DESIGN AND CONSTRUCTION OF A COMPUTER AIDED CONTROL AND MONITORING SYSTEM FOR GREENHOUSES

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ABSTRACT

High expenditure is one the major disadvantages of using human or labor work force in agriculture division. Lack of accurate and precise processing, low working speed and the effect of physical tiredness on their efficiency are same other disadvantages. Using modern technology and replacing human work force with the automated mechanisms and instruments or intelligent machinery leads to the reduction of these expenses, enhancement of precision, accuracy and work speed and finally increase productivity, quality and quantity of crop production.
This automated system is created using basic parts of suitable sensors, PC hardware and written software, proper power supply, measuring and control parts as well as a calibration program for accessing above purposes. Having this continuous control and monitoring system and installation in a greenhouse we will be able to measure and control some important and vital variable parameters i.e. temperature, air relative humidity, soil moisture content and light intensity automatically. Thus, if the degree of existence of these parameters goes up and down from permitted limit, the related designed utility systems would be activated to control them automatically.

This system also would be inactivated when the variable parameters fit in the admitted limit. Meanwhile, whenever one of the variables value enters the critical zone, an alarm (if connected to the system) would go on to quit proper circuit.
This is an electro-computerized system which measures each variable parameter via frequency with minimum pulses noise within a complicated processing circuit, saves its values and draws the related diagrams precisely too. The final evaluated workshop tests showed this facility has excellent flexibility for calibration and timing setup via programmable software that might be used for specific research purposes, following the events and changing the effective factors even more required ones than in this project inside any developed commercial greenhouse size.

Key words: Measure, Control, Monitoring, Greenhouse, Temperature, Light intensity, Air relative humidity, Soil moisture content, Computer

INTRODUCTION

With social development of human being live, the value of human or labor work unit has been promoted. As the result, the level of wage and salary expense is also increased in following of higher inflation rate. For instance, the minimum labor wage in Iran was $5 per day during 2003, while it has been increased almost three times ($15) today (2009). This shows that inflation rate is very high in our country which causes continuous labor expenses annually. Other human or labor work problems are low precision, accuracy, and speed of work and subsequently, low work quality and quantity because of labor tiredness.

Thus, any employer is searching a suitable option to solve this extra expenses problem by substitute with labor work force. One of the best choices of this substitution is using intelligent system included electronic and computerized mechanisms in work chain cycle of a production unit.

The computer is day by day more used in various human being living activity scenes because of its great advantages such as, high decision speed, precise processing, programmability, capability of entry, register and saving data information with high volumes and also simultaneously, luck of tiredness problem in continuous long term works.

The closed greenhouse environment is also one the much used fields in agricultural activities which is frequently demanded because of specific regional conditions all over the country. Therefore, greenhouse is a controllable artificial closed environment which is used when the plant has not compatible with natural conditions. Obviously, in work frame of using greenhouse the role of proper control and on time of effective environmental parameters on growing plant is more significant. Then, for solving this vital problem, we can take in our account, the computer and electronic circuits or instruments more seriously.

This project was carried out towards accessing above purposes through designing and construction of an intelligent automated system to monitor vital variables in greenhouses. In this system the computer via a written programmable software measure, register and save by entry data into a folder of PC hard drive for controlling four basic variables required to grow plants inside of a greenhouse such as temperature, relative air humidity, light intensity and soil moisture content.

The conducted research of this project is included a few major parts as following:

1- Research in relation to choose best required sensors
2- Designing structure of hardware elements for this system
3- Writing required programmable software

Basically, this unit as an automated system is used for superintendence or stewardship and control of other production units such as storages, animal husbandry and poultry.

Finally, this automatic and relative intelligent system is also programmable and capable for monitoring and control all other related required environmental variables for plant growth precisely within a greenhouse. This created system decreases labor work hardship and expenses and increases production quality and quantity as well as having controllable vital variables despite on the farm. All

registered informative data and graphs are also used to analysis scientifically or save in archives for other research purposes.

MATERIALS AND METHODS

USED SENSORS:

A- Light Dependent Resistor (LDR) was used as a luminance sensor. The limit of sensor sensitivity is within 370-870 nm which covers 400-700 nm limits of Photo-synthetically Active Radiation (PAR) and maximum sensitivity is in the middle of this limit. LDR is a kind of nonlinear resistive sensor which its resistance is decreased by increasing light. The variations of resistance is highest in minimum light instead of one light variation unit and by increasing light, the variations rate is also decreased.

B- ALM35 as a temperature sensor was used. This sensor is a kind of PN sensors in which output voltage is linearly increased following higher temperature. LM35 is a production of National Semiconductor in which output voltage is increased to 10 mV for any increased centigrade degree of temperature. The range of sensitivity for this sensor is within -55-150 centigrade (Anon, 2000) that could cover variation limits of temperature in greenhouse.

C- A Philips H1 sensor was used to measure weather or air humidity. This sensor is a kind of nonlinear capacitive sensors. This sensor is concluded of two gold plates in which a fiber sheet is located between them. The dielectric index of this fiber sheet varies in following of relative air humidity variations. The above assembly is located within a gridded chamber. As the result, capacity of this sensor is increased in following of increasing air humidity. The sensitivity limits of this sensor are within %10-%90 RH (Anon, 1996) that covers variations range of air humidity in greenhouse.

D- A gypsum block as a sensor was used to measure soil moisture content. Gypsum Block is a kind of non linear capacitive sensor in which its resistance decreases following increasing soil moisture content. The limits of sensor sensitivity are from -0.1 to -17 bars (Dela, 2001) that covers limits of between -0.33 bars as field capacity to -15 bars for wilting point (Tear and Peat, 1995).

UNIT HARDWARE

PC interfacing: This interfacing in unit is done through parallel port that is also named Line Printer Terminal (LPT). This port is accessible via a plug from material of D-25 on the back of PC case which has three registers of data, control and status. These registers are included of 8 signal lines for only reading, 4 signal lines for reading/writing and 5 signal lines only for writing. The register of data enables for both reading and writing if parallel port locates in bi-directional state. This specification exists only in mode of SPP (Standard parallel Port), EPP (Enhanced Parallel Port) and ECP (Extended Parallel Port) (Peacock, 1998).

Today, new computers more often have this capability. In this developed unit, also the data register is used for reading data by computer. As the result used parallel port in computer must have capability for reciprocal data register. A

control register system also was used for addressing to any different ports of circuit.

POWER SUPPLY

An AC 220V to DC 6V transformer was used to reduce city electricity voltage in which the outlet was equipped to a bridge rectifier to receive directional current. The output direction current voltage was bout 8.7V which also was not a clean voltage. For this purpose, a 470 mF (micro farad) capacitor was connected first of all to outlet for cleaning voltage relatively and subsequently to two L7805. A series of L78XX as voltage regulator connected to advisable inlet voltage (as mentioned in information leaflet) can deliver a constant clean voltage at the outlet port (Anon, 1997). Finally, a 100mF capacitor as a final cleaner was used for any L7805 regulator as figure1.

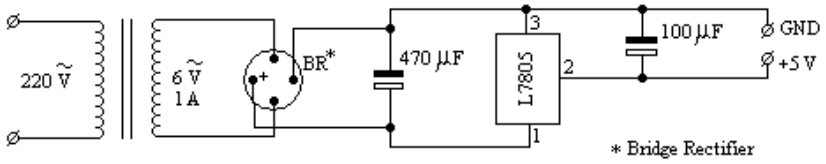

Fig.1: A circuit of power supply

MEASURING DIVISION

The method of measuring air humidity, light intensity, soil moisture content was done by measuring frequency. This means that resistance or capacity variations will be resulted to change frequency or from measuring frequency and calibrating received data, above mentioned parameters will be calculated as follows:

Equation 1 $F = \dfrac{1.44}{(R_A + 2R_B).C}$ Equation2 $T_H = 0.693(R_A + R_B).C$

Equation3 $T_L = 0.693(R_B).C$

Therefore, an IC555 (Integrated Circuit) was used for each related parameter. One of applications of this kind of IC has been shown in figure 2. Based on this, by changing R_A, R_B and C square pulse frequency of outlet will be also changed according to equations 1, 2 and 3 (Anon, 2003). The relation between frequency and period and time of going up and down of outlet pulse rather than R_A, R_B, C in equation 1, 2, 3 has seen. In this design, gypsum block is replaced instead of LDR, RB, or R_A Philips HI and C. By deriving of frequency function relation to variable factor, we can access to each constant parameter value in above functions.

For instance, gypsum block as RB is used instead of variable of frequency equation and then calculates the value of R_A and C. Considerable points in calculating above values are variation rate of F instead of one unit of variable change that indicates range of variations for sensor parameter, and maximum

value of F. In this project in the purpose of preventing circuit enlargement, the count of pulses is done by the computer. As the result, maximum of F value is limited to computer speed.

Gypsum block and LDR used in this project have a range of resistance variations from 570 K to 1 Mega ohms and 2 to 70 Mega ohms subsequently. Also the range of capacity variations of Philips HI is between 112-144 Pico Farad (Anon, 1996). Output pulse of any IC555 is connected to a terminal base of IC74LS245 and extra bases of 74LS245 and the ground (Anon, 1994a). This has used to urge “Shift register” and also buffering of a signal that could protect parallel port.

Finally, exit bases of 74LS245 is connected to data register of port and receives an activator signal OE (Output Enable) from one of activator signals 74LS138 (Anon, 1998). Also a +5 V power supply is connected to an activator of NOT IC74LS04 (Anon, 2000a) and its outlet to one of inlet bases 74LS245. This is stated because the written program could diagnosis whether the unit is in accessing or no. The mentioned circuit has shown in figure 3.

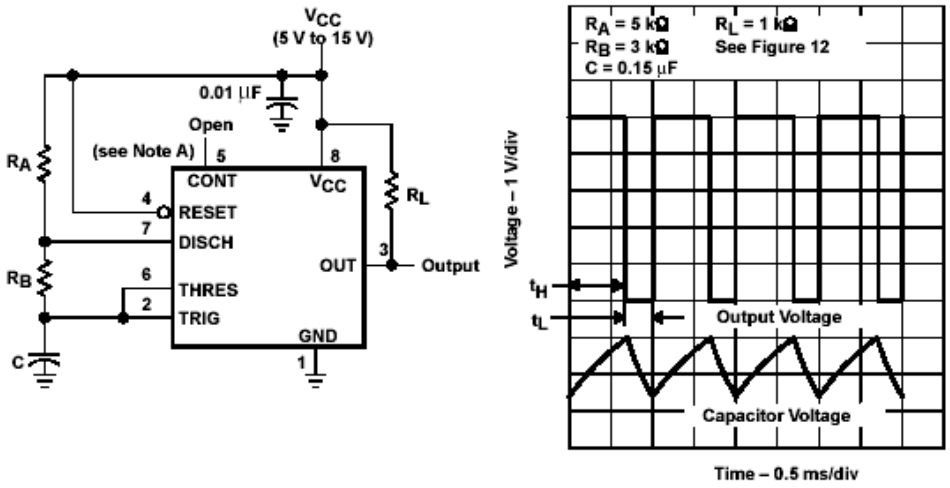

Fig.2: Use of IC555 for creating hour pulse

To measure output voltage LM35, an IC ADC0804 is used. This IC do measurement by relative method or ratio-metrically. This means that measurement is done based on $V_{ref/2}$ (Anon, 1994b).
This circuit is recommended by Mazidi,2000 and information sheets of LM35.

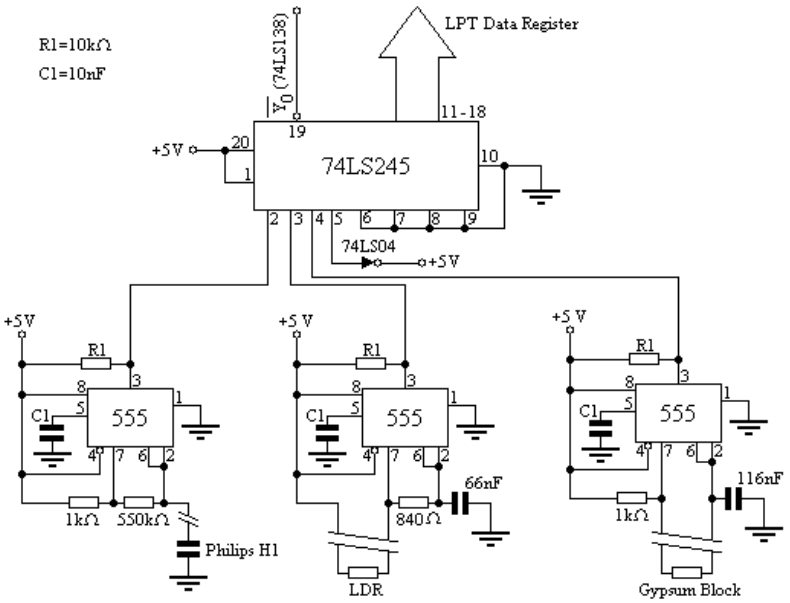

Fig.3: Circuit of humidity measurement, light and soil moisture

To calibrate temperatures that have been read, mentioned referenced voltage variation is used by using a potentiometer. The output binary number shows potential different between V (-) to V (+) and this mentioned output is connected to data register and receives its activator signal CS (Chip Selector) from actuator signals of 74L5138 (figure 4).

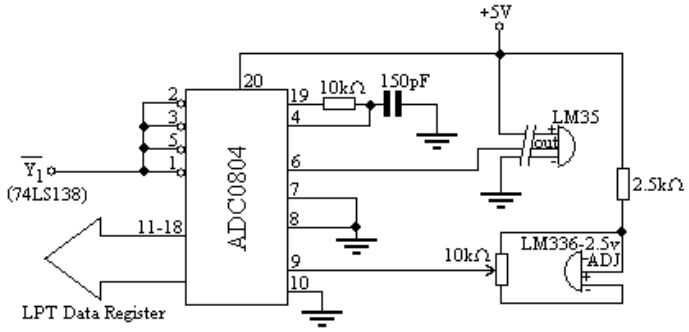

Fig.4: Circuit for measuring temperature

CONTROL SYSTEM

IC74LS373 works as a control core of this part (Anon, 2001). The order of performance for rely is received and latched via data register of parallel port. Each line of lines shows activation or non activation of each establishment system. The maximum output signals current has not capability of rely activation (Anon, 2001). As the result, a resistance and a transistor are used to make buffer of signals. Then, rely connects to C945 and is fed from supply power directly. The signal G when are down, outputs will be latched. For receiving new order, it must be go out of latched state and then it must be latched again after receiving other

order. As the result, one of signals 74LS138 (Anon, 1998) connects to an actuator NOT IC74LS04 (Anon, 2000a) and its output to G signal bases (figure 5).

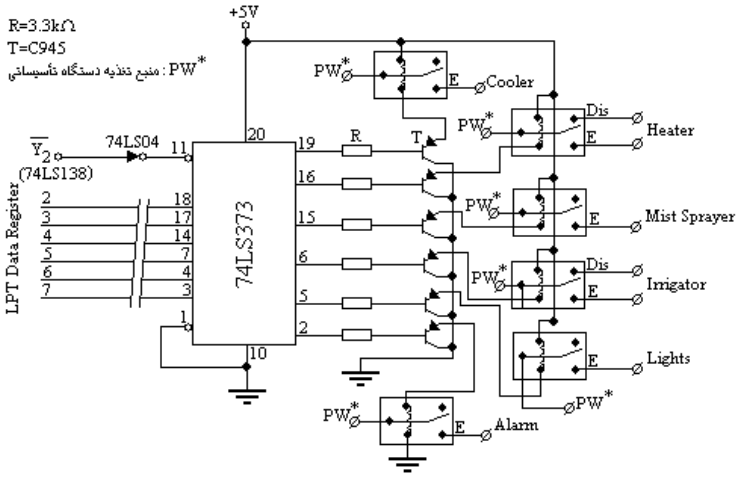

Fig.5: Circuit of control system

In over all, IC 74LS138 is used as a decoder (Anon, 1998) in which signals receive their addresses from control register of parallel port. The select printer signal is used to activate mentioned IC. By this mean, it is possible to install a terminal on the system back for connecting to the printer.
Therefore, PC capability is not denied from point of view not accessing printer via LPT port. Thus, to activate system or unit, the mentioned signal must be high (Peacock, 1998).
As the result, it prevents interference of system signals and printer and we can use a printer in any software environment. Each line of signal lines for register of data and control is connected to resistance up to 10 K ohms. These resistances are used as a “pull up” to protect ports (Mazidi, 2000, and Peacock, 1998).

SYSTEM SOFTWARE

System software is written in visual basic program. The software is addressed to different parts to activate for recording each mentioned data. Then, these data are readable through a port or write orders on it. This program actuates IC74LS24S and read number of output pulses until suitable frequency has been calculated via three related sensors.

For this, a numerical method is used, in which suitable frequency is measured through three sensors simultaneously. Therefore, wasting time is decreased to one third. Time of measuring frequency is 100 msec.

In PC, windows run different actuated programs in parallel virtually. As the result, in order to don’t create any error in reading number of pulses, an order is used that could be able to run program in real time state. This order is presented in a file of Dynamic Link-Library (DLL) by Brent and Cainca, 2002.

The program receives a table from operator to calibrate receiving data. In this way, mentioned table receives data from operator (or pre-prepared table) in form of one by one for each frequency related to system and proper amount related to

parameters. The software convert all numbers between mentioned rates in to linear form and finally give us a calibrated numbers.

In overall, sampling from situation of each environmental parameter is done once in each minute. In this time, the temperature is read 15 times in space of one second. This problem is available because of created error for electrical noises in readable temperature data. This error is removed by numerical methods.

To control environment, two procedures in the program is presented. The operator can introduce two numbers as admitted rate limits for each environmental parameter in two constant state or time tabled program. The software, with comparing processed information in admitted limits, activates or inactivates establishment system. Also, the operator would be able to introduce warned critical limits if he/she would like. Thus, where as each parameter is located within these critical or alarmed limits, a bell rings (if it is installed to system) as soon as activated. Also, it is possible, that system could be go out of automatic control, then operator would be able to do “on or off” establishment system by hand through software.

It is essential to mention that light control is done by connecting light source to the system based on minimum and maximum numbers of required light hours for plant. System registers and monitors all readable data information related to each sensor and situation of settled devices in each 5 minutes.

Also, a variation graph of each parameter is drawn in real time state. This is possible for the operator, to demonstrate, monitor and print details or graphs related to registered data via determination of initial and finishing times demanded. The specifications of graph drawing is based on lack of limits on determining initial time and ending time demanded and the program calculates time scales and draw graphs automatically.

RESUTS AND DISCUSSION

SENSORS: The studies in relation to selected light sensor showed that using Quantum sensor in agricultural fields is better to measure light intensity (Both et, 2002 and MkGree, 1972) showed, it s better to measure PAR via reading numbers of photon impacted with area unit (MkGree, 1972). This concept is not in direction of meaning old units of light.

As the result related sensors to measure light based on old units to access light in PAR are not usable (Both et, 2002 and MkGree, 1972). However, principle problems are higher price and lack of accessing to quantum sensors. Then, if measuring light relatively is important, using old ones couldn’t create any problem. In this situation, LDR sensors could be a suitable sensor from point of view, price, accessibility, noise, sensibility and variations rate which are recommended.

In over all, using LM35 is recommended for systems in which the precision is not very important and circuit application is also limited. The precision of this sensor is one centigrade degree (Anon, 2000b) that is not suitable for precise measurements. It also many factors create noises in output data. In addition, the

calibration could be done because of using PC. Thus, using a thermistor is recommended.

The designing and fabrication of this automated system has resulted this fact that they are not suitable to measure moment by moment, because of using laboratory soil moisture content instruments. These instruments are expensive and inaccessible in the market. Hence, the choice was limited to gypsum block. The performance of gypsum block is better in dry soils (because of more variations rate). However, in overall, this is usable for low precision conditions. It was approved that its variations graphs by passing time also will be changed.

Then, the system need to calibrate again after sometime (Anon, 1997a). The gypsum block also must be changed after 1-3 years (Dela, 2001). Other notation is doing recalibration required for each gypsum block (Dela, 2001). Our investigations showed that the variety of choices for air humidity sensor is limited to small ones. However, the used Philips HI sensor was suitable from point of view noise and variations rate.

Circuit: Our studies approved that procedure by frequency was a suitable method. This method was involved to an acceptable precision and very low noise. The only problem was time consumption of measuring frequency. To resolve this problem, it was proved that in systems with significant processing time consuming, we can calculate signals periods and their up and down times too. The workshop also showed that for measuring frequency, it is better to read number of pulses by circuit rather than by PC with extra wasting time.

The experiences related to a developing workshop prototype sample of this system showed us;"It is also recommended that all IC555 be accommodated in a sensor box if all sensors are connected to circuit by a long cable". Thus, all received pulses in the box must be stronger to compensate the effect of cable length.

CONCLUSION

In overall, this system was capable for a high performance and suitable precision. The precision of measuring temperature, air humidity and light intensity (subsequently, CO, % relative and lux moisture) each was on unit and soil moisture was 1/10 bar.

This point must be taken in account that greenhouses based on their applications and dimensions have various conditions. Then, this developed automated system must be designed based on requirements of each greenhouse.

This fabricated system could be adapted by some minor changes for this purpose. For instance, it might be possible a greenhouse includes several compartments for growing different plants, herbs or vegetables. Therefore, this system must be having several assemblies of sensors which after minor changing in their circuits and software could be used in new conditions. Also, each assembly of related sensors must be accommodated in a place with medium parameters values. The significant specification of used software in the system is self-flexibility and programmability as following:

1- Capable to accept timely programming in relation to admitted limit or range for each parameter. This facilitates to change or setup each parameter's value or limit if the cultivated plant needs during growth.

2- Capability to change calibration of the unit system. All different used sensors could be changed physically and chemically by time passing. Then, their precision will be decreased. For this reason, this system is designed including facilities to help operation, calibrate each sensor of each parameter via installed software of the system. This helps unit system works with acceptable and essential precision under each period of time and place condition. This processing also prevents lowering precise or changing sensor.

REFERENCES

1. Brent, H. & Cainca, B. (Translator; Shargh, H.). 2002. PC Interface, Measuring and Control by use of Standard Ports under Windows, Published by Chortkeh (p 289). Tehran. Iran
2. Tear, I.D. & Peat M.M. (Translators; Koocheki, A.; Hosainei, M.; Nassiri, M.). 1995. Soil and Water Relation in Crops, Jehad Daneshgahi. Mashhad (pp 9-36). Iran
3. Mazidi, M.A. & Mazidi J.G. (Translator; Sepidnam, Gh.). 2000. Arbitrator Circuits of IBM Computers 80x86 and competitive with it, Design and interfacing IBM Computers. Khorasan Publisher (pp760). Mashhad. Iran
4. Anon; 1994a. 74AHC245, 74AHCT245/Octal bus transceiver, 3-Stage; Philips electronics/ http://WWW.semiconductors.com; Netherlands; 20 pages.
5. Anon; 1994b. ADC0801/ADC0802/ADC0803/ADC0804/ADC0805–8-bit compatible A/D converters (data sheet); National Semiconductors; USA; 36 pages.
6. Anon; 2000a. DM74LS04 Hex inverting gates (data sheet); Fairchild Semiconductors/ http://WWW.fairchildsemi.com; USA; 5 pages.
7. Anon; 1998. DM74LS138,DM74LS139-Decoders/Demultiplexers (data sheet); Fairchild Semiconductors/ http://WWW.fairchildsemi.com; USA; 8 pages .
8. Anon; 2001. DM74LS373-DM74LS374/ 3-Stage Octal D-type transparent latches and Edge-Triggered Flip-Flops (data sheet); Fairchild Semiconductors/ http://WWW.fairchildsemi.com; USA; 8 pages.
9. Anon; 1996. Humidity Sensor (data sheet); Philips; Netherlands; 3 pages.
10. Anon; 1997a. L7800 Series/ Positive voltage regulators (data sheet); SGS Thomson; Italy; 25 pages.
11. Anon;1997b. Light dependent resistor (Data sheet);RS Components; USA; 4 Pages.
12. Anon;2000b. LM35/Precision centigrade temperature sensors (data sheet); National Semiconductor; USA; 13 pages.
13. Anon; 2003. NE555, SA555, SE555/ Precision timers (data sheet); Texas Instruments; Dalas,Texas; 24 pages.
14. Both.A.J; Mears.D.R; Reiss.E; Roberts.W. J; 2002. Horticultural Engineering/ http://WWW.aesop.rutgers.edu/~horteng ; USA; 8 pages.
15. Dela.B.F; 2001. Measurement of soil moisture using gypsum blocks; BY BYG; Urban; 28 pages.

16. McGree. K.J; 1972; Test of current definitions of photosynthetically active radiation against leaf photosynthesis data; Meterol .
17. Peacock.C;1998; Interfacing the Standard Parallel Port; http://WWW.senet.com.au/~peacock; USA;17 pages