Formula SAE Paddle Shift System

University of Central Florida

Group Members

Richard Pittman - EE
Musab Hmeidan - EE
Sean Feschak – ME/EE
Kevin Castillo - CpE

Motivation

- UCF Formula SAE Team
  - Replace mechanical push-pull cable
  - Increase competitiveness of team
- Represents a product that could have other useful applications
  - Enable handicapped riders
  - Drag-racing motorcycles
  - Other forms of amateur and professional racing
- All members interested in project and subsystems

Goals

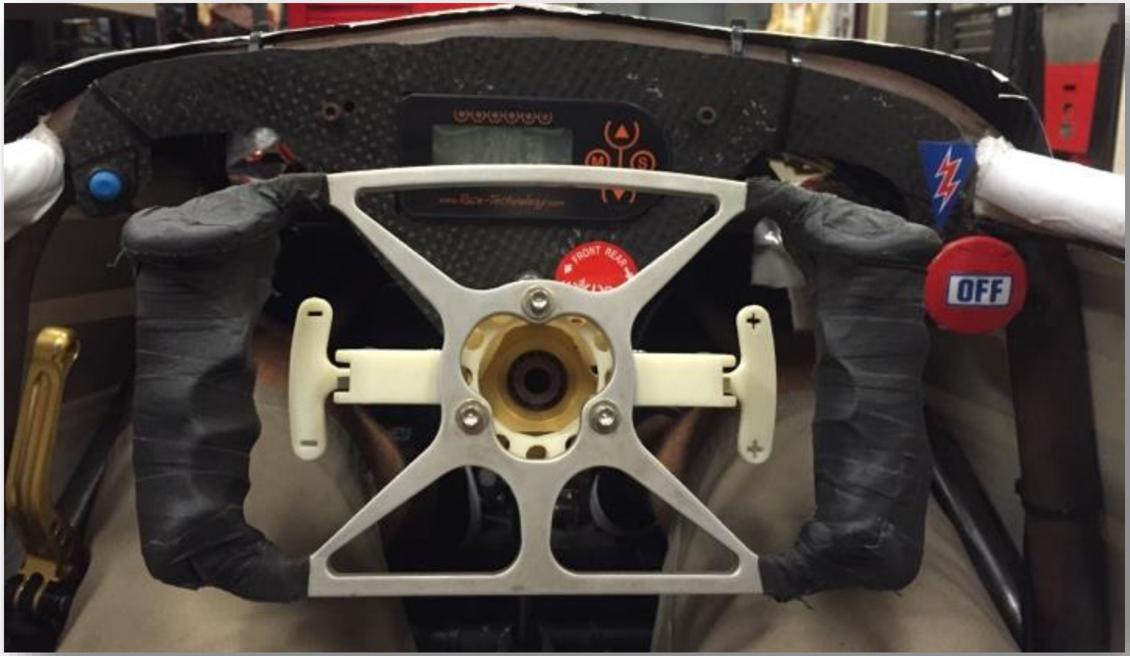
- **Accessibility and ease of use**
- **Reliable and highly durable**
- **Maintainable**
- **Controllable**
- **Transferable**
- **Safe**

Requirements

Requirement ID	Requirement Description
EPS. 1	Steering wheel mounted gear display
EPS. 2	Display brightness, 400 nits minimum
EPS. 3	Total system weight, 15 lbs maximum
EPS. 4	Operating temperature range of 20º to 120º F.
EPS. 5	Water Resistant
EPS. 6	Impact Resistant
EPS. 7	GPS tracking
EPS. 8	Data logging with removable SD card
EPS. 9	Complete gear shifting functionality

Realistic Design Constraints

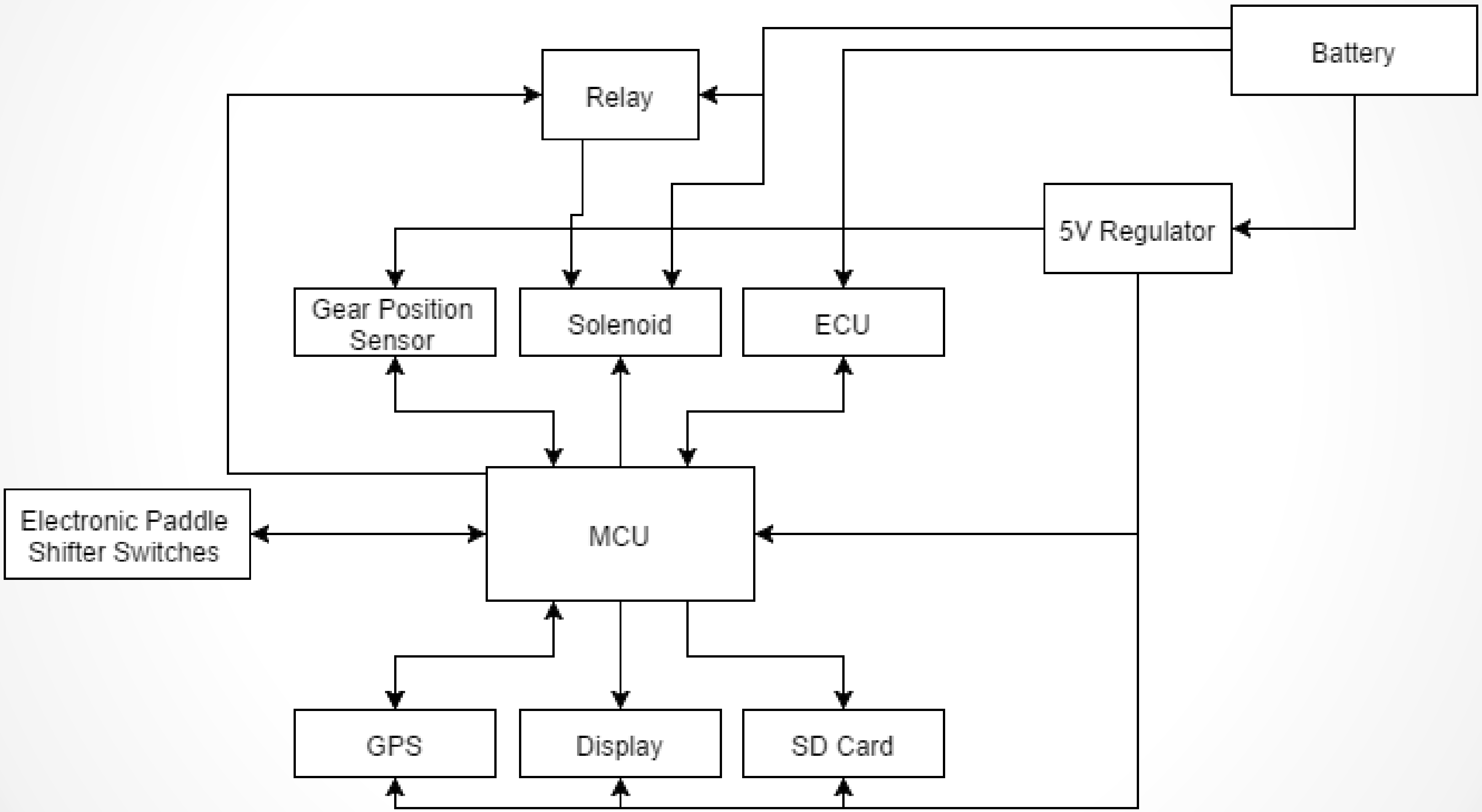
- Small Budget from the Formula SAE team
- Must pass all Formula SAE rules and regulations
- Designed around current Formula SAE car
- Must be able to transfer over to future FSAE car



Challenges

- Challenged with 5V output of Tiva-C development board
  - Swapped MCU to Arduino UNO
- Challenged with learning how to properly create a schematic on Eagle with no library files for some parts
  - Had to create the .lbr files based upon Cad file dimensions
- Challenged with coding for components
  - Group is not familiar with many of the components
- Challenged with Soldering of SMD products
  - Group is not properly equipped to handle such a task with the equipment they have

Block Diagram



Strategic Components

- Shift Component
  - Low Power Consumption
  - Fast Response time
  - Reliable
- MCU
  - Able to control all Inputs and be able to give the number of outputs needed
- GPS
  - Accurate and easy to use for data logging
- Display
  - Highly visible
  - Small
  - Use of few wires

Shift Methods

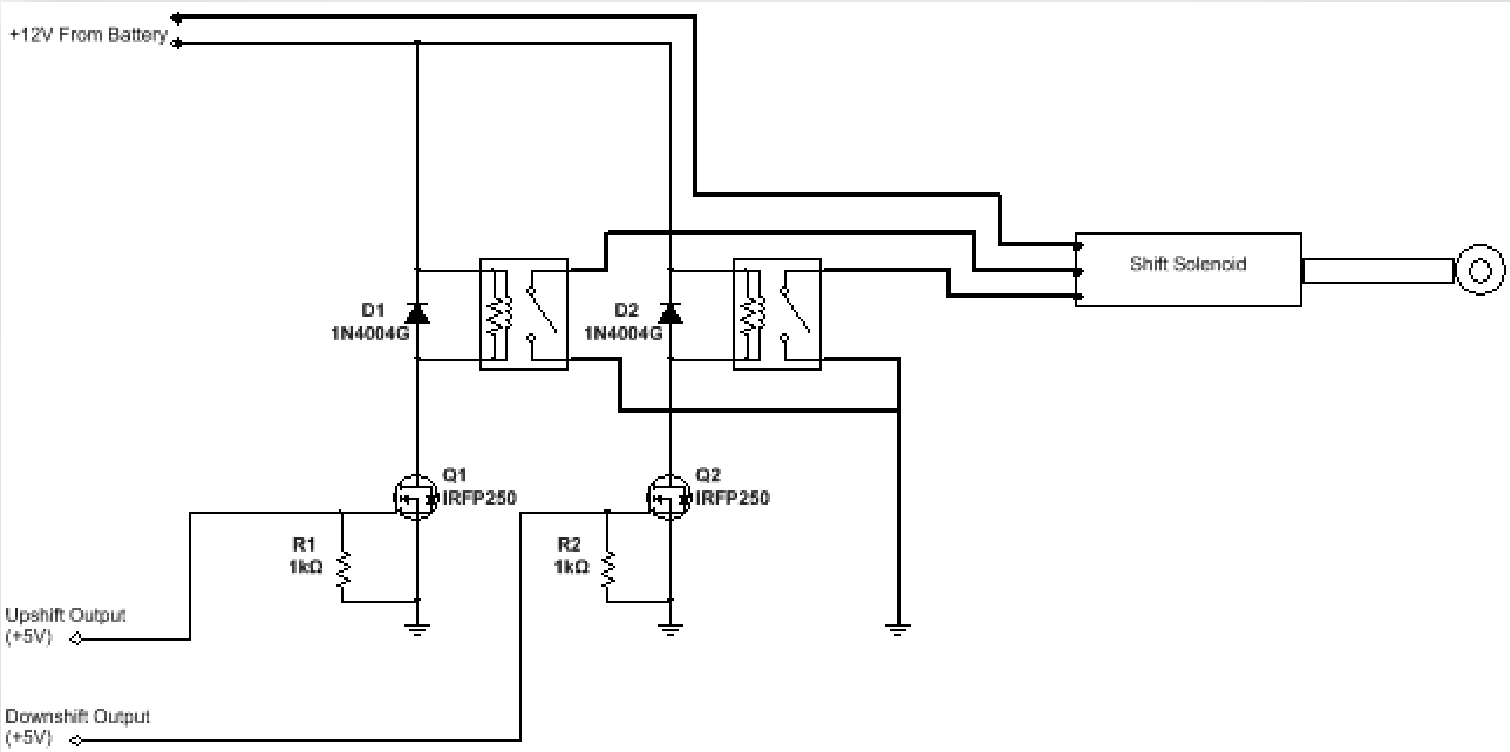
Pneumatic shifters

- Requires Tank
- Limited number of shifts with no Air Compressor
- Air compressor has large power consumption and weight

Electronic Actuator

- Uses short bursts of power
- Unlimited Shifts
- Does not require other components to function

Actuator

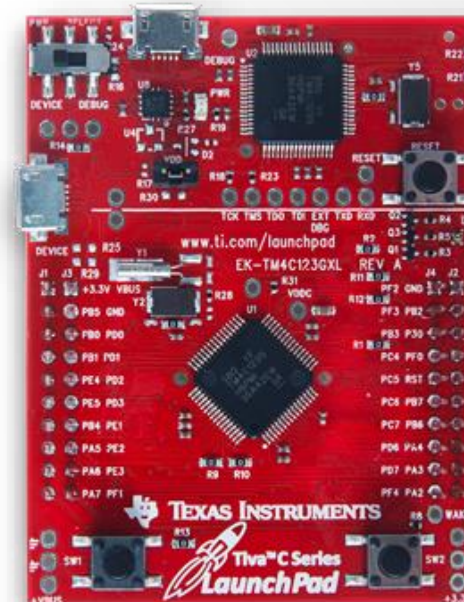


- Takes a minimum of 11lbs of force for the lever to shift into gear.
    - The actuator chosen has 35lbs of force in both the push and pull functions.
- The actuator also needs to travel 1 1/8" in both directions for a shift to occur.
    - The actuator chosen has a travel of 1 ½" in both directions making it ideal for shifting will not push too far past the required amount adding extra stress on the transmission.

MCU

Arduino Uno
(ATmega328P)

Primary Features	Values
Clock	16 MHz
Flash Memory	32 KB
SRAM	2 KB
Operating Voltage	5V
Extended Temperature	-40°C - 85°C
Current Consumption	46.5 mA, active 1456 μA, sleep

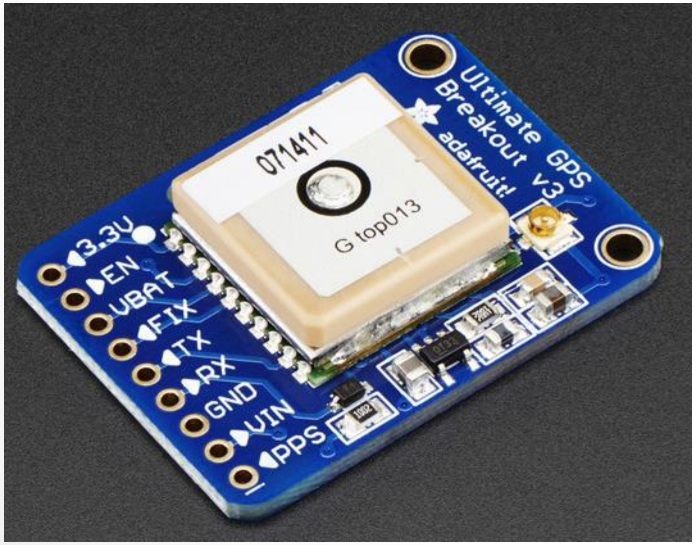


Tiva C Launchpad
(TM4C123GH6PM)

Primary Features	Values
Clock	80 MHz
Flash Memory	256 KB
SRAM	32 KB
Operating Voltage	3.3V
Extended Temperature	-40°C - 125°C
Current Consumption	45 mA, active 1.38 μA, hibernate

GPS

- Ability to attach a larger antenna to the ANT pad
- Compatible with a majority of Arduino libraries capable of parsing NMEA 0183 data
- Used TinyGPS for parsing

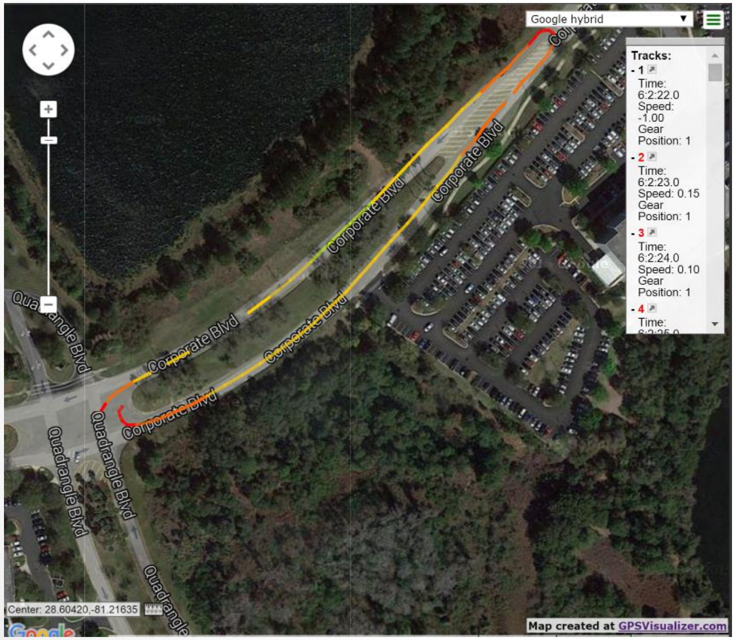


Adafruit Ultimate GPS (MTK 3339)

Primary Features	Values
Satellites	22 tracking, 66 searching
Size	16mm x 16mm
Update Rate	1 to 10 Hz
Position Accuracy	3 meters
Velocity Accuracy	0.1 meters/s
Cold Startup Time	34 seconds
Acquisition Sensitivity	-145 dBm
Tracking Sensitivity	-165 dBm
Maximum Velocity	515 m/s
Voltage In Range	3.0 – 4.3 VDC
Operating Current	25 mA tracking, 20 mA navigation
Output	NMEA 0183, 9600 baud
Operating Temperature	-40 ℃ to 85 ℃

GPS Imaging

- **GPS Visualizer: Do-It-Yourself Mapping**
- Online utility that creates maps and profiles from GPS data.
- **Free** and easy to use
- Powerful and extremely customizable.

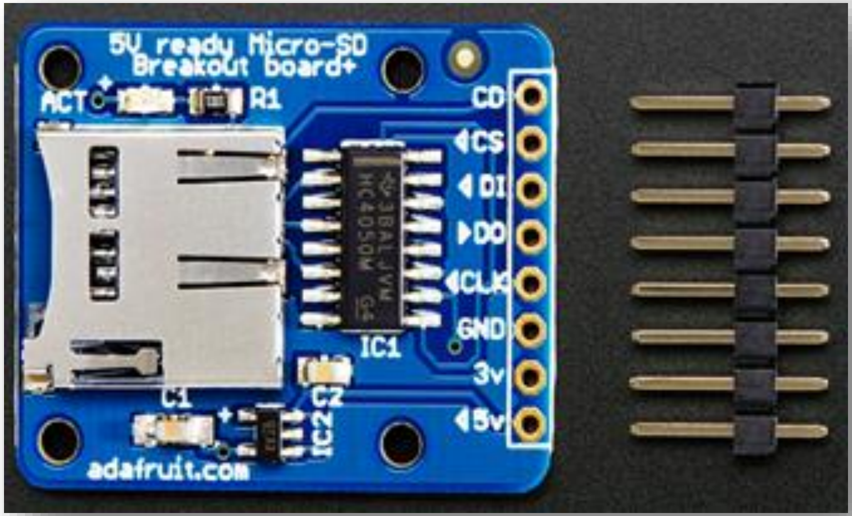


GPS Testing

Software Test	Description	Passing Criteria
Rapid Shifting	Shift once per second for one minute	All 60 outputs from MCU are correct
Save Data	Save data to external storage, with formatting	All data is saved, correct and formatted
GPS Short Distance Read	Move the GPS in 4 meter increments and read location	All coordinates match Google Maps/Earth coordinates with less than 5% error
GPS Rapid Short Distance Read	Move the GPS at approximately 60 mph and read location and speed every 150 milliseconds	All coordinates match Google Maps/Earth coordinates with less than 5% error All speeds match actual speeds with less than 5% error
Formula One Track Run	One lap around the track, reading and recording location, speed, shifts and time once per second	All coordinates match Google Maps/Earth coordinates with less than 5% error All speeds match actual speeds with less than 5% error All shifts match actual shifts All times match actual times

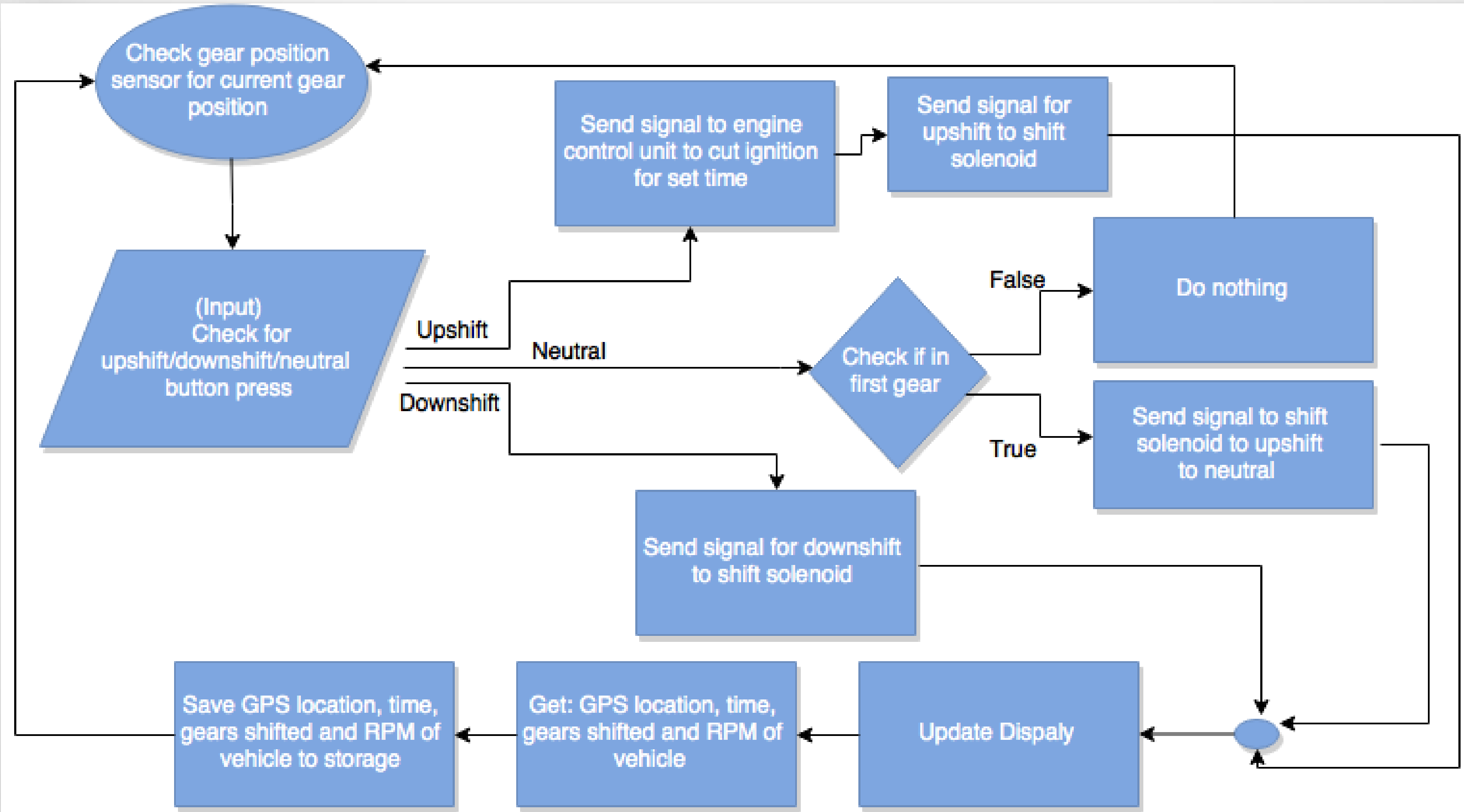
Data Logging/ SD Card Slot

- Works well with Arduino
- Useful resources online
- Quick and easy to use



	Details	Description
Power Input	3-5V	Onboard 5v->3v regulator
Pin usage	4 Pins	Read and write 2Gb+ of storage
LED Activity	Yes	Lights up when the SD card is being read or written
Socket Type	Push-Push	Easy to insert and remove
Mounting	Four #2 mounting holes	Can be Mounted securely

Coding Plan

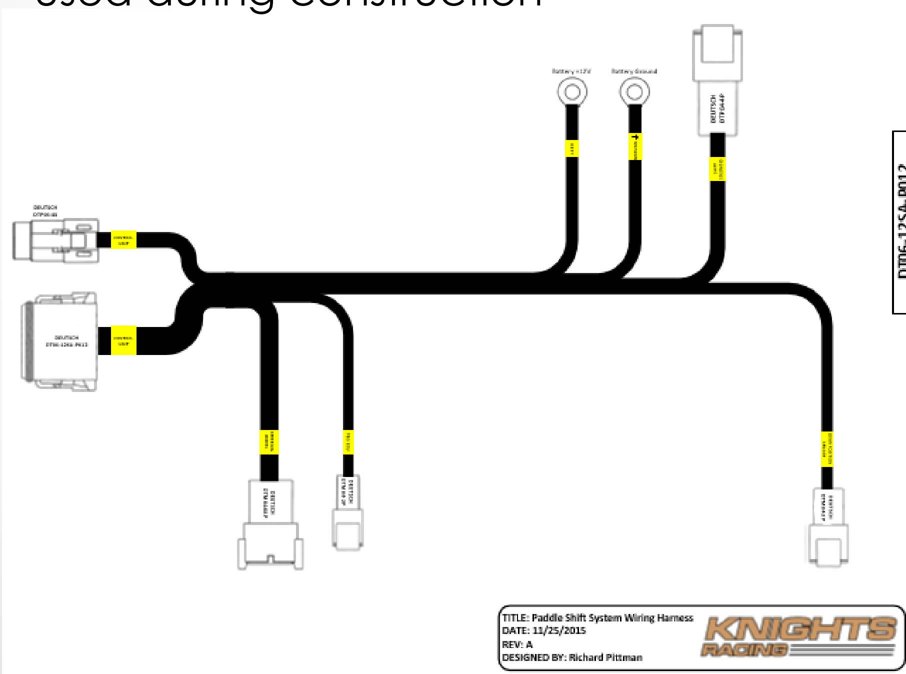

Check gear position sensor for current gear position
(Input) Check for upshift/downshift/neutral button press
Upshift
Neutral
Downshift
Send signal to engine control unit to cut ignition for set time
Send signal for upshift to shift solenoid
False
True
Check if in first gear
Do nothing
Send signal to shift solenoid to upshift to neutral
Send signal for downshift to shift solenoid
Save GPS location, time, gears shifted and RPM of vehicle to storage
Get: GPS location, time, gears shifted and RPM of vehicle
Update Dispaly

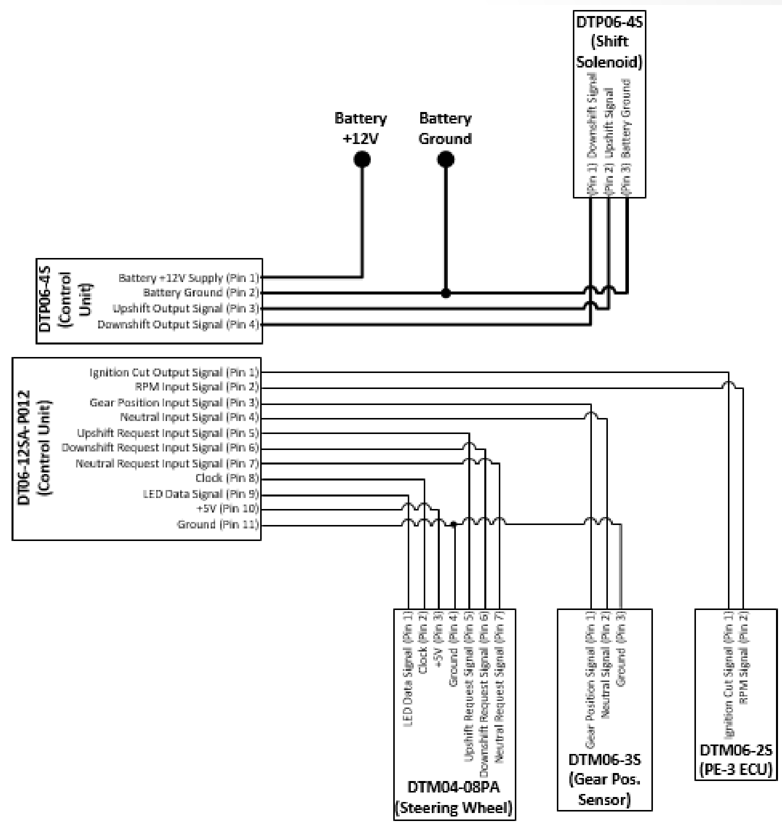
Driver Controls

- Integrated into current steering wheel setup
- Ergonomically designed
- Paddles for upshift and downshift
- Thumb button for neutral
- Conforms to FSAE competition rules

Wiring Harness

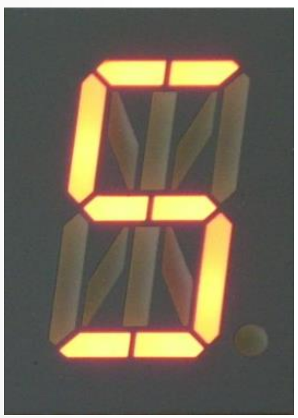
- Essential component of the system
- Must be able to withstand a motorsports environment
- Constructed using mil-spec components
- mil-spec techniques
  used during construction

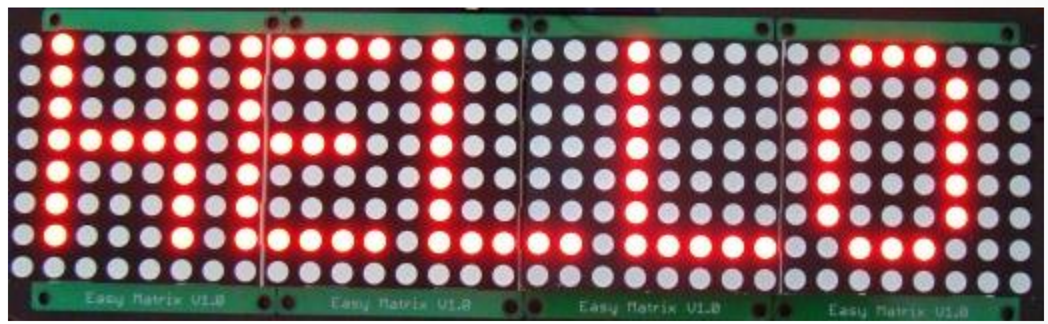




Display Types

TFT LCD Display
- High cost for High brightness





16 Segment Display
- Bright (Visible in direct sunlight)
- Cheap

Dot Matrix Display
- Many LEDs not needed
- Hard to see in direct sunlight

Display

- Able to be seen clearly direct sunlight
- Displays the Characters
  1, 2 , 3, 4, 5, 6, and N
- Should be small enough to fit on the Steering Wheel but large enough to clearly see

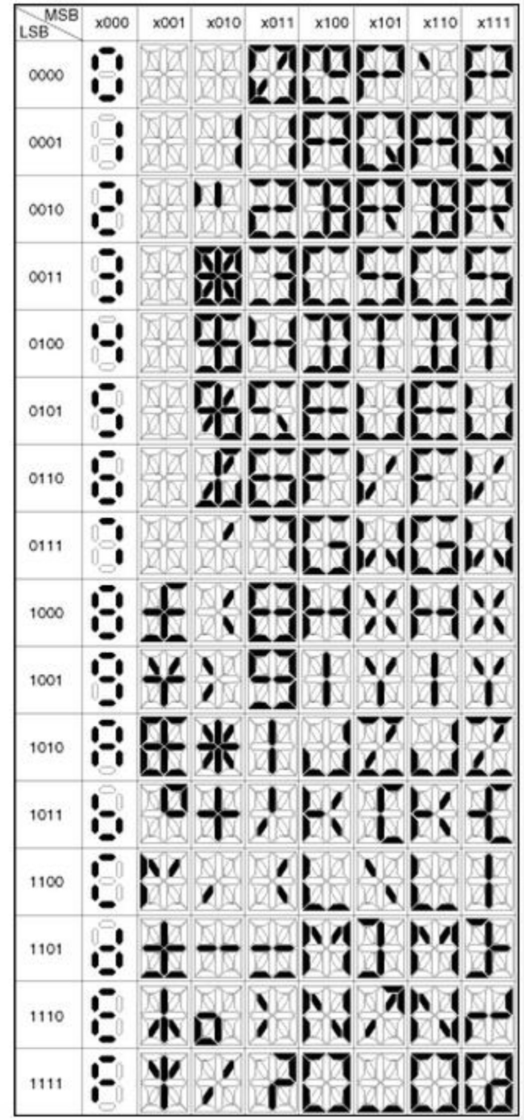
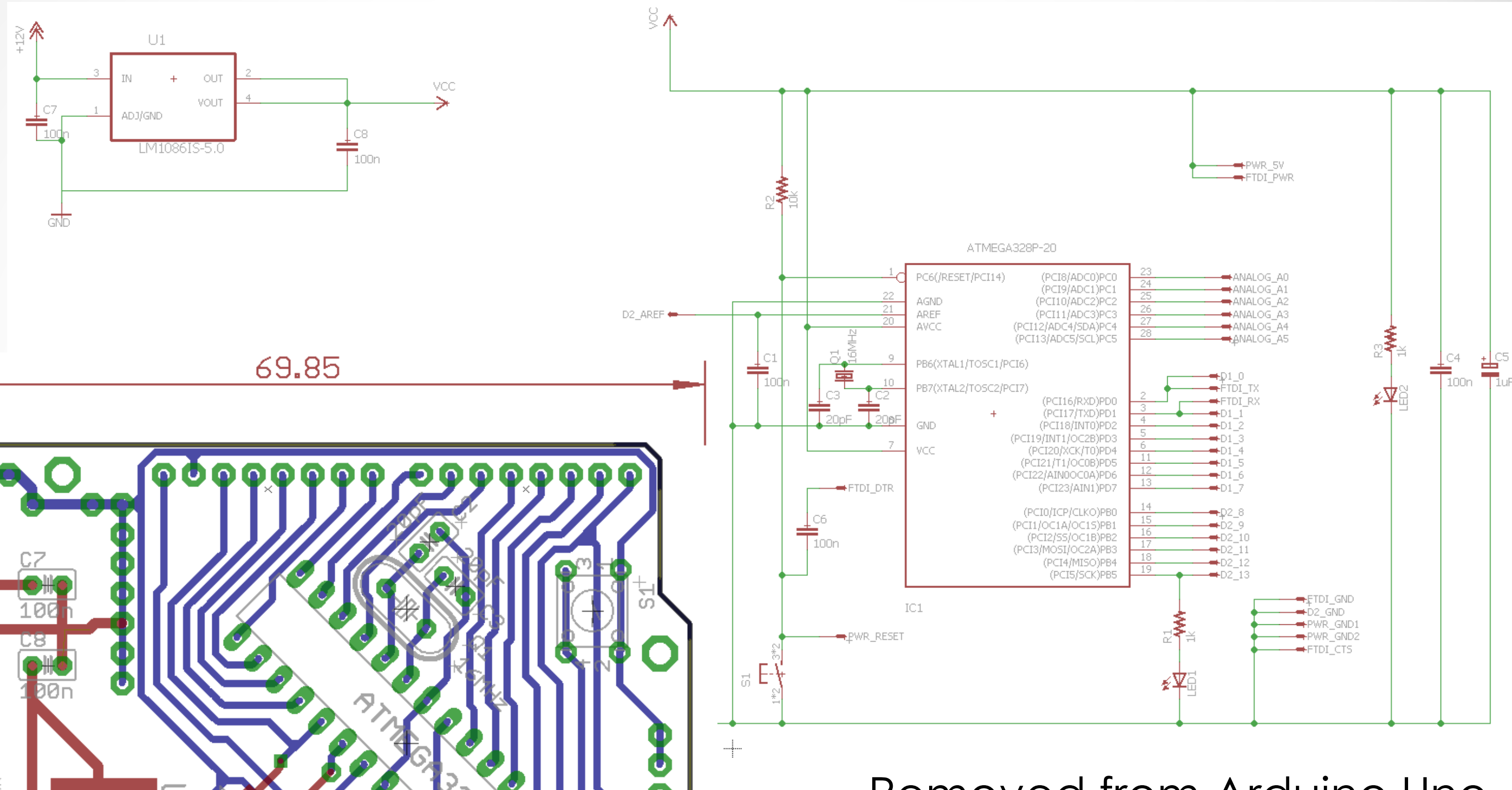
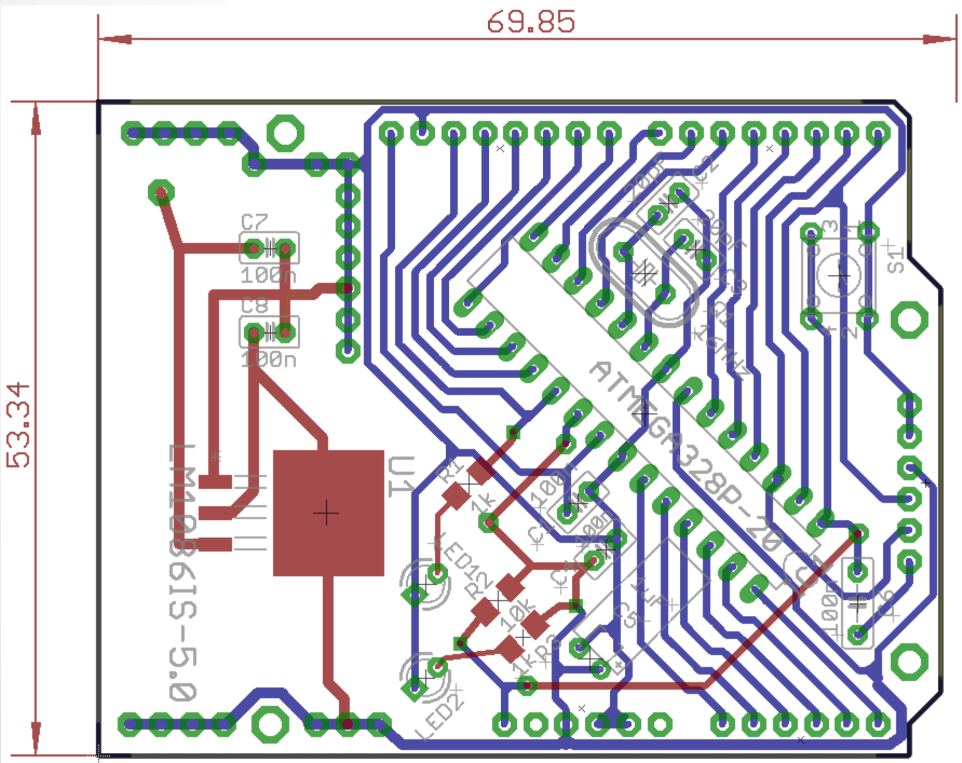


Image provided by Maxim

PCB of Main Board

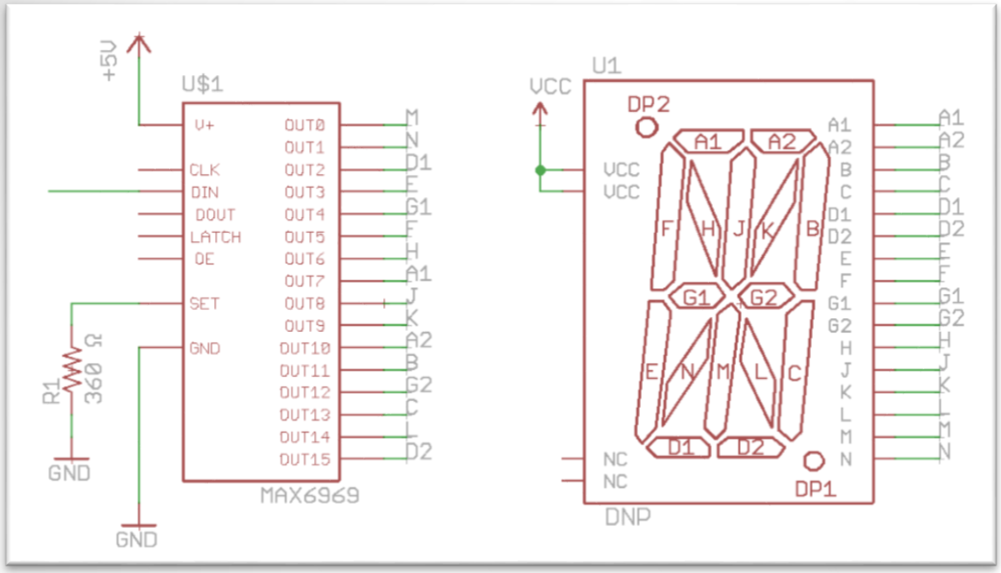


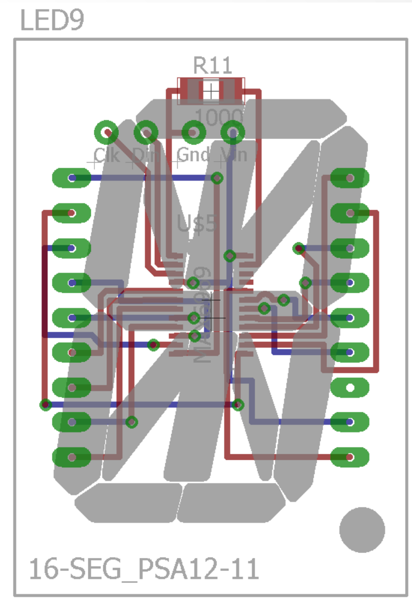


Removed from Arduino Uno

- On board USB to serial converter
- DC jack and power regulator (7-12V input)
- Power regulator (3.3V output)
- ICSP connector
- Serial communication LEDs

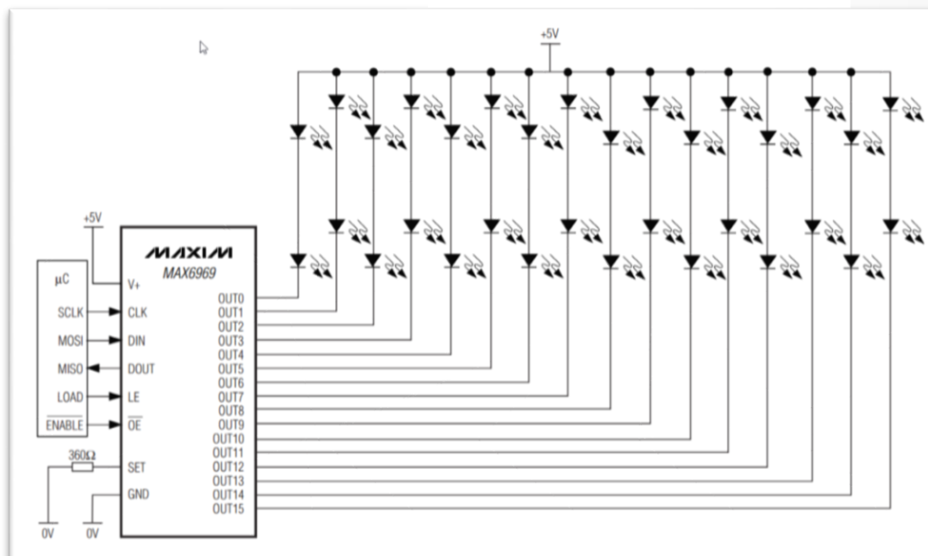
Display Driver





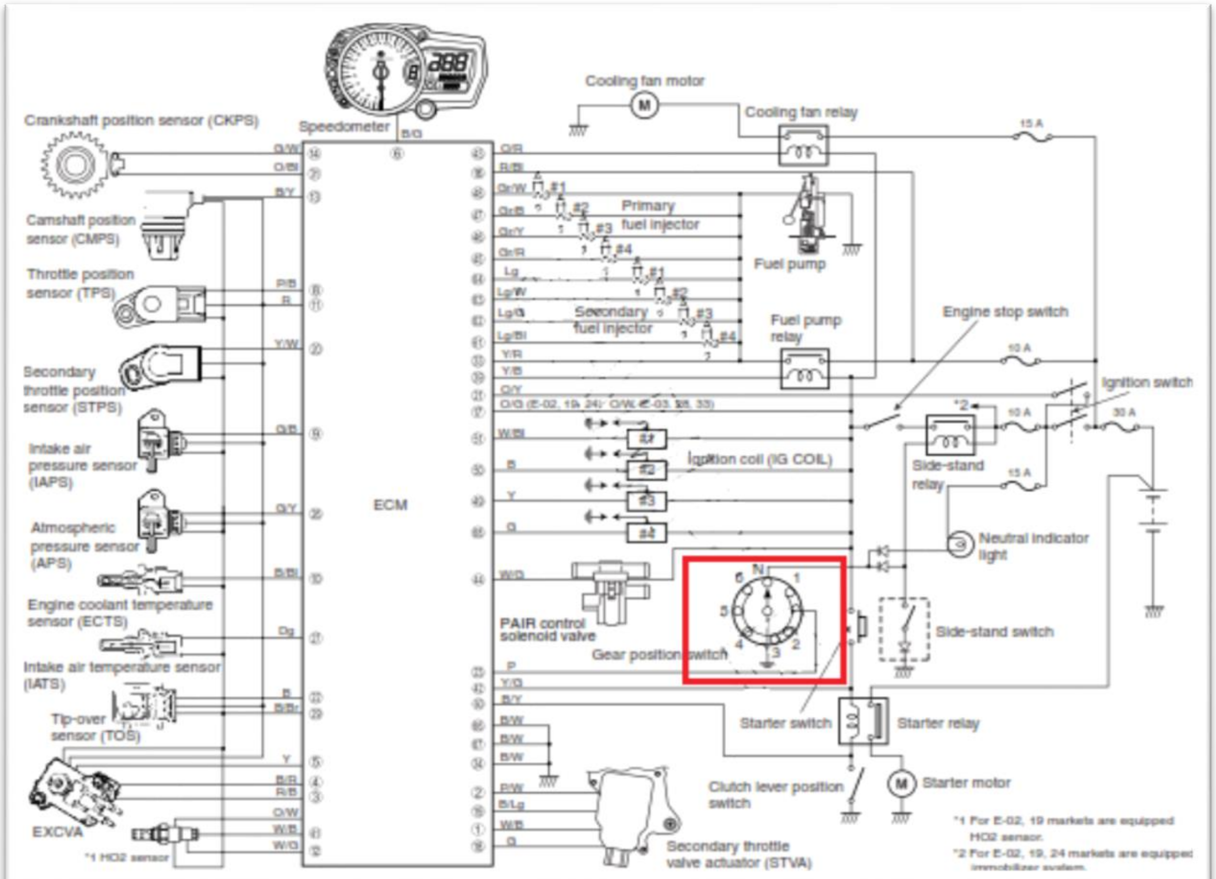
Design Requirements:

- Design the Driver to be the same size of the Display
- Use less than 4 wires
- Be able to be fully enclosed



Gear Position Sensor

- Communicates the gearshift's position to the electrical system of the vehicle.
- Assists driver to indicate current gear position.



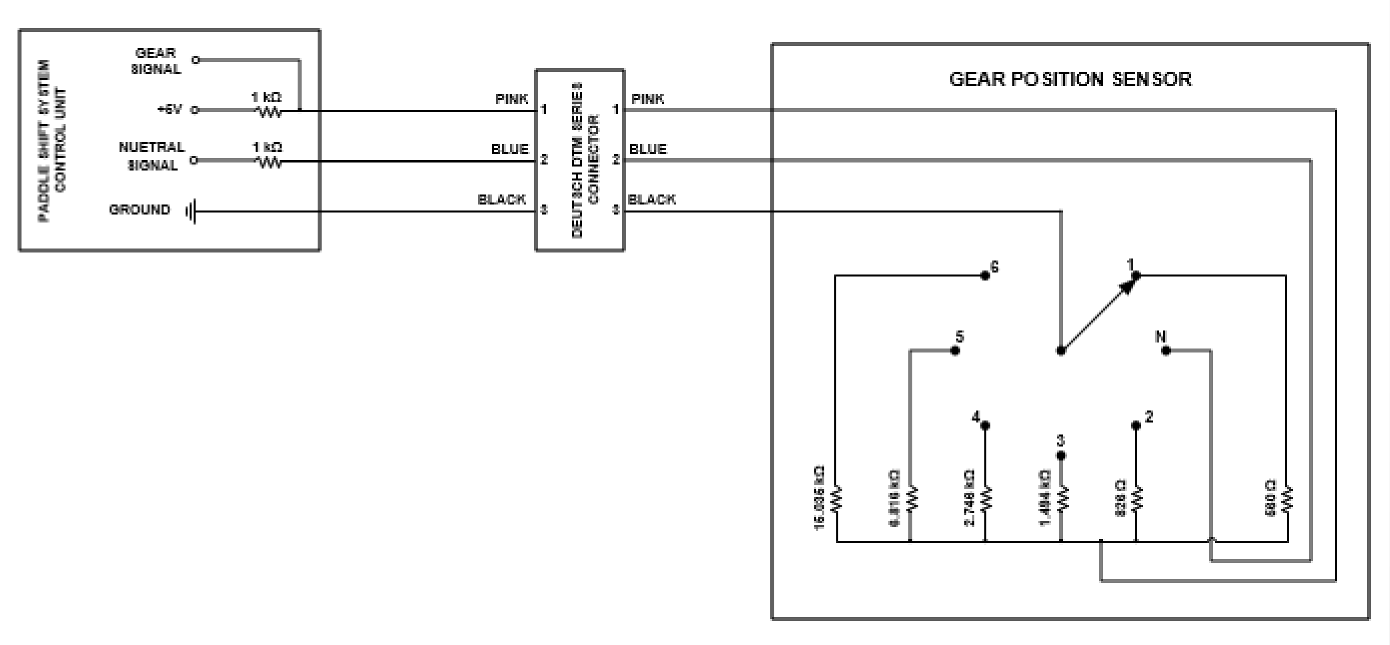
Gear Position Sensor

- Come up with a physically similar sensor to be able to fit it in its original place.
- Certain voltage and resistance values are associated with each gearshift.

Gear	Resistance (Ω)	Voltage (V)
Neutral	open	5
1	570	1.8
2	830	2.26
3	1500	3
4	2700	3.68
5	6800	4.38
6	15000	4.70

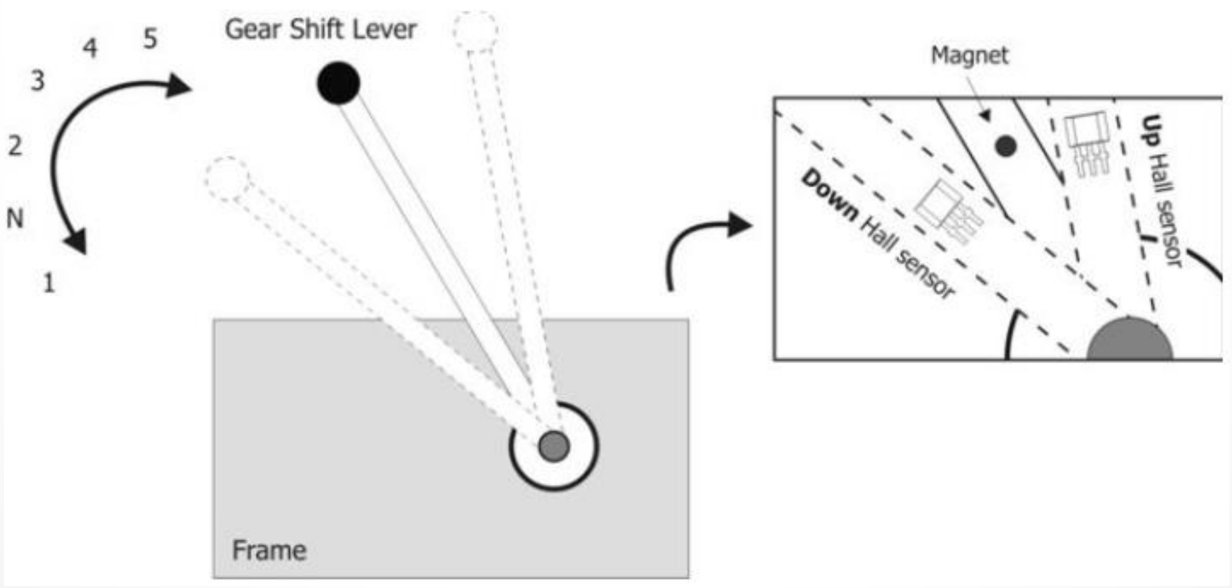
Gear Position Sensor

- Applied reverse engineering to factory sensor.
- Realized the values of resistance and voltage for gears.
- Used voltage divider to obtain the voltages for each gear.



Gear Position Sensor

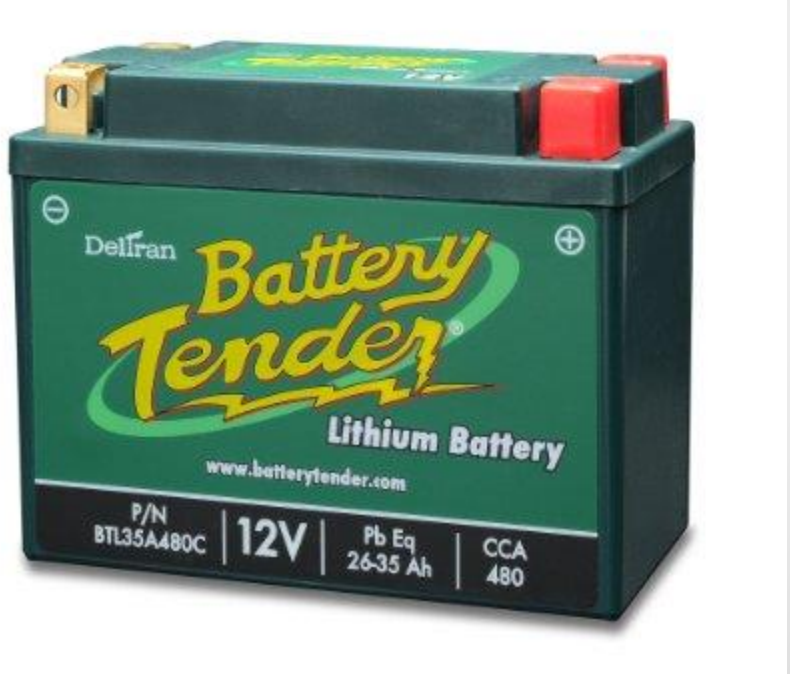
- Different approach to design.
- Use of hall sensors, magnet, and 7-segment LED indicator.
- MCU reads signals of the hall sensors and outputs gear number to the segment through a counter/decoder.



Power

Battery

- Battery Family: Lithium Iron Phosphate
- Voltage: 12V
- Capacity: 35Ah
- Charge Rate: 10A
- Weight: 3.75 lbs
- Operating Temp: 40-140°F



Power

Component Requirements

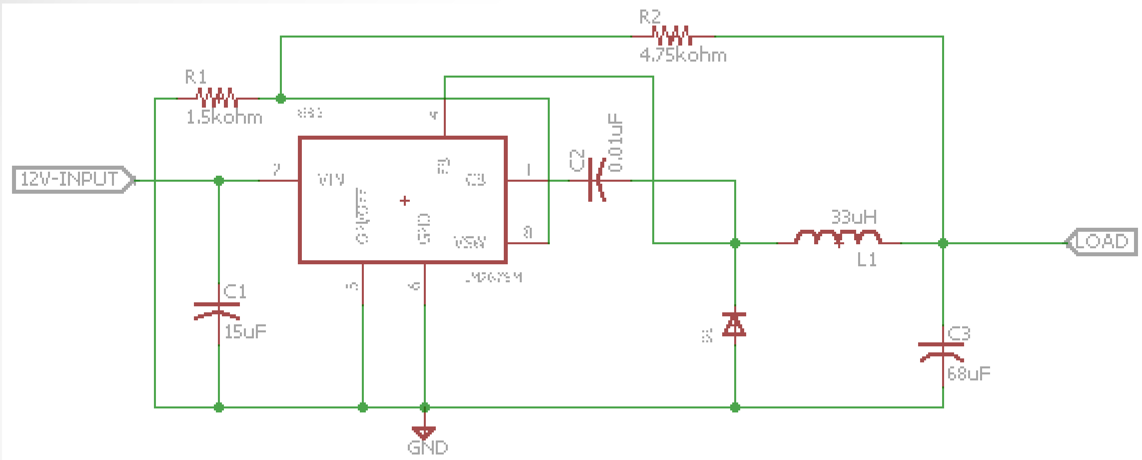
Component	Current (Input)	Voltage (Input)
Arduino	50 mA	5 V
Relay	40mA	5 V
SD Card	5mA	3.3-5 V
GPS	30mA	5 V
Display	180mA	5 V
Actuator	4.6A	12 V
Gear Position Sensor	16mA	5 V

Power

- Must provide recommended voltage rating of 5V for the MCU.
- Power wasted=(V_{in}-V_{out})(load current)

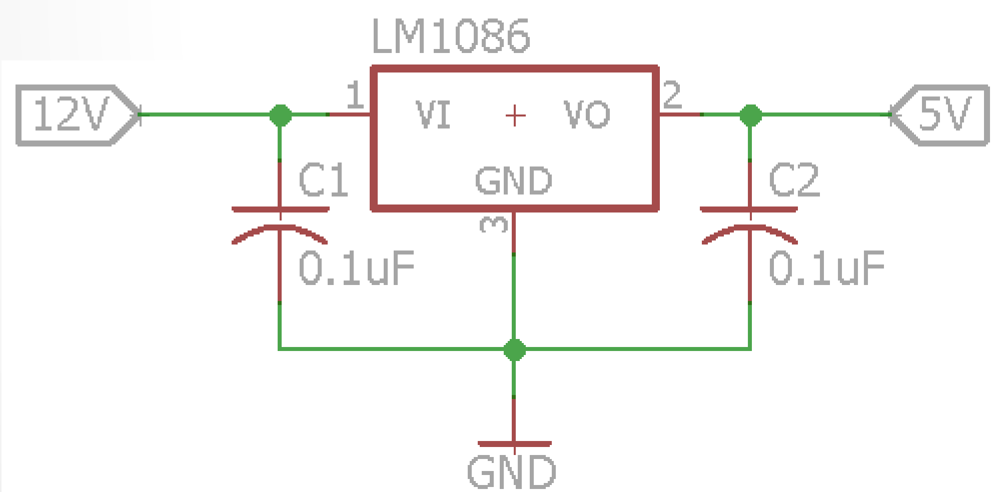
Name	I_{out}	Efficiency	Footprint	BOM Cost	Topology
LM2672	1 A	96%	218mm^2	$2.42	Buck
LM1086	1.5 A	47%	400mm^2	$1.72	Buck
LM2675	1 A	90%	313mm^2	$2.41	Buck

Power



5V switching regulator

$$V_o = V_{ref}(1 + R_2/R_1)$$



5V linear regulator

SAE Testing

FSAE	Applicable Formula SAE Competition Rules
T4.6	Accessibility of Controls – All vehicle controls, including the shifter, must be operated from inside the cockpit without any part of the driver, e.g. hands, arms, or elbows, being outside the planes of the side impact structure defined in rule T3.25 and T3.34.
T4.8	Driver Egress – All drivers must be able to exit to the side of the vehicle in no more than 5 seconds. Egress time begins with the driver in the fully seated position, hands in driving position on the connected steering wheel and wearing the required driver equipment. Egress time will stop when the driver has both feet on the pavement.
T6.5.4	The steering wheel must be attached to the column with a quick disconnect. The driver must be able to operate the quick disconnect while in the normal driving position with gloves on.
T11.2.1	All critical bolts, nuts, and other fasteners on the steering, braking, driver's harness, and suspension must be secured from unintentional loosening by the use of positive locking mechanisms.
T4.1.2	During the template test, the steering wheel, steering column, seat and all padding may be removed. The shifter or shift mechanism may not be removed unless it is integral with the steering wheel and is removed with the steering wheel. The firewall may not be moved or removed.
T4.2.4	Cables, wires, hoses, tubes, etc. must not impede the passage of the templates required by T4.1.1 and T4.2.

Overall testing

- Overall system testing will be carried out in three stages

- Stage one
  - Bench test the entire system to ensure it is operating properly as designed
- Stage two
  - Initial testing on the Formula SAE car
  - Will be conducted with the FSAE car on stands for safety

- Stage three
  - Testing to be carried out jointly between senior design group and Formula SAE team
  - To be conducted at an approved testing location

Group Dynamics

Richard Pittman - Electrical Engineer
SAE Member, knowledgeable in wiring of vehicles

Sean Feschak - Electrical / Mechanical Engineer
Knowledgeable in both the Mechanical and Electrical aspects of this project

Musab Hmeidan - Electrical Engineer
Knowledgeable in Power Systems

Kevin Castillo – Computer Engineer
Knowledgeable Computer Programmer

Richard	Sean	Musab	Kevin
Wiring harness	Display	Gear position sensor	GPS
Shifting	Solenoid/Actuator	Neutral	Data transmission
Paddles	ECU	Power distribution	Programming
SD card	Design Integration		Microcontroller
	Assisting with GPS		

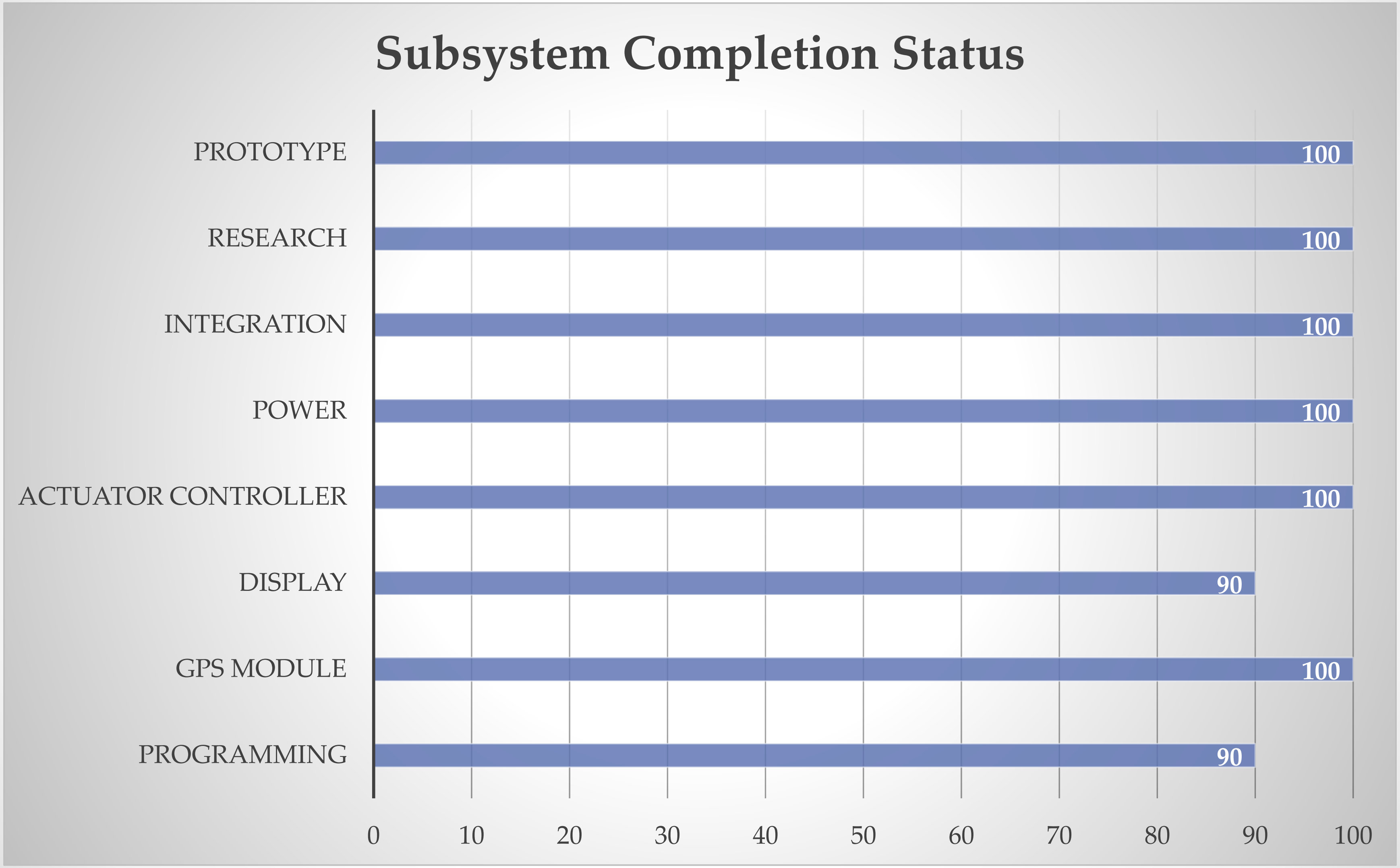
Project Scheduling

Task Name	Start	End
Senior Design Project Plan	06/02/2015	12/02/2015
Meeting to initiate project	06/02/2015	06/02/2015
Design flowchart and define roles	06/02/2015	06/04/2015
Research microcontrollers	06/04/2015	06/11/2015
Research actuators/ solenoids	06/11/2015	06/15/2015
Research displays	06/15/2015	06/20/2015
Research GPS technologies	06/20/2015	06/23/2015
Meeting to summarize research	06/23/2015	06/24/2015
Design paper and continue research	06/24/2015	07/01/2015
Meeting to revise paper	07/01/2015	07/02/2015
Continue design paper	07/02/2015	07/10/2015
Design paddles and 3D print	07/10/2015	07/13/2015
Learn EAGLE PCB	07/13/2015	07/16/2015
Design wiring harness	07/16/2015	07/20/2015
Design upshift and downshift circuit	07/20/2015	07/24/2015
Meeting before rough draft	07/24/2015	07/24/2015
Design GPS system	07/24/2015	07/28/2015
Finish and edit paper	07/28/2015	08/06/2015
Order parts	08/06/2015	08/07/2015
Break between semesters	08/07/2015	08/23/2015
Begin senior design 2	08/24/2015	08/24/2015
Revise ordered parts	08/24/2015	08/25/2015
Implement paddles	08/25/2015	09/09/2015
Implement gear position sensor/ neutral button	09/09/2015	10/07/2015
Design and test Actuator and Solenoid	10/07/2015	10/12/2015
Design and test Software	10/12/2015	10/19/2015
Design and test GPS/Display	10/19/2015	10/23/2015
Design and test Paddles	10/23/2015	10/26/2015
Design and test Gear Position Sensor	10/26/2015	10/31/2015
Design and test Actuator	10/31/2015	11/05/2015
Put system together	11/05/2015	11/10/2015
Test final system	11/10/2015	11/20/2015
Finish documents	11/20/2015	12/02/2015
Present project	12/02/2015	12/02/2015

Budget

Part	Unit Price	Quantity	Funded	Total Cost To Group	Description
Display	$40	1		$40	Purchased
Wiring	$180	1	SAE	$0	Purchased
PCB Manufacturing	$40	1		$40	Purchased
Breadboard	$10	1		$10	Purchased
GPS Unit	$50.68	1		$50.68	Purchased
Microcontroller (exact TBA)	$20	3		$60	Purchased
Voltage Regulator	$10	3		$30	Purchased
Paddle	$25	2		$50	Purchased
Actuator	$300	1	SAE	$0	Purchased
Micro SD	$20	1		$20	Purchased
Battery	Free	1		$0	Already Installed
Micro switch	$5.86	2		$11.72	Purchased
Gear sensor	$20	1		$20	Purchased
Receiver	$35	1		$35	Purchased
Tool Box (Sockets, Bearings, Screws, etc.)	$20	1	SAE	$0	Purchased
Transistor	$2	3		$6	Purchased
Total Cost			$500	$373.4	

Current Status



Questions

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ENGINEERING
MOTORSPORTS