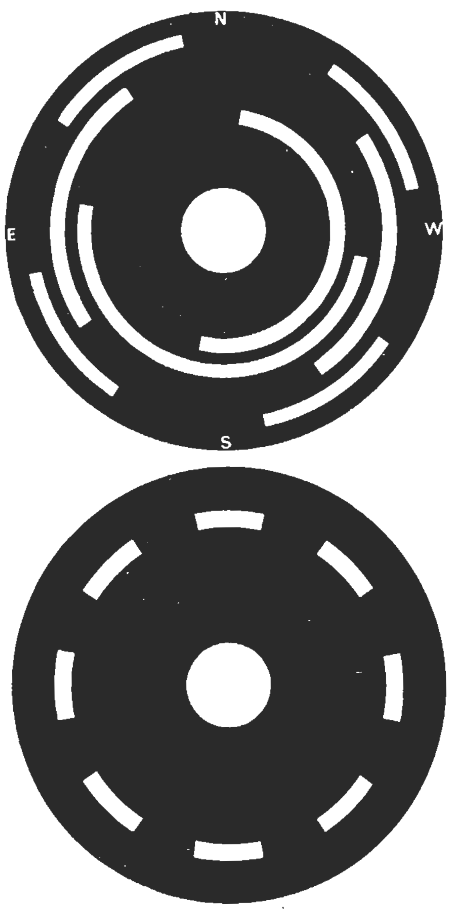


Fig. 3. Connection to the head. Note that transistor bases are not used.



Discs used in the sensor head — 1.5 mm thick, clear plastic with photographic film glued on.

will normally have to be washed out to give low enough friction with a light spray of WD40 or similar to give some protection.

While our housing is a little ornate, it did work but the more usual half ping pong balls may be more suitable.

Calibration

Wind Speed.
The easiest method for wind speed calibration is to provide the unit with a DC supply (via the common and one of the AC inputs) and to take a drive in the car with the unit supported above the vehicle. Providing there is no wind the potentiometer should be adjusted until the reading corresponds to the speedo.

Direction alignment is simply a matter of aligning the vertical rod so that it gives the correct results.

ETI

BUYLINES

The metalwork for this project we must leave to our readers, as this will be fabricated to suit individual requirements. The displays can be any type no's really; just observe polarity. Similarly with the LEDs. The photodarlingtons can be supplied by Marshalls.

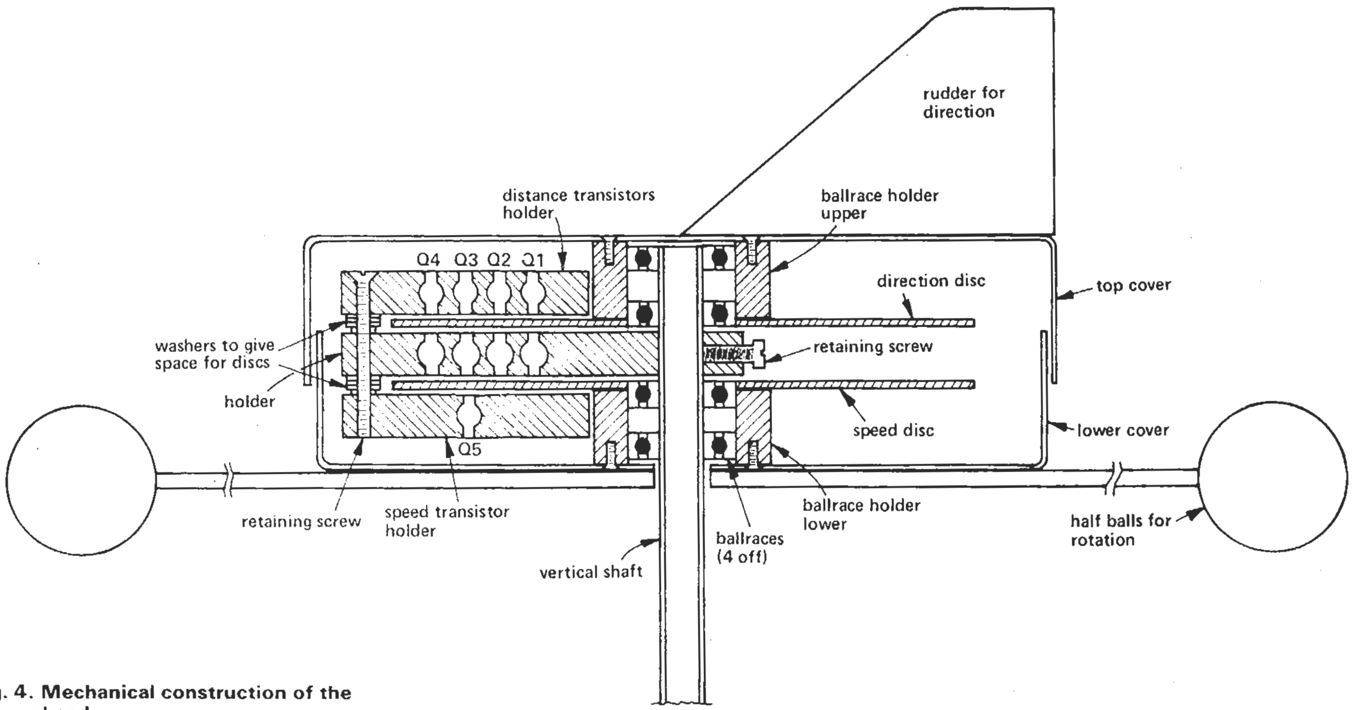


Fig. 4. Mechanical construction of the sensor head.

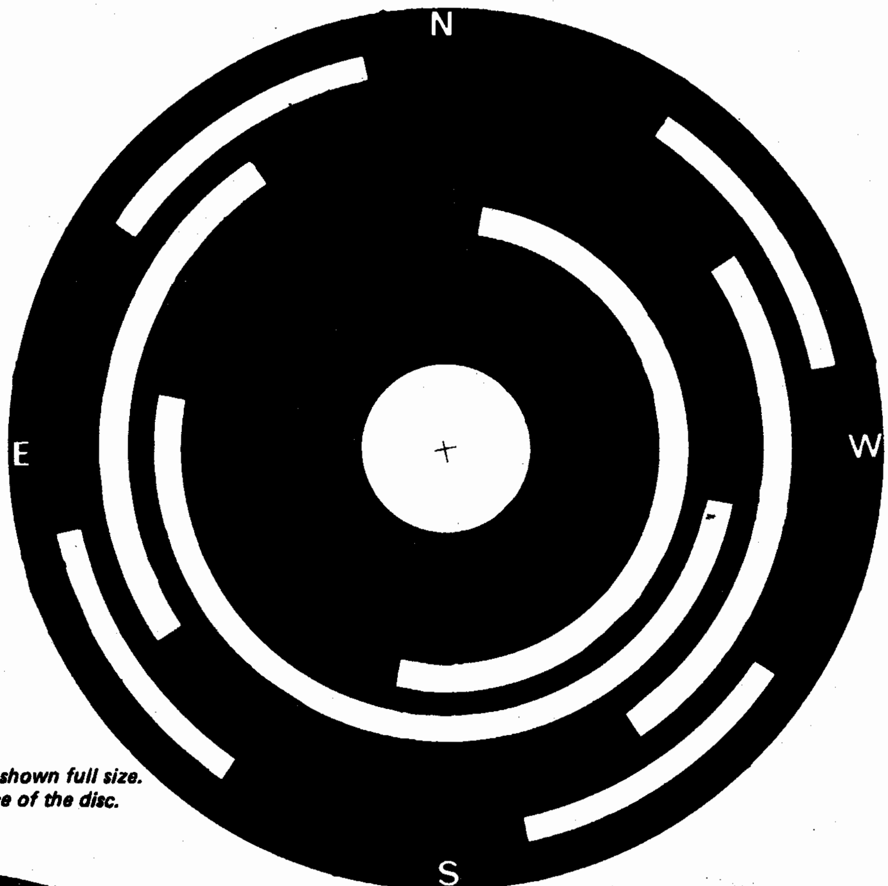


Fig. 5. The direction disc used shown full size. Note that this is the top surface of the disc.

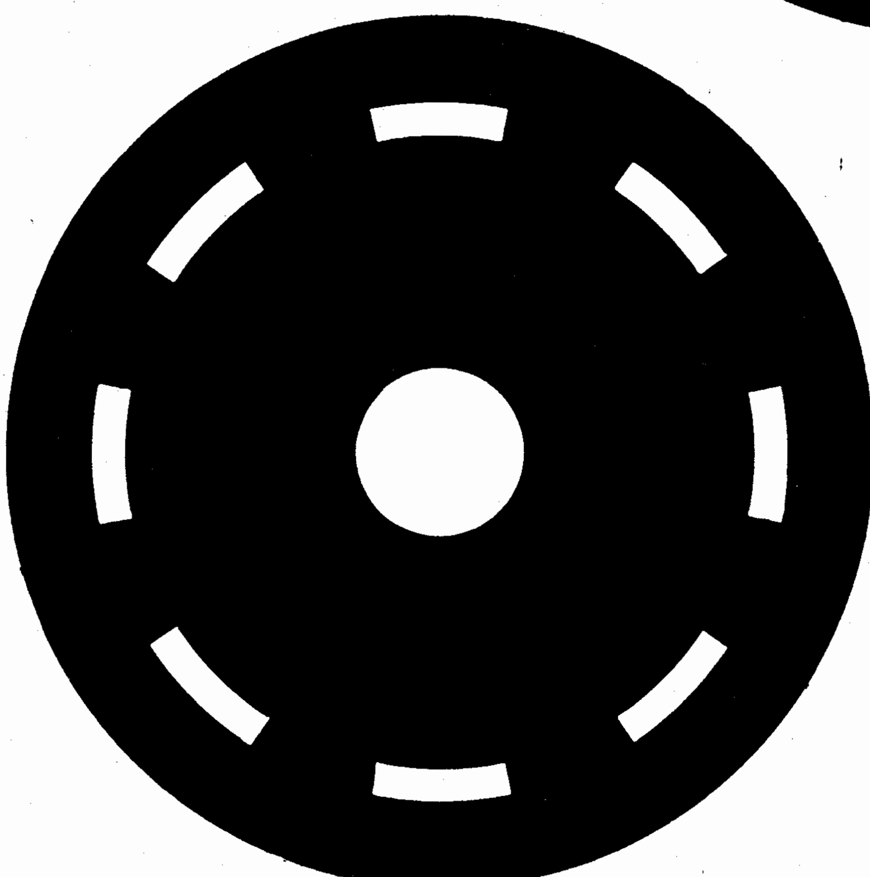


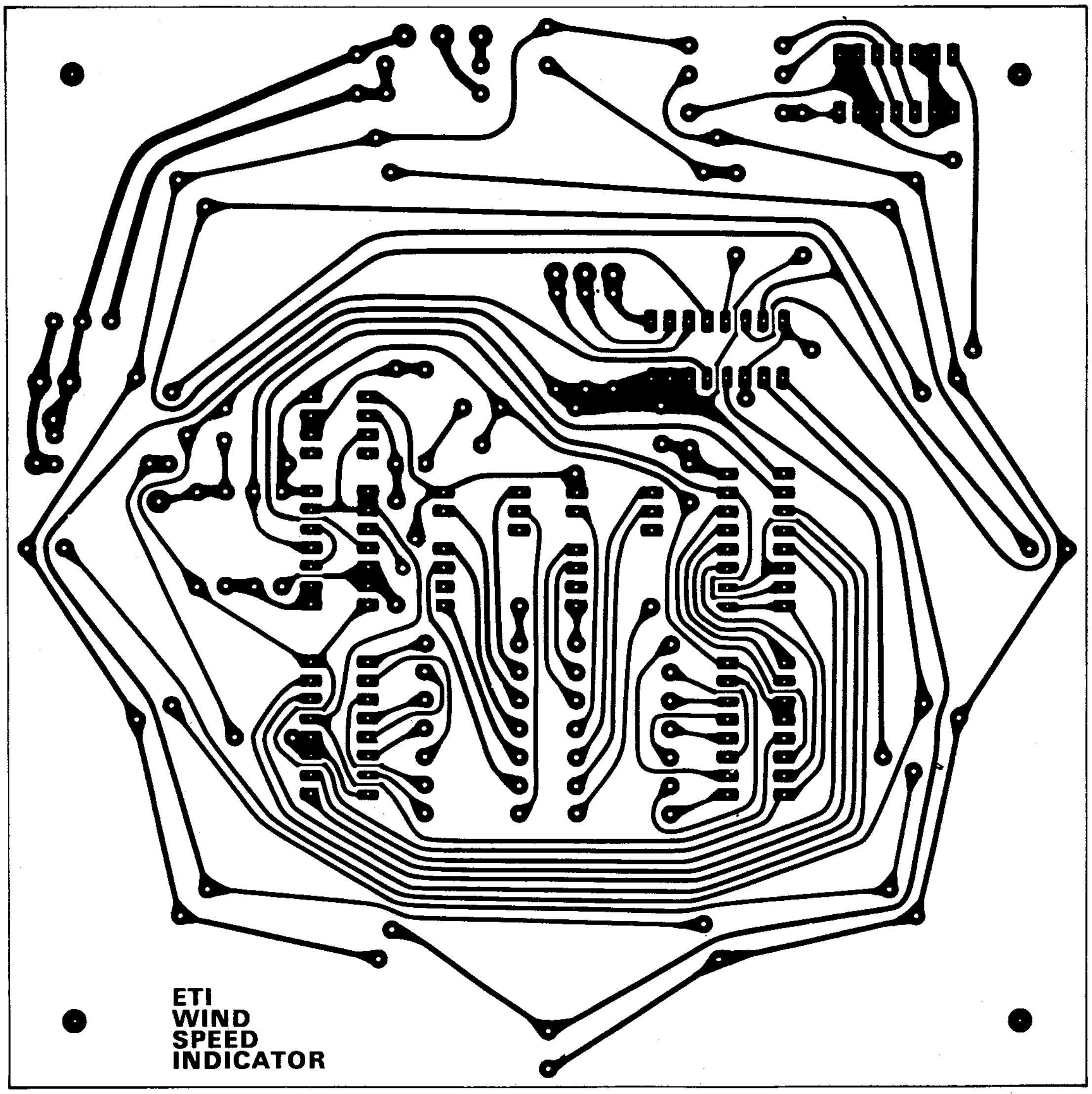
Fig. 6. The wind speed disc shown full size.

PCB FOIL PATTERNS

GATHERED HERE are all the PCBs for this month's projects. From now on the boards will be grouped together like this in order to facilitate their use by those readers wishing to produce their own PCBs from these patterns.

All are shown foil side up, and full size. Companies wishing to produce these for sale as ready made PCBs should note that where the board carries a copyright symbol, the designer retains that copyright to himself, so his company, and that particular board may *not* be produced on a commercial basis.

These pages form the basis of our ETIPRINT sheets, which are etch resistant transfers of the foil patterns, designed to simplify one-off PCB production. See the ad on page 49 for further details.



Cupless anemometer has diode wind-sensor

by J. P. Scoseria
Montevideo, Uruguay

Working well as a differential thermometer, this simple circuit can also be used to find wind speed by detecting the difference in junction voltage between two forward-biased diodes. Here, one junction is heated to a fixed temperature, and the other's temperature-dependent junction potential is made to vary with the cooling effect of the wind. Being totally solid-state, the unit eliminates all mechanical difficulties. The unit can also function as a psychrometer, or humidity indicator, if the heated junction is wetted down instead.

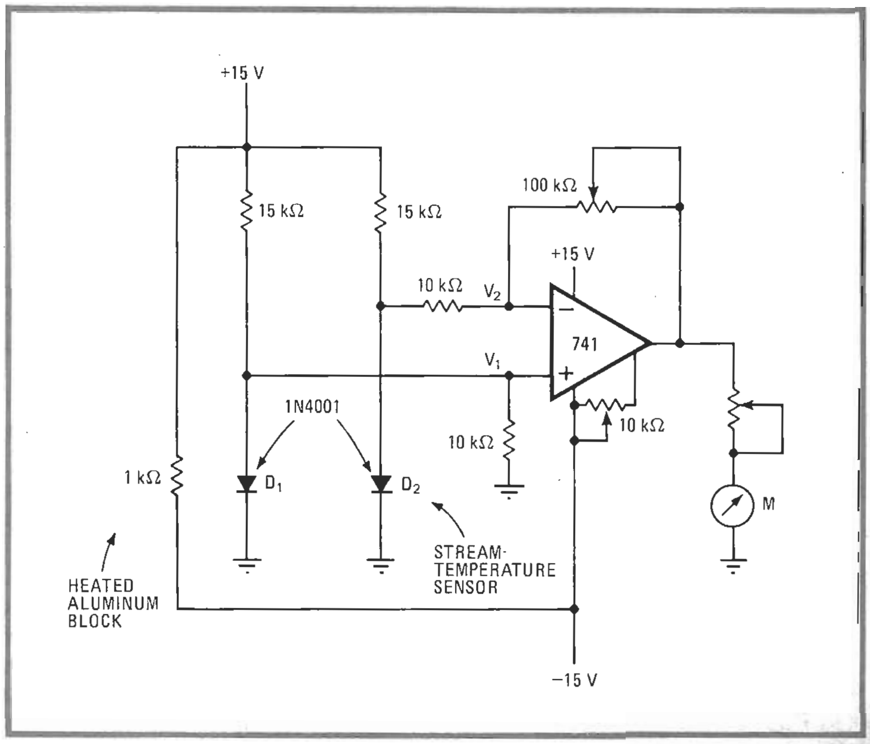
Diode D_1 and a resistor are situated within the confines of a small one-of-a-kind aluminum enclosure built for this circuit. D_1 is heated by the power dissipated by the resistor. The enclosure maintains a constant temperature throughout, independent of environmental changes, as in an oven. Although the absolute temperature reached by the diode junction is of little importance in this circuit, it will be a direct function of the power supplied to the block, the area of the block available for heat transfer, and its heat transfer coefficient.

The same general considerations exist for the stream-temperature sensor, D_2, which is placed in a similar aluminum block to reduce temperature variations due to changes in wind speed (settling time ≈ 2 minutes). Here, however, the power supplied to the block is small, being about 1 milliwatt to activate D_2, and heat variations reach the junction from the outside.

Generally, the output from the 741 op amp is $e_o = K(V_1 - V_2)$, where K is a constant and V_1 and V_2 are functions of the temperature associated respectively with the heated block sensor and the wind speed. The voltages across both D_1 and D_2 drop by 2.5 millivolt for each degree Celsius rise, and so $V_{d1} \approx 0.7 - 2.5(10^{-3})T_f$, and $V_{d2} \approx 0.7 - 2.5(10^{-3})T_w$, where temperature T_f corresponds to V_1 and T_w to V_2. As a result, $e_o = K(-2.5)(10^{-3})(T_f - T_w)$, and so the output of the op amp will be proportional to the temperature difference. The current that flows through ammeter M will thus vary linearly with temperature.

The relation between the wind's cooling factor and temperature is nonlinear, however, and because the initial zero-wind current in meter M is a function of the block temperature (and thus block size), and because the sensor temperature, and D_1 and D_2 are not driven from true constant-current sources, the calibration will not be uniform for any two units.

Although it would be ideal to have access to a wind tunnel for calibration, good results can be obtained with the aid of an automobile. Placing the sensor on the auto's antenna, with the meter set at maximum for zero wind speed, the unit can be calibrated satisfactorily on a windless day by noting M's output as a function of the car's speed. □



Ceaseless wind. Temperature difference between heat oven surrounding diode junction D_1 and stream sensor D_2, whose junction temperature varies with wind speed, is reflected as a change in current at M. Unit can be satisfactorily calibrated with auto's speedometer on a calm day.

tary switches with one position for each desired indication. The switch contacts are connecetd to lamps marked N, E, S, W, etc. In many instances, it is difficult to protect the switch, pot or other pickup against ravages of the weather so these systems required frequent maintenance.

Wind-direction indicator

A number of methods have been developed for remote-indicating wind vanes. Among them are selsyns with the repeater driving a pointer around a compass rose; bridge circuits in which the resistance of one leg varies with vane position so wind direction is shown on a meter which indicates bridge unbalance; and vane-driven rotary switches with one position for each desired indication. The switch contacts are connecetd to lamps marked N, E, S, W, etc. In many instances, it is difficult to protect the switch, pot or other pickup against ravages of the weather so these systems required frequent maintenance.

This solid-state wind indicator, described in *Le Haut-Parleur,* uses a small vane-driven bar magnet and reed switches as pickups (Fig. 7). The switches are normally open types connected between V_{cc} and the base of a 2N525 transistor (Fig. 8). The indicator is a 2-volt lamp in the collector circuit. The diagram of a 4-point indicator is shown in Fig. 9. The reed switches are hermetically sealed and are not affected by weather or corrosive elements in the air. Leads from the switches are run through a cable to the transistors and lamps at the remote point. **R-E**

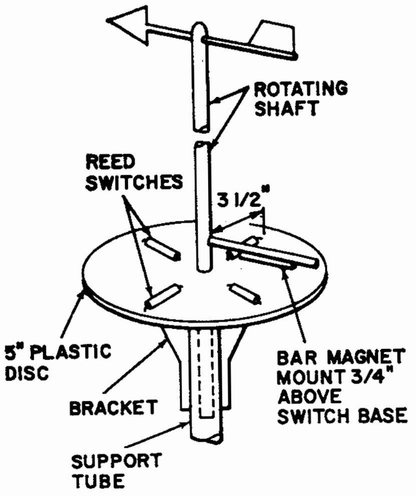


Fig. 7—Solid-state wind indicator uses reed switches as pickups and a vane-driven bar magnet. Reeds are open normally.

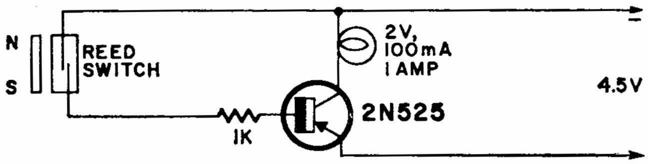


Fig. 8—Reed switches are connected between base and V_{cc} of 2N525's.

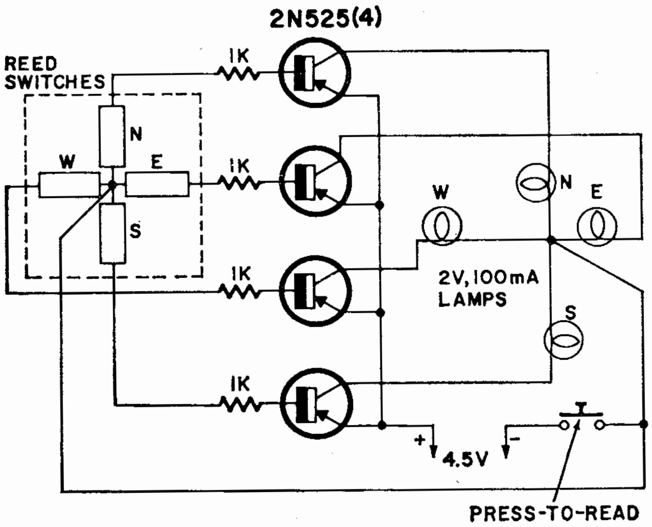


Fig. 9—Overall diagram of wind indicator. Indicator lamps indicate what position the vane is in.

CORRECTION

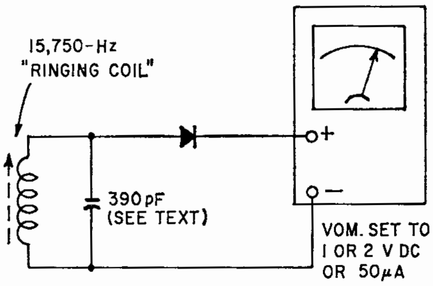
There is an error in the circuit of the Turn and Backup Indicator on page 95 of the April issue. Mr. J. M. Borde of Bombay, India noticed that the right-turn lamps are in series with the buzzer and will not function if both are rated at 12 volts. Actually Mr. Ives, the designer, connected the right-turn lamps between the flasher and ground as in the left-turn circuit. Our thanks to M. Borde for calling the drafting error to our attention.

QUICK TEST HORIZONTAL OSCILLATORS

For those odd occasions when you want to know if the horizontal oscillator is on-frequency, but don't have a scope with you, try this. You'll need a standard "ringing-coil" of the type used in horizontal multivibrators, the correct size capacitor to make it resonate at 15,750 Hz, and a diode.

Connect the diode in series with one of the VOM leads and then connect the meter across the coil terminals (see diagram). Now, if you hold the coil near the set's horizontal oscillator coil, the horizontal output tube plate lead, the flyback, or any other point where there is a high 15,750-Hz energy field you'll get a good-sized reading on the meter.

This can be read on the 0-1 or 0-2.5 dc volts scale, if the meter is at least a 20,000 ohms per volt type. A more sensitive range is the 0-50 microampere scale.



If you want to do a bit of gadgeteering, mount the coil on the end of a small metal or plastic box. Inside the box, mount a small variable capacitor, say about 0-100 pF., and then add enough fixed capacitance to bring the coil back to resonance with the variable capacitor set at about half-range or 50 pF. for the standard horizontal oscillator coil, this would be about another 220 pF for a total around 390 pF. (This varies with different coils; check the one you use to make sure.)

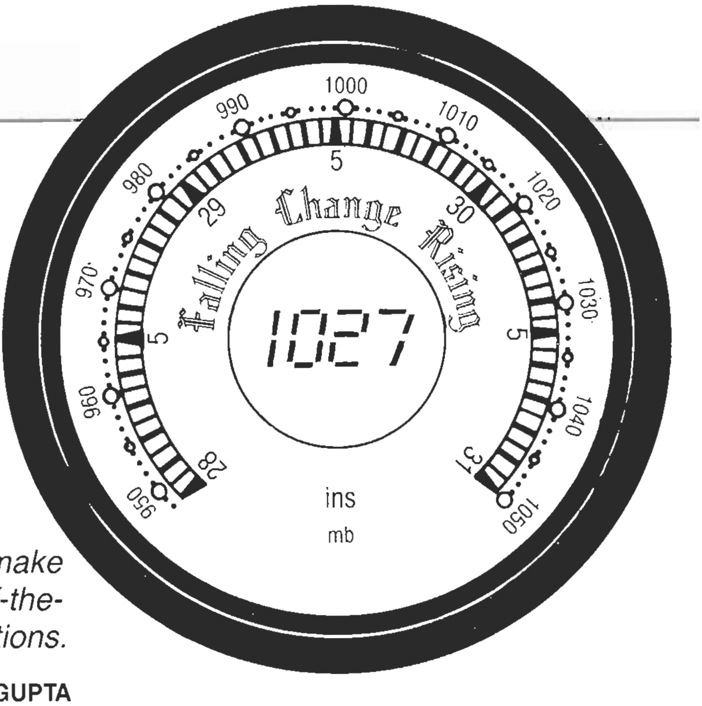
You can make a small dial-scale on the box, and use a pointer knob. This should be set at zero when the frequency is exactly 15,750 Hz, and then go + or − in either direction.

You can use this as a sort of rough 'output indicator', since it will indicate the presence or absence of a strong energy field on the plate cap of the horizontal output tube, the plate lead to the high-voltage rectifier, the damper tube or the flyback.

The 'frequency' calibration may be a bit wide, if you get a low-Q coil, but the output indication will be OK. You'll get readings like 1-1.5 volts dc with the pickup coil held against the set's oscillator coil.—*Jack Darr*

BUILD THIS

Solid State BAROMETER



Measuring and charting the atmospheric pressure has long been recognized as an effective way to make weather forecasts. Now you can build this state-of-the-art barometer and make your own weather predictions.

SUDHIR K. GUPTA

BEFORE WEATHER SATELLITES CAME INTO use, the barometer was perhaps the most useful instrument for providing information about future changes in the weather. Both mercury and aneroid barometers have long been used to measure the atmospheric pressure. But we're going to show you a new type of barometer—a barometer that uses a state-of-the-art solid-state pressure transducer and gives a digital readout of atmospheric pressure.

The barometer that we'll build can be thought of as being made up of four basic building blocks. As shown in Fig. 1, they include the pressure transducer, power supply, signal conditioner, and the measurement-and-display section. Let's look at each separately.

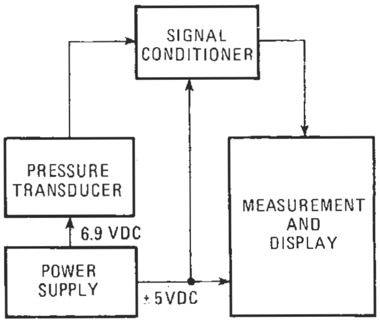


FIG. 1—THE SOLID-STATE BAROMETER can be thought of as being made up of four blocks of circuitry.

The pressure transducer

A transducer is a device which transforms one form of energy to a different form of energy. In this barometer, we'll be using a pressure transducer that converts barometric pressure into electrical signals. The transducer is made by SenSym (1255 Reamwood Ave, Sunnyvale, CA 94809) and is shown in Fig. 2. It is an absolute-pressure device. That is, it measures pressure relative to a vacuum. (Another pressure-transducer type is the *gage* type, which measures pressure relative to ambient pressure.)

The transducer's sensing circuitry is deposited on a silicon chip that has a cavity etched out to form a diaphragm. On the top of the diaphragm (the "exposed" side) is the pressure-sensing circuitry. The other side of the diaphragm is a vacuum. Figure 3 shows the structure of the device along with the transducer's pinout and its schematic.

FIG. 2—THE LX0503A pressure transducer is ideal for barometric applications.

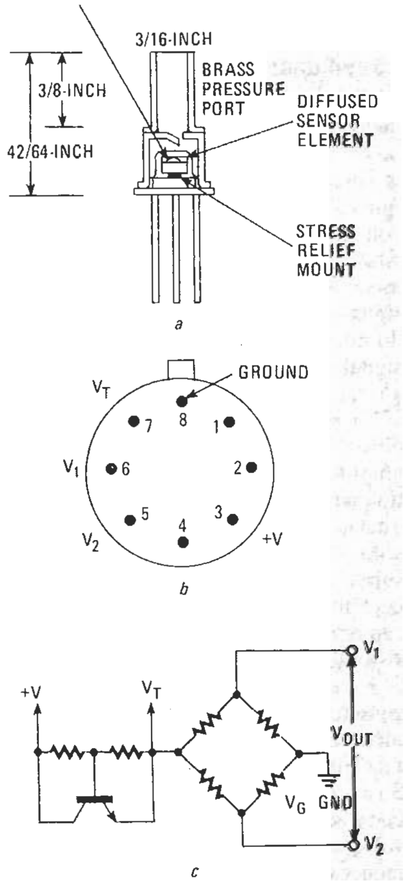


FIG. 3—THE STRUCTURE of the LX0503A is shown in *a* and its pinout is shown in *b*. The schematic of the device is shown in *c*. We will not use the V_T pin, which is normally used for temperature compensation.

Changes in ambient pressure affect the deflection of the sensing diaphragm. The resistance of the piezoresistive elements changes as the pressure changes, and thus the output voltage changes. The voltage on pin 6 (V_1) increases with an increase in pressure. The voltage on pin 5 (V_2) decreases (or goes negative) with increasing pressure.

The signal-conditioner section is necessary to provide zero and offset corrections for the transducer output. The signal from the transducer (about 40 millivolts) is amplified to about 1 volt. That corresponds to a display of 100 kilopascals (abbreviated kPa). We'll discuss that unit, and others, shortly.

We want the power-supply section to provide +5 volts DC for the signal-conditioning and measurement section as well as 6.9 volts DC for transducer excitation. Therefore we can use an AC adapter that provides 8 – 11 volts DC. Such adapters are readily available from many sources, including Radio Shack. The adapter's output is filtered and regulated by IC3, a 7805 5-volt regulator. A monolithic voltage converter, IC4 (an ICL7660 from Intersil) provides –5 volts DC. Finally, a Zener diode is used to provide 6.9 volts DC to the transducer.

The measurement-and-display section is based on a single-IC A/D converter from Intersil: their ICL7106. The author's prototype used Intersil's ICL7106 EV panel-meter evaluation kit for a display. It is capable of displaying 199.9 millivolts or 1.999 volts full-scale. In our application, the full-scale reading is set to 1.999 volts.

Circuit description

Conventionally, the pressure transducer is powered by a 10 – 15-volt DC power supply, and a 6.9-volt Zener diode is shunted across the supply terminals (pins 3 and 8). That provides an excitation voltage of 6.9 volts DC. Unfortunately, when that is done, there is a common-mode voltage of about 1.8 volt DC at the signal-output terminals (pins 5 and 6). We do not want the small transducer output signal of 30 – 40 millivolts to ride on such a large common-mode signal.

To get around that problem, we can either use an expensive instrumentation amplifier with large common-mode rejection ratio (CMRR), or we can play a trick. That is, we can use a bipolar supply of ±5 volts DC instead of a 10 – 15 volt DC supply. As shown in Fig. 4, we can connect pin 3 directly to +5 volts DC and we can connect pin 8 through a dropping resistor to –5 volts DC. (We can obtain the –5 volts from the ICL7660 that we discussed earlier: the power-supply schematic is shown in Fig. 5. The ICL7660, incidentally, is listed in this year's Radio Shack catalog.) A precision Zener reference across pins 3 and 8 regulates the voltage to 6.9 volts DC. That technique reduces the common-mode voltage to a mere 100 millivolts. Now it is feasible to use a conventional op-amp (like the LM324) as a differential amplifier.

One quarter of that quad op-amp (IC1-a) is used as a differential amplifier. It amplifies the input signal by a factor of about 22. We use IC1-b, another section of the LM324 quad op-amp to introduce the offset that will be required to calibrate the barometer. The signal is further amplified by IC1-c to about 1 volt. That gives us a scaling factor of 10 millivolts per kilopascal.

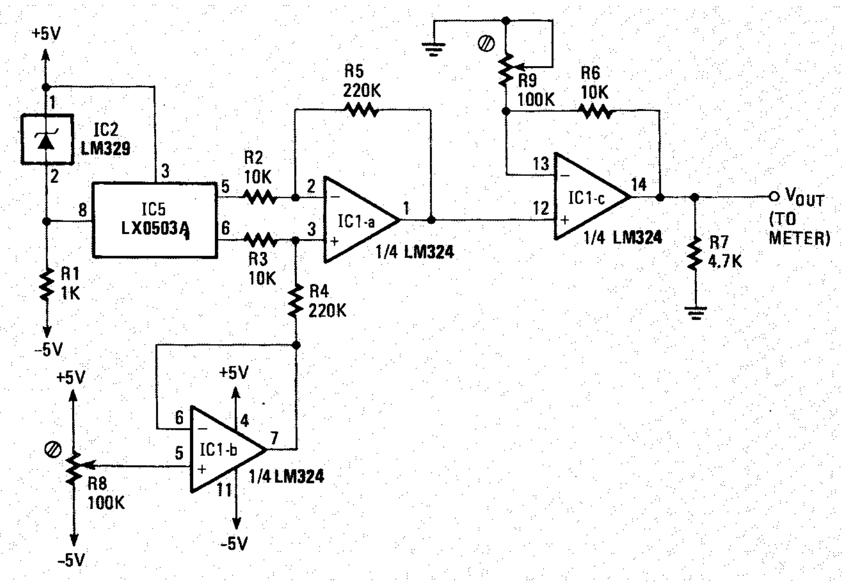


FIG. 4—A ZENER DIODE is used to regulate the transducer's input voltage to 6.9 volts.

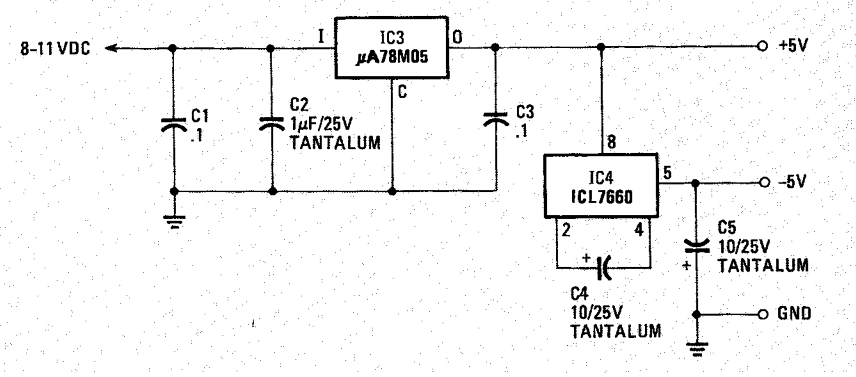


FIG. 5—THE POSITIVE 5-volt supply is easily converted to a bipolar supply by using the ICL7660 voltage converter.

Scaling the display

Barometric pressure is expressed in a variety of units, including pounds-per-square-inch (psi), bars, millibars, pascals, inches of mercury, atmospheres, torr, etc. Table 1 is a conversion chart to help you convert from one unit to another. To use that chart, look across the top for the unit you want to convert *from* then look down the side for the unit you want to convert *to*. Multiply the units you have by the conversion factor indicated by the table, and your answer will be in the units you want.

Because we are using a 3½-digit display, the maximum resolution is obtained when the pressure is displayed in kilopascals (millibar/10) or millibars. A barometric scale of 95 kilopascal (28 inches of mercury) to 105 kilopascal (31 inches of mercury) more than covers the useful barometric pressure range. You may think that using the unit of pascal (a unit that you've probably never heard of) is not a good idea. However, that's not necessarily so. The pascal is the standard unit for pressure or stress in the International System of Units (SI). ANSI (the *A*merican *N*ational *S*tandards *I*nstitute) has adopted the pascal as its standard pressure unit. It is equal to one newton per square meter (N/m^2). Weather reports often give barometric readings in millibars as well as in inches of mercury just as they give temperature readings in both Fahrenheit and Celsius. Conversion from kilopascals to millibars is simply a matter of multiplying by a factor of 10.

Construction

The project is built in two parts; the transducer/power-supply board, and the display board. A suggested layout for a printed-circuit transducer board is shown in Fig. 6. A parts-placement diagram is shown in Fig. 7. However, it's not really necessary to use a PC board. It is just as well to use perforated construction board and point-to-point wiring. We do, however, recommend that you use IC sockets for all IC's.

As we mentioned before, the display

PARTS LIST

All resitors 1/4 watt, 5% unless otherwise noted
R1—1000 ohms
R2,R3,R6—10,000 ohms
R4,R5—220,000 ohms
R7—4700 ohms
R8,R9—100,000 ohms, multiturn trimmer potentiometer
Capacitors
C1,C3—0.1 µF, ceramic disc.
C2—1 µF, 25 volts, tantalum
C4,C5—10 µF, 25 volts, tantalum
Semiconductors
IC1—LM324 quad op-amp.
IC2—LM329 6.9-volt precision voltage reference
IC3—µA78M05 5-volt regulator (Fairchild) or similar
IC4—ICL7660 voltage converter (Intersil)
IC5—LX0503A pressure transducer (SenSym)
Miscellaneous: IC sockets PC or perforated construction board, Intersil evaluation board ICL 7106 EV kit or any meter with a 2-volt range, AC adapter, 8 – 11 volts DC

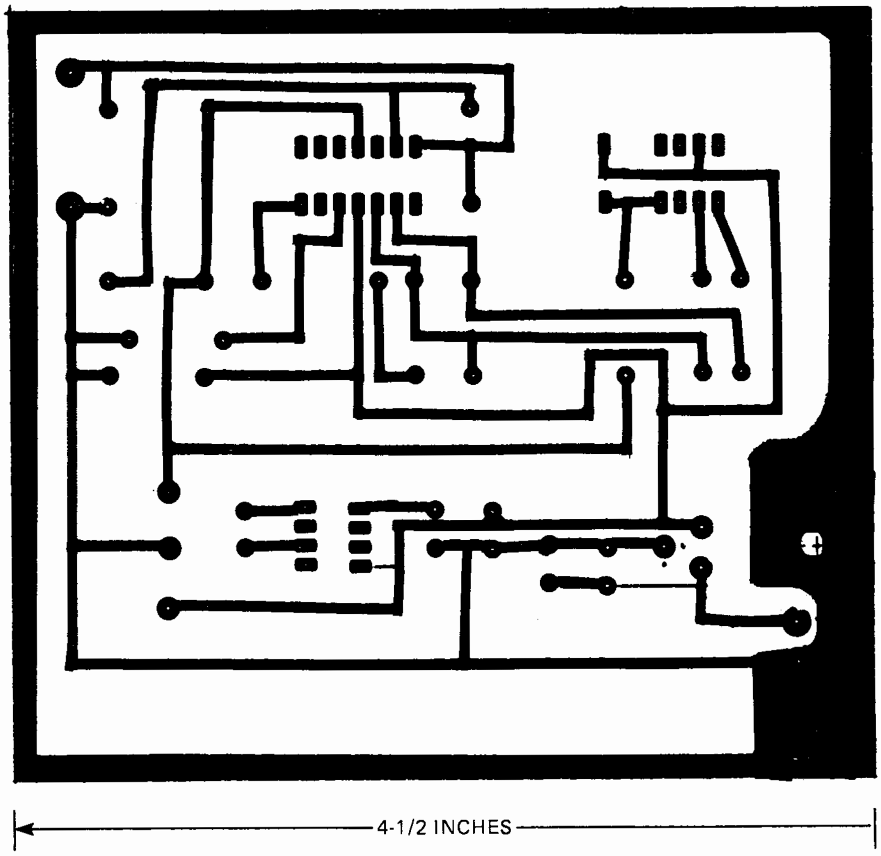


FIG. 6—FOIL PATTERN for the barometer is shown full-size above. The layout is not critical, and point-to-point wiring can be used—but be sure to use a socket for the transducer.

section of the author's prototype is based upon an evaluation board from Intersil—their ICL 7106 EV kit. That was used as a dedicated display. If you want to avoid the expense of that kit (about $35), you can use an ordinary digital voltmeter or even an analog meter with a full-scale range of 2 volts DC.

If you do use the Intersil evaluation board, follow the instructions that are supplied with it to set the full-scale display to 2.000 volts. Keep in mind that there is no need to use a battery to power the ICL7106 EV—the transducer/power-supply board generates ±5 volts that can be used for powering the display board. Connect +5 volts to the v+ input on the evaluation board and −5 volts to the v− input. We should note here that the current drain from the +5-volt supply should be limited to a few milliamps. Otherwise, degradation of −5-volt supply will result. You should, however, have no problem powering the display.

As we mentioned before, the use of IC sockets is strongly recommended. The pressure transducer can be installed in an eight-pin socket. But don't install it—or any IC's—yet. First install all resistors, capacitors, potentiometers, and IC sockets. Check for solder bridges and clean all of the flux off the board. If you used point-to-point wiring, be especially careful of cold-solder joints. When you have double-checked your work, you can install all the IC's except the transducer.

Apply 8 – 11 volts DC to the transducer/power-supply board and check for ±5 volts DC at the output indicated in the parts-placement diagram of Fig. 7. Also check for 6.9 volts DC at the transducer socket. Bend the transducer pins, recheck the orientation, turn off the power, and install it in the socket. If you wish, you may install the transducer remotely and connect it to the transducer board through a four-wire shielded cable.

You can mount the unit in just about any cabinet, but you should keep the transducer outside the cabinet, or make

TABLE 1—CONVERSION FACTORS

	PSI	PASCAL	kPa	MILLIBAR	in.Hg	mm Hg	ATM	TORR
PSI	1	1.4504×10^{-4}	0.1450	1.4504×10^{-2}	0.49118	1.9337×10^{-2}	14.696	1.9337×10^{-2}
PASCAL	6.8946×10^{3}	1	1000	.100	3.3865×10^{3}	133.32	1.0132×10^{5}	133.32
kPa	6.8946	1×10^{3}	1	10	3.3865	0.13332	1.0132×10^{2}	0.13332
MILLIBAR	68.946	1×10^{-2}	10	1	33.865	1.3332	1.0132×10^{3}	1.3332
in.Hg	2.0359	2.9529×10^{-4}	0.2953	2.9529×10^{-2}	1	3.9368×10^{-2}	29.920	3.9368×10^{-2}
mm Hg	51.714	7.5006×10^{-3}	7.5006	0.75006	25.401	1	760.00	1
ATM	6.8045×10^{-2}	9.8692×10^{-6}	9.8692×10^{-3}	9.8692×10^{-4}	3.3422×10^{-2}	1.3158×10^{-3}	1	1.3158×10^{-3}
TORR	51.714	7.5006×10^{-3}	7.5006	0.75006	24.401	1	760	1

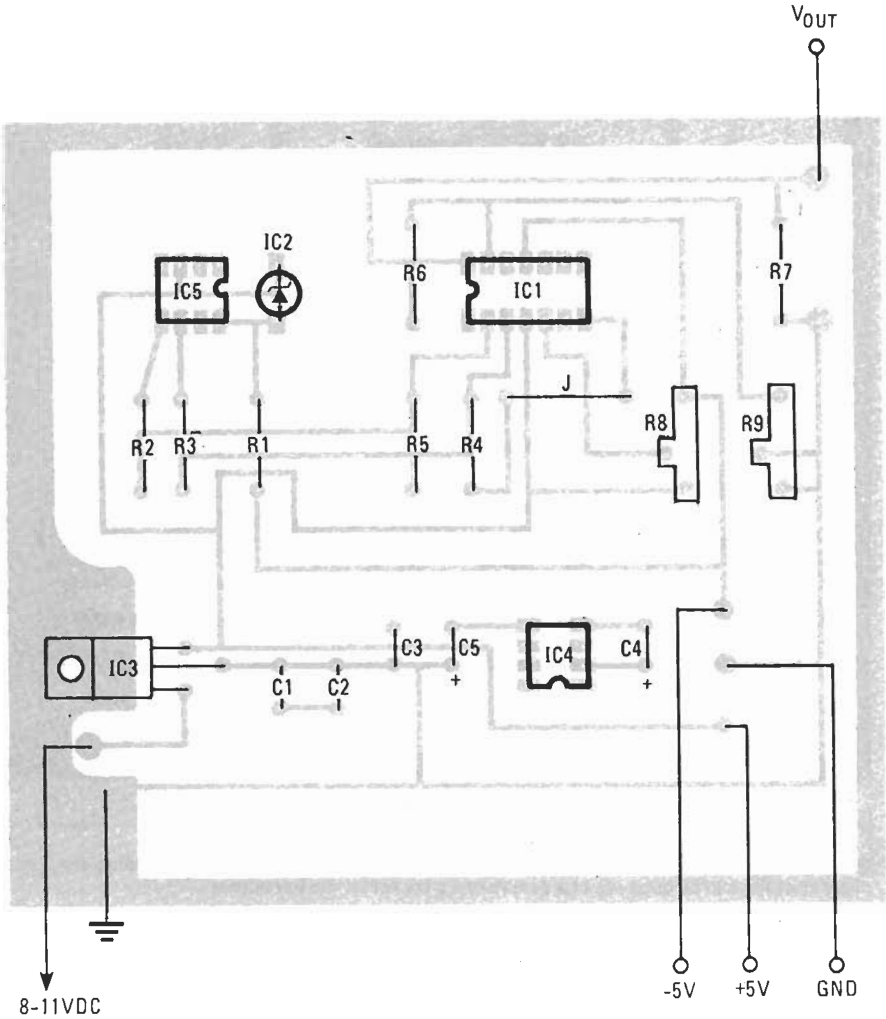


FIG. 7—THE PARTS-PLACEMENT diagram for the foil pattern shown in Fig. 6.

How to use your barometer to predict the weather.

Although some of you will build this barometer simply because you enjoy building electronic projects, many more will actually want to use it to predict the weather. So that you can do that, here's a crash course on what barometric-pressure changes usually mean.

High-pressure cells generally bring fair weather. In the northern hemisphere, the air circulation is clockwise and winds are usually light. The temperature can be warm or cold, but will remain constant for relatively long periods of time.

Low-pressure cells generally bring cloudy weather, with rain or snow. In the northern hemisphere, the air circulation is counter clockwise, and winds are usually strong. Tropical lows are warm, but other lows are cold, or change to cold.

A steady barometer usually indicates unchanging weather for one or two days.

Any rapid fall usually indicates that rain or unsettled weather is on it's way. (A rapid rise or fall in barometric pressure is generally considered to be 0.05 to 0.09 inches (0.16–0.30 kPa) over 3 hours.) The lower the pressure before the rapid change, the sooner the rain will approach. For example, if the pressure is 29.8 inches (100.9 kPa) and falling rapidly, a severe storm wll pass within a few hours. A rapid rise signals that the storm is ending, and clear and colder weather is on its way.

A suggestion to make the barometer more useful is to inteface it with a computer (such as the control computer that concludes with Part 3 in this month's issue). Then you could automatically chart the changes in pressure and record the highs and lows that occur. We'd like to hear about your successes (and failures).

sure that your cabinet is not-tight fitting. The best place to mount the unit is in an old aneroid barometer. Then you not only have an interesting conversation piece, but you can also use the old barometer's pressure scale as a conversion scale!

Transducer calibration

A typical transducer requires a two-point calibration to correct for offset and gain over the entire operating range. In the case of this barometer, the actual operating range is limited to ±5% of the top of the scale (95 – 105 kPa). Therefore, a single-point calibration performed at the middle of the range (100 kPa) may be acceptable. So that we can please everyone, we'll discuss both methods.

Before doing any calibration, switch the unit on and let it warm up for about an hour. Set potentiometer R8 to its middle position. Obtain the barometric pressure (using the local weather forcast or a barometer that you know to be accurate). Using Table 1, convert the barometer's reading to kilopascals or millibars. (The closer the reading is to 100 kilopascals, the better.) All that is to be done for single-point calibration is to adjust potentiometer R9 until the meter displays the barometric pressure.

If you can, it is best to use two-point calibration. That's because a typical transducer requires an offset correction as well as slope correction.

As a first step, perform the single-point calibration that we just discussed and leave the unit operating over a period of a few days. Try to obtain two readings: one at the low end of the scale (around 98 kPa) and the other at the high end of the scale (around 102 – 104 kPa). On both those days, note the actual barometric pressure as well as the corresponding meter readings. We'll use a little mathematics to arrive at the calibration values. Following are some sample calibrations.

Let the old barometric pressure, P_1 = 98 kPa and the corresponding meter reading, M_1 = 972 mV.

Let the present barometric pressure, P_2 = 102.5 kPa and the present meter reading, M_2 = 1030 mV.

The change in barometric pressure is $P_2 - P_1 = 102.5 - 98$ kPa = 4.5 kPa

The change in the meter reading is, of course, $M_2 - M_1 = 1030 - 972$ mV = 58 mV.

The generated slope is $\Delta M/\Delta P$ or $(M_2 - M_1)/(P_2 - P_1) = 58/4.5$ mV/kPa or 12.88 mV/kPa.

The slope that we require is 10 mv/kPa. Therefore, the change in the gain required is 10/12.88 = 0.776.

What we are going to do is to reduce the gain generated by the op-amp by a factor of 0.776. An example of how to do that follows.

Measure the voltage at the output of IC1-a. We'll call it V_i. Presume that V_i = 755 millivolts. Then the gain of IC1-c = M_2/V_i = 1030/755. The required gain, however, is 1030/755 × 0.776 = 1.059. So the required output at IC1-c is 1.059 × V_i = 1.059 × 755 = 799 mV.

Adjust the gain potentiometer, R9, until the meter reads 799. Now adjust the offset potentiometer, R8 until the meter reads 1025 millivolts, corresponding to the present barometric pressure. That completes the calibration. Now you can substitute your own values in the calculations and perform the calibration on your digital barometer. **R-E**