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RESEARCH ARTICLE

Ideal Battery Charging For a Solar-Powered Robotic Vehicle Using Microcontroller

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ABSTRACT: This paper focuses on the design and construction of an optimization charging system for Li–Po batteries by means of tracked solar panels. Thus, the implementation of a complete energy management system applied to a robotic exploration vehicle is put forward. The proposed system was tested on the VANTER robotic platform—an autonomous unmanned exploration vehicle specialized in recognition. The interest of this robotic system lies in the design concept, based on a smart host microcontroller. On this basis, our proposal makes a twofold significant contribution. On the one hand, it presents the construction of a solar tracking mechanism aimed at increasing the rover's power regardless of its mobility. On the other hand, it proposes an alternative design of power system performance based on a pack of two batteries. The aim is completing the process of charging a battery independently while the other battery provides all the energy consumed by the robotic vehicle.

INTRODUCTION

SOLAR power systems in autonomous robotic vehicles have been often used for some years. A real example is the Sojourner rover, in which most of the supplied energy is generated by a reduced-size photovoltaic (PV) panel. However, in case of scarce to no solar light, the rover should minimize consumption, since its batteries in line could not be recharged when depleted. The use of rechargeable batteries in a space mission was used for the first time in the Mars Exploration Rovers.

Nevertheless, the need for greater operation autonomy by Spirit and Opportunity was solved by means of larger deploy solar panels .This solution works as the basis for the design of solar panels for the future ExoMars mission. This rover, thanks to its high-efficiency ultrathin-film silicon cells constructed on carbon-fiber reinforced plastic, is capable of providing higher power. NASA designs inspired different generations of exploration vehicles. This is the example of K9, a rover for remote science exploration and autonomous operation ; field integrated design and operations, an advanced-technology prototype by Jet Propulsion Laboratory for long-range mobile planetary science ; and Micro5, a series of robotic vehicles devised for lunar exploration .As its main design advantage,this rover series has a dual solar panel system coupled to an assisted suspension mechanism. This prevents the manipulator arm mounted on the middle of the rover from having to minimize solar panel-generated power and allows it to dust solar panel surface.

Other robotic exploration vehicles have also been developed in academic spheres. This is the case of SOLERO, developed by the Ecole Polytechnique F´ed´erale de Lausanne, which reached optimal energy consumption by a combination of a smart power management and an efficient locomotion system. On the other hand, the Carnegie Mellon University developed Hyperion, a rover in which the major technological milestone a solar-powered robotic vehicle. The implementation of solar-synchronous techniques to increase the amount of energy generated by solar panels ; and Zo¨e, a rover capable of long-distance traverses under extreme environmental conditions devoted to science investigation at the Atacama desert . With an educational approach, Carnegie Mellon University also developed a personal exploration vehicle called PER.

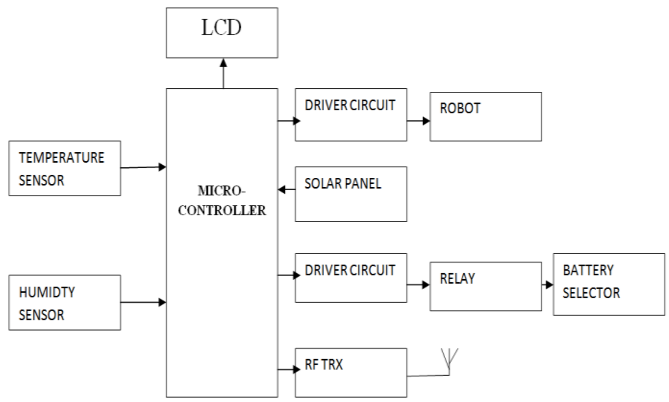
More recently, Lever and co-workers and have described the concepts of modeling, design, and fabrication of a robot-box prototype to be used in polar environments. The platform—known as Cool Robot—uses a control algorithm of maximum power point (MPP) aimed at maximizing system-supplied power for five PV modules designed as a cube. Finally, there are some noteworthy projects which main achievement is the optimal selection of solar energy and different power sources according to the operation conditions of a robot. The VANTER robotic exploration vehicle aims to improve various aspects of the aforementioned rovers with scientific and academic purposes.

To introduce the developed robot, the main features and properties are compared in Table I. Subsequently, this paper is organized as follows. The next section presents the mobile robotic system. Its main features are described and its hardware and software architecture are presented. Section III introduces the concept of smart host microcontroller (SHM) for intelligent power management applied to an exploration vehicle.

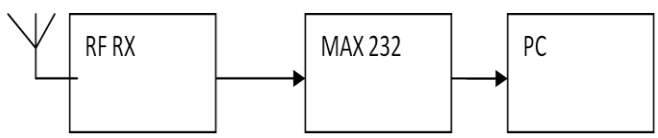
The following sections present the control of the battery-charging system by means of tracked solar panels, which is the main aim of this paper. Therefore, Section V puts into practice the developed methodology by testing the rover power systems. Finally, the results and findings from the developed work are presented.

BLOCK DIAGRAM

TRANSIMETER SECTION



RECEIVER SECTION



BLOCK DIAGRAM DESCRIPTION

POWER SUPPLY

A power supply unit (PSU) converts mains AC to low-voltage regulated DC power for the internal components of a control unit.

The Transformer:

The transformer initially takes the input supply from AC mains voltage of 220V and steps it down to a lower voltage level of 12V (0-12V). However, after construction, the desired voltage range was obtained at the output.

The Rectifier:

The AC voltage from the transformer is rectified using half wave rectifier to give equal positive and negative voltages. The output is DC in a sense that it does not change polarity, but it has periodic variations in voltage about a steady value called ripples.

The Smoothing Circuit:

The ripples are smoothened using a low-pass filter in the form of a shunt capacitor. Choosing capacitors that are sufficiently large, the ripple voltage is reduced to a low level.

CONTROL UNIT:

The architectural decisions are directed at the maximization of speed-to-cost ratio. The PIC architecture was among the first scalar CPU designs and is still among the simplest and cheapest. The Harvard architecture, in which instructions and data come from separate sources, simplifies timing and microcircuit design greatly, and this benefits clock speed, price, and power consumption.

The PIC instruction set is suited to implementation of fast lookup tables in the program space. Such lookups take one instruction and two instruction cycles. Many functions can be modeled in this way. Optimization is facilitated by the relatively large program space of the PIC (e.g. 4096 × 14-bit words on the 16F690) and by the design of the instruction set, which allows embedded constants. For example, a branch instruction's target may be indexed by W, and execute a "RETLW", which does as it is named – return with literal in W.

Interrupt latency is constant at three instruction cycles. External interrupts have to be synchronized with the four-clock instruction cycle, otherwise there can be a one instruction cycle jitter. Internal interrupts are already synchronized. The constant interrupt latency allows PICs to achieve interrupt-driven low-jitter timing sequences. An example of this is a video sync pulse generator. This is no longer true in the newest PIC models, because they have a synchronous interrupt latency of three or four cycles.

The PIC16F887 is one of the latest products from Microchip. It features all the components which modern microcontrollers normally have. For its low price, wide range of application, high quality and easy availability, it is an ideal solution in applications such as: the control of different processes in industry, machine control devices, measurement of different values etc.

LIQUID-CRYSTAL DISPLAY:

A liquid-crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly.LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images which can be displayed or hidden, such as preset words, digits, and 7-segment displays as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements.

LCDs are used in a wide range of applications including computer monitors, televisions, instrument panels, aircraft cockpit displays, and signage. They are common in consumer devices such as DVD players, gaming devices, clocks, watches, calculators, and telephones, and have replaced cathode ray tube (CRT) displays in most applications. They are available in a wider range of screen sizes than CRT and plasma displays, and since they do not use phosphors, they do not suffer image burn-in. LCDs are, however, susceptible to image persistence.

The LCD screen is more energy efficient and can be disposed of more safely than a CRT. Its low electrical power consumption enables it to be used in battery-powered electronic equipment. It is an electronically modulated optical device made up of any number of segments filled with liquid crystals and arrayed in front of a light source (backlight) or reflector to produce images in colour or monochrome. Liquid crystals were first discovered in 1888. By 2008, annual sales of televisions with LCD screens exceeded sales of CRT units worldwide, and the CRT became obsolete for most purposes.

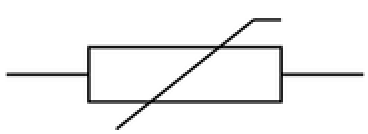
DRIVER UNIT:

A transistor switch is used to allow a 12volt relay to be operated (turned on and off) by a small input voltage. The voltage level of the input can be changed by sliding the black arrow- head up and down on this vertical scale. Changing the input voltage causes changes in the base current, collector current, and in the collector voltage. When the current in the relay coil (i.e. the collector current) exceeds a certain value, the relay switches on. The diode reduces the large transient voltages that are produced when the current through an inductor (the relay coil) is changed quickly by switching (called "inductive kick").

To see the current flow thought the transistor, click on the "Show current flow" button. You can change the input (base) resistor, the relay coil resistance, and the power supply voltage (V_{cc}). Just click on the number with the mouse pointer and edite like any text field. You can also inspect and modify the specifications of the transistor - click on the "Show specs" button on the left; this display a table of several specifications (such as the transistor's current gain, beta) that you can modify.

TEMPERATURE SENSOR

A thermistor is a type of resistor used to measure temperature changes, relying on the change in its resistance with changing temperature. Thermistor is a combination of the words thermal and resistor.



In this circuit the thermister is used to measure the temperature. Thermister is nothing but temperature sensitive resistor. There are two type of thermister available such as positive temperature co-efficient and negative temperature co- efficient. Here we are using negative temperature co-efficient in which the resistance value is decreased when the temperature is increased.

RS232 AND MAX232

In this project we have used RS232 for communicate the microcontroller and PC. In telecommunications, RS-232 is a standard for serial binary data interconnection between a DTE (Data terminal equipment) and a DCE (Data Circuit-terminating Equipment). It is commonly used in computer serial ports.

In this circuit the MAX 232 IC used as level logic converter. The MAX232 is a dual driver/receiver that includes a capacitive voltage generator to supply EIA 232 voltage levels from a single 5v supply. Each receiver converts EIA-232 to 5v TTL/CMOS levels. Each driver converts TLL/CMOS input levels into EIA-232 levels.

BATTERY

A battery is a device that stores energy. The way that it stores energy is by holding different electro-chemically active materials together is such a fashion so that they can generate and store free electrons (electrical potential energy) for long periods of time and only deliver that energy when the battery user demands it. The inherent properties of the electro-chemically active materials allow them to store energy chemically and then release that energy electrically as a bi-product of a chemical reaction. If we skip the explanation of how a battery is “brought to life”, and jump in at a point where the battery has already experienced several discharges and recharges, then we can say that the battery actually stores electrical charge.

SOLAR PANEL

A solar panel (also solar module, photovoltaic module or photovoltaic panel) is a packaged, connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each panel is rated by its DC output power under standard test conditions, and typically ranges from 100 to 320 watts. The efficiency of a panel determines the area of a panel given the same rated output - an 8% efficient 230 watt panel will have twice the area of a 16% efficient 230 watt panel. Because a single solar panel can produce only a limited amount of power, most installations contain multiple panels. A photovoltaic system typically includes an array of solar panels, an inverter, and sometimes a battery and or solar tracker and interconnection wiring.

Solar panels use light energy (photons) from the sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells based on cadmium telluride or silicon. The structural (load carrying) member of a module can either be the top layer or the back layer. Cells must also be protected from mechanical damage and moisture. Most solar panels are rigid, but semi-flexible ones are available, based on thin-film cells.

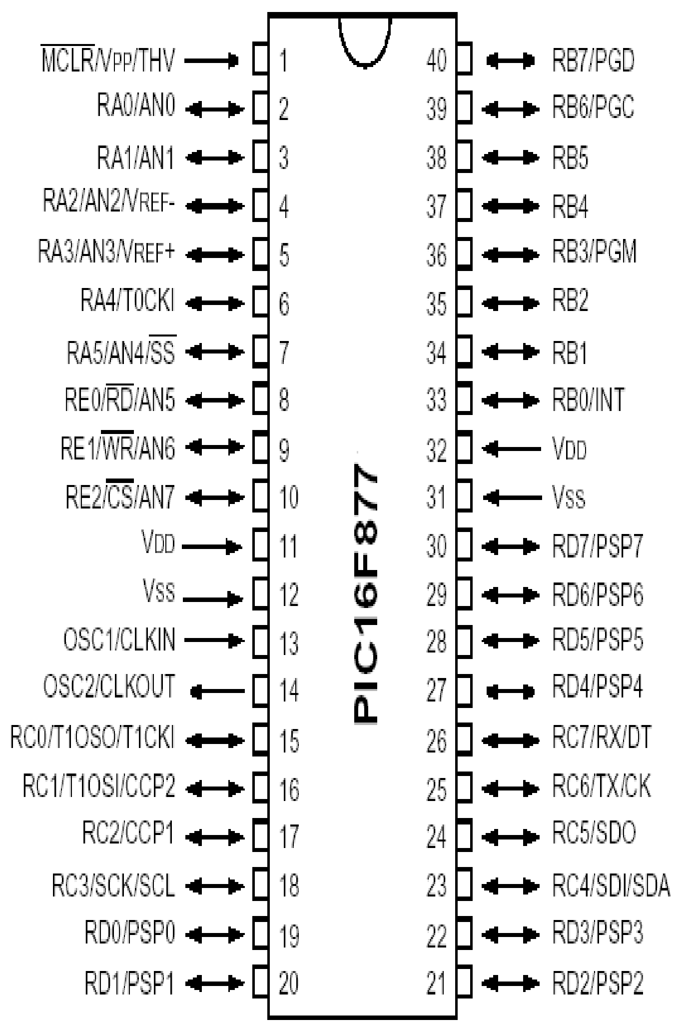
ARCHITECTURE OF PIC 16F877:

The complete architecture of PIC 16F877 is shown in the fig 2.1. Table 2.1 gives details about the specifications of PIC 16F877. Fig 2.2 shows the complete pin diagram of the IC PIC 16F877.

TABLE SPECIFICATIONS

DEVICE	PROGRAM FLASH	DATA MEMORY	DATA EEPROM
PIC 16F877	8K	368 Bytes	256 Bytes

PIN DIAGRAM OF PIC 16F877



PIN OUT DESCRIPTION

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	13	14	30	I	ST/CMOS(4)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	14	15	31	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP/THV	1	2	18	I/P	ST	Master clear (reset) input or programming voltage input or high voltage test mode control. This pin is an active low reset to the device.
						PORTA is a bi-directional I/O port.
RA0/AN0	2	3	19	I/O	TTL	RA0 can also be analog input0
RA1/AN1	3	4	20	I/O	TTL	RA1 can also be analog input1
RA2/AN2/VREF-	4	5	21	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage
RA3/AN3/VREF+	5	6	22	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage
RA4/T0CKI	6	7	23	I/O	ST	RA4 can also be the clock input to the Timer0 timer/counter. Output is open drain type.
RA5/$\overline{SS}$/AN4	7	8	24	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
						PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	34	37	9	I/O	TTL	
RB2	35	38	10	I/O	TTL	
RB3/PGM	36	39	11	I/O	TTL	RB3 can also be the low voltage programming input
RB4	37	41	14	I/O	TTL	Interrupt on change pin.
RB5	38	42	15	I/O	TTL	Interrupt on change pin.
RB6/PGC	39	43	16	I/O	TTL/ST(2)	Interrupt on change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	40	44	17	I/O	TTL/ST(2)	Interrupt on change pin or In-Circuit Debugger pin. Serial programming data.

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
						PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	15	16	32	I/O	ST	RC0 can also be the Timer1 oscillator output or a Timer1 clock input.
RC1/T1OSI/CCP2	16	18	35	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	17	19	36	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/ PWM1 output.
RC3/SCK/SCL	18	20	37	I/O	ST	RC3 can also be the synchronous serial clock input/ output for both SPI and I^2C modes.
RC4/SDI/SDA	23	25	42	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^2C mode).
RC5/SDO	24	26	43	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	25	27	44	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	26	29	1	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.
						PORTD is a bi-directional I/O port or parallel slave port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38	I/O	ST/TTL(3)	
RD1/PSP1	20	22	39	I/O	ST/TTL(3)	
RD2/PSP2	21	23	40	I/O	ST/TTL(3)	
RD3/PSP3	22	24	41	I/O	ST/TTL(3)	
RD4/PSP4	27	30	2	I/O	ST/TTL(3)	
RD5/PSP5	28	31	3	I/O	ST/TTL(3)	
RD6/PSP6	29	32	4	I/O	ST/TTL(3)	
RD7/PSP7	30	33	5	I/O	ST/TTL(3)	
						PORTE is a bi-directional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25	I/O	ST/TTL(3)	RE0 can also be read control for the parallel slave port, or analog input5.
RE1/$\overline{WR}$/AN6	9	10	26	I/O	ST/TTL(3)	RE1 can also be write control for the parallel slave port, or analog input6.
RE2/$\overline{CS}$/AN7	10	11	27	I/O	ST/TTL(3)	RE2 can also be select control for the parallel slave port, or analog input7.
V_{SS}	12,31	13,34	6,29	P	—	Ground reference for logic and I/O pins.
V_{DD}	11,32	12,35	7,28	P	—	Positive supply for logic and I/O pins.
NC	—	1,17,28, 40	12,13, 33,34		—	These pins are not internally connected. These pins should be left unconnected.

Legend: I = input O = output I/O = input/output P = power

= Not used TTL = TTL input ST = Schmitt Trigger input

Note :

1. This buffer is a Schmitt Trigger input when configured as an external interrupt.

2. This buffer is a Schmitt Trigger input when used in serial programming mode.

3. This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).

4. This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a

CMOS input otherwise.

I/O PORTS:

Some pins for these I/O ports are multiplexed with an alternate function for the peripheral features on the device. In general, when a peripheral is enabled, that pin may not be used as a general purpose I/O pin. Additional Information on I/O ports may be found in the IC micro™ Mid-Range Reference Manual.

CONCLUSION:

The proposal includes the construction of a solar tracker mechanism based on mobile PV panels aimed at increasing system energy. Its main advantage is that the amount of generated power is independent from the rover's mobility, since the proposed mechanism is capable of tracking maximum light intensity. This solution does not attempt to achieve high charging times or great operating times but to prove a sustainable and commercially feasible solution applied to a robotic vehicle.

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