A LOW-COST MICROPROCESSOR CONTROLLED MONITOR FOR WIND WATER PUMPING

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ABSTRACT

A simple system for monitoring wind water pumping performance which is suitable for a developing country is described. It is developed around a low-cost microprocessor system, Microprofessor IB of Multitech Industrial Corporation, to monitor the wind speed, water flow and pump strokes. It has low initial and running costs, is easy to operate and maintain, requires minimum manual attention and has low and simple power requirements.

INTRODUCTION

Wind energy is frequently used for pumping water. The choice of the windmill, the pump and the volume of the reservoir depends on the "wind regime" and the hydrogeological conditions. Therefore, to determine the best system, a pumping test with measurements of windspeed, pump strokes, and water output has to be carried out. A continuous monitoring of these parameters is, in most cases, very appropriate and sometimes necessary. It is useful to know both the distribution of wind speed and the average speed as a function of time. Since the power available from the wind is proportional to the cube of its speed (Le Gourie'res' 1982) knowledge of distribution of wind speed is very important to estimate the available power. However, knowledge of wind speed distribution alone is not sufficient to fully understand the "wind regime".

A common method is to measure the wind speed distribution with a compilator (McGowan 1984). This sorts out the wind speed according to its magnitude and stores the information in "bins" as the number of time intervals. This generates a histogram of wind speed distribution from the site. Each bar of the histogram represents the amount of time the wind blew with a speed in each speed range (bin). For example, bin no 0 counts all minutes when the wind was blowing with a speed in the range 0-2 kmh^{-1}, bin no 1 counts minutes in the range 2-4 kmh^{-1} etc. The last bin represents the number of minutes during which the speed was above a certain limit. The weakness of this method is that it does not tell us, at what time of day or on what day of the week, the wind speed was maximum, minimum, productive, unproductive, etc. Therefore it is desirable to have an instrument which can record both the wind speed distribution histogram and the average speed as a function of time.

A nationwide network of monitoring stations, as set up in Botswana, is sometimes necessary to gather the data for the proper planning and utilisation of wind energy on a national scale. The instrumentation to acquire reliable data with minimum level of manual attention can be very expensive, especially for a developing country. The power requirements of the data acquisition system, maintenance, data retrieval and analysis can also be difficult problems.

Therefore, it is important to choose a monitoring system meeting the following criteria:

1. Low initial and running cost

2. must be easy to operate and maintain
3. requires only a minimum level of manual attention, and
4. low and easy power requirement.

Various low-cost microprocessor systems (like home computers), which require only a very low level of power, are now available. Such a microprocessor system along with a few easily available ICs can meet most of the above-mentioned criteria.

An example of a monitor built around a low-cost microprocessor system, Microprofessor MPF IB (Multitech Corporation) is described here. This design can be adapted to other Z80 microprocessor systems like the Sinclair Spectrum without much difficulty. Special care is taken to minimise the number of components and to use easily available ICs. The number of channels are limited to three (which can be increased if necessary), to monitor wind speed, pump stroke and rate of flow of water.

The software (details available from the author) provides histograms for each parameter at every fourth interval with a sampling interval of one second. This has the advantage of continuous monitoring to give the average data as a function of time, while providing a detailed histogram of the distribution. At this rate, a C90 audio cassette (one side) can run for about a month without any attention. As indicated later in this paper, the software can easily be changed to have any convenient histogram and sampling intervals.

Following a general description of the system, the hardware and the software of the system are discussed. This is followed by a description of the loading of the program, data acquisition and retrieval and the power requirements of the system. Finally, the initial and running cost estimates are presented.

DESCRIPTION OF THE SYSTEM

Figure 1 shows a block diagram of the system. The sensors used in the present system are: a cup anemometer for wind speed, a flow meter for the water output, and a microswitch for the pump stroke. The cup anemometer has a reed switch operated by a set of four magnets rotating with cups. The switching "on" and "off" of the switches within all the three sensors are converted into standard TTL pulses by Schmidt triggers. The number of pulses produced in a given time interval is proportional to the magnitude of the parameter monitored. Three separate 8-bit binary counters count the pulses for a pre-determined interval of time (one second in the present case) referred to here as the sampling interval.

At the end of this interval, the counts are transferred to some temporary storage called "buffer". Within a few microseconds, the counters arecleared and counting starts again. In the meantime, the microcumputer reads the buffers, one after the other (and once in the sampling interval), and increments the content of an appropriate "bin" whose position represents the magnitude of the parameter monitored. Each "bin" is assigned to two successive bytes of the memory, so that the maximum number each bin can hold is 65,636. A block of 66 memory locations are reserved for each parameter, representing 33 bins. If the magnitude of the parameter is greater than 32 counts per second, it will also be registered in bin No 32.

The data recorded in bins 0-32 thus represent a histogram of the distribution. The histrogram data for the three parameters are recorded automatically on an audio cassette tape at regular intervals of time. This interval, denoted in the text as "histogram interval", in the present setup is 4 hours. After this interval the memory is cleared and a new histogram is recorded. In this way, a continuous record is obtained, while keeping the advantage of histogram records. The cassette recorder switches on automatically only six seconds before the recording and switches off when the recording is over, to save on power.

HARDWARE

Figure 2 shows a detailed circuit diagram of the monitoring system. The output of ICI (7413) is counted by two 4-bit binary counters (7493) in series forming an 8-bit counter. The clear/count control signed is provided by PAO - bit 0 of Port A of the Z80 PIO chip. The output of the 8-bit counter is latched by the respective tri-stake buffer - IC 4, 5, or 6 (74LS373) at the end of the sampling interval. The latching is done by the signal from PAI. The tri-state buffers are enabled by the control signals from PA2, PA3, and PA4 one after the other. The data on the data bus are read by the microprocessor from Port B of the Z80 PIO chip. Control signal from PA5 controls the power supply switch of the tape recorder through an opto-isolator IC7 and a relay.

Microprofessor MPF IB is the microcomputer controlling all the operations and storing the data temporarily. It is a simple system based on the micro -processor Z80 and having 2K RAM, 2K ROM, a hexadecimal keyboard (with some function keys), and a six digit read-out. The 2k-ROM holds a sophisticated monitor including routines for tape write and read. A complete listing of this program is available with the system. The System also has sockets for a EPROM, the Z80 counter-timer IC (CTC), and the Z80 Parallel Input/Output IX (PIO). The CTC and PIO are daisy-chained with the CTC having the higher interrupt priority. The CTC and PIO signals are accessed through the edge connector P_2 on the system board.

The function of the Z80 CTC in this design is to interrupt the micro- processor at regular intervals of time, to perform the Interrupt Service Routine (ISR) which acquires the data from PIO Port B and increments the count of an appropriate bin (two-byte memory locations). The CTC has four independent channels which can operate either in the counter mode or timer mode. In the counter mode, the CTC accepts and counts pulses from an external source. The CTC can be set to interrupt the microprocessor after a certain number of counts have occured. In the timer mode, the CTC counts the pulses from the system clock. In the present design, channel 2 is programmed to operate as a timer and channels I present and 0 respectively. Channel 0 sends the interrupt signals to the microprocessor. The interrupt period (sampling interval) is, thus, given by (system clock period) x (Pre Pascalar of channel 2) x (Time constant of channel 2) x (Time constant of channel 1) x (Time constant of channel 0); in this program one second.

The Z80 PIO has two bi-directional ports, Port A and Port B. In the design described here, Port A is set in the control mode and Port B in the input mode. Only 6 out of 8 available control signals from Port A (PA0-PA5) are used here.

SOFTWARE

As mentioned before it is desirable to know both the distribution and the average value of a parameter as a function of time. The software described here is a compromise between these two requirements. It samples the data every second and stores it as a histogram. A new histogram is generated every four hours. Adding these histograms, it is possible to get the distribution for a day, a week or a month. The average value of each distribution also provides wind speed as a function of time. Both the samping interval and histogram interval can be changed easily to suit a situation where one of the above mentioned requirements becomes more important.

The program consists of three parts:

1. Initialisation routine
2. Interrupt service routine
3. The routine for recording on an audio tape.

Initialisation routine

This routine resides in memory locations 1800_H - 1838_H, when the program is loaded into the machine. The first part of the routine allocates memory spaces for the three "compilators" - wind (1A00H - 1A40H), pump strokes (1A44H - 1A84H), and water flow (1A88H - 1AC8H). Memory locations 1A00H and 1A01H are assigned as the low and high bytes of bin 0 of the wind compilator, 1A02H and 1A03H as the low and high bytes of bin 1 of the same compilato, etc.

The second part specifies the sampling interval, histogram interval and the end of the tape. A software solution to detect the end of the tape is preferred here over a hardware solution, as it is safer and reduces the component count. By changing the sampling location (one second here) the histogram interval and the total time for a single run will also be changed. For example, if the sampling interval alone is changed to 0.5s, the histogram interval will be reduced to 2 hours and the total time for a single run with a C90 tape will be about 15 days.

Interrupt service routine

This part of the routine scans the counters of the wind, pump stroke and waterflow channels and receives the data. If a data item is not less than 32, a value of 32 is assigned to it. The processor uses this number (<32) to find a corresponding set of locations (bin) and increments its content by one. Each bin is 2-byte wide so that it can hold up to 256 x 256 = 65,536. After reading the wind channel, it passes on to pump stroke channel and then waterflow channel. During the operation, the counters are still counting. The counters stop counting only for a few micro seconds between the instructions. The ISR is repeated every second (or the sampling time).

Tape routine

When the data counter reaches zero, ie after 14,400 sampling intervals = 4h, the tape routine takes over. The power of the tape recorder is switched on and the system then waits for 6s to stabilise. A file number is automatically assigned. The first file number is the initial setting of the DE register-pair, 180 in the present case. The next file number will be 179 and so on. Instructions from 18FCH to 1907H specifies the memory area to be copied on to the tape. The program then calls a sub-routine from the Microprofessor monitor (instruction at 191H) to record the data on to the tape. After copying the three histograms, the tape recorder switches off automatically and the memory area in the micro computer is cleared. It then returns to perform another four-hour run. During tape-recording which lasts about 1 min, the counters stop counting.

PROGRAMME ENTRY

The machine code in hexadecimal notation is first loaded manually, using the hexadecimal keys of Microprofessor. (For details of loading a program, refer to the Microprofessor User's Manual.) Once the whole program is typed into the memory of the system, it can be copied onto a cassette tape. Since there is an extra socket provided for an EPROM on the system board, the program can be copied and stored permanently in an EPROM lC.

DATA ACQUISITION AND RETRIEVAL

After loading the program from the tape, alterations necessary to assign sampling interval, histogram interval, and tape length, can be made by entering the appropriate numbers in the locations mentioned earlier. The data acquisition can be stopped at any time by pressing the reset key and the stored data examined. The data recorded on the tape can be read back into the memory of the system, one file at a time (one histogram for each channel) and displayed by the six-digit read out. A low-cost thermal printer (PRT-MPF-1) is available from the manufacturer of Microprofessor to obtain a printout of the data. A more efficient method is to communicate the data directly into the memory of another computer (used for analysis) through an interface between the Z80 P10 and the user port of the microcomputer.

POWER SUPPLY

Microprofessor requires only unregulated power of between 7 and 24V. The interface needs 5V regulated power which is obtained from the same unregulated power supply of 7 to 24V using the circuit shown in Figure 3. Therefore, the whole system can be powered from a 12V car battery which can be charged by solar cells. The tape recorder requires an additional 6V source.

CONCLUSION

The complete system, excluding the battery and the audiocassette recorder weighs only about a kilogram and has a simple power requirement. The maximum current drawn is 0.5A. These factors make the system ideal for field use. The components used are minimum and easily available. The initial and running costs are very low (Table 1). With a proper housing, it can accumulate data for several weeks without the attention of an operator. A prototype of this system was built and found to run for several weeks under laboratory conditions.

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TABLE 1: An estimate of initial costs

	£
Microprofessor MPF-IB	100
ICs, Connectors and Cable	25
Tape recorder with tape, and recording cable	35
Total	**£160**

(Anemometer, flowmeter and battery are not included in the above estimate)

An estimate of running cost

No running cost is expected other than the cost of cassette tapes and charging of batteries.

FIGURE 1: Block diagram of the monitor

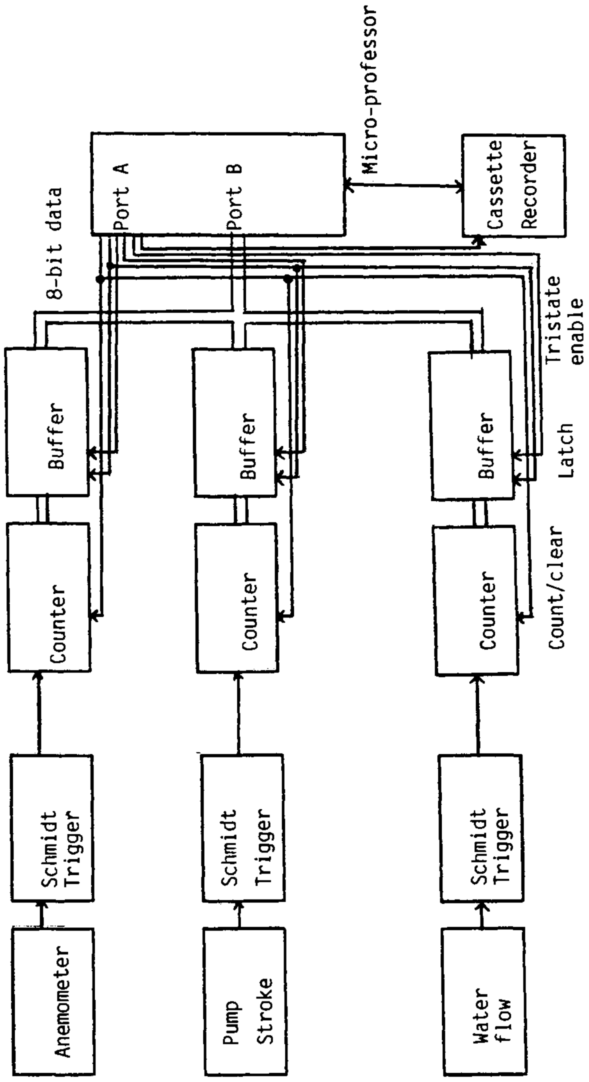

Fig. 1 Block diagram of the monitor

FIGURE 2: Circuit diagram of the monitor

(only one channel is shown)

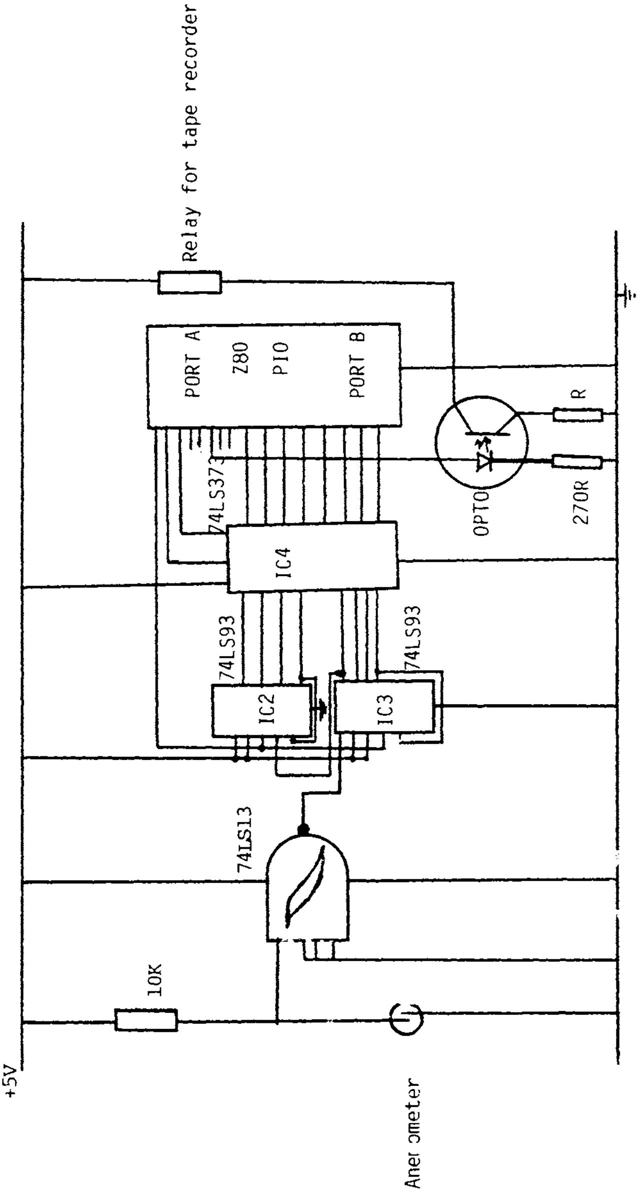

Fig 2. Circuit diagram of the monitor
(only one channel is shown)

FIGURE 3: Power supply for the monitor