Daylighting System Controller and Software Design

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Overview

- Motivation
- Solution
- Hardware
- Software
- Conclusion

Motivation

- 40% of energy used in U.S. is used in homes and buildings. [1]
- 22% of electricity in U.S. is used by lighting. [2]
- Energy Policy Act of 2005 allows savings up to $1.80 per sq. ft. [3]
- Department of Energy has 17 grants in “green lighting” totaling $37 million. [4]

[1] U.S. Energy Information Administration., "Energy Consumption by Sector", Annual Energy Review, 2006 (2007).
[2] Navigent Consulting, Inc., "Solid-state lighting research and development portfolio: Multi-year program plan fy'09-fy'15," tech. rep., Lighting Research and Development Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Dept. of Energy, Chicago (2009).
[3] Department of Energy, Energy-Efficient Commercial Buildings Tax Deduction, 2006. http://energy.gov/savings/energy-efficient-commercial-buildings-tax-deduction.
[4] Popular Mechanics, “17 Projects Shaping the Future of LED Lights,” Adam Hadhazy, 2010. http://www.popularmechanics.com/science/environment/green-energy/4343724

Solution

- Use solar lighting to save electricity.
  - Solar panels
  - Three mirrors
  - Motor
  - Microcontroller
  - Software
- Must use less energy than normal lighting.

http://images.wisegeek.com/solar-panel-blue.jpg

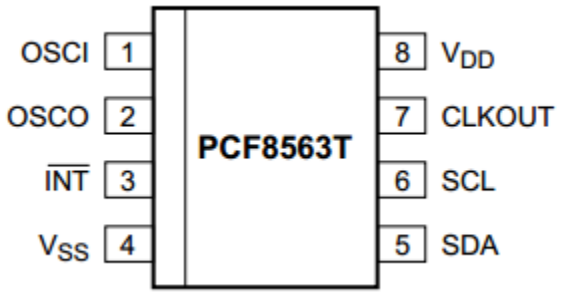
Hardware (Microcontroller)

- Atmega32L microprocessor.
  - Calculates daily sunrise, sunset, and azimuth of the sun.
  - Used to control rotation of motor.
  - Can operate in “power lost” state to save power.
  - Microprocessor operates on 2 μA in “power lost” state.

http://www.chinaicmart.com/uploadfile/ic-doc/313-44-TQFP.jpg

Hardware (Real-Time Clock)

- Phillips PCF8563 real-time clock.
  - Optimized for low-power consumption [5].
  - Gives the current time, used to track the sun.
  - Communicates using I^2C.
  - Timer interrupt is used to wake up microprocessor.
- Microprocessor and real-time clock are powered by a battery during “power lost” state.
  - Uses less than 5 μA.



http://www.nxp.com/documents/data_sheet/PCF8563.pdf

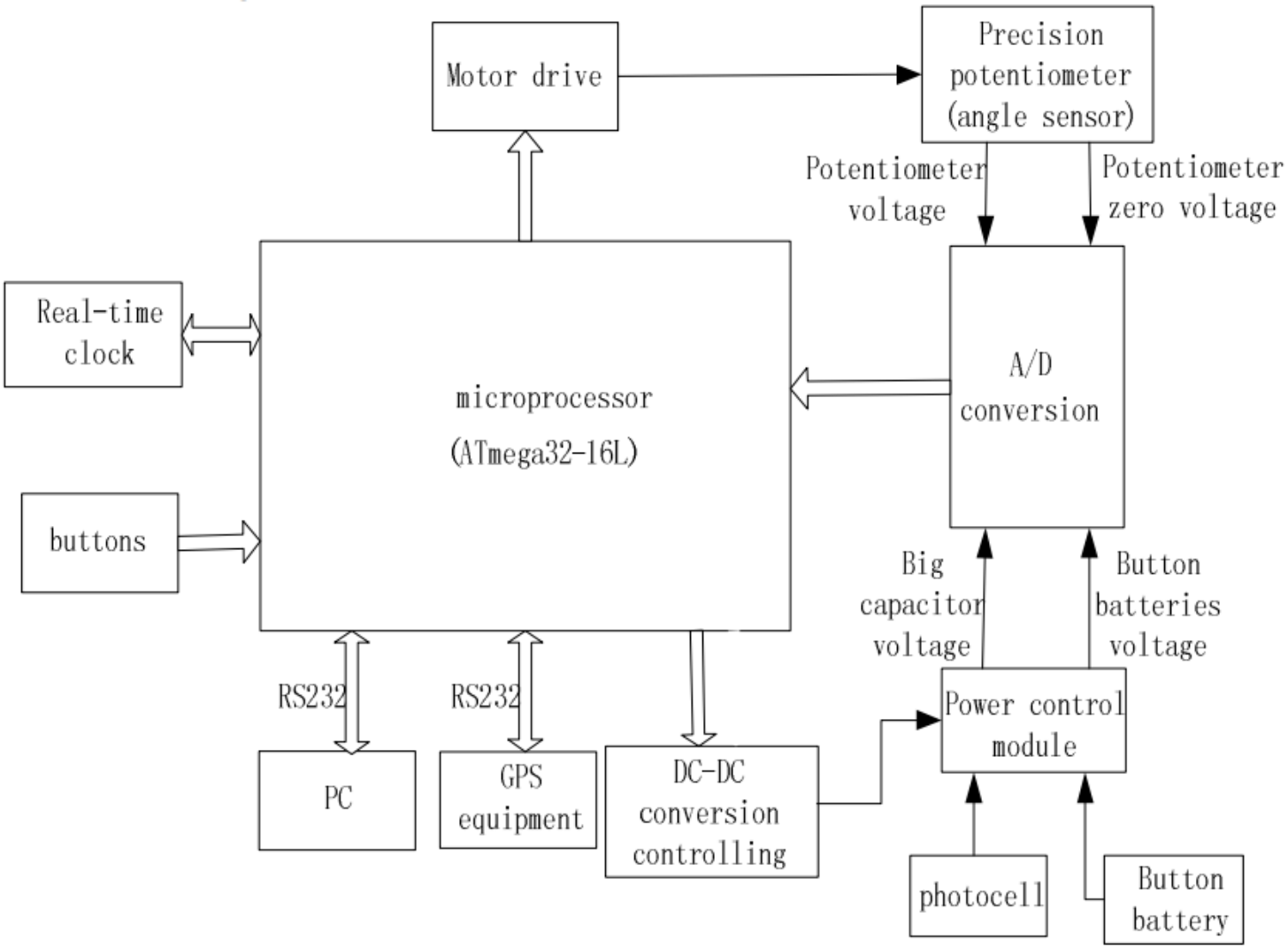
[5] Phillips PCF8563 Datasheet: http://www.nxp.com/documents/data_sheet/PCF8563.pdf

Hardware (Mirrors and Motor Control)

- Three mirrors are used to reflect and spread sunlight across the room.
- Motor and angle sensor drive motors and solar panels to follow the sun.
- Angle sensor is used to measure rotation error.
  - Feedback is sent back to microcontroller.
- Large capacitors store electricity from photocell
  - This powers the entire system when the motor is running.

http://gardnerglass.com/html/images/SolarMirrors1sm.jpg

Hardware (Diagram)



Software

- Two running modes: normal and debug.
- Can upload/download information to/from GPS or PC via RS232.
  - Latitude, longitude, date, and time can be input.
  - Serial interrupt cannot wake up microprocessor.
- Real-time clock wakes up microprocessor every ten minutes.
  - Microprocessor calculates sun movement.
  - Motors then move mirrors and solar panels to face sun.
  - Sunrise and sunset are calculated at noon local.
  - Stays in “power lost” state otherwise.
- Checks voltage from photocell before moving motors.

Conclusion

- Controllers based on this design have been implemented in San Diego and Los Angeles.
  - Has been used in large warehouses and supermarkets.
- This controller can be used in other solar applications.
- Simple solution to green lighting.

Some text and images are used from the paper cited below:
Meihua Xu; Xiaoli Cao; Shihao Weng; , "Daylighting system controller and software design," *Natural Computation (ICNC), 2011 Seventh International Conference on* , vol.3, no., pp.1721-1724, 26-28 July 2011