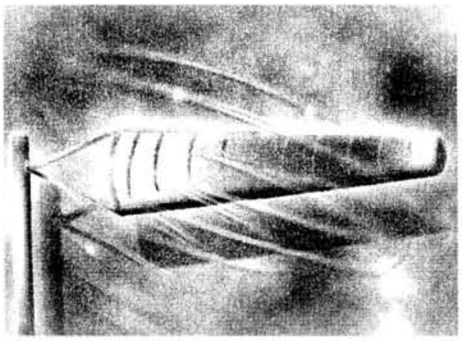
Constructional Project

WIND SPEED METER



JOHN BECKER

Using ultrasonic techniques, this solid-state design has no moving parts and does not need calibrating

THIS wind speed meter (anemometer) is intended for use in a variety of sports-type activities, such as track events, sailing, hang-gliding, kite and model aircraft flying, to name but a few. It can even be used to monitor the conditions in your garden.

A probe is pointed in the direction from which the wind is blowing and a screen displays the rate at which the wind is moving between two ultrasonic sensors. The readout is shown on an alphanumeric liquid crystal display (l.c.d.), with readings in metres per second, feet per second, kilometres per hour and miles per hour. The resolution is to the nearest tenth of a metre per second, from zero up to around 50mph, and possibly higher.

The design is one of two spin-offs from the author's wish to design a totally solid-state (no moving parts) Weather Centre in which several environmental criteria are monitored and logged, wind speed and direction, humidity, barometric pressure, temperature, rainfall, light and UV intensities, air humidity and soil moisture content. The design will be published in a few months time.

LET THE WIND BLOW FREE!

Having designed the Weather Centre, it became necessary to prove that the ultrasonic wind speed sensing technique (more on this presently) was indeed viable. The obvious method was to mount it on a car and compare the car's speedometer with the Weather Centre's l.c.d. readout. However, it was felt that the Centre's size was too great for this and could well prove the undesirable proximity of flashing blue lights and *ee-aw* sirens behind the car!

Consequently, the wind speed sensing circuit was constructed on its own, mounted in a small enclosure which was then unobtrusively positioned outside the car's window and comparative readings taken (spouses come in very handy for such things!).

The system was accurate up to about 25mph, and then began to fall off rapidly. It was concluded that the aerodynamics of the car began to take effect above this speed and it was decided to construct the second spin-off design – a wind tunnel.

An assembly comprising a cardboard tube and an electrically controlled fan was built. The fan had a known rate of air flow per minute, the tube had a known cross-sectional area and thus the airflow rate across the ultrasonic sensors was calculated and compared against the monitor's readings. By providing the fan with a speed control, its revolutions per minute were varied, and again comparative calculations and readings were made.

PRECISION CHECKING

It all seemed fine, although there was a bit of uncertainty about whether the fan's rotational rate linearly changed the air flow rate. Then, unexpectedly, two professional wind speed monitors were made available to the author.

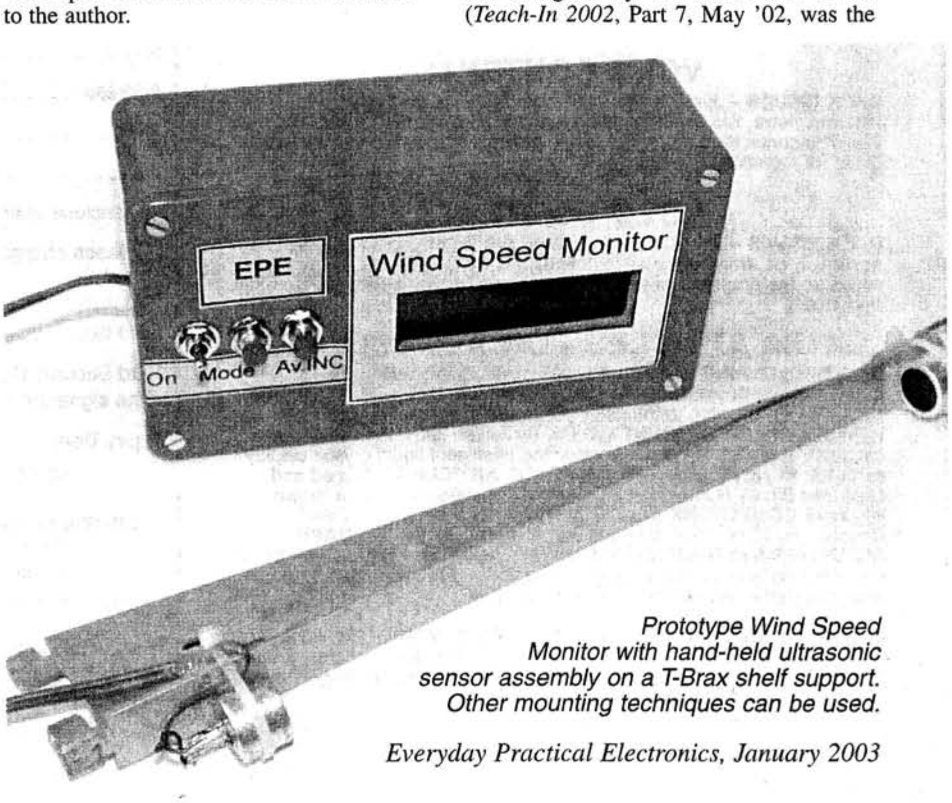
First, *EPE* contributor and schematic artist Andy Flind lent the author a hot wire/thermistor (thermal) anemometer which he had bought second-hand and uses in kite flying competitions.

Also, Mike Tooley, author and editor of *EPE*'s sister publication the *Electronics Service Manual*, arranged for the author to test his and Andy's anemometers in the wind tunnel at Brooklands College, Surrey, where Mike is a senior tutor in electronics. That wind tunnel is used by the College's aeronautical department. The readings on all three units corresponded.

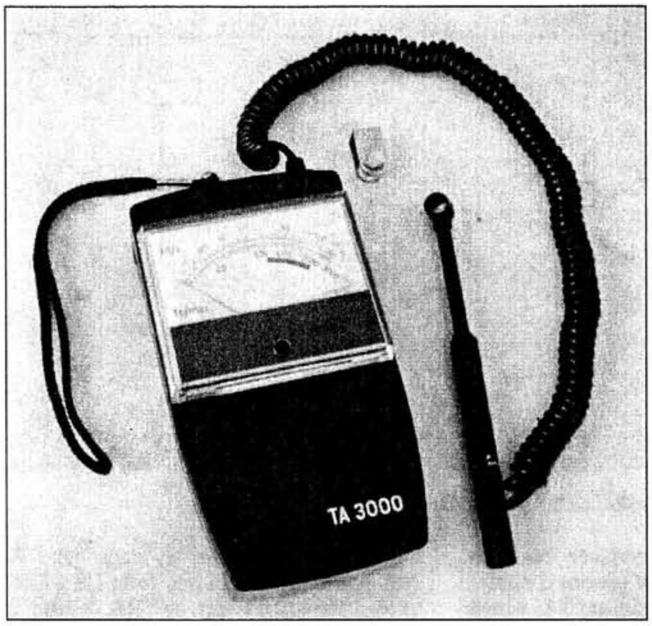
Using Andy's meter as a reference, the author's anemometer and wind tunnel were further developed.

WIND SPEED SENSING

Several techniques for measuring wind speed exist. The mechanical rotating assemblies with three cups are probably the most familiar. These are frequently seen along the verges of roads, used for localised meteorological monitoring. The technique is also used in commercial weather centres on general sale to the public. It has featured in previous weather centres designed by the author and others (*Teach-In 2002*, Part 7, May '02, was the



Prototype Wind Speed Monitor with hand-held ultrasonic sensor assembly on a T-Brax shelf support. Other mounting techniques can be used.



Commercial thermal anemometer lent to the author by Andy Flind.

last time it was demonstrated, thanks to Ian Bell and Dave Chesmore).

S-shaped rotational mechanisms are frequently seen as well, rotating at speeds relative to wind movement. They are typically used in an advertising capacity outside petrol filling stations. The author used the technique in his *Met Office* design of about eight years ago.

In the thermal technique just mentioned, a component (typically a thin wire) is heated and the amount of heat loss caused by air moving across it is sensed and compared with the heat generated by an enclosed reference source. Andy's meter appeared to use a tiny and delicate thermistor arrangement in its directional probe (see photo). Such sensors are likely to be priced well above the pockets of most readers.

Pressure sensing techniques are used in high speed air flow applications, such as in aircraft. With the Provost jet trainer in the Brooklands College workshops, a rigid tube is mounted in the leading edge of one wing, running back inside the wing to a pressure sensor mounted in the fuselage. A second sensor compares the air flow pressure with atmospheric pressure monitored in a wind-tight enclosure.

This arrangement provides data about the aircraft's speed through the air, but not in relation to the ground, for which other techniques are required, such as radar and GPS (Global Positioning Satellite) systems.

PROPELLOR UNITS

There are neat little (but quite expensive) handheld units in which a propellor is rotated by the wind. The rate at which the propellor rotates is metered to display the equivalent wind speed. The propellor is mounted on precision low-friction bearings to allow very slow wind speeds to be sensed. Typically, internal blades mounted as extensions to the propellor shaft break a light beam aimed at an optical sensor, and the number of pulses generated is counted across fixed periods of time.

Some small d.c. motors can have propellors mounted on them, and the wind-activated rotations cause an output voltage to be generated. The voltage peaks are monitored and the resulting meter readout shows the equivalent wind speed. Generally speaking, such systems have too much friction to respond to slow wind speeds.

The author has not experimented with thermal sensing, but he has previously tried various pressure sensing techniques to monitor wind speed. Regrettably, the pressure sensing transducers inexpensively available on the hobbyist market proved to be too insensitive to slow wind speeds.

BI-MORPHS

It did look for a while as though bi-morph elements might be usable. These are a type of strain gauge, made from thin piezo-electric rod which generates a voltage across two output wires when subjected to bending. The voltage generated *during* the bending depends on the rate at which the stress of bending changes. Attaching a scope probe to one in the workshop, voltages in excess of 50V were generated when just minor finger pressure was applied, much to author's astonishment, having expected just a few millivolts!

Bi-morphs, though, proved to be too uncontrollable for a wind speed sensing application. They are also fragile, which would have made their mounting difficult.

ULTRASONIC SENSING

For some years the author has been determined to find a way in which a solid-state wind speed sensor could be designed. Having eliminated the techniques just discussed, either because they are mechanical, too insensitive or too fragile, his attention turned to the use of sound. You are probably aware that sound travels through dry air at a speed of 750 miles per hour, 331·4 metres per second, at standard temperature and pressure (STP), effectively 15°C at sea level with an atmospheric pressure of 1013·2 millibars.

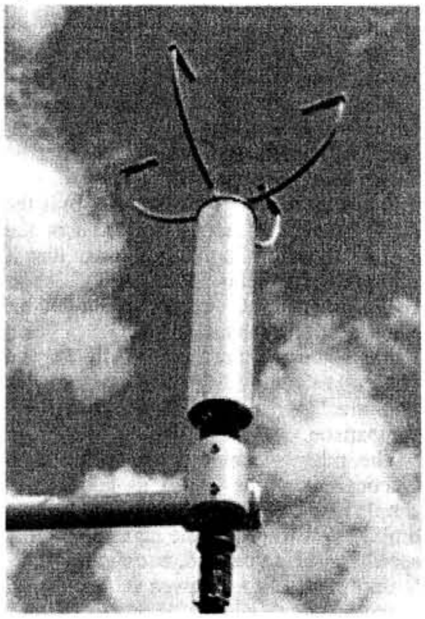
If the air is moving, the rate at which sound reaches a listener from its source varies with the direction in which the air mass is flowing – faster if the wind is coming from the same direction as the sound, slower in the opposite direction.

The time it takes for a sound to travel between a source and a receiver can be easily measured. Knowing the basic speed of sound under specified conditions, the rate at which the air mass is moving can be calculated from the measured timing. When using a single source and receiver, for the answer to be meaningful, of course, the wind must be moving directly in line with them. In practice, it does not matter whether the wind flows towards or away from the source, electronic techniques can compensate accordingly.

As will be demonstrated in the forthcoming *Weather Centre*, if several sound sources and receivers are used at different angles to each other in a fixed location, the direction of the wind can also be calculated as well as its speed.

PRACTICAL SOUNDINGS

The use of an *audio* sound source and receiver would not be practical since such a system would be subject to interference from many extraneous sounds. Ultrasonic methods, though, are much less susceptible to interference. Having searched the Web, the author found that there are indeed commercial wind speed and direction sensors that use ultrasonic techniques. One such is shown in the photograph below. It operates at 200kHz.



CAT1/2 solid-state ultrasonic wind speed and direction sensor. Photo Courtesy **www.apptech.com/cati2.htm**, Applied Technologies, Inc.

The wind's directional sensing will be discussed in the *Weather Centre*, but the speed assessment is easy to understand. Imagine two ultrasonic transducers facing each other across a known distance. One shoots a pulse at the other and the time it takes for the signal to cross between the two is measured. Using a sufficiently fast timer, times can be measured in microseconds.

Ensuring that the transducers are in line with the wind direction, the wind's speed can be readily calculated from the timing value. However, the answer only holds true if the air conditions are those specified at STP. The answers will differ if the conditions differ.

There is very simple technique that essentially allows the changes in air condition to be nullified. A signal is shot from transducer 1 to transducer 2 and a timing measured. Immediately, the roles of the transducers are reversed – now transducer 2 shoots the signal and transducer 1 receives it, and again a timing is recorded.

Two methods can then be used to establish the wind speed. In the first, an average is taken between the two timings. This provides the current speed of sound existing in that location under those conditions. Knowing the current speed of sound and the distance between the transducers,

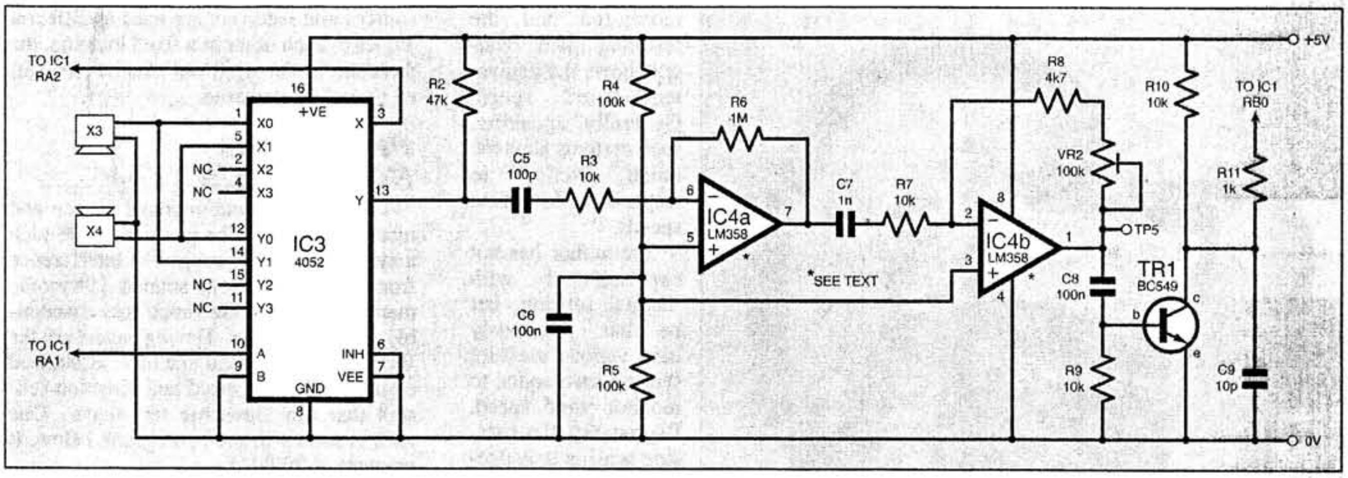


Fig.1. Ultrasonic transmission and reception circuit diagram for the Wind Speed Meter.

either of the two individual timings can be used to calculate the rate of air flow between the transducers. At a stroke, temperature, density and pressure as specific values become irrelevant.

It is worth noting that temperature is the main factor that causes a change in the speed of sound. One source states that if the speed of sound is 332m/s at 0°C, it will be 344m/s at 20°C and 386m/s at 100°C. Thus there is a change of only 3·5 per cent across a temperature range of 20°C. The effects of humidity and barometric pressure are insignificantly small by comparison.

The other technique, which for most practical situations is just as good, is to simply take the difference between the two timings and from this the equivalent wind speed can be calculated, each unit of difference representing a given value of speed change.

Both techniques are easy to implement with an accurately controlled ultrasonic pulse source and timer. It is also facilitated by the fact that even low cost ultrasonic transducers can be interchangeably used as transmitters and receivers. Although they are specifically designated as being a transmitter, or a receiver, under pulsed conditions and using a suitable circuit they can be used as either.

Indeed, in some echo sounding applications, where the time between the transmission and reception is comparatively long, only one transducer is needed, acting as both transmitter and receiver.

It is ultrasonics and the second calculation technique that are used in this design.

ULTRASONIC CIRCUIT

The circuit diagram for the ultrasonic transmission and reception functions is shown in Fig.1. The two transducers are shown as X3 and X4. As just said, they are both used interchangeably as transmitter and receiver. Analogue multiplexer IC3 selects the mode in which the transducers are used.

The transducers operate at the usual ultrasonic frequency of 40kHz. The transmission pulses are generated by a PIC microcontroller, which is described presently in relation to Fig.2. The route that the pulses take through IC3 is selected by the logic level applied to its pin 10, also controlled by the PIC.

When pin 10 is held low, the pulses are routed from IC3 pin 3 to pin 1, and out to transducer X3. This transducer transmits the pulses across a gap of several centimetres to the second transducer, X4, which receives the pulses and routes them to IC3 pin 12. The pulses, which are much attenuated by their journey, pass through IC3 to pin 13 and to the analogue amplification circuit formed around op.amps IC4a and IC4b. A MAX412 op.amp was used in the final circuit, but an LM358 was also found to be satisfactory.

When IC3 pin 10 is held high, the pulses are routed from IC3 pin 3 to pin 5, and this time out to transducer X4. Now transducer X3 receives them and they pass via pin 14 to pin 13 and so out to the amplifier.

From IC3 pin 13, the received pulses are a.c. coupled via capacitor C5 to the first amplifier, IC4a. A gain of about 100 is provided by this stage, as set by the values of resistors R3 and R6. The signal is then a.c. coupled by C7 to the stage around IC4b. Here the gain can be varied between about ×0·5 and ×10, as controlled by preset VR2. The potential divider formed by R4 and R5 applies mid-rail bias to the non-inverting inputs of the two op.amps (pins 5 and 3 respectively).

The final gain stage is provided by transistor TR1. Its base (b) is biased normally low by resistor R9, so holding it in a turned-off condition. The output from IC4b is a.c. coupled to TR1 by capacitor C8. Any positive-going pulses from C8 which exceed about 0·6V turn on TR1, causing a full line-level negative-going pulse at its collector (c). This pulse is coupled via resistor R11 back to the PIC.

For reasons unknown, the PIC16F628 microcontroller used in this design would not respond correctly when R11 was replaced by a direct link wire. A 10pF capacitor (C9) was also found necessary between the collector and the 0V line. This was discovered by accident when using an oscilloscope probe, which itself has a circuit capacitance of about 10pF.

CONTROL CIRCUIT

As shown in the control circuit diagram of Fig.2, the PIC16F628 microcontroller (IC1) is responsible for generating and sending pulses to the ultrasonic transducers, and for timing the return of the received signal. The results of its calculations are output to the 2-line 16-character alphanumeric l.c.d., X2. This is operated in 4-bit control mode, with its screen contrast adjustable by preset VR1.

The PIC is operated at 20MHz as set by crystal X1 in conjunction with capacitors C3 and C4. It can be programmed *in situ* via connector TB1, whose pins are in the author's standard order suited to

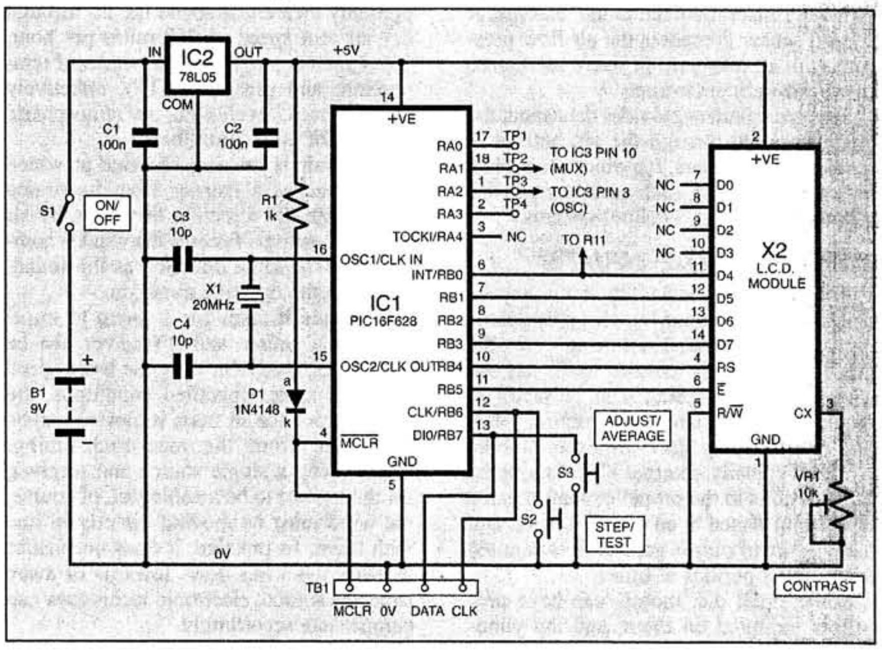


Fig.2. Circuit diagram for the control and display functions.

programming by *Toolkit TK3*. Note, however, the comment later about programming brand new PIC16F628 devices.

POWER SUPPLY

It is intended that a 9V PP3 battery should be used to power this design, although any d.c. supply between 7V and about 15V could be used. The input voltage is regulated down to 5V by regulator IC2.

Capacitors C1 and C2 encourage stability in the power lines. Current consumption in the prototype is about 14·5mA.

TRANSMISSION

In the transmission routine (SONICTX) the PIC sends a quantity of pulses whose cycle period is the equivalent to a 40kHz pulse train. The quantity to be sent is stored in the PIC's data EEPROM and can be adjusted by the user (see later). The prototype requires just two pulses to activate the transmission transducer.

Immediately prior to transmission, multiplexer IC3 is set to route the transducers to become transmitter and receiver in the order required. The PIC's Timer 1 is then stopped, reset and restarted. The pulses are then sent.

There follows a brief "masking" pause before the PIC starts expecting the return signal. This allows the amplifier circuit to stabilise in the event of any capacitively induced "ringing" which can be triggered during the transmission. The masking period value is stored in the PIC's data EEPROM and is set at 80 loop cycles in the prototype, but can be adjusted if required (see later).

Following the masking period, the PIC's interrupt function is activated and the program enters a holding loop from which it will only exit if an interrupt signal is generated, or the timer overflows.

The received and amplified signal from transistor TR1 is fed via resistor R11 to the PIC's pin RB0. This is set as an input and a signal change on it causes an RB0 interrupt to be generated. Using a modification of one of Malcolm Wiles' interrupt processing routines published in the Mar-Apr '02 issues (*Using PIC Interrupts*), the interrupt causes the Timer 1 counter to stop, the interrupt function to be turned off, and an exit made from the holding loop.

The timer value is now read and stored into one of two memory locations, depending on which transducer is doing the receiving.

ROLE SWAPPING

The roles of the transducers are then swapped through IC3, and the same transmission/reception routine is repeated. Having received the second timing, a correction value is added or subtracted according to another value which is stored in the data EEPROM, and which can also be adjusted by the user (again see later).

The difference between the two timings is then found by subtraction, inverting the result if a negative value is created. A check is then made to see if the answer is within a reasonable maximum range. If it is not, the result is limited to an increase of 16 above the previous value received. This helps to damp the effect of any extraneous sounds within the 40kHz range that might be picked up by the receiving transducer.

The answer is stored into one of 16 double-byte memory locations accessed cyclically and from which an average value is calculated from all 16 values stored. This result is then stored into a second memory block, from which a further average can be calculated if the user requests it via panel-mounted pushswitch S3.

Following storage of each final result, calculations of wind speed are made and displayed on the l.c.d. There follows a brief pause, after which the next pair of transmissions and receptions is triggered and processed. The overall sampling rate is about 3Hz.

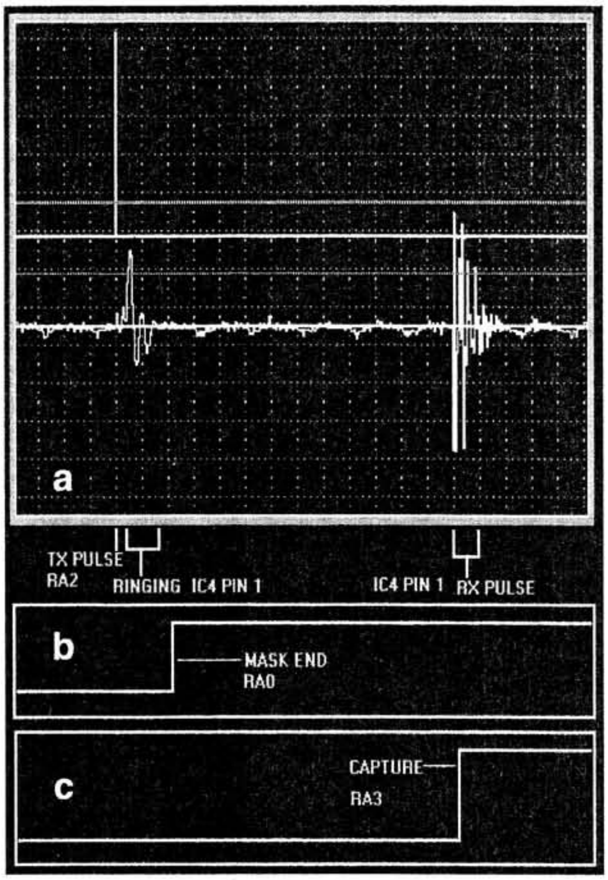


Fig.3. Waveforms associated with the ultrasonic transmission and reception functions.

A screen dump image of the waveforms created by this design is shown in Fig.3a. It was captured using the author's *PIC Dual Channel Scope* of Oct. '01. '00.

The vertical line in the upper trace shows the transmission (TX) pulse. The second trace shows the "ringing" generated through IC4 by the pulse, followed by a delay as the pulse crosses to the receiving transducer. Then occurs the output waveform at IC4b, caused by the amplification of the received (RX) pulse. Again note the "ringing" generated.

In Fig.3b and Fig.3c, the schematic graphs show the relative points during the screen trace at which the masking period ends (monitored at IC1 pin RA0), and at which the interrupt routine captures the amplified pulse (monitored at IC1 pin RA3).

SOFTWARE

The PIC program software is available for free download from the *EPE* ftp site. It is also available from the Editorial office on 3·5in disk, for which a small handling charge applies. Details of obtaining the software, and preprogrammed PICs, are given in this month's *Shoptalk* column.

There are three software files, suffixed ASM (TASM grammar), HEX (MPASM) and OBJ (TASM). The MPASM hex file has configuration and data EEPROM values embedded in it. If the OBJ file is used, the PIC has to be configured separately (crystal HS, WDT off, POR on) and the data EEPROM values set manually during the value correction process that will be described shortly. Note that the unit may respond unpredictably until the values have been installed following OBJ programming.

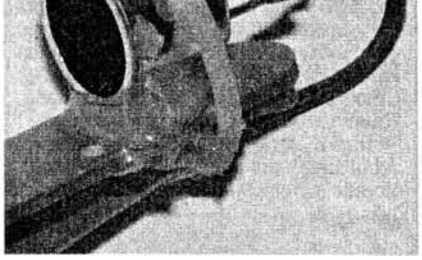
The values are decimal 2, 80 and 0, to be stored at EEPROM locations 0, 1 and 2, respectively.

TRANSDUCER ASSEMBLY

The ultrasonic probe assembly is shown in the first photograph. This is only a suggested arrangement and other mounting techniques could be used instead. The author used a 10-inch T-Brax shelf support. This was found to be shaped so that it felt comfortable in the hand. It also allowed the transducers to be secured using cable ties and holt-melt glue (see photo below), delivered from an inexpensive "gun" available from d.i.y. centres. A handle could be fitted if preferred.

The distance between the transducer faces in the prototype was set to about 7·3ins (18·5cms) but the distance is not critical and a fraction either way does not matter.

The transducers used in the prototype were the standard front-facing open-mesh type, available from many component suppliers. Fully enclosed waterproof types were tried but it was found that they were not satisfactory in this application.



Transducer secured to probe mount using a cable tie and hot-melt glue.

Investigation showed that their transmission/reception surfaces can cause significant "ringing" in the response, disrupting the pulse shaping.

No attempt was made to waterproof the open-mesh transducers. It might be possible, though, to cover them using the end section of a finger from a thin latex glove or similar. Perhaps even cling-film might be usable.

It does not matter in which order the transducers are mounted and connected. Although supplied as a pair comprising one transmitter and one receiver, as explained earlier, they are used interchangeably in both capacities.

COMPONENTS

See SHOP TALK page 71

Resistors

R1, R11	1k (2 off)
R2	47k
R3, R7, R9, R10	10k (4 off)
R4, R5	100k (2 off)
R6	1M
R8	4k7

Potentiometers

VR1	10k min. preset, round
VR2	100k min. preset, round

Capacitors

C1, C2, C6, C8	100n ceramic, 5mm pitch (4 off)
C3, C4, C9	10p ceramic, 5mm pitch (3 off)
C5	100p ceramic, 5mm pitch
C7	1n ceramic, 5mm pitch

Semiconductors

D1	1N4148 signal diode
IC1	PIC16F628–20 microcontroller, pre-programmed (see text), 20MHz
IC2	78L05 +5V 100mA voltage regulator
IC3	4052 2-pole 4-way analogue multiplexer
IC4	MAX412 or LM358 dual op.amp. (see text)
TR1	BC549 or similar *npn* transistor

Miscellaneous

S1	min. s.p.s.t. (or s.p.d.t.) toggle switch
S2, S3	min. s.p. push-to-make switch (2 off)
X1	20MHz crystal
X2	2-line 16-character (per line) alphanumeric l.c.d. module
X3, X4	40kHz ultrasonic transducer (2 off, matched transmitter/receiver pair)

Printed circuit board, available from the *EPE PCB Service*, code 380; 8-pin d.i.l. socket; 16-pin d.i.l. socket; 18-pin d.i.l. socket; 1mm terminal pins or pin header strip; 9V PP3 battery and clip; p.c.b. supports (4 off); plastic case, 150mm x 80mm x 50mm; metal support for transducers, about 260mm (see text); cable ties; nuts and bolts to suit l.c.d. module; connecting wire; solder, etc.

Approx. Cost Guidance Only £30 excl. batt.

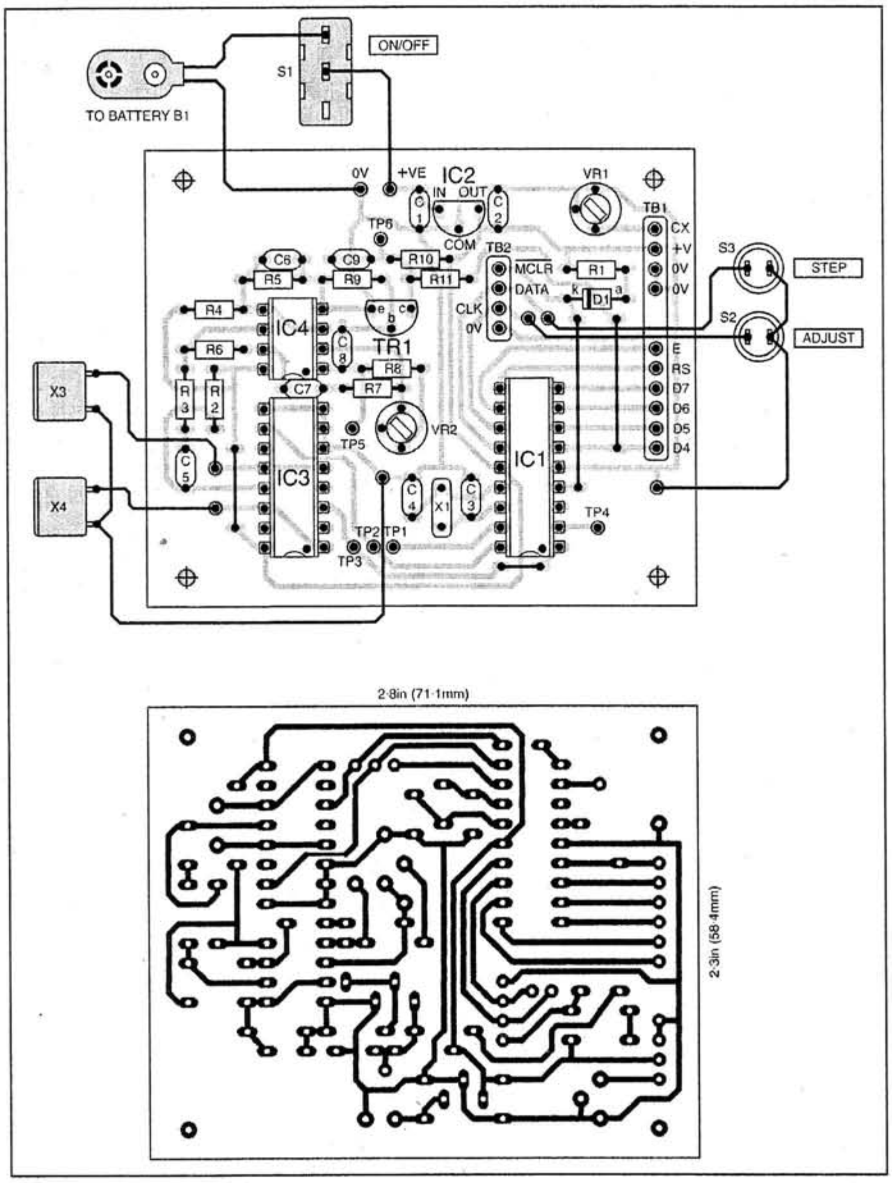


Fig.4. Printed circuit board component layout and full-size copper foil master track pattern for the Wind Speed Meter.

Screened stereo cable was used for the transducer connections back to the board, simply because it was to hand. It is thought that the screen is unnecessary and that any type of 4-way cable could be used. If the common 0V connections are made between the transducers on the probe assembly, 3-way cable could probably be used. However, these two alternative wiring techniques have not been tested.

At the unit end, the cables were passed through a hole in the box and soldered to the p.c.b. Plug and socket connections were tried, but were found to be unreliable, frequently causing signal disruption.

CIRCUIT CONSTRUCTION

Component and track layout details for the Wind Speed Meter are shown in Fig.4. This board is available from the *EPE PCB Service*, code 380. Assemble in any order you prefer, but it is suggested that you do so in order of ascending component size. Don't overlook the four link wires.

Use sockets for the dual-in-line (d.i.l.) i.c.s but do not insert these i.c.s until you have made sure that the power supply is functioning correctly. Ensure that polarity conscious components, i.e. D1, TR1 and IC2, are inserted the correct way round.

Insert 1mm terminal pins or pin-headers for the off-board connection points. Note that the TB1 and TB2 pins are in the author's standard order. The l.c.d. is connected to the pins for TB1, and typical pin arrangements for the l.c.d. itself are shown in Fig.5. Do not connect the l.c.d. until you have checked the power supply. Connection of the ultrasonic transducers can be made now, but may be left until later if preferred.

Having assembled the board and thoroughly checked the correctness of the component positions, their orientation where

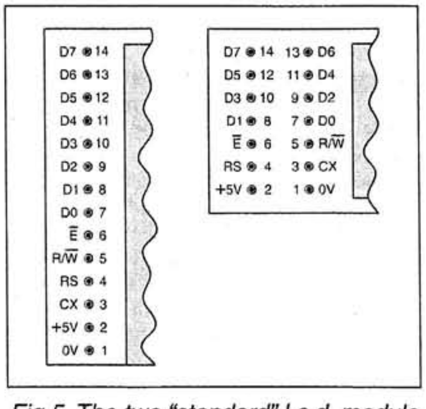
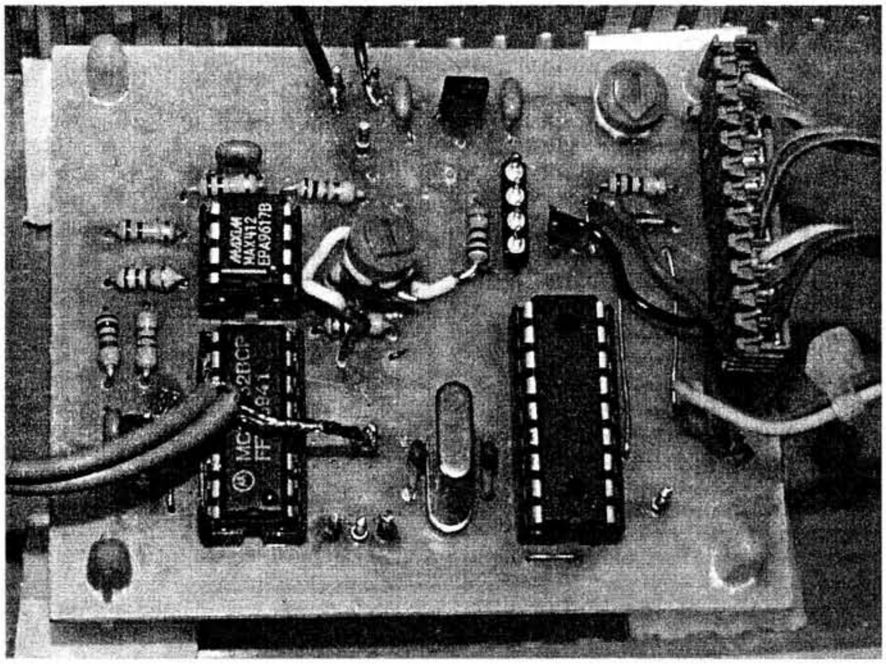


Fig.5. The two "standard" l.c.d. module pinout arrangements.



Prototype p.c.b. assembly. The changes visible have been incorporated on the final p.c.b.

appropriate, and the quality of your soldering, switch on the battery. Immediately check that +5V (within a few percent) is present at the output of voltage regulator IC2. If not, immediately switch off and correct any assembly error. Always switch off the power before making any changes on the board.

Then insert the remaining i.c.s, ensuring that they are the correct way round, and connect the l.c.d. module. The l.c.d., IC1 and IC3 are CMOS devices and the usual handling precautions should be observed, touching a grounded item of equipment before handling them, to discharge static electricity from your body.

The PIC microcontroller, IC1, should have been preprogrammed, either purchased as such, or via a suitable programmer.

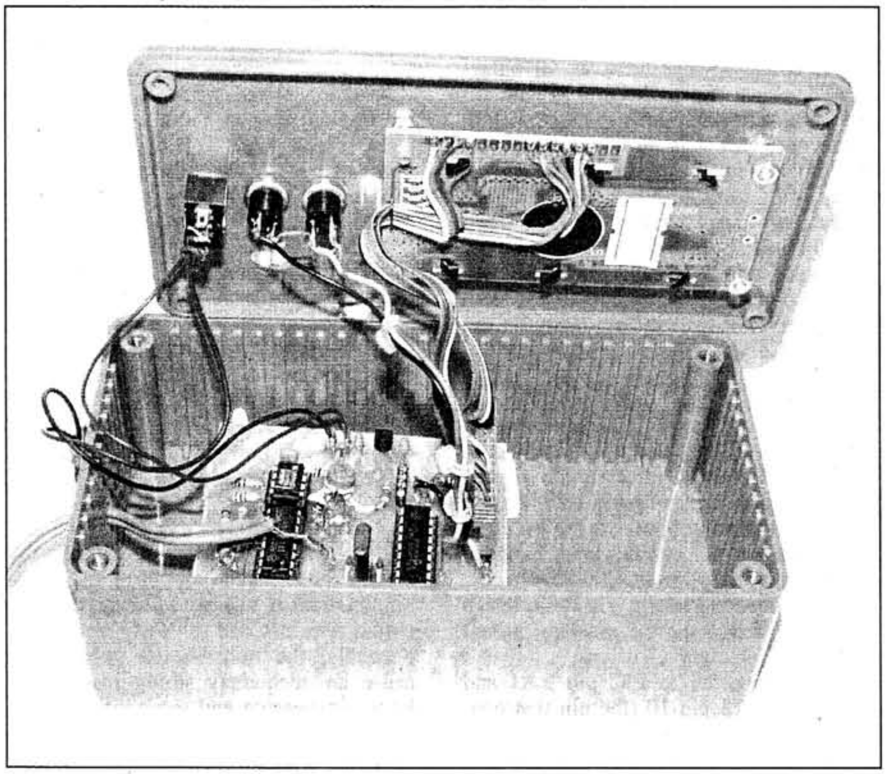
Although PIC programming connections have been provided on the p.c.b., it was found that any previously unused (brand new) PIC16F628 device could not be programmed in situ due to it being connected to other components. These PICs, it seems, need to have their first programming carried out using a normal PIC programmer, such as *Toolkit TK3*.

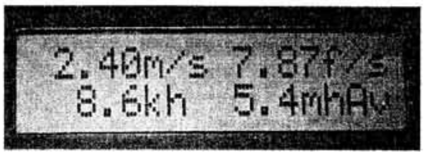
It was found that previously used PIC16F628 devices are capable of being programmed *in situ*, and the development of this design was carried out in this fashion.

Switch on power again, and once more check the power supply output at IC2. Adjust the l.c.d. contrast setting using preset VR1 until a screen display is seen clearly. Ignore the immediate details at present.

DISPLAY VALUES

When you know that all is well, and if you have not already done so, connect the transducers. Support the probe assembly so that nothing obscures the direct path between the





Example of main monitoring display, during a slight breeze.

transducers. The room in which the testing is to be done *must* be free of draughts, so that the unit just responds in still air.

Switch on the power. Four sets of values will be seen on the l.c.d., possibly changing a bit erratically at present (see above photo).

On the top line are shown the monitored wind speed values in metres and feet per second, both having two decimal places to the nearest 0·01 value. The maximum integer value that can be shown is 99.

The lower line shows the speed in kph and mph, to one decimal place, with a maximum integer value of 999 – good luck if you ever see that shown! In fact, it is not actually known how high a wind speed the unit will correctly respond to, but it should be at least 50mph (80kph) and likely to be much higher.

The unknown factor is whether or not at really high wind speeds the transducer grills, or other aspects of the probe assembly, might cause interference by generating ultrasonics that could affect the amplifier response, a bit like wind whistling in telegraph wires, only higher pitched.

Pressing switch S3 sets the unit into full averaging mode, signified by the letters Av being shown at the far right of l.c.d. line 2. In this mode, the second block of 16 values previously mentioned is averaged and the calculations use that result instead of the immediate value that is shown when averaging is off, and Av replaced by two blanks on screen. Repeated pressing of S3 toggles between the two modes.

Pressing switch S2 selects the Test mode, replacing the top line values with the actual timing values detected during each pair of transmission cycles. These are the actual values read from the PIC's Timer 1 register. To their right is shown the absolute difference between them (without + or – signs).

Example display when in Test mode.

It is normal for the values to fluctuate slightly. In the prototype they typically hover at around 3400, but this value depends on the exact distance between the transducers.

The first two values shown were used by the author during software development, but otherwise have no practical purpose. The right hand value is used during the unit's alignment, in the unlikely event that this should be found necessary.

Pressing S2 again once more causes the metres per second (m/s) and feet per second (f/s) speeds to be shown.

ALIGNMENT

The proof of whether or not corrective alignment is needed depends on the value shown at the right of the top line in still air conditions, having pressed switch S2 to display the test values. First adjust preset ~~VR1~~ VR2 until the received pulses are being adequately amplified, i.e. the displayed values are pretty consistent.

If the right hand value hovers around 0 to 1, preferably nearer to 0, no correction is needed. If it is any greater, though, adjustment can easily be carried out as described in the third of the following three correction options:

Switch off the power and wait for the screen display to go blank (supply line voltage has dropped to 0V). Hold the Averaging switch S3 pressed down, switch on the power, wait a moment and then release S3.

Screen line 2 will be blank and line 1 should show the message WIND PULSE 2. This states the number of pulses that the PIC transmits during each detection cycle. Do not adjust this value unless you have an oscilloscope to monitor the waveforms generated by the PIC.

Correction mode screen 1.

Correction mode screen 2.

Correction mode screen 3, showing confirmation that the value has been saved.

Press switch S2 (but not S3). Line 1 then shows WIND MASK 80. Again this value should only be changed if you have an oscilloscope. It is improbable, though, that either of the foregoing values will need changing.

Press switch S2 again (without pressing S3), to display CORRECTION –0 (or 0). This is the third correction mode, which you might need to use.

The data EEPROM holds the correction factor as a value between 0 and 15. Any values below 8 are subtracted from 8, and the answer is then subtracted from the sample values. For example, if the value is 7, it is subtracted from 8 and the answer of 1 is subtracted from the samples.

Conversely, values of 8 and above are ANDed with 7 (binary 111) and the result is then added to the sample values. Thus if the data EEPROM value is 9, this is ANDed with 7 to produce a value of 1, which is then added to the samples.

The ANDing process is invisible to the user, who only sees the result on screen, expressed with or without a polarity sign (+ or –) as appropriate. Zero may be returned with either sign (or without), depending how it has been reached.

To change the value, press switch S3. The value will decrement (downwards) in steps of one, from –1 to –7 for each press of S3. It will then show 0, followed by an increment (upwards), again in steps of 1 for each press of S3, from +1 to +7. After 7, it again shows 0 and decrements to –7, etc.

Having set the value, press S2 and the word SAVED will be shown on line 2. This confirms that the PIC has stored the new value back to the data EEPROM.

The SAVED message will also appear if switch S3 has been pressed with the first two correction modes. It is then necessary to press S2 to step to the next mode.

That completes the correction cycle. The next press of S2 returns the screen to show the wind speed values.

Note that pressing the switches may seem to have a lethargic response. This is due to the software continuing to take samples between each occasion it looks to see if a switch has been pressed. The switch must be released before the response occurs.

Should you need to reinstate (or install for the first time) the author's values to the EEPROM via the switches, they are Wind Pulse = 8, Wind Mask = 80, Correction = 0.

THIRD CORRECTION MODE

The third correction mode just described can be used if the sampling difference value at the right of line 1 is not fairly consistently showing zero in still air conditions. The difference is due to the two transducers not responding identically when used in receiving mode.

Note the value and then set the correction value to cancel it. For example, if the difference value consistently shows 5 then it needs to be corrected by 5.

However, the difference value is not accompanied by a polarity sign. Consequently it may not be immediately clear whether 5 needs to added or subtracted. Try setting first for one polarity, i.e. –5, and if that makes matters worse, use +5. The object is get the difference value as consistently close to zero as possible.

There will always be a bit of value-changing seen, due to the simple nature of the transducers and the amplifier. Remember that it is an analogue system being used for pulse transmission and reception amplification. The digital aspect, as shaped by transistor TR1 and read by the PIC through its interrupt function, may not necessarily respond each time to precisely the same analogue voltage level of the waveform output from op.amp IC4b.

ADVANCED SETTING

As said previously, it is highly improbable the Mask and Pulse values will need changing. However, readers who have a dual-trace oscilloscope might be interested to experiment with these two values.

Several test points have been included on the p.c.b., as follows:

TP1. Connected to PIC pin RA0, which goes high following the masking period and the PIC starting to "listen".

TP2. Connected to PIC pin RA1 and multiplexer IC3 pin 10 (the pin that controls the signal routing to and from the transducers).

TP3. Connected to PIC pin RA2 and IC3 pin 3, carrying the 40kHz output signal pulses.

TP4. Connected to PIC pin RA3, which goes high on receipt of signal capture by the interrupt routine.

TP5. Connected to the output (pin 1) of op.amp IC4b, allowing the fully amplified signal to be monitored prior to being pulse-shaped by transistor TR1.

TP6. Connected to the collector of TR1, at which the pulse-shaped signal appears.

Raw transducer signals can also be monitored at the p.c.b. points to which their leads are connected.

The most useful scope monitoring that can be done is to first connect scope Channel 1 to TP3, and set the scope to synchronise to positive-going pulses on this channel. The 5V transmission pulses being sent to multiplexer IC2 will be observed. Keep this probe connected to TP3.

Connect Channel 2 to the active pin of each transducer in turn and observe how only alternate transmission pulses are seen on this channel. With a sufficiently good scope set to a high gain setting for Channel 2, you might just also see the received signal being generated on the transducers between transmission pulses.

Monitoring TP2 with Channel 2, the multiplex path selection logic pulses will be seen. With Channel 2 on TP4, the relationship between the occurrence of the transmission pulses and the point at which the PIC's masking period ends can be observed. The software triggers TP4 at the end of the masking period, and just prior to the PIC starting to "listen".

Monitoring TP5 with Channel 2, observe the shape of the received and amplified pulse. With sync still on Channel 1, view Channel 2 on its own. At the start of the waveform, the sympathetic reaction of the amplifier to the transmission signal will be seen as a brief pulse, of about 2V peak-to-peak, depending on the setting of preset VR2.

The masking delay allows this pulse to be ignored before the PIC starts waiting for the true received pulse. This pulse's occurrence will be seen a little to the right of the first pulse, following a "quiet" gap. Note how the received pulse is considerably lengthened compared to the length of the transmission pulse. This clearly illustrates the "ringing" of the receiving transducer in response to it being hit by the transmission pulse. If you expand the scope trace, you will probably see that the ringing is at 40kHz, the frequency to which the transducer is most responsive.

Monitoring TP6 with Channel 2 shows how the op.amp output pulse train triggers the transistor into full saturation pulses. It is the first of these to which the PIC's RB0 interrupt responds. Adjust ~~VR1~~ VR2 back and forth and see how the gain set for IC4b affects the transistor's reaction.

EXPERIMENTING

If you want to experiment with the values for the transmission pulses and masking, the trick is to ensure that the masking period does not end too early or too late. Secondly, the transmission pulses must cause an adequately strong response of both transmission and reception transducers, yet not cause either to "ring" for too long.

It is just possible, although unlikely, that a single transmission pulse will be adequate. Probably up to five or so will keep the "ringing" within bounds. Two pulses, though, were found to be best with several transducer units, some from different manufacturers.

The pulse count range is 1 to 9, followed by a rollover to 1. The masking value range is 1 to 255, followed by a rollover to 1. The values are changeable in the correction mode by using switch S3.

If you have PIC programming facilities, you can also confirm that the transmitted frequency is indeed roughly 40kHz. There is a command line in the SONICTX routine which has been REMmed (commented) out with a semicolon, saying GOTO BEAMITW. If you reinstate this line, reassemble and download to the PIC, the frequency output at TP1 can be monitored on a frequency counter. It is a permanent loop until the PIC is reprogrammed without the additional line.

Unless you are familiar with PIC program writing, do not attempt to change the software's transmission frequency loop values.

To reinstate the software's pulse transmission, REM-out the GOTO BEAMITW line again, and reprogram.

To temporarily speed the rate at which pulses are transmitted, switch off the power, wait briefly, then, with switch S2 pressed, switch the power back on. Release S2 a moment or two after the power has been switched on. In this mode, the PIC's Timer 0 rate is increased, so shortening the delay between sending pulses. Normal working is resumed next time the unit is switched on.

IN USE

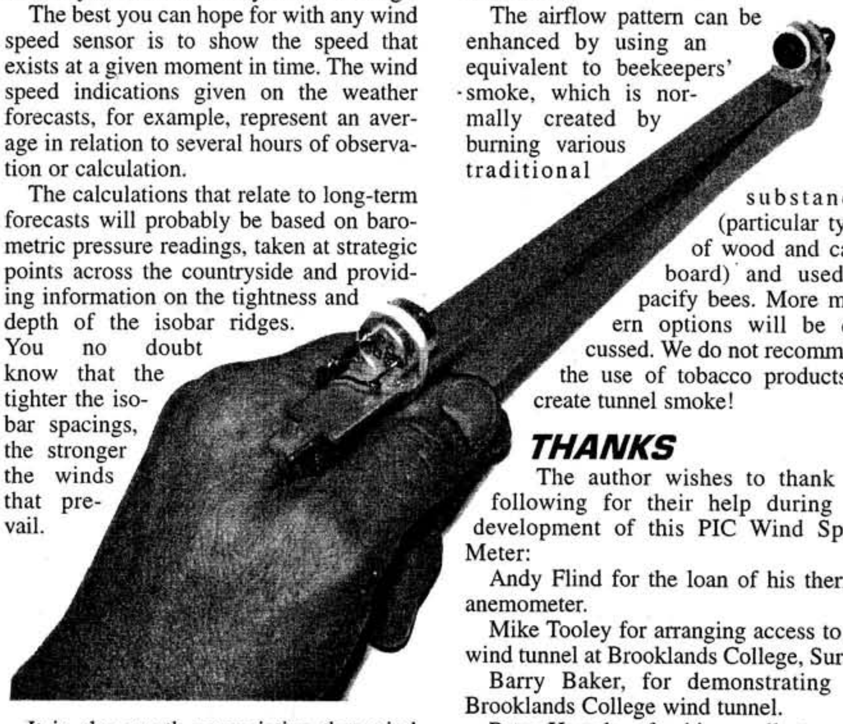
To use the Wind Speed Meter, point the transducer assembly in the direction from which the wind is blowing. To avoid the possibility that your body may disrupt the wind flow, hold the probe somewhat away from your body.

To observe peak wind speeds, the Av message on line 2 should be absent. To obtain average wind speeds, press switch S3 so that Av is shown. The speeds shown are the average taken over 16 transmission cycles, but updated on each cycle.

Be aware, as you will soon find, that wind is not just the uniform flow of a mass of air past a given point. It is full of turbulence and the eddies within it swirl at different rates. Turbulence is even more prevalent near to fences, buildings, trees, and even other people. Where possible, take readings while well out in the open. Even then, turbulence will still be there. The transducers themselves will actually cause a bit of turbulence, but not enough to radically affect the validity of the readings.

The best you can hope for with any wind speed sensor is to show the speed that exists at a given moment in time. The wind speed indications given on the weather forecasts, for example, represent an average in relation to several hours of observation or calculation.

The calculations that relate to long-term forecasts will probably be based on barometric pressure readings, taken at strategic points across the countryside and providing information on the tightness and depth of the isobar ridges. You no doubt know that the tighter the isobar spacings, the stronger the winds that prevail.



It is also worth appreciating that wind speeds vary with height. Wind near to ground level will flow at a slower rate than wind higher above the ground. Measurements taken at heights differing by only a few metres can be different.

Although an averaging mechanism has been built into the software, always observe the meter for several seconds, mentally noting the range of values between which the readings change.

NEXT MONTH

In next month's issue, the construction of a simple wind tunnel will be described. This uses the same basic wind sensing circuit and software, but additionally includes a circuit which controls the rate at which an electrical fan rotates, so allowing the rate of air flow through the tunnel to be changed.

The system is ideal for demonstrating how air flows around differently shaped structures placed within the tunnel. From this it is possible to see how winds can damage buildings, cause wings to lift aircraft, and how important streamlining can be for any vehicle, airborne or road-based.

The airflow pattern can be enhanced by using an equivalent to beekeepers' smoke, which is normally created by burning various traditional substances (particular types of wood and cardboard) and used to pacify bees. More modern options will be discussed. We do not recommend the use of tobacco products to create tunnel smoke!

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