European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

International Conference on Renewable Energies and Power Quality (ICREPQ'10)
Granada (Spain), 23rd to 25th March, 2010

Microcontroller-Based Moving Message Display Powered by Photovoltaic Energy

F. H. Fahmy, S. M. Sadek, N. M. Ahamed, M. B. Zahran, and Abd El-Shafy A. Nafeh

Electronics Research Institute, PV Dept., NRC Building, El-Tahrir St., Dokki, 12311-Giza, Egypt Tel./Fax+202-33310512/33351631
Ninet321@yahoo.com, mbazahran_2007@yahoo.com, abdelshafyn@yahoo.com

Abstract.

The aim of this paper is to design a textual display system, based on a light emitting diode (LED) dot matrix array powered by solar energy. The paper involves taking the device from an initial concept, through a design phase, to constructing a prototype of the product. The system consists of the display unit, which is powered from a photovoltaic (PV) module and a solar sealed lead acid battery.. The self-contained nature of the intended design will allow the display to be mounted almost anywhere it is needed. Therefore, the main purpose of this paper is to utilize the solar energy and a rechargeable battery to power a universal self-contained characters display unit. This display unit is useful for creating attention-getting messages, location identifiers such as maps and address identification display modules. The implementation of a moving message display panel which displays a text containing 22 characters (i.e., PHOTOVOLTAIC DEPARTMENT), and is powered by a PV module has been achieved. The control of this panel is based on an Atmega 8515 a Microcontroller. The used Atmel Microcontroller is programmed using Assembly language, through using AVR studio software and STK500 kit. The photovoltaic module charges the battery during the day and the battery is continuously feeds the display panel. The system consists of a single PV module that produces 75 watt, a rechargeable battery (12 V, 100 Ah), a charging battery controller with an extra regulator circuit (that can produce 5 V , 1.5 A to feed the display panel and microcontroller) and moving message dot matrix display panel with its rows and columns drivers. (Atmega8515 microcontroller, dot-matrices, rows and columns drivers). The advantages of the designed display system is easy to set up, program and handle, it also allows the outlet to simply and clearly present the scrolled text. Finally, it is found that the designed system is suited to be used for many other applications.

Keywords
Solar cells**,** microcontroller, moving message unit, PV sizing and charge controller.

1. Introduction

As the energy demands around the world increase, the need to alternative energy sources is increased. Therefore, it must exploit new and renewable sources of energy (e.g. solar energy, wind, hydrogen geothermal ….etc.) [1].

Solar energy is a renewable energy source that is environmentally friendly, unexhausted and unlike fossil fuels, solar energy is available just about everywhere on earth and this source of energy is free. Stand-alone photovoltaic (PV) systems are designed to operate, independent of electric utility grid. They are excellent for remote applications where utility grid is inaccessible and in locations where significant connection cost makes grid power prohibitively expensive. Such applications include parking, emergency telephones, temporary traffic signs, and remote guard posts and signals. Also, PV systems are generally designed and sized to supply certain. DC and/or AC electrical loads. Stand – alone PV system with battery backup can supply power to electrical loads with availability about 100% during all the operating environmental conditions. PV systems are generally designed so that there is a deficit in energy in winter, but a surplus in summer. This deficit and surplus can lead, respectively, to over discharging and overcharging of the batteries, which damage the batteries, shortening their life and increasing maintenance. A battery regulator prevents over discharging and overcharging, and therefore minimizes damage to the batteries and prolongs their life. A single module is connected to a single low cost battery through a simple charge regulator as illustrated in Fig. 1. The regulator has terminals for connecting to message display system. The research relating to the design of LED displays and microcontroller-based circuits was investigated throughout this paper. This knowledge provides better methods for approaching the task while helping to gain an understanding of microcontroller systems that will be useful for future works. The design for a sign message display that can be mounted outdoor the department, is then implemented in this work in the initial prototype, to verify its physical viability and to investigate any possible improvements. From which a viable product can be developed in the future.

2. Scope of the Paper

- Design a microcontroller-based circuits and size the PV required array and battery that are sufficient to power the LED moving message displays panel.
- Study the specifications of all the display system components (data sheet).

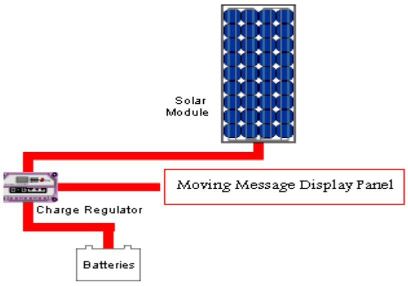

Fig.1 Stand– alone PV powered message display panel.

- Design the needed software that can provide the pre-programmed messages, and that of the animations for the display panel.
- Construct a prototype of the display system and studies its performance.

3. Objectives of This paper

- Using renewable energy sources, the Photovoltaic solar energy, in one of the terrestrial applications (Moving message display).
- Using Atmel Microcontroller to input, store, control and output the data for the message characters on a dot-matrix.
- Design and realizing the moving message display panel.

4. Display Systems Design Procedure

The initial step was the evaluation of the requirements that needed to be met. Also, the technical features, physical operation and possible applications for the design were addressed. Also, the functional specifications that outlined the purpose and features that the design would ultimately fulfill were also addressed. The main control circuit was initially tested on a breadboard because the microcontroller ports used for various tasks would ultimately change as the work developed and until the layout was finalized. Thus, the pin connections could easily be altered as required. The microcontroller requires very few external parts for typical operation.

An illuminated display usually consists of smaller modules (dot matrix units) arranged together to form a larger screen, each module usually consisting of a 5 x 7 matrix of LEDs. The minimum number of bits that a control system has to address for a small 27 module display is 945, one bit for each LED. The goal of this paper is to create a display containing approximately 27 modules (22 characters + spaces). This means the control system is required to handle 945 LEDs at any one time. The Atmel AVR family of controllers provides the engineer with cost effective solutions in designing low power control systems.

5. Expansion of LED Usage

In selecting the LEDs to use for the display the most freely available units were chosen for their ease of supply. These units needed to be successively side stackable to create a large rectangular matrix that forms the display screen. The most common form of modules of this type are the 5 x 7 dot matrix units which are widely available in a variety of sizes. Fig. 2 shows the configuration of this 5 x 7 dot matrix unit [2]. These displays were also preferred as they have pins that are aligned in a similar fashion to a DIL integrated circuit. The pin configuration made it easy to push in and orientate the LED modules on breadboard and stripboard, as well as making connections to the pins straightforward. The dot matrix LEDs has a common anode connection for each of the 5 columns and a common cathode for each of the 7 rows. This feature of the LED modules is utilized for the multiplexing process. The use of a LEDs dot matrix for creating a text display system is quite common with its usage expanding greatly in recent years. Such displays can be found in airports, where they are used to display flight information, and in stock exchanges to display share prices. The wide usage of LED displays is a result of its ability to convey information to large audiences quickly and efficiently. As LED displays are often controlled by digital technology the information can swiftly and easily be updated. This feature of LED displays has led to a great flexibility of such products in countless applications. An additional benefit of using this form of display is that LEDs are a very efficient form of illumination. Unlike incandescent bulbs, LEDs do not generate a large amount of wasted energy in the form of heat.

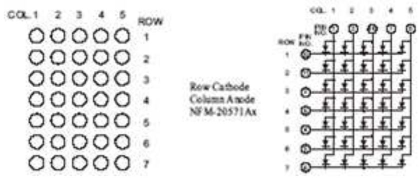

Fig. 2 Configuration of 5x7 dot-matrix.

[1] A. Serial-In Parallel-Out Shift Registers:

The 74HC595 IC is an 8-bit shift register, with this IC you can shift 8 bits to the outputs with only 3 wires, that are Data (Ds) and two shift inputs (Shcp, STcp). In order to obtain control over the 945 LEDs in a 27-module display, multiplexing of the I/O to the microcontroller is required. To do this, a series of serial-in to parallel-out shift registers are used to convert a stream of serial bits from the Atmel to a parallel output port to the LEDs. This process effectively extends the I/O of the microcontroller by converting a serial port to a parallel one. To accomplish the large parallel output port required to address each LED, the shift registers (74HC595) are daisy chained together. This means the serial output of one stage of the shift register sequence is cascaded to form the input to the next shift register. The shift registers used are a 74HC595, serial-in 8-bit parallel-out IC, which is shown in Fig. 3 and its data sheet can be found in [3].

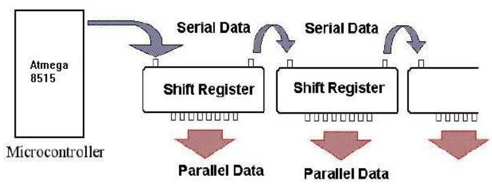

Fig.3 Conversion from serial to parallel data.

The device has a high current 3-state output that goes into a high impedance state when the output-enable pin is driven high. The devices have two separate registers within it, a shift register and a storage register; each register is provided with a separate clocking input. In operation, individual data bits are applied to the serial data input (D_s) and clocked into the shift registers using the shift register clock pin (SHCP). Once the entire 8 bits of serial data have been entered, the data can then be latched into the storage register where it becomes the parallel output. The output is latched by a positive-edge trigger on the storage register clock pin (STCP) when connected in this cascading manner, the shift register overflow pin (Q_7`) is used to transfer the excess data bit, caused by clocking more than 8 bits into the device, to the serial input pin of the next shift register in the chain [4]. The parallel outputs of the shift registers are not rated to handle enough current to illuminate the LEDs that they control. To get full illumination of the LEDs in the prototype, each will be pulsed with 50mA, which is above the 35mA rating of the 74HC595. As a result, current drivers are used to supply each all the LEDs with enough current to fully illuminate them. The driveres used are ULN2003A that contain seven high current darlington arrays [5].

All darlington pairs have an open collector which forms the input channels of the IC, and all pairs have a common emitter which is grounded. Each channel is capable of withstanding 500 mA and the inputs are pinned opposite the outputs to simplify the layout on a board. The large parallel output created from the shift registers control the pattern of LEDs that are turned on. As the darlington arrays are configured as an open collector and a grounded emitter, they in fact control the LEDs by sinking current i.e., they effectively becoming inverters. Each column is then routinely illuminated by power supplied through a column.

B. Display Scanning

A commonly used method to control the illuminated displays is to turn the rows or columns of the display on and off in quick succession. Multiplexing, as it is termed, reduces the amount of input and output (I/O) lines required to control the individual elements of a large display. In multiplexing a common set of control lines is used to join each display to the control system. As a consequence the amount of conductors and ports required for controlling is significantly reduced when compared with connecting each display individually to the system. A sub-unit of the display, typically a row or column of LEDs, is connected to the common bus, which is controlled to output the required pattern for that sub-unit at each instant. The sub-units are then sequentially illuminated with the corresponding pattern. Repeatedly cycling through this process, called scanning is used to create the phenomena of visual persistence. An example of this process is shown in Fig. 4, where rapidly illuminating sections of the display causes an observer to see a single image. Note that the trick is to build one character on the display by scanning the columns very fast [4].

The text effects such as scrolling and flashing, is implemented within the software of the display, to enhance its ability to attract attention as well as displaying messages longer than the screen length. Single color LEDs are primarily used when the exhibited information is principally simple text i.e., where no emphasis or highlighting is required. Single color LEDs were selected to be used in this work. The creation of the LED display for this paper clearly is not pioneering a new technology or product line, as many examples of similar devices can be found in the market today. But the main purpose of our paper is to use the solar energy, as one of the renewable energy sources, for one of the terrestrial applications in remote areas.

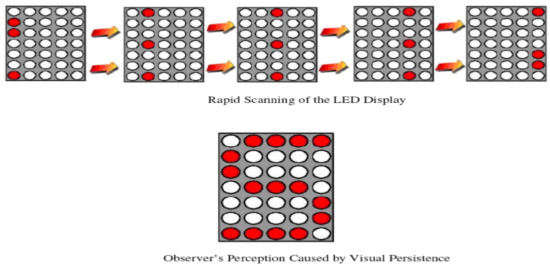

Fig. 4 Scanning of the led display.

6. Testing Procedure

The procedure of continually testing the circuit, as it was progressively built upon, was an essential part in maintaining the integrity of the design. When each new section of the system was developed, it was tested to see that it functioned properly, and then integrated within the existing circuit. Finally, the combined circuit was tested to verify that, jointly both systems operated as expected. This process of testing in a modular fashion ensured that once a new module was constructed it was checked for faults before integrating it with the existing system. The first form of testing done was on the Atmega-8515 programmer and microcontroller circuit. It was important to establish the functionality of this circuit, as it forms the central control for all other parts of the system. The microcontroller circuits were constructed and a series of simple experimental programs were developed to test each of them.

7. Stand-Alone Photovoltaic System

The stand-alone photovoltaic systems are normally used in remote or isolated places where the electric supply from the power-grid is unavailable or not available at a reasonable cost. PV system offers a reliable, low maintenance with zero fuel costs and does not require an attendant to be present during operation. PV stand-alone system can supply power from milliwatts to several kilowatts. They do not have a connection to an electricity grid. Therefore, since most moving message displays are connected to local power supplies; Thus a stand-alone PV system is used to power these panel in this work. No single component in a photovoltaic system is more affected by the size and usage of the load than storage batteries. If a charge controller is not included in the system, oversized loads or excessive use can drain the batteries charge to the point where they are damaged and must be replaced. If a controller does not stop overcharging, the batteries can be damaged during times of low or no load usage or long periods of full sun. Therefore, a solar battery charger must be used to protect the battery. Simple solar battery charger comes in many flavors [6]. The plainest flavor is the simple on-off type shunt charger. It has the advantage of simplicity, extremely small power dissipation, low cost, high reliability, but in spite of these advantages one has to accept that the voltage on the battery is always going slightly up and down, that the battery is switched between full charging current and no charging current, and that disconnection of the battery will result in high voltage output pulses from the charger. Depending on the application, one has to choose the most appropriate type of charger. In most solar installations, a linear solar charger have been used, which has the advantages of smooth voltage regulation and under voltage load dumping, at the cost of higher cost, larger size and high power dissipation. More appropriate than a linear regulator, Fig. 5 and Fig. 6 show the schematic diagram and the implemention of the designed simple on-off type shunt charger circuit respectively.

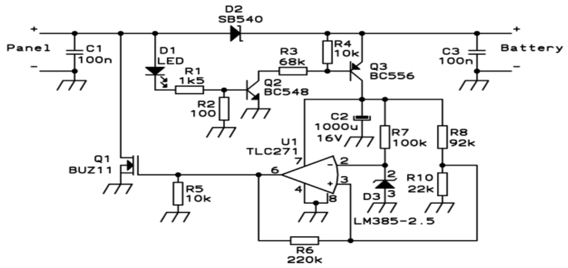

Fig.5 Schematic diagram of a charge controller circuit.

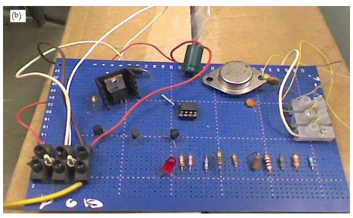

Fig. 6 The implemented charge controller circuit on a stripboard.

A. Sizing of the PV System

PV modules produce electricity only when sunlight shines on them. When sizing a stand-alone PV system, the energy output of the PV panels and the storage capacity of the batteries should be high enough to operate devices at night and on cloudy days when little sunlight is available. To determine the amount of energy needed, multiply an electrical devices power in watts by the number of hours a day the device will be used Since the electrical supply reliability is not of paramount importance in the moving message display thus, a relatively simple sizing procedure can be adopted to size the stand–alone PV system of the display panel. The sizing procedure then recommends the size of the photovoltaic generator and battery capacity that will be suitable for the load application. Our constant electrical load energy demand on a typical day (E_L) can be calculated as follow:

Voltage = 5 V,
maximum current = 1.5 A,
operate for = 24 h

Since, the output voltage of the voltage regulator is 5 V and the maximum required current is 1.5A. Thus, the power demanded is 7.5 W, Therefore, for 24 h display operation

Load energy (EL) = 7.5 * 24 = 180 Wh (1)

where, E_L is the Load energy

The sizing of PV module is calculated based on [7, 8] as follows:

$$P_{PV} = \frac{P_L(T_N + K_2 T_D)}{K_1 K_2 T_D} \tag{2}$$

$$P_{PV} = \frac{7.5(14 + 0.75*10)}{0.85*0.75*10} = 25.3Wp$$

where:

P_L is the load power,
T_N&T_D are the night and daylight periods
K_1 is the direct energy transfer path efficiency,
K_2 is the stored energy transfer path efficiency,

It should be noted that the size of the PV module result has a 30Wp power rating, while the available one during test has a 75Wp as shown in Fig. 7, which is a monocrystalline silicon solar cell module (SP-75 module) and its specification given in [9].

[2] B. Sizing of Battery:

Ideally, a battery bank should be sized to be able to store power for one day of autonomy during cloudy weather. If the battery bank is smaller than one day capacity, it is going to cycle deeply on a regular basis and the battery will therefore have a shorter life. As the battery size is determined from the following equation.

$$WH = \frac{N_C E_L}{DOD \eta_B \eta_{sys}} \tag{3}$$

where,

DOD max. Depth of discharge (= 0.75)
η_B Battery efficiency (=0.85)
η_{sys} System efficiency (=0.8)

thus,

$$WH = \frac{1.0 \times 180}{0.75*0.85*0.8} = 353.0\text{Wh} \tag{4}$$

$$AH = 353.0 / 12 \approx 30Ah \tag{5}$$

Although, the sizing result of the battery bank is 30 Ah, we used in this work the available 12V FP deep cycle lead acid battery type that has a storage capacity of 100 Ah. It is to be noted here that, the required load voltage is 5 volt but the battery voltage is 12V. Therefore, a step down voltage regulator (LM7805) is used to yield a fixed level of 5V.

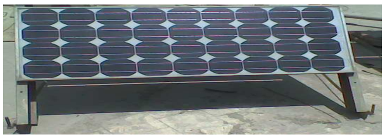

Fig.7 The used PV module.

8. Implementation of the Moving Message Display

In this paper, we designed and implemented a LED sign which used as a department name (i.e., PHOTOVOLTAICDEPARTMENT). Atmega8515 microcontroller needs a few external circuits (oscillation and reset) [10]. Also, once the control of ports on the Atmega8515 was established, through simple test programs, the connection of the serial to parallel shift register chain was attempted. Embedded control software always depends on hardware design and it is used to pump display data and control how data are displayed using assembly program [11, 12]. A microcontroller provides both dot matrix display elements and driver circuit substantially on the same circuit board. The drivers are intermediate section between the microcontroller and the output display LEDs. It is mainly composed of a 17 pieces of 74HC595 shift register, one piece of ULN 2003 darlington sink driver and one piece of 74HC 259 buffer [13]. Display control signals are serially transmitted to the dot matrix display element driver circuit as indicated in Fig. 8. Firstly a single shift register was wired to the microcontroller and tested, and then two shift registers were cascaded on the breadboard to trial the cascading process. The procedure of continually testing the circuit as it was progressively built upon was an essential part in maintaining the integrity of the design. As each new section of the system was developed, it was tested to see that it functioned properly, and then integrated with the existing circuit. Characters were checked on a breadboard before building them on a stripboard.

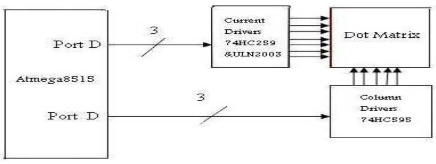

Fig.8 Block diagram of the circuit elements.

The significant number of IC's used in this circuit means that it could not be constructed on a single stripboard due to size limitations; instead a number of stripboards were used. Instead of soldering the integrated circuits directly onto the board, the IC socket method was used, where the components could easily be exchanged and reused in further prototypes. This process is shown in Fig. 9.

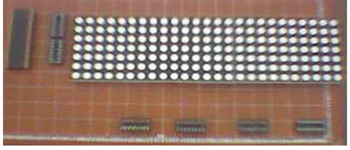

Fig. 9 IC Sockets and dot-matrices mounted on a stripboard.

The current for each dot is delivered by the 74HC595 outputs (can source about 25mA max.) The current for the Row(s) will be sinked by the ULN2003. The 74HC259 switches the Rows, one at a time (Rows scan) The sequence can be as follows; Set data ready on the 74HC595 stages, activate the first Row (Q0 of HC259 active), then store the data at the 74HC595's outputs, wait a few msec, and switch the outputs of the 74HC595's off again, then switch the 74HC259 to the next Row (3-bit upcounter), and repeat this 7 times (7 Rows) This is one complete frame. This frame (image) must be set on the displays faster than you can observe [14]. The diagram in Fig. 10 shows one line with all 74HC595 outputs high state (all dots first Row On). If you watch the diagram closely, you see the 74HC595 outputs are drawn bitwise, from Q_0 to Q_7 (one byte for each shift-register), so 17 bytes (17 x 8 = 136 bits) of serial data are needed for each Row, so a total for the whole display of 5 x 7 = 35 bytes is needed. Therefore, a one bit in the last shift register (No. 17) is not connected. The display consists of 27 dot matrix cascaded horizontally to produce a display of 135 columns and 7 rows to display our text in one line. The 5x7 dot matrix is used widely and gives nice representation of characters. The design results can be indicated in a 17.5 cm height by 12.5 cm long display panel.

9. Design Strategy

The proposed LED display consists of 135 columns x 7 rows of LEDs. It has in total 135 input lines to show a message. The rows inputs and the column inputs are used for different tasks from each other; either for input data or to enable a row or a column. As a result, there are two different strategies for controlling the display of message [15].

A. Row switching

In this strategy, the data is first loaded into the columns inputs serially with one data line. The enabling of the 7 rows of the display is carried row by row, i.e. only one raw is enabled and the others are OFF, then the next raw is enabled and the others are disabled and so on i.e., it goes into infinite loop. When this is carried out so fast, the message appears as it is ON all times since human eyes cannot follow the enabling and disabling processes.

B. Column switching

In this approach, on the other hand, one column is selected to be enabled and at the same time the data to be displayed is sent through the rows inputs and so on (for all columns).

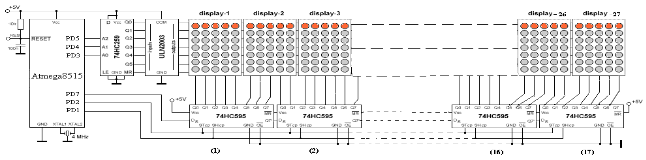

Fig.10 Simplified diagram of the display panel elements which used for debugging software.

10. Test Results

The first routine is developed to display one word,12 characters that uses 12 dot matrix units without spacing.

Figure11 shows one word output results that is “PHOTOVOLTAIC”. The software is modified for displaying a text of two words, 22 characters "PHOTOVOLTAICDEPARTMENT " without spacing.

Fig. 11 Two stripboard display PHOTOVOLTAIC (12 characters) without spacing.

Then, another routine is developed to display this text with spacing between characters (one column off) and a complete off module between two words as shown in Fig. 12 that presents the two English words “PHOTOVOLTAIC DEPARTMENT” with spaces. Figure 13 presents three Arabic words represent the translation for the photovoltaic department name with spaces also.

Fig. 12 Fixed message display for 22 characters with spacing (27 Dot-matrices).

Fig. 13 Message display for Arabic characters.

Finally, a sub-routine is added for creating a scrolling text through the display panel as shown in Fig. 14. we must display the letters for a certain time before shifting a new letter into the display.

Fig. 14 The moving message display for 22 characters with spacing (27 Dot-matrices) after moving some characters.

Also, Fig.15 shows the whole designed and implemented moving message unit with its accessories.

Fig. 15 The display panel inside the enclosure.

Figure 16 shows the indoor test facilities of the implemented moving message system powered by the PV module and a solar rechargeable battery.

11. Conclusion

The set goals within this paper have been achieved, proving the feasibility of the display. The prototype was extremely developed economically using several stripboards on which the components were mounted. Through this type of construction, modifications could be easily made before entering into the development of larger scales, and more costly prototypes. The designed stand-alone PV system is cost-effective.

Fig. 16 Indoor test for the complete system.

In addition, it offers a reliable and a robust energy source which make it suitable for applications in low power demand in remote areas. The researches related to the implementation of moving message displays based on microcontroller and powered by a stand-alone photovoltaic system (PV module, charge controller and battery storage) were investigated throughout this paper. Also, we gained grateful knowledge for approaching the task while helping to understand the microcontroller systems that will be useful for future work. In addition to this, an evaluation of the implemented display was undertaken and the extra features that could be implemented in further designs were found. The complete system can be mounted in remote areas as an addressable guide panel. This document details the process used in creating the design, detailing how it functions and suggests future improvements and forms the working specification for the initial prototype and a basis from which a viable product can develop in the future.

References

[1] Bent Sqrenses " Renewable Energy , Its Physics, Engineering, Environmental Impacts, Economics and Planning" , Elsevier Inc., 2004.

[2] 7-Ningbo Flying Electronics Co., Ltd. 5*7 Single Color Dot Matrix Display data sheet.

[3] Motorola Semiconductor Technical Data, 8-bit Serial-Input / Serial or Parallel- Output Shift Register with Latched 3-State Out Data Sheet puts.

[4] Michael Costa , "In – Vehicle Display System "University of Southern Queensland –Faculty of Engineering and Surveying ,Oct.2005.

[5] Seven Darlington Arrays ULN2003A.

[6] www.elecfree.com/.../simple-solar-panel-shunt-regulator-by-tlc271.

[7] M. Zahran, A. Hanafi, S. El-Hefnawi, M. Kamel, O. Mahgoub and F. Fett, “Optimal Sizing for Photovoltaic Diesel-Generator Hybrid Power Systems”, EuroSun’96 10. Internationales Sonnenforum, Freiburg, Germany 1996.

[8] M. Zahran, M. Okasha and Galina A. Ivanova, “Assessment of Earth Remote Sensing Microsatellite Power Subsystem Capability during Detumbling and Nominal Modes”, Journal of Power Electronics, Vol. 6, No. 1, January 2006

[9] PV Module Technical Specs

[10] ATMEL 8-bit AVR Microcontroller with 8K Byte In-System Programmable Flash, ATS90S8515 , data sheet.

[11] ATMEL AVR STK500 User Guide.

[12] ATMEL 8-bit AVR Assembler and Simulator Manuals.

[13] Philips semiconductors, Product Specification 74Hc/HCT 259, 8-bit addressable Latch data sheet, Dec. 1990.

[14] http://www.attiny.com/scroll5.htm "Writing software & building (prototype) LED sign.

[15] A. Zidouri, M. Deriche, M. Al-Otaibi, M. Al-Shahrani, M. Al-Mutairi, T. Al Maleki, S. Al-Ghunaim, A. Al-Nutaifi, H Al-Issa, F. Al-Anazi" Design and Implementation of a Bilingual LED Message Board" .Electrical Engineering Department KFUPM, Dhahran 31261, Saudi Arabia.