

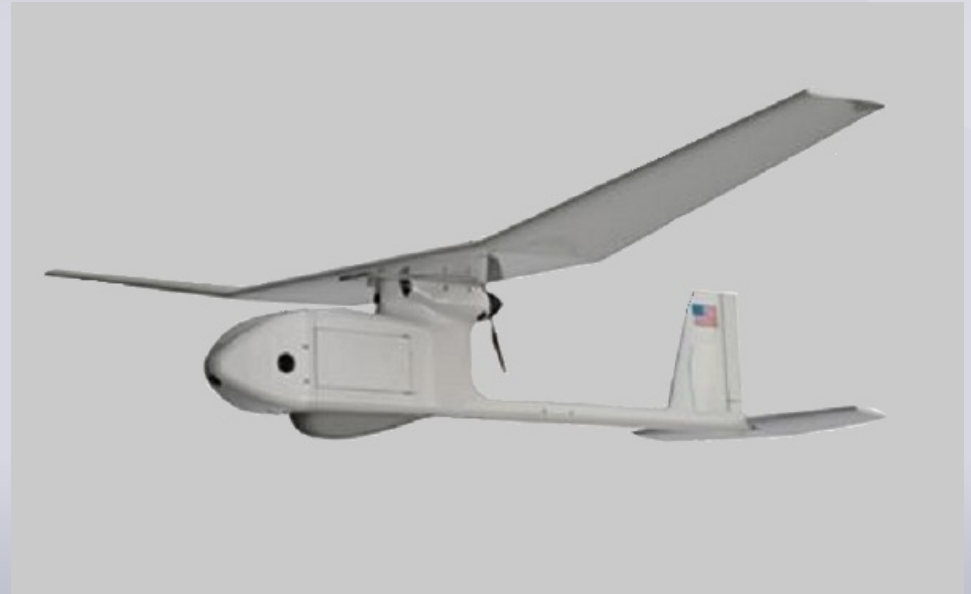
S.E.V

Solar Extended Vehicle

EEL 4914

Senior Design II
Group #4

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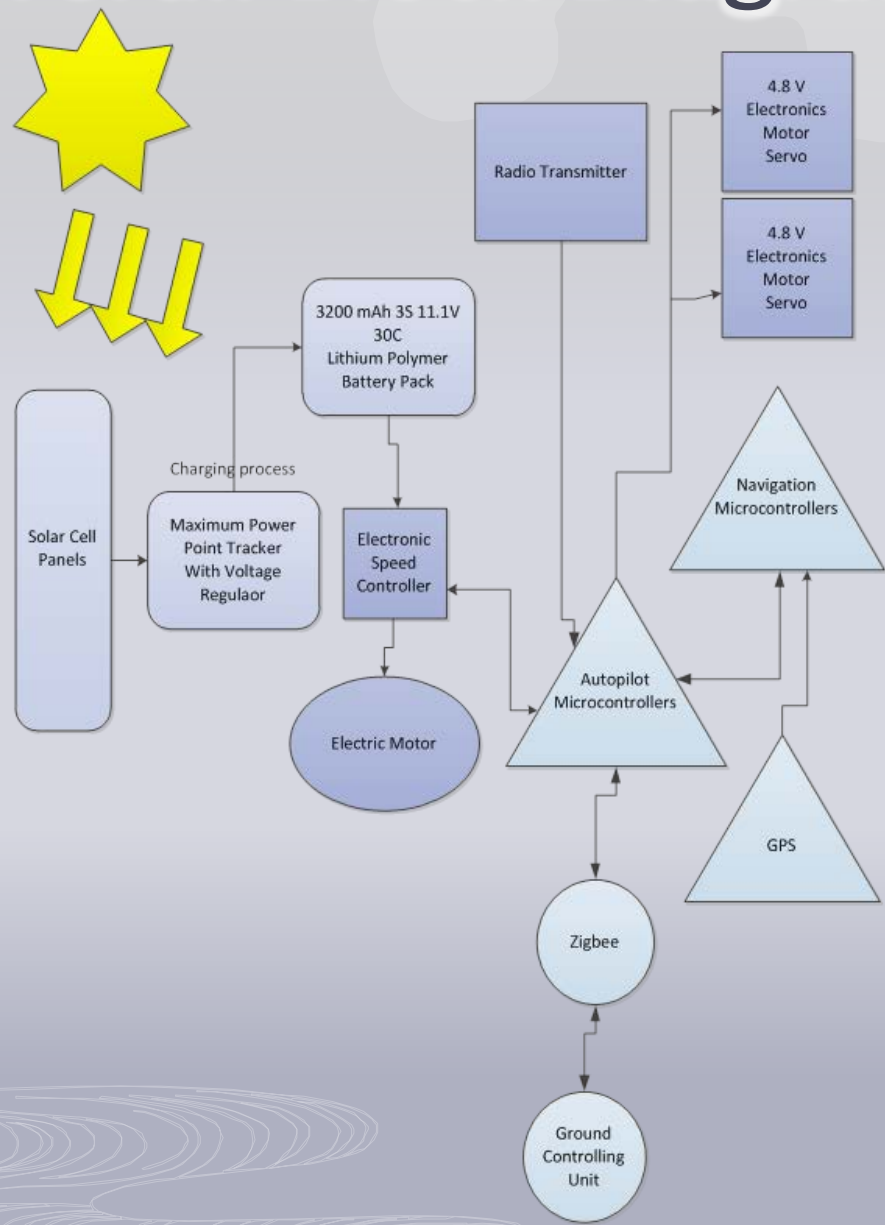
Motivation

- The majority of electric motor RC planes tend to have a low flight time
- Solar panels are not typically used in small UAVs
- There is a high demand for autonomous drones in military applications

Goals

- Build an aerial vehicle that uses solar power to extend the overall flight time of a RC plane
- To have the plane fly autonomously in a slow, descending circular path
- To further reduce power consumption by allowing the plane to periodically glide with the motor turned off, then throttle up and climb to max alt

Overall Block Diagram



Airframe: Specifications

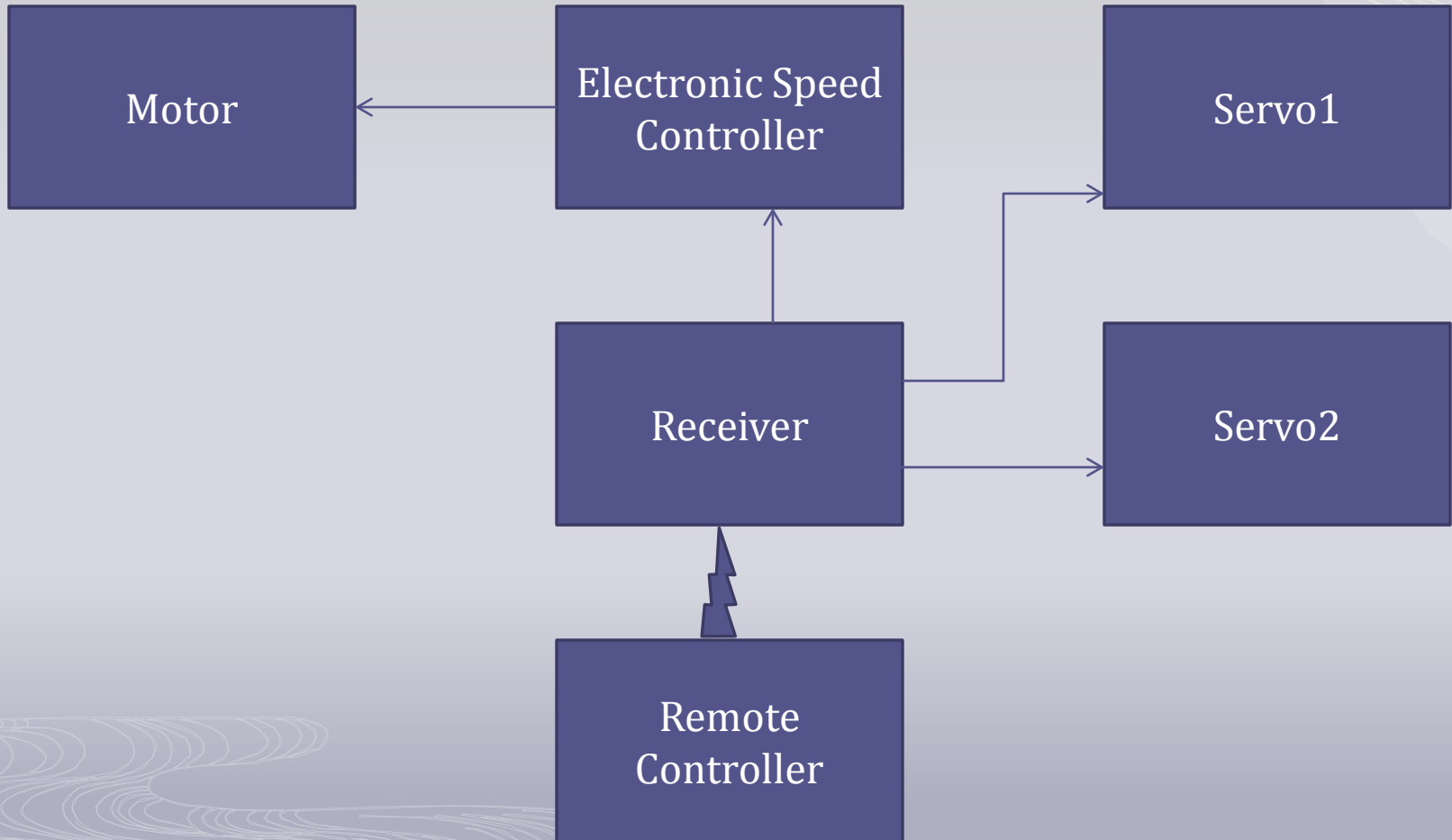
- Wing Area: 465 in² (30 dm²)
- Wing Span: 51.18 in (1300 mm)
- Length: 65.35 in (1660 mm)
- Total Weight: 2.2 lb (1.0 kg)
- Wing Loading: 2.1935 g/in² (34 g/dm²)

Functionality: Physical Features

- Overhead wing (gliding)
- No ailerons on the main wing
- Push propeller rather than pull propeller
- Hand-launched take-off method
- Deep-stall landing method



Typical Interaction of Motor, Servos, and ESC



Motor Selection

Features

- Lightweight
- Large KV output (RPM/Volt)
- Outrunner motor

Specifications

- KV Rating: 1100 rpm/volt
- Input Voltage: 7.2-12V
- Continuous Current: 30A
- Max Burst Current: 42A



ESC Selection

Requirements

- Current rating must be greater than or equal to the motor.



Specifications

- Cont. Current: 60A
- Burst Current: 75A
- Operating Voltage: 4.8-6.0V
- Weight: 66g (2.33 oz)

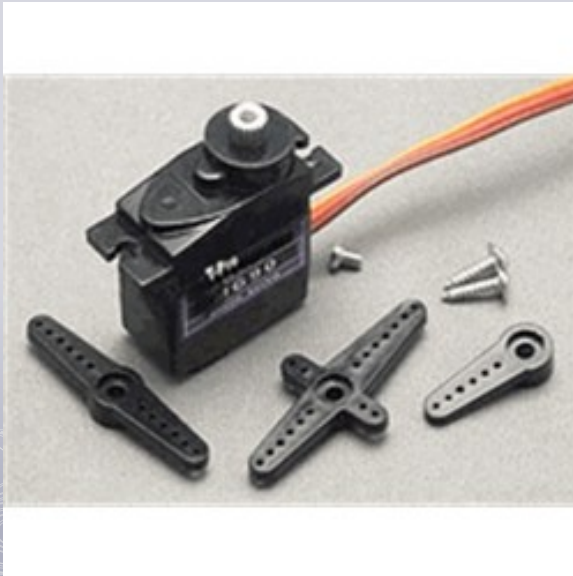
Servo Selection

Operation

- Vertical tailfin rudder
- Horizontal tailfin elevator
- Metal gear

Specifications

- Torque: 2.0 kg/cm
- Operating Speed: 0.11 sec/60 degrees
- Operating Voltage: 4.8-6.0V
- Weight: 9g (0.32oz)



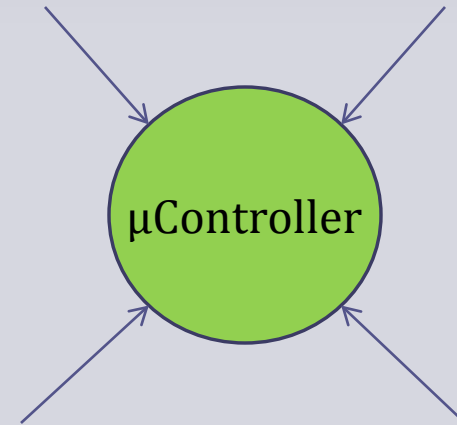
Airframe: Testing

- The E-Flite Apprentice 15E served as our initial prototype
- Allowed for testing our electronic connections
- Practice our RC flying skills



Hardware Design

- ❑ Solar Extended Vehicle
- ❑ μ Controller
- ❑ GPS
- ❑ 3-axis Gyroscope
- ❑ 3-axis Accelerometer
- ❑ Solar panels
- ❑ Charging Circuit
- ❑ Battery



ATmega328 by Atmel

- 8-Bit AVR RISC Architecture
- Arduino Development Environment
- TQFP package
- 8 ADC
- Two Wire Interface/USART
- Yaw/Pitch/Roll stabilizes the SEV
- Inertial forces

Navigation Unit

ATmega328

LY530ALH → Z-axis

LPR530AL → X/Y axis

ADXL335 → X/Y/Z axes

MT3329 → GPS

ATmega328	LY530ALH	LPR530AL	ADXL335	MT3329
Sample	\$9.95	\$7.95	\$9.95	\$63.51
1.8 – 5.5 V	3 V	3 V	3V	4.5 – 6.5 V
8-channel 10-bit ADC	Analog Output	Analog Output	Analog Output	Rx/Tx

Autopilot Unit

ATtiny45	Xbee-Pro (RF)	RC Rx (RF)
Sample	\$95.37	\$9.00
1.8 – 5.5 V	3 – 3.6 V	4.5 – 6.5 V
-	900 MHz	2.4 GHz
	UART	UART

ATmega328

ATtiny45

Xbee-Pro 900MHz

2.4G 6-channel Receiver

Throttle/Rudder/Elevator

Ground Station

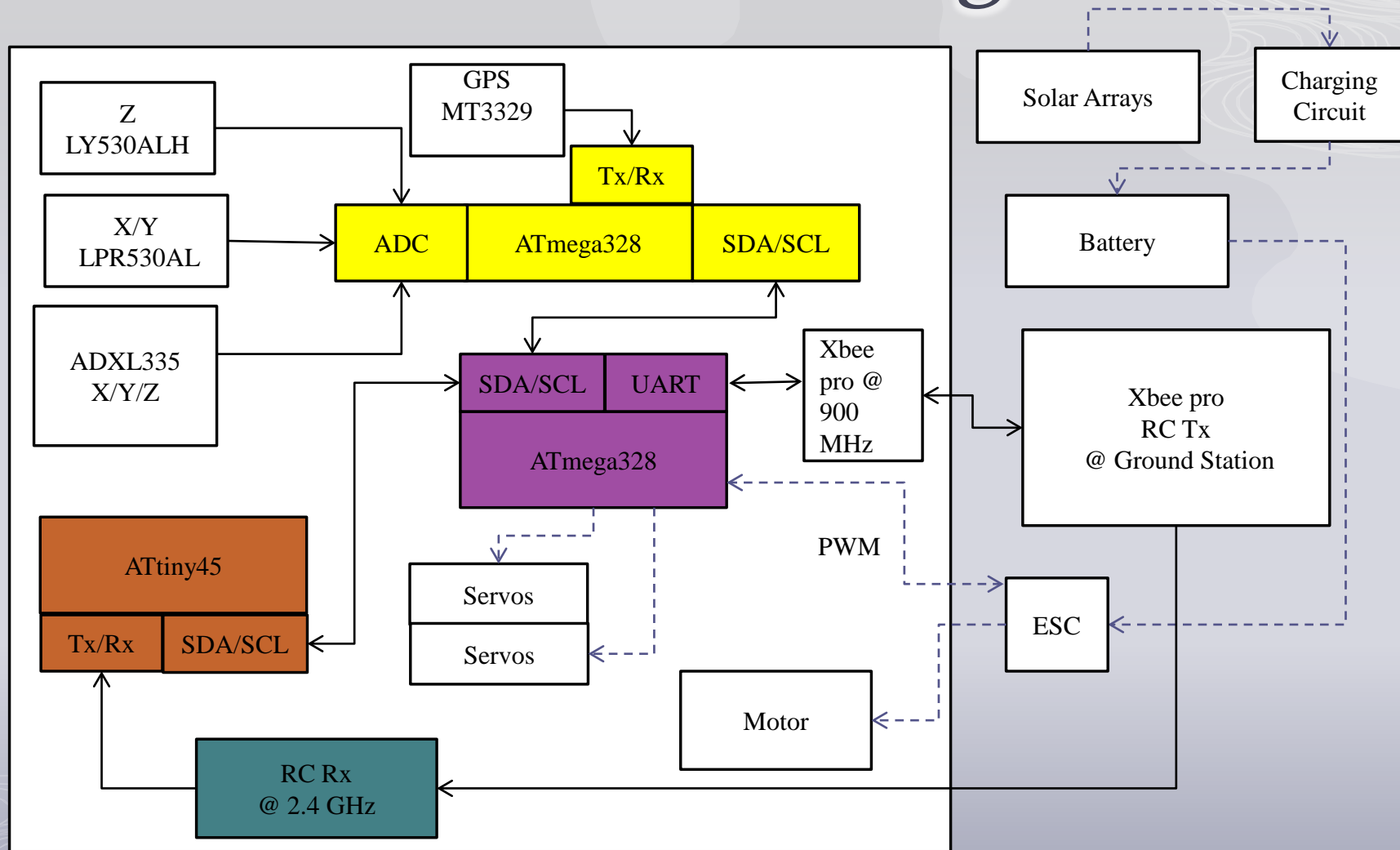
Laptop

Xbee-Pro 900MHz

2.4G DX5e 5-channel

Transmitter

Hardware Block Diagram



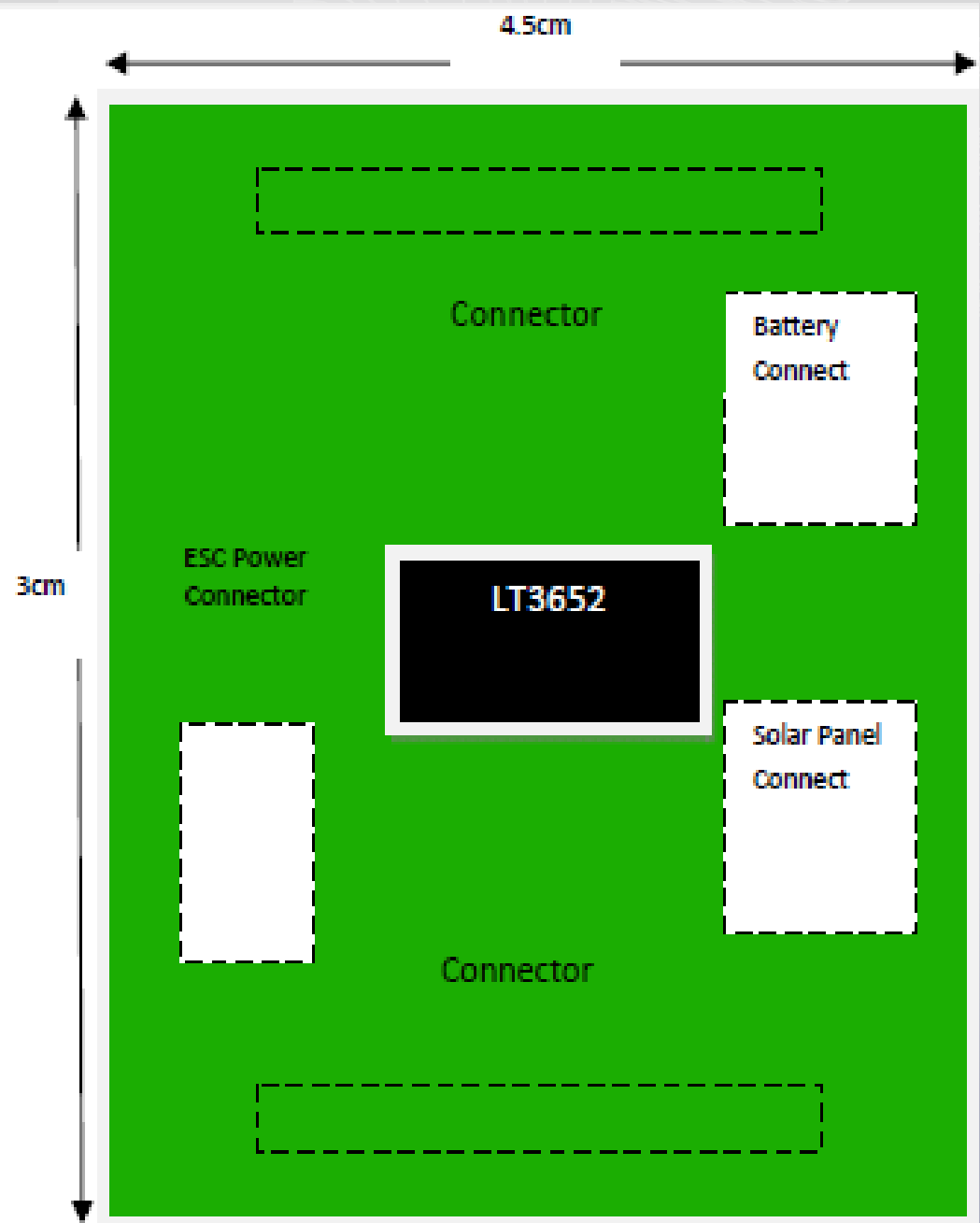
Printed Circuit Boards

Charging Circuit Board

LT3652 MPPT

Charging Controller

Connectors: Solar
Cells, Battery, ESC



Autopilot Circuit Board

Autopilot Circuit Board

Single and dual axis

Gyroscopes

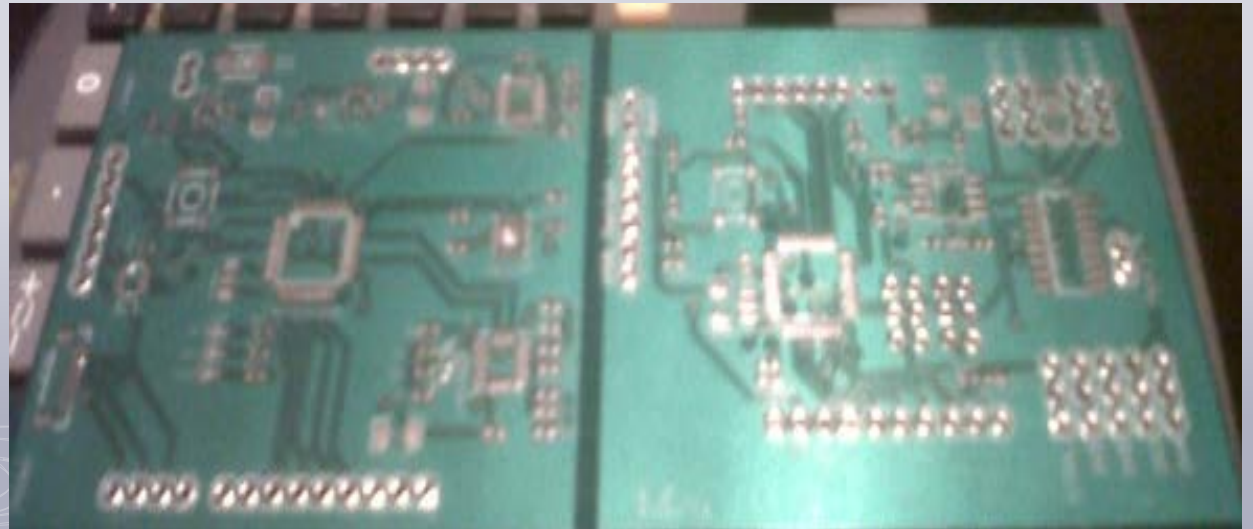
Accelerometer

Center of Gravity

Connectors: Charging-

Circuit Circuit-Board, GPS,

Xbee-Pro, and Servos



Power System

The power system will consist of the following items:

- Solar Panels
- Lithium Polymer Battery Pack
- Maximum Power Point Tracking Circuit



Solar Cells

The solar cells that we were integrating into our S.E.V project had to meet three very important design criteria.

- High Total Maximum Output
- Lightweight
- Easy System Integration



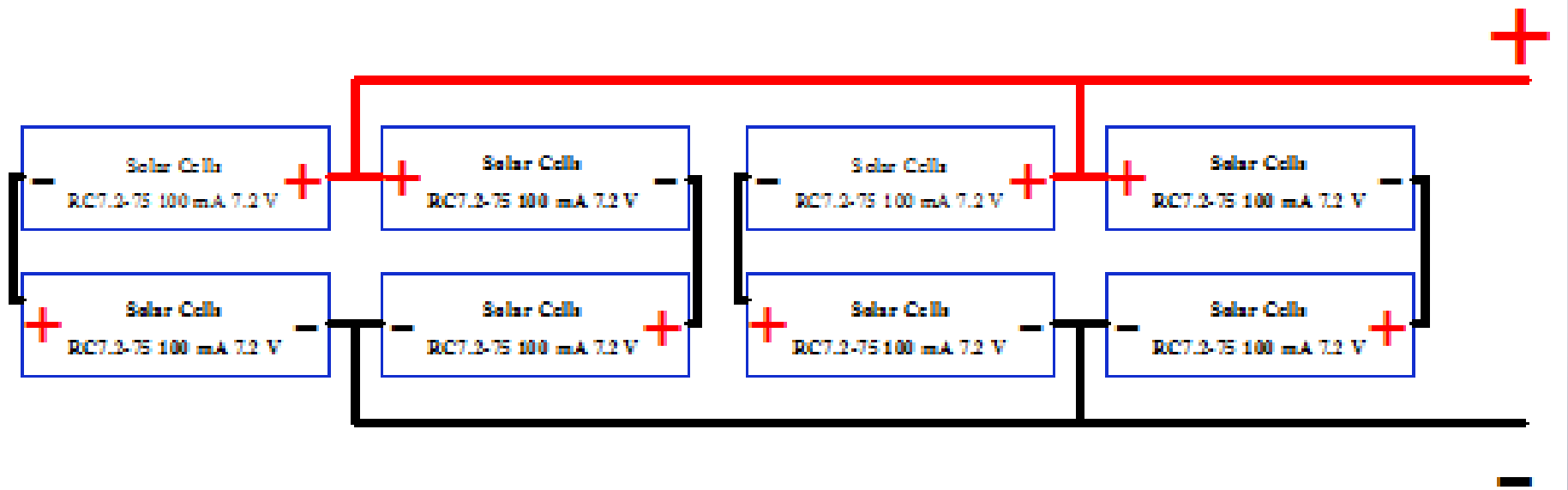
Comparison of Solar Cells

Panel	SolMaxx Flex 7.2V 100mA	SolMaxx Flex 7.2V 200mA	PowerFilm RC7.2-75
Dimensions:	10.6" x 3.9"	10.6" x 6.9"	10.6" x 3.5"
Weight:	1.1 oz	1.9 oz	0.2 oz
Total Weight:	8.8 oz	7.6 oz	1.6 oz
Thickness:	NA	NA	0.2 mm
Voltage:	7.2V	7.2V	7.2V
Total Output:	291 mA @ 19.8V	291mA 19.8V	291mA 19.8V
Price:	\$20.95 ea.	\$37.75 ea.	\$27.45 ea.

Solar Array Configuration

Series/ Parallel

19.8V @ 291 mA



LiPo Battery Pack

E-flite EFLB1040

Type:	LiPo
Capacity:	3200mAh
Voltage:	11.1V Connector
Wire Gauge:	12 AWG
Weight:	9.9 oz (251g)
Configuration:	3S
Length:	5.20 in (132mm)
Width:	1.70 in (43.2mm)
Height:	0.90 in (22.9mm)
Maximum Continuous Discharge :	15C
Maximum Continuous Current :	48A



What is Maximum Power Point Tracker

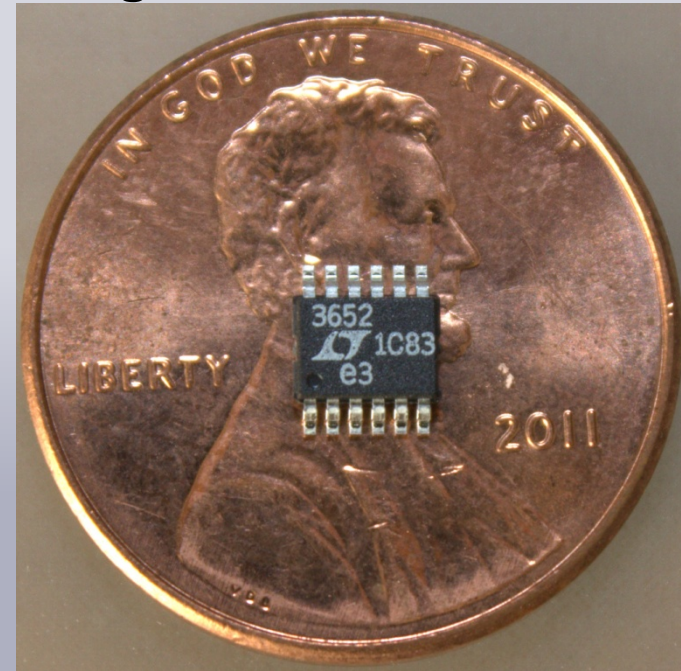
MPPT or **Maximum Power Point Tracking** is an algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage).

Maximum power varies with:

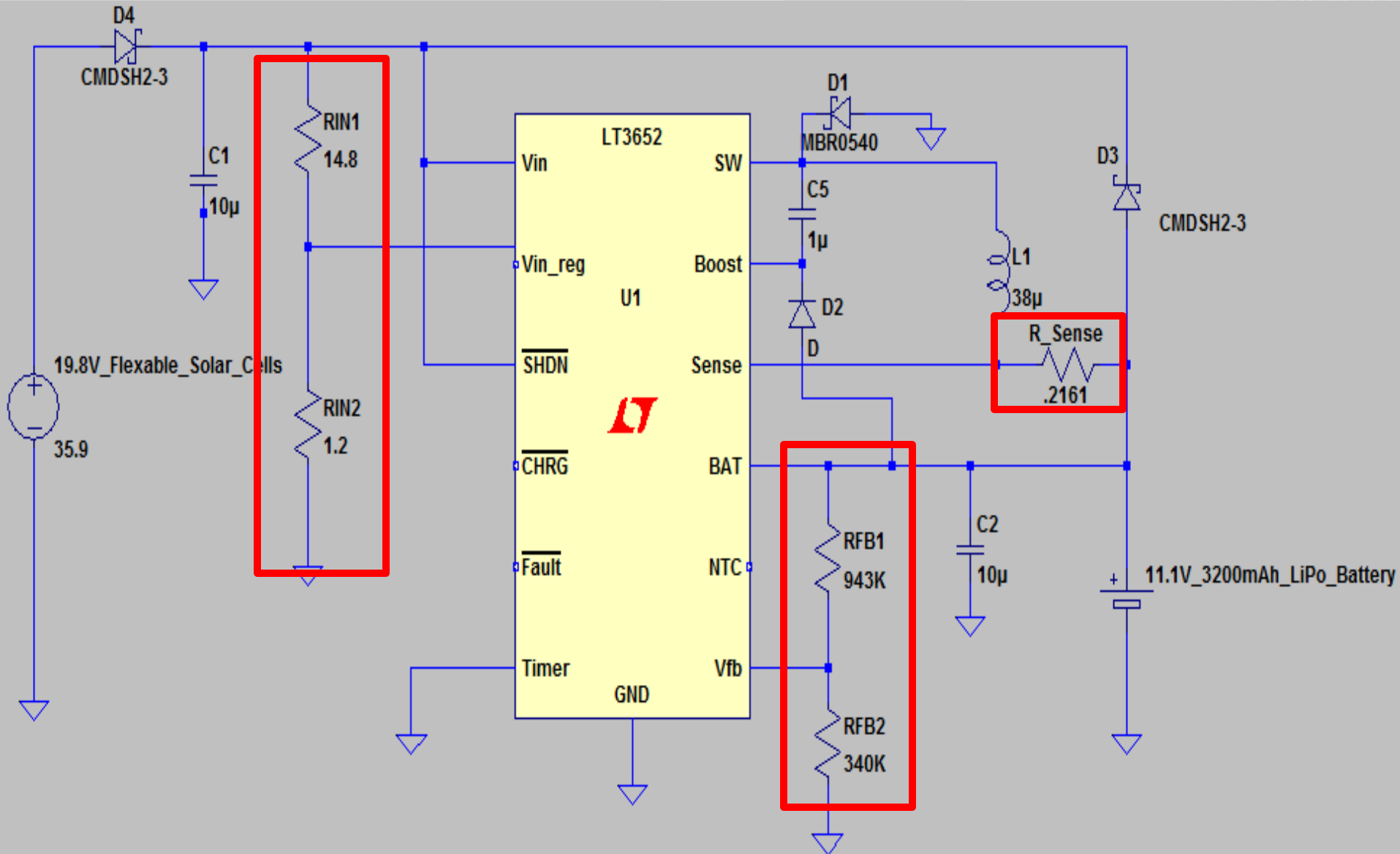
- Solar Radiation
- Ambient Temperature
- Solar Cell Temperature.

LT3652 - Power Tracking 2A Battery Charger for Solar Power

- Wide Input Voltage Range: 4.95V to 32V (40V Abs Max)
- Programmable Charge Rate Up to 2A
- User Selectable Termination: C/10 or On-Board Termination Timer
- Resistor Programmable Float Voltage Up to 14.4V Accommodates Li-Ion/Polymer, LiFePO₄, SLA, NiMH/NiCd Chemistries
- No V_{IN} Blocking Diode Required for Battery Voltages ≤ 4.2V
- 1MHz Fixed Frequency
- 0.5% Float Voltage Reference Accuracy
- 5% Charge Current Accuracy
- 2.5% C/10 Detection Accuracy
- Binary-Coded Open-Collector Status Pins
- 3mm × 3mm MSOP-12 Package

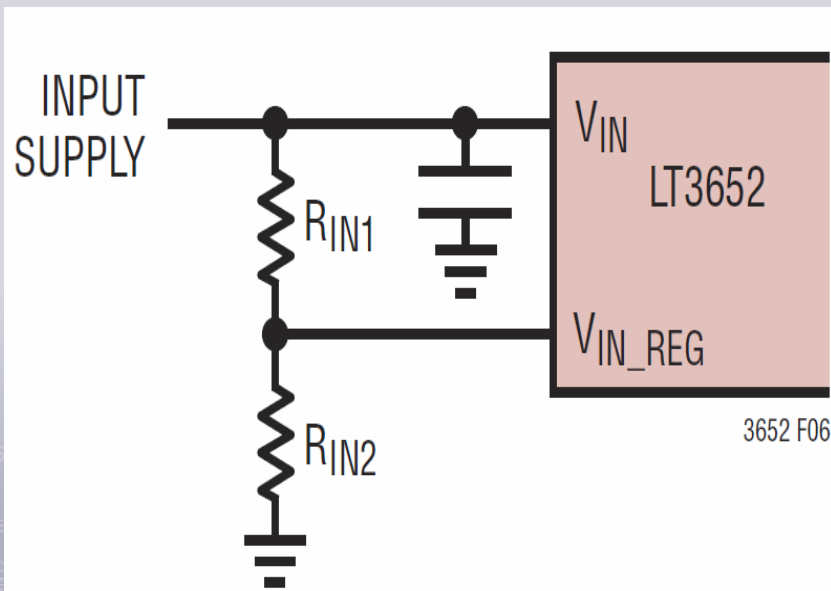


LT3652 Maximum Power Point Tracking Circuit



Voltage Monitor Programming

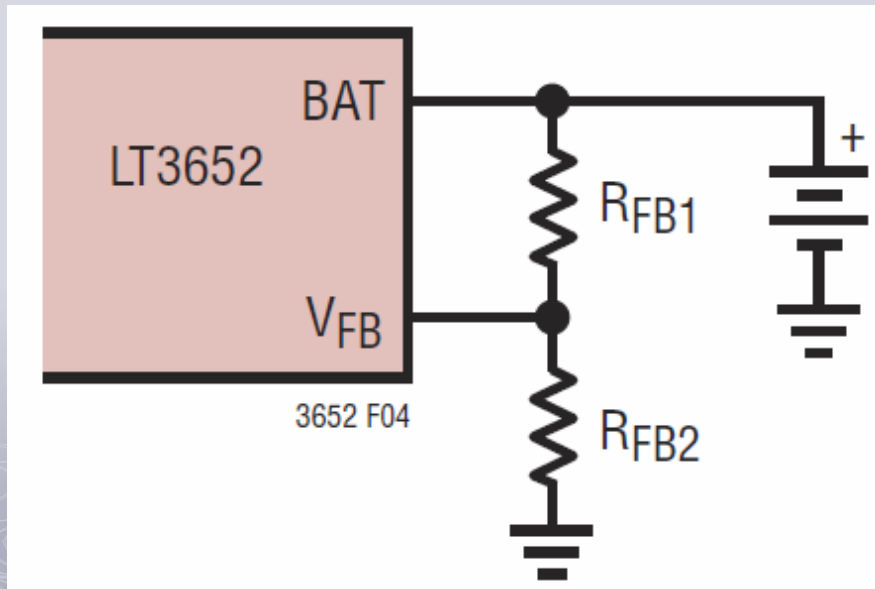
- The LT3652 also contains a voltage monitor pin that enables it to monitor the minimum amount of voltage coming into the MPPT. The input supply voltage regulation is controlled via the voltage divider resistor R_{IN1} and R_{IN2} . An operating supply voltage can be programmed by monitoring the supply through the resistor divider network. This is done by having a ratio of R_{IN1}/R_{IN2} for a desired minimum voltage. In order to achieve the 11.1V needed:



$R_{IN1}/R_{IN2} = (V_{IN(MIN)}/2.7) - 1$	$R_{IN1}/R_{IN2} = 12.185$
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Float Voltage Monitor Programming

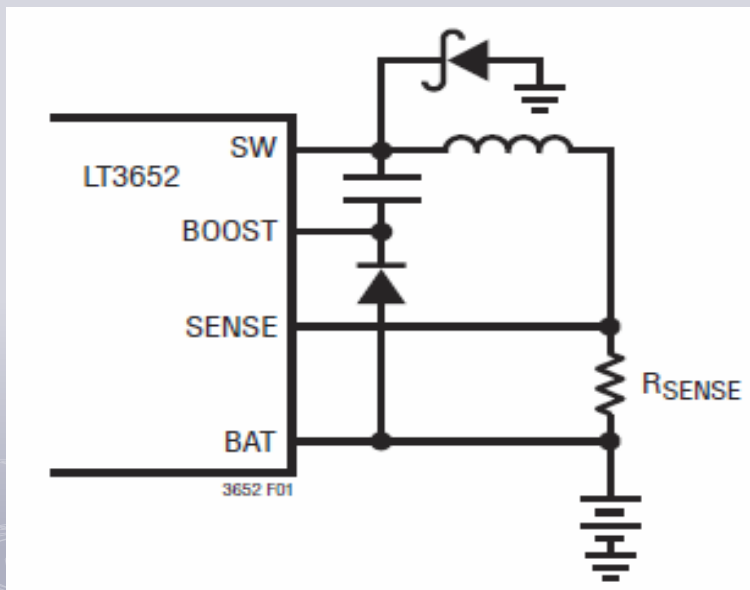
- Using a resistor divider is needed to program the desired float voltage, $V_{\text{BAT(FLT)}}$, for the battery system. In particular, resistors R_{FB1} and R_{FB2} will have to have the correct values to set the 12.6-volt float charge needed in the lithium polymer battery pack.



$R_{\text{FB1}} = (V_{\text{BAT(FLT)}} * 2.5 * 10^5) / 3.3$	$R_{\text{FB1}} = 943.18 \text{ K}\Omega$
$R_{\text{FB2}} = (R1 * (2.5 * 10^5)) / (R1 * (2.5 * 10^5))$	$R_{\text{FB2}} = 340.16 \text{ K}\Omega$

Charge Current Programming

- Charge current programming is set by choosing an inductor sense resistor. For our particular circuit that we are designing the total expected max current that we would see from the circuit is 463mA. The expected value for R_{Sense} would be a resistor with an approximate value of 0.2161Ω .



$R_{\text{SENSE}} =$	$R_{\text{SENSE}} =$
$0.1 / I_{\text{CHG(MAX)}}$	0.2161Ω

Software Design

- Arduino IDE
- ArduPilot: Open source autopilot platform
- AHRS
- Ground Control Station
- Simulator: XPlane

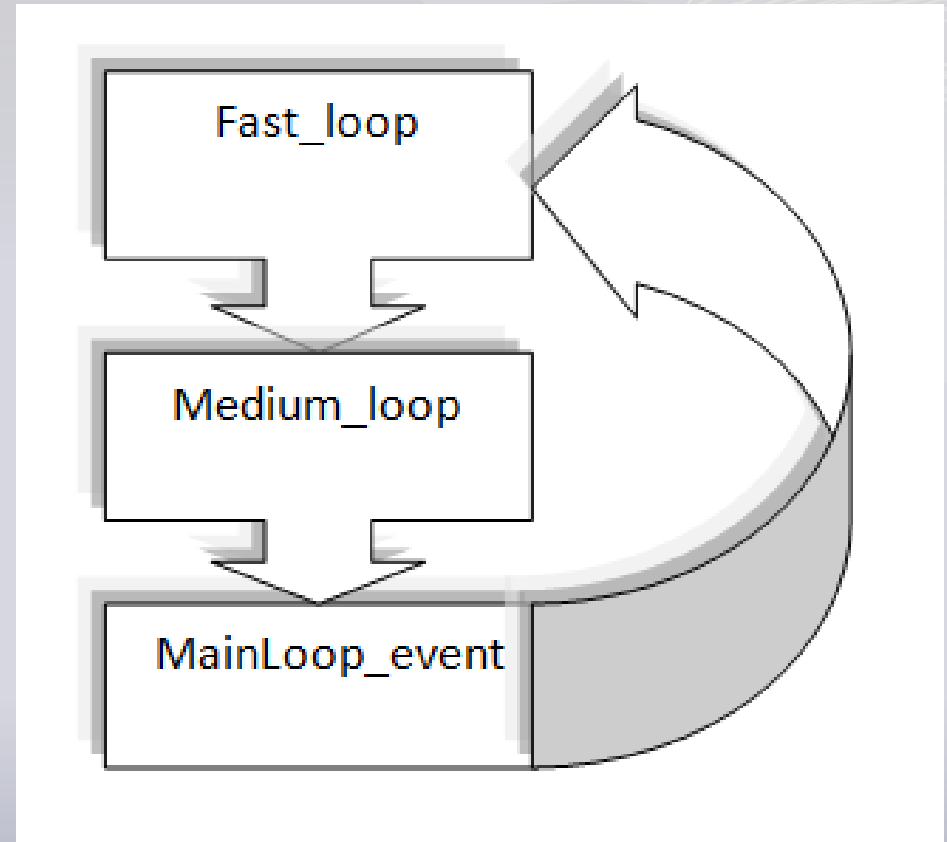


ArduPilot

- **Manual-** Full manual control
- **Circle-** Fly in a stabilized circle, this is used when there is no GPS present
- **Stabilize-** This mode will have the plane maintain level flight
- **Fly-by-wire A-** Autopilot style control via user input, manual throttle
- **Fly-by-wire B-** Autopilot style control via user input, airspeed controlled throttle Power
- **Auto-** All control of the UAV are through the ArduPilot
- **RTL-** The UAV will return to its launch location and circle until manually controlled
- **Loiter-** The UAV will circle in the current location
- **The Fly-By-Wire B mode is where we have chosen to place our power saving code. This allows us to use the control switch to enter and exit the power saving mode.**

ArduPilot Cont.

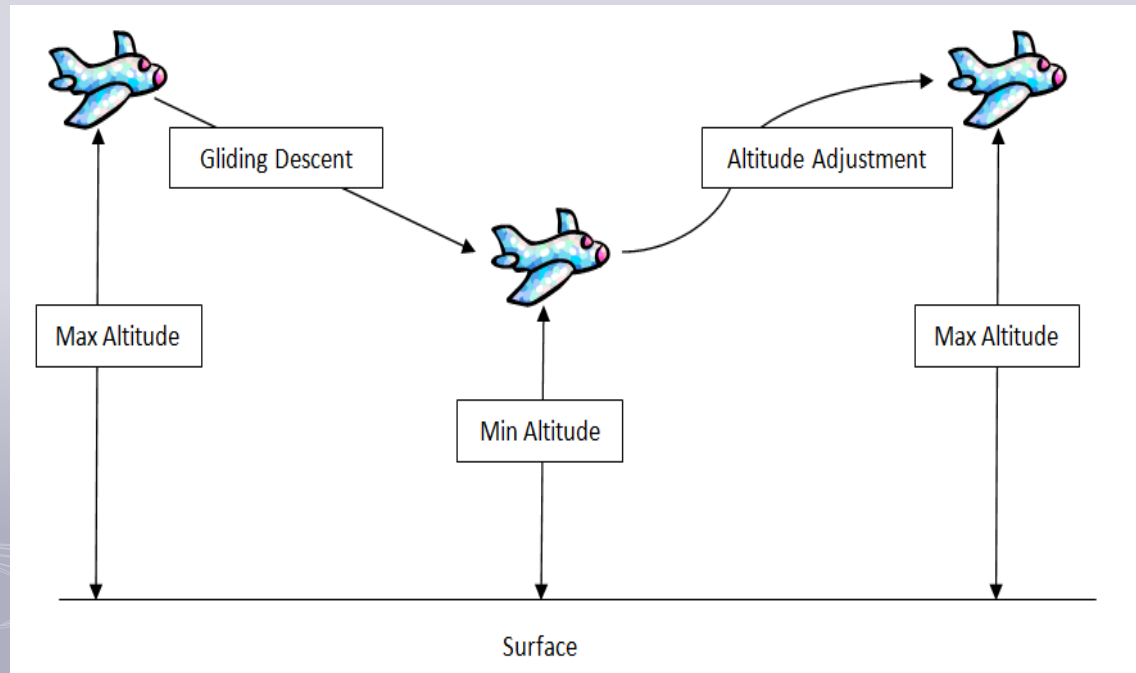
- The code consist of one main loop.
- Within the main loop there are three Functions.
- The **fast loop** checks to see if the radio controller is sending a signal, it will calculate the altitude and bearing error and last will update current flight mode.
- The **medium loop** is comprised of 5 different cases that will be executed one at a time. These cases range from navigation to timers. And most importantly checks to see if the control switch has been changed.



Power Saving Code

```
servo_out[CH_THROTTLE] = temp_thro;
```

```
if(current_loc.alt < 3000){  
    temp_thro = THROTTLE_MAX;  
    servo_out[CH_THROTTLE] = THROTTLE_MAX;  
    nav_roll = 0 ;  
    nav_pitch = 1500;  
}  
if(current_loc.alt > 6000){  
    temp_thro = THROTTLE_MIN;  
    servo_out[CH_THROTTLE] = THROTTLE_MIN;  
    nav_roll = HEAD_MAX / 3;  
    nav_pitch = 500;  
}
```

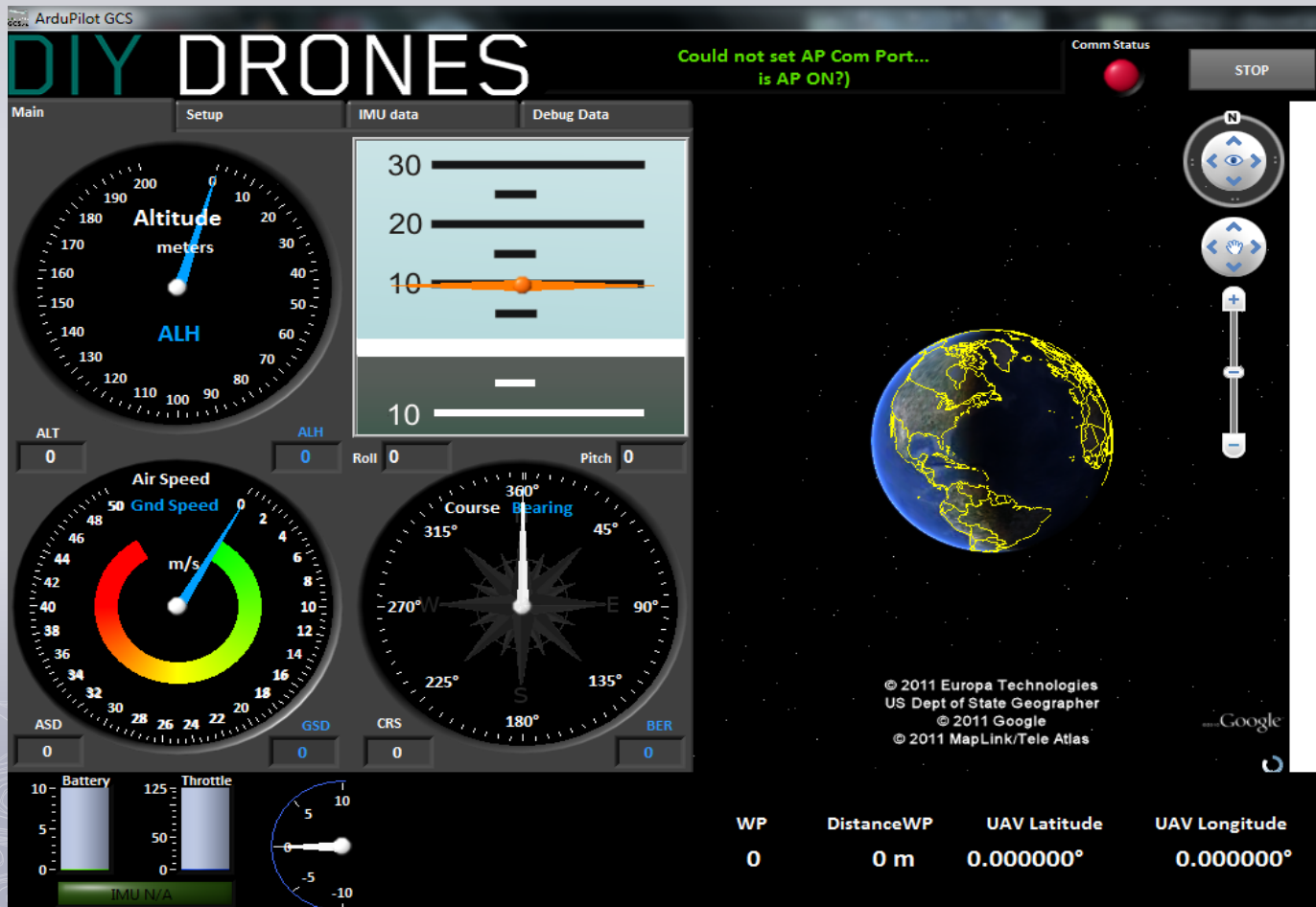


Altitude Heading Reference System

- The code will be used to maintain a model of the UAV's orientation in space.
- This code is based on Bill Premerlani's Direction Cosine Matrix (DCM) algorithm.
- The DCM is a 3 by 3 matrix array; the gyro data is used in a time step integration to update the matrix. With this data from the sensors and GPS can be used to correct for errors.
- With this data we can determine pitch, roll and yaw; but for this project we will only be using the pitch and yaw. With this code we are now able to fly, without the control of a user, our UVA to waypoints.

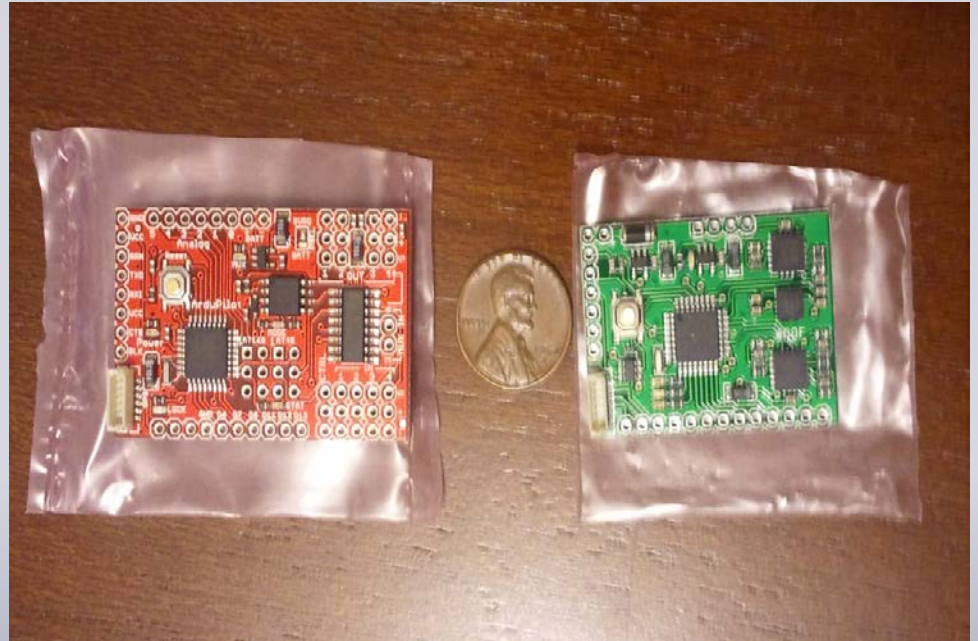
Ground Control Station

- Through the use of Xbee modules we will be able to track the S.E.V



Software Testing

- Before we flew the plane we tested the software.
- This was done in a simulated environment, we chose to do this to avoid destroying our airframes
- We used the XPlane software to simulate the software code.
- Testing was done by using development boards purchased from SparkFun



S.E.V Actual Budget

Description	Quantity	Price Each	Total Price
Plane	1	\$89.95	\$119.80
Motor	1	\$54.99	\$58.56
Prototype plane incl. servo & ESC	2	Incl	\$300.00
Electronic Speed Controller	1	Incl	Incl
Microcontroller ATmega 328 & ATtiny45	1	Sample	Free
Triple-Axis Accelerometer- ADXL335	1	\$5.00	\$5.00
Barometric Pressure Sensor – BMP085	1	Sample	Free
Gyroscope LY530ALH & LPR530AL	2	Sample	Free
GPS Mediatech MT3329	1	\$63.51	\$63.51
Transmitter/ Receiver	1	\$32.78	\$32.78
Zigbee Pro	2	\$47.69	\$95.37
Solar Panel PowerFilm RC7.2-75	8	\$31.34	\$250.69
Lithium-Ion Polymer Battery Pack	2	\$53.24	\$106.48
LT3652 Charging Circuit	2	\$27.98	\$48.88
Sub-Total			\$1,023.00

Difficulties

- Weather Conditions
- Landing Protocol
- Less solar radiance during winter months
- The motor was over powered for this airframe
- High maintenance testing
- Software communications difficulties

Distribution of Responsibilities

Group IV	Power	Software Design	Hardware Design	Air Frame	Mechanics
Hamed Alostath		√	√		
Daniel Grainger		√	√		
Frank Niles				√	√
Sergio Roig	√				√



Questions?