Automated transportable solar panel array

Group: 7

DESCRIPTION OF OPERATION

Deploying the solar panel mechanism requires interaction with the main operating panel, situated on the base plate oriented towards the rear of the truck (*Figure 2*). Note that - to access the panel, opening the tailgate may be required. To extend the solar array, displace the toggle switch (shown in *Figure 1*) towards the "ON" position and hold in place continuously until fully extended. Displacing the switch towards the "OFF" pole will reverse the direction, retracting the panels into their initial folded state. Returning the switch to the neutral position at any point; or forms of obstruction along the deployment path will both interrupt the sequence. A small lamp is used to indicate to the user whether the mechanism is in motion regardless of direction.

THE OPERATING PANEL

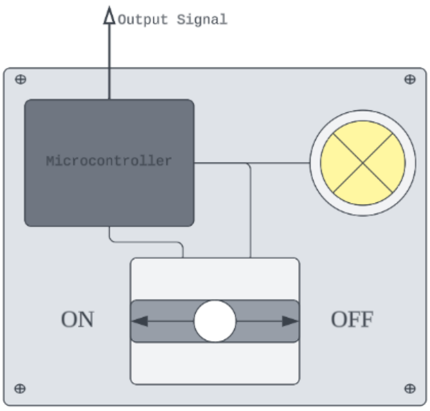


Figure 1: Operating panel interface showing main toggle switch and indicator bulb Dimensions (6.4 x 3.4cm)

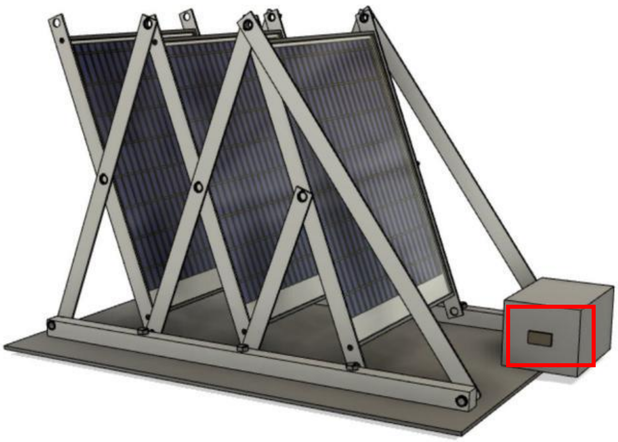


Figure 2: Position on full mechanism affixed to the gearbox, highlighted in red

RATIONALE FOR CHOICE OF SENSORS AND SWITCHES

Initial concepts were to include up to 6 sensors to provide accurate control over the system operation; Including proximity sensors positioned on the leading edge of the panels and several types on the motor shaft to record torque, angular displacement and velocity quantities to compare against normal operating conditions. Identified anomalies to a significant degree i.e.. situations involving wind loading may introduce variation to the angular velocity graph. However, objectives in lowering cost and complexity; in addition to limitations in the length of microcontroller code led to most being omitted from the final design.
The system employs the use of two sensors – one hall sensor and an ultrasonic sensor, both incentivized to meet the requirements while maintaining low cost, and matching low current draw from the main battery of the truck. Each sensor must also physically fit within the space of the baseplate while permitting motion of the panels while in motion;

Hall sensor: Attached to near contact with the gearbox, the hall sensor detects variations in magnetic flux density of a specific gear while in rotation. More specifically, this allows for indirect measurements of angular velocity. If the mechanism encounters a significant shift in angular velocity above a threshold limit ($0.3 rads^{-1}$), the system will terminate regardless of the button state.

Ultrasonic sensor: The ultrasonic sensor is mounted with the emitter upwards at the furthest point along the base plate, and operates by emitting a short pulse of 40kHz waves and detecting obstructions prior to deployment by receiving reflected pulses. This is calibrated for the system by selectively detecting signals within the range of the fully extended array i.e. (>983mm). Likewise, an obstruction will cause the system to terminate.

Figure 3 – Table of convergence for sensor selection

Sensor		Data Utlity	Sensitivity/ Resolution	Implement Complexity	Acquired Data Complexity	Cost	Total
Name	Type						
Strain Gauge	Linear distance (Contact)/Strain	4	2	2	4	6	18
Hall Effect	Linear distance / Angular Velocity	9	7	8	6	8	38
Potentiometer	Linear distance / Angular distance	8	8	3	7	5	31
Inductive	Linear Distance	7	8	8	4	4	31
Ultrasonic	Linear distance/Proximity	8	8	8	7	3	34
Optical	Linear distance	6	7	7	7	1	28
DC Generator	Linear Velocity	5	4	1	3	6	18
Gyroscope	Angular Velocity	8	5	8	6	5	32
Accelerometer	Linear Acceleration	4	7	5	8	6	30
Torque sensor	Torque/Linear force/Strain	5	6	4	6	5	26
Thermistor	Temperature	1	7	4	7	7	26
Venturi	Pressure difference	1	2	3	3	4	10

The following sensors were compared by using the selection matrix above (*Figure 3*) considering several selection properties which were regarded as most desirable. As shown, the Hall effect and Ultrasonic sensors scored the highest in context of the system so were incorporated accordingly. A more detailed description of each heading is listed below;

- *Data utility*: Certain types of quantities are not as applicable in the scenario of the deployable array; for instance temperature-related quantities are unlikely to change significantly, and even if so will have intrinsically less influence.
- *Sensitivity/Resolution*: Though different, the two properties can be attributed to a single convergence entry as they are generally correlated. Higher values of either will correspond to better quality of data providing more accurate values that closely represent the environment at a given time.
- *Implementation Complexity*: Smaller, more compact sensors can minimize design tolerances. Additionally, sensors with fewer pins and pre-existing integrated methods of fastening onto the controller are more desirable.
- *Acquired Data Complexity*: Digital data requires less post processing than analogue data, and removes the necessity for a signal conditioner or PWM.
- *Cost*: The average cost of the specific type of sensor - more expensive sensors are less desirable and will increase the cost of the resulting design.
- *Supply(Unlisted)*: Ideally, the same voltage from a single source is sufficient to supply all the sensors to reduce complexity. The demand of sensor input should also remain under the truck's maximum output of 12V.

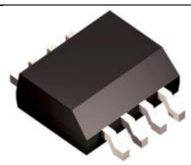
A justification for each particular switch model and sensor in the mechanism is provided:

<u>Toggle Switch (Stock Number 734-7233):</u>
A single pole double throw manual switch such as the one selected allows the user to manually operate between 2 separate connection and 1 "off" states. This is ideal for the application required as the two active states can be assigned to deploy and retract transitions respectively. Additionally, the component includes a mount to fasten onto the operating panel.

<u>Hall sensor (Stock Number 169-7662):</u>
This specific hall sensor type is compact (4.06 x 3 x 1.57mm), designed to be integrated directly into a PCB. Like most hall sensors, the non-contact mode of measurement is desirable especially in the application of moving components. It provides a digital output, which is easily manipulated without the use of analogue pins in the arduino circuit.

<u>Ultrasonic sensor (Stock Number 215-3181):</u>
Unlike most other ultrasonic based sensors, the 215-3181 is much more affordable costing £2.10, significantly less than externally based sensors and other BBC modules of the same type while compromising resolution and frequency. Adaptation to the microcontroller can be achieved without difficulty as the voltage draw (5V) is within the limit of the truck power supply.

PARTS LIST

RS Catalogue number	Description	Image
734-7233	RS PRO Toggle Switch, Panel Mount, On-Off-On, SPDT, Solder Terminal	
215-3181	Ultrasonic Distance Sensor HC-SR04 5V Version	
169-7662	Honeywell Through Hole Hall Effect Sensor, Digital Output, 3.8 → 30 V dc, 30V	
262-5841	Infineon IMI111T026HXUMA1, BLDC Intelligent Power Module, 600 V 2A 22-Pin, DSO-22	
168-6428	TS272IDT STMicroelectronics, Op Amp, 3.5MHz, 5 → 15 V, 8-Pin SOIC	
761-5463	Texas Instruments LM22675MRE-5.0/NOPB, 1-Channel, Step Down DC-DC Converter 8-Pin, PSOP	
360-7878	RS PRO BA9s Indicator Light, Clear, 130 V, 20 mA, 3000h	

HARDWARE SCHEMATIC DIAGRAM

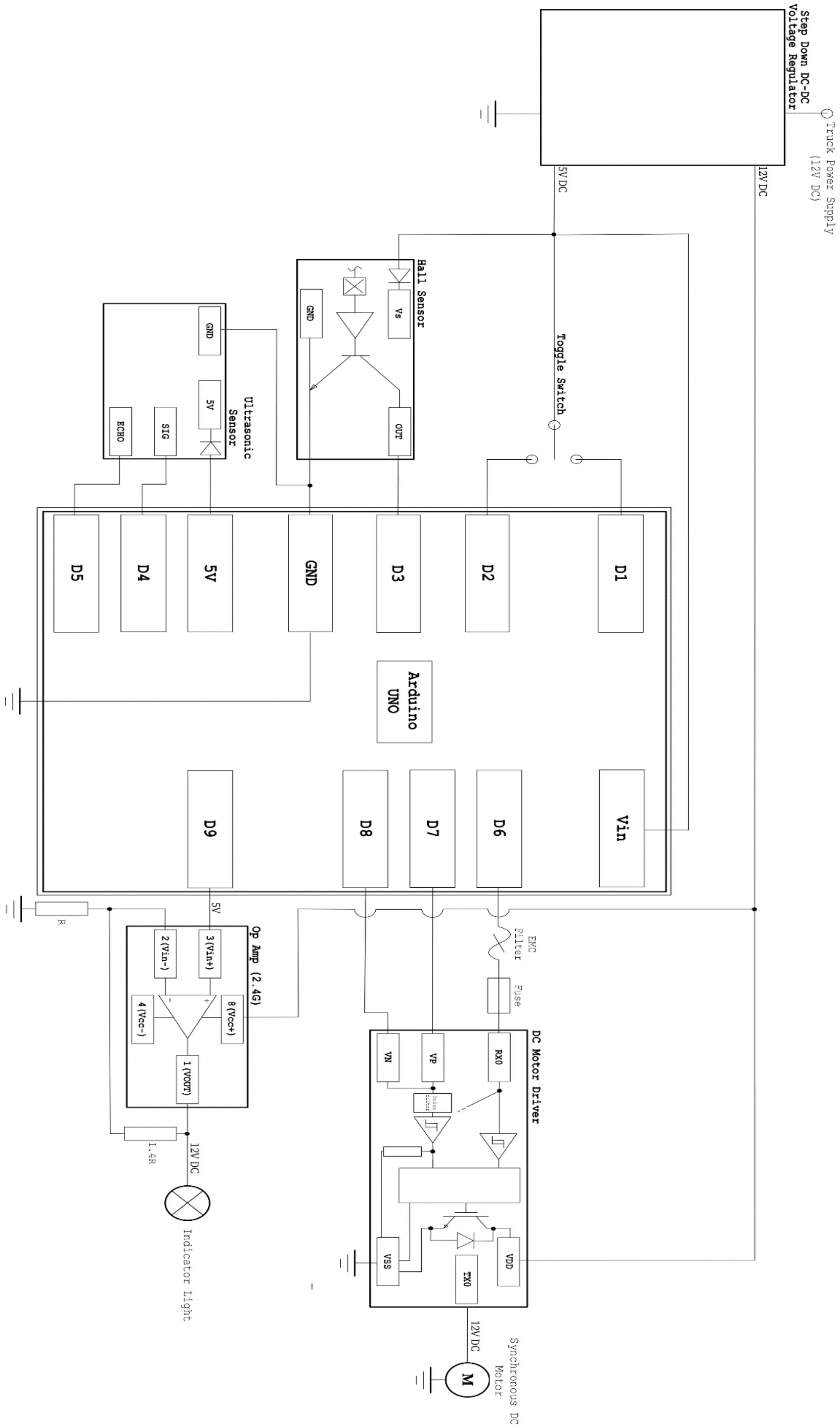


Figure 4 – Hardware Schematic Diagram

STATE TRANSITION DIAGRAM FOR THE SYSTEM

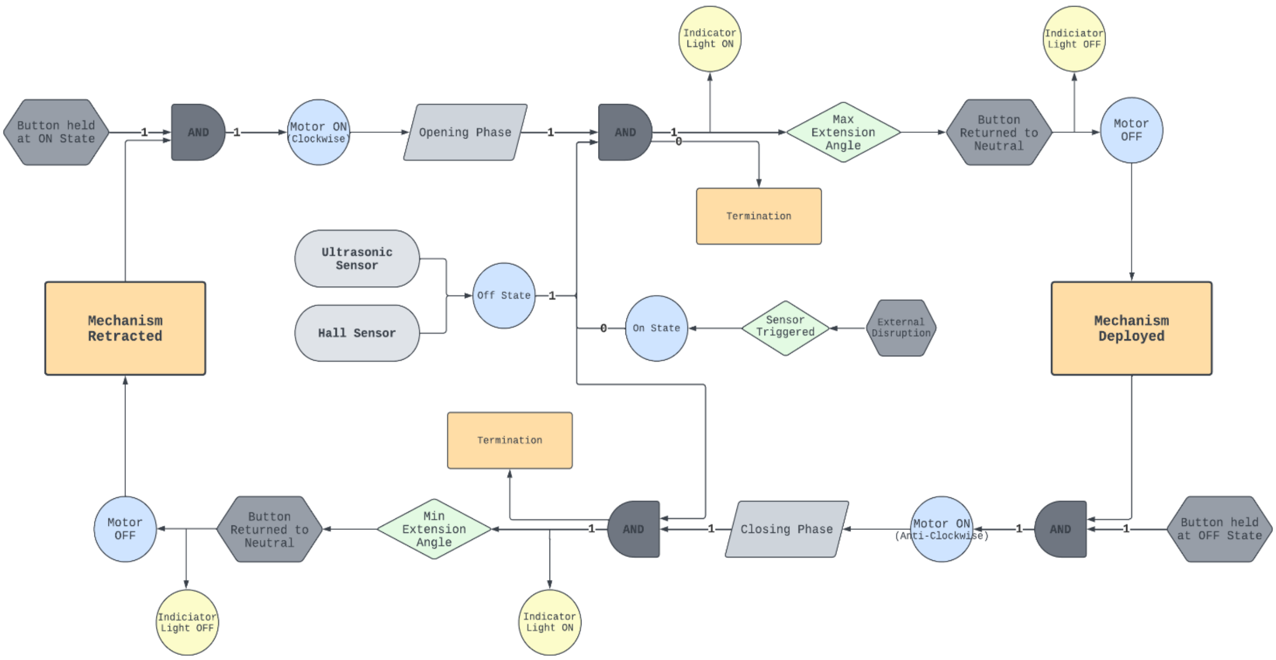


Figure 5 – State Transition Diagram

MICROCONTROLLER SOURCE CODE

```
const int switch_OPEN = 1
const int switch_CLOSE = 2
const int sensor_hall = 3
const int sensor_US_sig = 4
const int sensor_US_echo = 5
const int driver_power = 6
const int driver_direc_CW = 7
const int driver_direc_ACW = 8
const int lamp_PIN = 9
int Open;int Close;int hall_data
float pulse_duration;float US_distance;float lamp_data

void setup(){
 pinmode (switch_OPEN,INPUT);
 pinmode (switch_CLOSE,INPUT);
 pinmode (sensor_hall,INPUT);
 pinmode (sensor_US_sig,OUTPUT);
 pinmode (sensor_US_echo,INPUT);
 pinmode (driver_power,OUTPUT);
 pinmode (driver_direc_CW,OUTPUT);
 pinmode (driver_direc_ACW),OUTPUT);
 pinmode (lamp_PIN,OUTPUT);
}

void loop(){
 Open = digitalRead (switch_OPEN);
 Close = digitalRead (switch_CLOSE);
 hall_data = digitalRead (sensor_hall);
 lamp_data = analogRead (lamp_PIN);

 digitalWrite(sensor_US_sig,HIGH);
 delay(0.01)
 digitalWrite(sensor_US_sig,LOW);
 pulse_duration = pulseIn(sensor_US_echo,HIGH);
 distance = 0.18 * pulse_duration

 if (Open ==HIGH) {digitalWrite (driver_direc_CW, HIGH); digitalWrite
(driver_direc_ACW,LOW)}
```

```
 else if ((Close == HIGH) {digitalWrite (driver_direc_ACW, HIGH); digitalWrite (driver_direc_CW, LOW)}
if ((Open == HIGH)&& (0< distance < 990)) {digitalWrite (driver_power = LOW)}
 else if ((Open == HIGH|Close == HIGH) && (hall_data < 0.3)){
  digitalWrite (driver_power, HIGH); analogWrite (lamp_PIN,HIGH)}
 else if ((Open == LOW) && (Close == LOW)) {
  digitalWrite (driver_power = LOW); analogWrite (lamp_PIN,LOW)}
 else{}
}
```