Solar Chaser

Group 3 Project Report

ECE 511 - Fall 2014

Abstract

Solar panel efficiency depends, in part, on the incident angle of sunlight striking the photovoltaic cells. The angle for optimal efficiency changes throughout a day. The Solar Chaser project presents a low-power prototype for continuously reorienting a solar panel. The repositioning will track the movement of the sun and increase the amount of collected energy compared to a static panel. The project is primarily controlled from an MSP430 Launchpad.

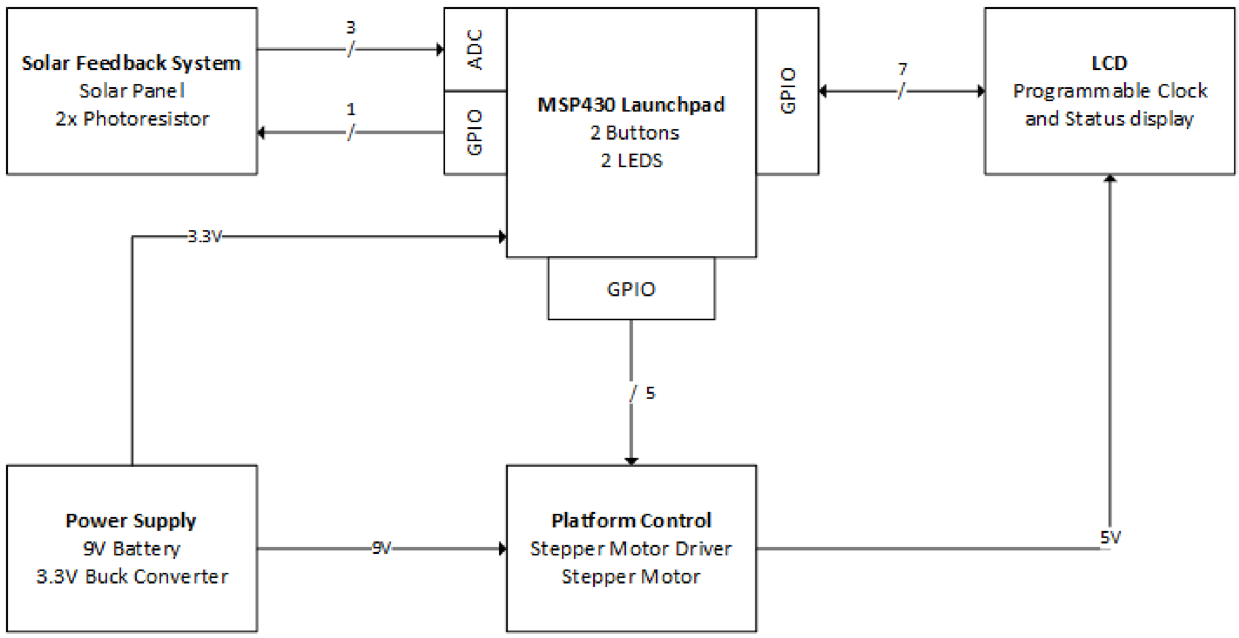
Table of Contents

Motivation

Our group met to discuss and brainstorm project ideas. Out of this meeting, we agreed to pursue the Solar Chaser project for two reasons. The idea allowed for a good use of the MSP430's features and would provide a useful green-energy output. We also had some inspiration from a blog posting describing a solar tracking device (see references). However, the device in the blog used a GPS sensor and orbit prediction algorithms to track the sun. Our goal was to replicate the functionality and produce the same efficiency gains of tracking the sun using a simpler sensor interface and lower power processing.

Block Diagram

Figure 1 - Block Diagram



Description of parts

Photoresistors

MSP430 Feature: Ports 6.1 and 6.2 used in ADC mode

Two photoresistors are mounted near the solar panel, oriented 30 degrees away from perpendicular. The anode of each resistor is connected to port 6.3 used as digital I/O. When set high, the output from this pin flows through each photoresistor and to ground through a 10 k-ohm resistor. The node between the photoresistor and resistor is connected to an ADC port on the MSP430.

The photoresistors behave similarly to a photovoltaic cell in regards to incident light angle. The same light source hitting the photoresistors at different angles will produce different outputs. Orienting the resistors allows the MSP430 to compare the ADC readings and determine when there is more light energy in one direction. The software computes the difference between the sensors to account for background/ambient light and then compares that result to a threshold. If the threshold is exceeded, a movement command may be issued.

Solar Panel

MSP430 Feature: Port 6.0 used in ADC mode

The solar panel interfaces to the MSP430 through a resistor network. We choose to use three 5k-ohm resistors wired in series to step the voltage down from the panel's maximum of 6.0V. The MSP430 port 6.0 is connected to the node between the second and third resistor. In this configuration, the MSP430 will sense a maximum voltage of (6.0V/3) = 2.0 Volts, which is inside the allowable range.

In software, ADC channel A.0 is configured to read the voltage from Port 6.0. This port is read along with the photoresistors by triggering an ADC single sequence capture. The MSP430 enters sleep mode while waiting for an interrupt armed on the completion of channel A2 conversion. Entering sleep mode saves power while waiting for the ADC results.

The raw value returned for A0 is converted to volts using the following formula:

panel_voltage = (raw_value / 4096) * 3.3 * 3.0

The raw_value is multiplied by 3.3 to account for the MSP supply voltage and the multiply by 3.0 accounts for the voltage division over the three resistors.

For informational purposes, the computed voltage is also displayed on the LCD panel in a fixed-point format.

Stepper Motor / Controller

MSP430 Interface: 5 Digital I/O pins (2.2, 2.3, 2.4, 2.5, 2.7)

The stepper motor controller provides an easy to use interface between the stepper motor and the MSP430. The interface obfuscates the voltage and current differences between the control and physical driving circuits. Each of 4 inputs, along with two enable lines, indirectly controls one pole in the motor. The software steps through the inputs in the following order to move clockwise:

1 -> 3 -> 2 -> 4

Both enable pins are wired to the same MSP430 output and are set high at the same time as one of inputs. When moving the motor, the software uses a switch statement and global variable to remember which of the 4 steps should be taken next.

To avoid any issues with wiring and allow 360 degree rotation, all components for the projects are mounted on a rotating platform. The stepper motor rotates a wheel, turning the entire platform. Each step of the motor turns the shaft 1.8 degrees. Since the shaft and wheel require nearly 20 complete rotations to move the platform, a finer resolution for panel orientation of 0.09 degrees is available. Our software currently moves the panel ten steps at at time, 0.9 degrees.

LCD Panel

MSP Feature: 7 Digital I/O pins (1.3, 1.4, 1.5, 1.6, 3.4, 3.5, 3.6)

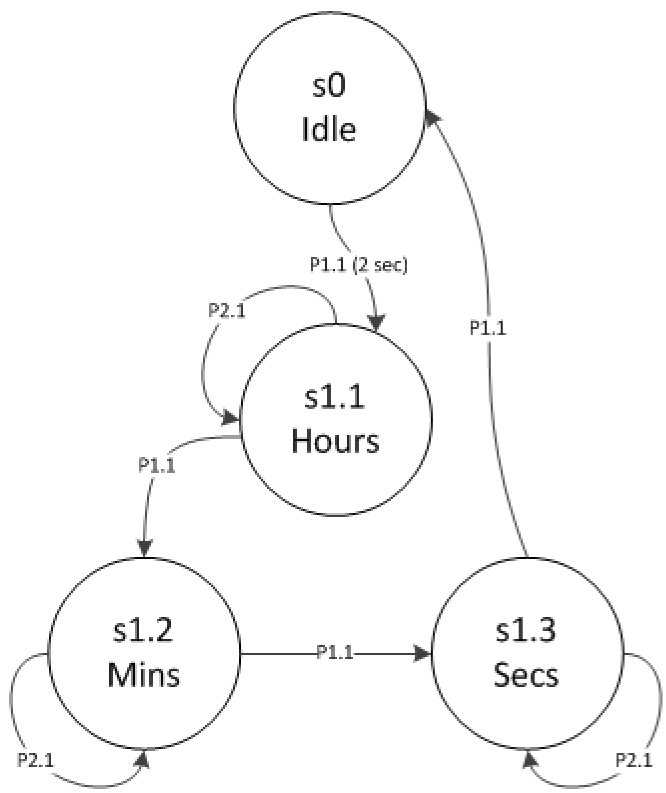
The panel runs on a 5V input, which is provided as an output from the stepper motor controller. However, as listed on the data sheet and tested in our circuit, the data and control lines will operate correctly when driven by the 3.3V from the MPS430.

ASCII characters can be written to the LCD screen using three control lines and four parallel data lines. The screen displays a clock and the current panel voltage for status and debugging. The LCD screen maintains state, so the MSP430 can enter a low-power mode with the screen still on. Every second, the RTCA interrupt triggers a refresh, but only of updated values.

Real Time Clock / Buttons

MSP430 Feature: Real Time Clock subsystem, Buttons 1.1 and 2.1 on Launchpad

The real-time clock system (RTCA) runs in BCD mode to allow for more efficient data processing. The user can program the clock by using the two launchpad pushbuttons and following the programming sequence, which allows adding to specific BCD mode registers.



LCD Clock Programming Sequence

Buck Converter

MSP430 Feature: Connected to and powering the 3.3V network

In order to allow a single 9V battery to power our entire project, a conversion to 3.3 volts is needed to power the MPS430. The buck converter efficiently steps down any input voltage between 4 and 24 volts to 3.3 volts. Software has no interface to this device.

Results/Conclusions

The Solar Chaser demonstrates the feasibility of using a photo resistor array to track the sun. Using the feedback from the photoresistors it was possible to accurately detect the location of a light source. Since the sun travels a path that requires unidirectional change during rotation along one fixed axis, the direction of motion for the platform was designed to be in only one direction. Additionally, a light source can be tracked with only two photoresistors if the starting location of the source is known. For example, if the sun rises at a particular orientation from the Solar Chaser, the approximate position will be known the following morning. In order to add robustness and make the system able to detect a light source behind it, a more slightly more complex design would be required.

The two-photoresistor array is successfully capable of determining the direction of rotation, which is indicated on two LED outputs on the MSP430 Launchpad. During operation, the green LED indicates when the motor should be turning. Additional status information is displayed on the LCD, which also is used to program an on board system clock that interrupts every second. The service interval of one second was chosen for a low power design, which only wakes from low power mode to update the LCD, analyze sensor readings, and rotate the platform. When processing is complete, the MSP430 returns to the low power mode, LPM3.

During execution without the motor turning, the system consumes about 18 mA, and when the motor is not on and 0.4 A otherwise. Trying different service intervals did not have much effect on power consumption.

What Doesn't Work

- The LCD display flickers while the stepper motor is being driven
- The weight balance of the platform causes the rotation wheel to lose traction at certain points
- A light source directly behind the Solar Panel will not be tracked

Appendix

Team Members/Work Division

Joe Parrish, Ahmed Ferozpuri, Jason Allen

Joe Parrish: Solar Panel/Photoresistor layout, wiring, and code. Power supply wiring.

Ahmed Ferozpuri: LCD/Real Time Clock layout, wiring, and code. Initial breadboarding of Launchpad and LCD.

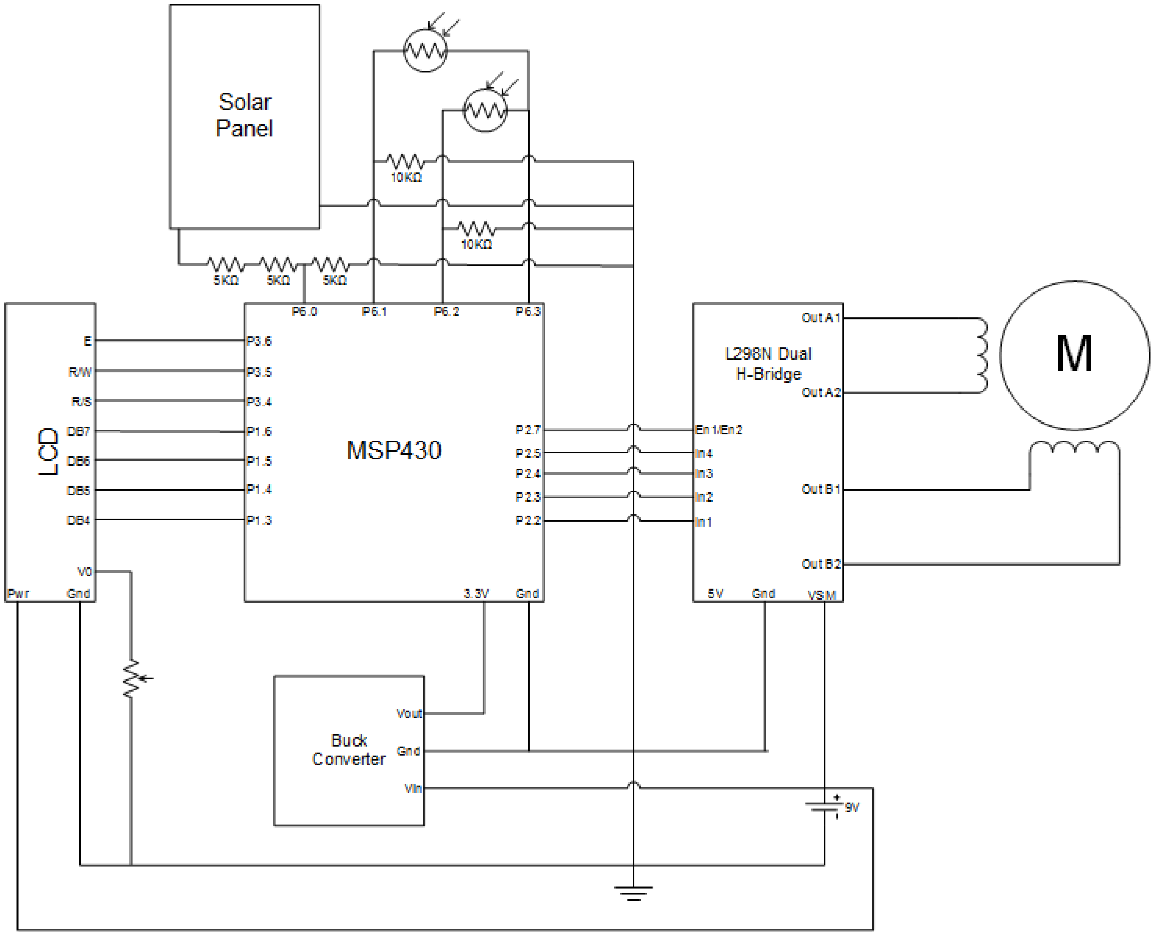
Jason Allen: Stepper Motor layout, wiring, and code. Construction of rotating platform.

All group members worked on final breadboard wiring, integration, and assembly.

Parts List

Item	Source	Part Number	Quantity
5k-ohm resistor	Already owned		3
10k-ohm resistor	Already owned		2
3.3V Buck Converter	www.pololu.com	2842	1
Slide-Switch	www.pololu.com	1408	1
4-pin Terminal Block	www.pololu.com	2422	2
9V Battery	www.allelectronics.com	PRC-1604	1
9V Battery T-Type Leads	www.allelectronics.com	BST-81	1
6V Solar Panel	www.allelectronics.com	SPL-618	1
Photoresistor	www.allelectronics.com	PRE-24	2
Launchpad	www.ti.com	MSP-EXP430F5529LP	1
Trimpot, 240k-ohm	Already owned		1
16x2 LCD	Already owned		1
Stepper Motor	www.robotshop.com	RB-Soy-20	1
Stepper Motor Controller	Already owned		1
Wheel	www.robotshop.com	RB-Pol-121	1
Rotating Platform	Hand-Assembled from a Lazy Susan, scrap wood and erector set		1

Schematic


Solar
Panel
10KΩ
10KΩ
5KΩ
5KΩ
5KΩ
P6.0
P6.1
P6.2
P6.3
LCD
E
R/W
R/S
DB7
DB6
DB5
DB4
V0
Pwr
Gnd
P3.6
P3.5
P3.4
P1.6
P1.5
P1.4
P1.3
MSP430
P2.7
P2.5
P2.4
P2.3
P2.2
3.3V
Gnd
L298N Dual
H-Bridge
Out A1
Out A2
En1/En2
In4
In3
In2
In1
Out B1
Out B2
5V
Gnd
VSM
M
Buck
Converter
Vout
Gnd
Vin
9V

Resources / References

Initial idea for Solar Chaser project:

http://circuitcellar.com/cc-blog/the-sun-chaser-energy-harvesting-system/

Register mapping and information on ADC operation referenced from MSP430x5xx and MSP430x6xx Family User's Guide:

www.ti.com/lit/ug/slau208n/slau208n.pdf

LCD Pinout and voltage specs referenced from datasheet:

http://www.lcd-modules.com.tw/data/SC1602Z.pdf

LCD controller reference:

http://www.datsi.fi.upm.es/docencia/Micro_C/lcd/ks0066u.pdf

MSP430 Lower power mode operation from TI:

http://processors.wiki.ti.com/index.php/MSP430_LaunchPad_Low_Power_Mode

Code Examples referenced from the following One-Click Projects in the TI Resource Explorer:

MSP430F55xx_1
MSP430F55xx_adc_01
MSP430F55xx_adc_05
MSP430F55xx_adc_10
MSP430F55xx_ta0_02