WINDY JOULES

Windy Joules has the following features:

- measures light level in milliwatts per square centimetre
- measures wind speed in revolutions per second
- logs light or wind values every 15 minutes over 24 hours
- calculates peak and average values

Construction

Construction is relatively straightforward. First fit and solder the resistors R1 to R14 and trim their legs. Identify the resistors by the coloured stripes on the body.

Next fit the chip sockets IC1 and IC2 matching the notch in the socket against the notch in the symbol on the board. Care should be taken when soldering these components to avoid solder bridges between the pins. It is not recommended that the chips are soldered directly to the pcb.

Fit and solder the capacitors, paying attention to the polarity of the electrolytics C2 and C3 (negative is marked by a stripe on the side of the body). The ceramic capacitor C1 can be fitted either way around and should be bent flat on the board after soldering to avoid shadowing the light sensor.

Then fit the Hall effect sensor (HALL) and the regulator (REG). The symbols on the pcb indicate the orientation of these components (flat side of the component against the flat side of the symbol). The Hall effect sensor should lean slightly towards the edge of the board.

Next fit the dual 7-segment display (note the decimal points on the pcb symbol). Care should be taken when soldering this component to avoid solder bridges between the pins.

Solder the three push switches S1, S2 and S3.

Fit the PP3 battery snap BATTERY. Support holes are drilled on the pcb for the battery snap leads. Feed the leads up through the support holes from the track side of the board and then down the solder holes. Red is positive and black is negative.

Don't fit the two chips into their sockets until you have thoroughly checked your construction. Check that all the components have been inserted correctly and that there are no dry joints and no solder bridges between pins. Then match the small notch or circular recess in each chip to the notch in its socket.

Attach the plastic tube to the top of the circuit board (on the component side) using the three short cable ties. It is important that the ends of the tube are flush with the two sides of the circuit board and not projecting over the edge.

Glue the magnet and the two nuts (which act as counterweights) to the large gearwheel on the side with the boss (i.e. the side which isn't flat). The three objects should be evenly spaced around the perimeter of the gearwheel and should be close to its outer edge. Don't worry about which face of the magnet is uppermost.

Attach the small gearwheel to one end of the steel shaft (with the aid of a small hammer if necessary) then insert the shaft into the tube from the left hand side. Attach the large gearwheel to the other end of the shaft with the magnet and nuts side nearer the board, pushing the shaft through the gearwheel so that a few mm of shaft projects on the other side. Adjust the position of the gearwheels so that the shaft can rotate freely but is not too loose. Finally attach the propeller to the right hand end of the shaft on top of the large gearwheel. The deeper pitch of the propeller blades should be outermost, the shallower pitch nearer the board - i.e. the wind should strike the steeper part of the blades first. Note that this is the reverse of the way a propeller is normally mounted (because the blades are not being used in this case to actually propel the unit but are acting instead as a turbine). If the propeller is too loose on the shaft then secure it with a little glue.

Connect a 9V PP3 battery to the battery snap. The software includes a power-on self-test. All the segments of the LED display should flash once if the board is functioning correctly. The display should then show "--" indicating the unit is ready.

Note that the battery used should be a good quality alkaline battery such as a Duracell.

The set of three pairs of larger holes and long cable ties are for attaching the unit to a pole or similar to hold it firmly while recording wind speeds.

How to Use

Test that the light sensor is working correctly by pressing the SOLAR pushbutton then shining a light onto IC2 (the smaller chip). The display should change as the amount of light changes. The displayed value is in mW/cm^2 and if it is 100 or more then it flashes 99.

Then test that the wind sensor is working correctly by pressing the WIND pushbutton and spinning the propeller. After a few seconds the display should show the speed in revolutions per second. As the propeller is spun faster the speed should increase. (The displayed value is a moving average of the last 4 readings taken over a 10 second sampling period.) If it fails to register the speed then bend the Hall effect sensor slightly closer towards the magnet.

To log light levels, press and hold down both the MODE and the SOLAR pushbuttons for about 2 seconds. The display will change to a clock showing elapsed minutes with the decimal points flashing every second.

Light level values are recorded every 15 minutes over a 24 hour period, to give a maximum of 96 individual readings.

The unit should be positioned so that the light sensor is angled towards the arc of the sun, as near at right angles as possible to ensure that the maximum amount of light falls on the sensor's surface.

(If the intensity of the sun's rays is such that the display consistently exceeds its maximum value, then the light sensor can be covered with a small piece of translucent material. This will reduce the amount of light that reaches the sensor. By comparing the readings on the display with and without the material it is possible to calculate the fraction of light that is absorbed and to scale results accordingly.)

While logging, pressing the SOLAR or WIND pushbutton cycles through a display of the last recorded value, the elapsed hours, and the elapsed minutes.

After about 20s the display is blanked to save power.

To abort logging press the MODE and SOLAR pushbuttons together.

Similarly to log wind speeds, press and hold down both the MODE and the WIND pushbuttons for about 2 seconds.

Note that you can't log both light levels and wind speeds simultaneously.

To view the recorded log of light levels, press the MODE pushbutton and the SOLAR pushbutton then release them (i.e. don't hold them down for 2 seconds).

The display will first show the (Pe)ak recorded value, then after the SOLAR or WIND pushbutton is pressed it will show the (Av)erage recorded value. The latter is a simple mean of all the values in the log. Pressing the SOLAR or WIND pushbutton repeatedly will then step the display through all the recorded values one at a time (up to 96 readings).

To abort viewing press the MODE and SOLAR pushbuttons together.

If the unit hasn't recorded any light levels then it will display "Er" indicating an error.

Similarly to view the recorded log of wind speeds, press both the MODE and the WIND pushbuttons then release them.

The logged values can be entered into the Excel spreadsheet "Windy Joules.xls" which will automatically plot a graph of the readings over time. It will also calculate a measure of 'available power'.

In the case of solar power this 'available power' is simply the average light level (normalised to a 24 hour period). The spectral response of the light sensor peaks at about 750nm and approximates the spectral response of a photovoltaic solar cell, so to calculate real solar power one could simply multiply the average light level by the area of the solar cell in square centimetres by its efficiency to arrive at a power output in milliwatts. Bright sunlight is about $100mW/cm^2$, which is the same as $1kW/m^2$.

The calculated wind power is a sum of the cubes of the recorded values because wind power output is proportional to the cube of the wind speed. A simple average of the wind speed can understate the available power.

These two 'available power' calculations are really dimensionless quantities because the size of any solar cell used is unknown, and the relationship between actual wind speed and turbine rotational speed depends on the specific turbine used (but is assumed to be linear). However they can be used in comparisons between different locations and between different times of the year.

Component List

Resistors

R1 - R8	100R (brown, black, brown, gold)
R9, R10, R11	1k (brown, black, red, gold)
R12, R13, R14	0R (black)

Capacitors

C1	100nF ceramic (brown, marked ‘104’)
C2, C3	10uF electrolytic (blue or black)

Semiconductors

HALL	Hall effect sensor (black, thinner than regulator)
REG	78L05 regulator (black)
IC1	PIC16F628A-I/P microcontroller (A51X) + 18-pin socket
IC2	TSL230R light sensor + 8-pin socket
DISPLAY	dual 7-segment LED display

Miscellaneous

S1 - S3	miniature tactile push switch
BATTERY	PP3 moulded battery snap

PCB
3 x long cable ties
3 x short cable ties
Plastic tube
Steel shaft
Small gearwheel
Large gearwheel
Neodymium magnet
2 x M3 nuts
Propeller